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An investigation into the neural substrates of virtue to determine the key place of virtues in human moral development

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An investigation into the neural substrates of virtue to determine the key place of virtues in human moral development.

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Doctor of Philosophy.

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Abstract

Virtues, as described by Aristotle and Aquinas, are understood as dispositions of character to behave in habitual, specific, positive ways; virtue is a critical requirement for human flourishing. From the perspective of Aristotelian-Thomistic anthropology which offers an integrated vision of the material and the rational in the human person, I seek to identify the neural bases for the development and exercise of moral virtue. First I review current neuroscientific knowledge of the capacity of the brain to structure according to experience, to facilitate behaviours, to regulate emotional responses and support goal election. Then, having identified characteristics of moral virtue in the light of the distinctions between cardinal virtues, I propose neural substrates by mapping neuroscientific knowledge to these characteristics. I then investigate the relationship between virtue, including its neurobiological features, and human flourishing. This process allows a contemporary and evidence-based corroboration for a model of moral development based on growth in virtue as understood by Aristotle and Aquinas, and a demonstration of a biological aptitude and predisposition for the development of virtue. Conclusions are drawn with respect to science, ethics, and parenting.

Declaration of Authorship

This thesis is my own work and contains no material which has been accepted for the award of any degree or diploma in any other institution. To the best of my knowledge, the thesis contains no material previously published or written by another person, except where due reference is made in the text of the thesis.

Andrew P.J. Mullins

20 December 2012

Acknowledgements

Fresh out of school I was visiting our old retired parish priest, Fr Tosi. When I told him I was thinking of teaching, he boomed, “Blessed are those who instruct others in the paths of virtue, they shall shine like bright stars.” Well, in life I have had many stars that have not given up on me. As for any wanderings from the path, they are of my doing alone!

In this project I have many stars to thank. I am deeply grateful to my supervisor Professor Hayden Ramsay. Hayden took this on despite desperately busy commitments. Without Hayden’s reassurance and belief in this project, it most certainly would not have materialized. To a large degree, any success it may enjoy will be due to his patient, good humoured guidance. I am also greatly endebted to Professor Julie Quinlivan, my neuroscience supervisor, who provided crucial direction in overseeing my neuroscience research, and to Dr Paul Foley of Neuroscience Research Australia, the NeuRA institute. Paul has shown genuine interest in this undertaking and has generously given of his expertise over the past year. His close knowledge of the basal ganglia and dopamine systems in the brain has been invaluably reassuring.

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At this time I remember Mum, whose eyes never lost their sparkle, Dad whose gift of the telescope represented something far more, and St. Josemaria who put the star chart of the virtues in my hand. I thank Michael and Richard, the best sounding boards in the business, and Rosemary who is, now and always, the brightest of stars in the firmament.

Abbreviations

5-HT	5-hydroxytryptamine (serotonin)
ACC	anterior cingulated cortex
ACh	acetylcholine
ADHD	Attention Deficit Hyperactivity Disorder
AMPA	α-amino-3-hydroxyl-5-methyl-4-isoxazole-propionate
AMPAR	AMPA receptor
A-O	action-outcome
aPFC	anterior PFC
aTL	anterior temporal lobes
ATP	adenosine triphosphate
BDNF	brain derived neurotrophic factor
BG	basal ganglia
BLA	basolateral complex of the amygdala
BOLD	blood oxygen level dependent
cAMP	cyclic AMP (AMP is agonist for AMPA channels)
CAT	computerised axial tomography
CEA	central nucleus of the amygdala
CNS	central nervous system
CREB	cAMP response-element binding protein
CRF	corticotrophin releasing factor
DA	dopamine
DLPFC	dorsolateral prefrontal cortex
DLS	deep limbic system, also, dorsolateral striatum in rodents
DMPFC	dorsalmedial PFC
DMS	dorsomedial striatum in rodents
DSCAM	Downs Syndrome cell adhesion molecule
DT-MRI	Diffusion tensor magnetic resonance imaging
EC	endocannabinoid
EEG	electroencephalography
elF2x	a particular translation initiation factor
Epi	epinephrine
EPSP	excitatory postsynaptic potential
ERP	event related potentials
FAPs	fixed action patterns
FGF	fibroblast growth factor
FGF-2	fibroblast growth factor 2

fMRI	functional magnetic resonance imaging
GABA	γ-Aminobutyric Acid
GP	globus pallidus
GPi	internal segment
GPe	external segment
GPCR	G-protein-coupled-receptor
HFS	high frequency afferent stimulation
HSV1	herpes simplex virus type 1
IGF	insulin-like growth factor
ILN	intralaminar nuclei of the thalamus
IMM	medial mesopalium
IT	inferotemporal cortex
ITM	intermediate term memory
LA	lateral amygdala
LC	locus ceruleus
LGG	low grade glioma
LIP	lateral intraparietal cortex
LOFC	lateral OFC
LTD	long term depression
LTM	long term memory
LTP	long term potentiation
M1	primary motor cortex
MA	motor adaptation
MEG	magnetoelectroencephalography
MRI	magnetic resonance imaging
MRS	magnetic resonance spectroscopy
MSL	motor sequence learning
MSN	medium spiny neuron
MTL	medial temporal lobe
mPFC	medial PFC (in some literature, the rodent equivalent to human DLPFC)
NAc	nucleus accumbens
nAChR	nicotinic receptor
NE	norepinephrine
NMDA	N-methyl-D-aspartate
NMJ	neuromuscular junction
NMP	neuromotor prosthesis
NMR-MOUSE	nuclear magnetic resonance mobile universal surface explorer
NOIR	near optical infra red

NTF	nerve growth factor
OCD	obsessive compulsive disorder
OFC	orbitofrontal cortex
PAS	paired associative stimulation
PCD	programmed cell death
PET	positron emission tomography
PKA and PKC	particular protein kinases
PNS	peripheral nervous system
PPC	posterior parietal cortex
preNMDARs	presynaptic NMDARs
PSP	post synaptic potential
pSTS	post central gyrus
rTMS	repetitive transcranial magnetic stimulation
SACD	social and character development programs
SMA	supplementary motor area
S-O	stimulus-outcome
SN	substantia nigra
SNpc	substantia nigra pars compacta
SNr	substantia nigra pars reticulata
STDP	spike timing dependent plasticities
S-R	stimulus response
S-S	stimulus-stimulus
STN	subthalamic nuclei
STS	posterior superior temporal sulcus
TAN	tonically active neuron
tDCS	transcranial direct current stimulation
tLTD	spike timing-dependent LTD
TMS	transcranial magnetic stimulation
VBM	voxel based morphometry
VGCC	voltage gated calcium channel
VL	ventrolateral nucleus of the thalamus
VLPFC	ventrolateral PFC
VMPFC	ventromedial PFC
VP	ventral palladium
VTA	ventral tegmental area

Chapter 1

Aristotle and the neuroscientists sit down to talk.

"There is something at work in my soul, which I do not understand."
Frankenstein; or, The Modern Prometheus
Mary Shelley

1.1 The structure of this study.

This study argues that the Aristotelian-Thomistic theory of human flourishing, the acquisition and development of virtues that are understood as stable and intentional dispositions of character to behave in habitual, specific, positive ways, is supported by neuroscientific knowledge.

Chapter 1 commences with a preamble in which *prima facie* evidence is presented to support the view that there are both material and non-material factors involved in the analysis of human rationality. I situate this task on the spectrum of contemporary approaches to philosophy of mind, discussing advantages of the hylomorphic philosophy of the person and critiquing various other philosophies of mind. I place the study within eudaimonist virtue ethics in the tradition of Aristotle and Aquinas. Further possible outcomes of this study are then projected: a scientific validation of virtue ethics, benefits to be derived by virtue ethics itself from the cross disciplinary insights of neurobiology, and brief reflections on the potential contribution of moral education and parenting.

This multidisciplinary study will focus both on current neuroscience and on Aristotelian-Thomistic notions of virtue. **Chapter 2** proposes six lines of neural investigation that appear to be of most relevance to this study. In **Chapter 3** I examine the Aristotelian-Thomistic view of virtue illustrated by real life case studies. In **Chapter 4** I investigate the distinctive contributions of prudence, justice, temperance and fortitude, the virtues which Aristotle and Aquinas regarded as core dispositions of mature character. I seek to draw conclusions about what is known as the “unity of the virtues”, the view that these four cardinal virtues play an integral part in every human act.

The central methodology of the study will be to propose the neural structures and processes that appear to underpin the identified characteristics of virtue. **Chapter 5** proposes this alignment of neuroscientific data. Finally, in the light of what has proceeded, in **Chapter 6** I investigate the notion of flourishing. I reflect on the biological aptitude of the human being for the acquisition and development of virtue, and draw out implications of this study for science, ethics and moral education.

In summary, the central areas of investigation in this thesis are:

- To develop a methodology by which I can identify the core characteristics of the Aristotelian-Thomistic view of moral virtue.
- To identify, on the basis of current neuroscientific knowledge, the neural substrates that may reasonably be demonstrated to play a substantial role in the acquisition and exercise of virtue.
- In the light of neurobiological evidence, to draw conclusions about the role of virtue in human flourishing.
- To consider wider implications of these findings, with particular respect to philosophy of mind, ethics and parenting.

1.2 Preamble. The *prima facie* case.

The monster that Victor Frankenstein fashions from the sinew and cartilege of dead men is endowed with intelligence, a yearning for happiness and love, but also a fearsome capacity for burning hatred and vengeance. Frankenstein had proclaimed that his experiments would “unfold to the world the deepest mysteries of creation”,[1] and he does not disappoint us. There is a depth of being in the creature for which dead flesh can offer no account. I do not intend a

[1] Mary Shelley, *Frankenstein*, (New York: Barnes & Noble, Inc., 1993), 40.

deeper analysis of this fable, yet, as an introduction to the task of this study, it confronts us with questions about human existence, about that by which we are constituted, and about that to which we look for fulfilment. We too are bone and sinew, yet we too yearn for happiness.

In this preamble I overview *prima facie* evidence that our biological processes are implicated in our rational function. First of all in **1.2.1** I examine phenomena that suggest there is a physical substrate to human rationality. Second I consider phenomena suggesting that any wholly material conception of human rationality may have explanatory deficiencies. Third I look briefly at intimations of a profound integration of the rational and the material.

In **1.2.2**, I consider the *prima facie* evidence for neuronal implication in the acquisition and exercise of moral virtue, understood as good habits.

1.2.1 Material and non-material constituents to human rationality.

Phenomena at the genetic, biochemical, and neuroscientific level suggest that the material is implicated in what is commonly understood as the rational. Philosophy also offers arguments that implicate the physical in mental activities.

At first sight many of the points below (in **1.2.1.1**) would seem to invite material explanations for rationality that would overcome the apparent problems. Yet (as will be seen in **1.2.1.2**) material explanations for rationality struggle to account for human freedom.

1.2.1.1 We are not disembodied spirits. Evidence of the involvement of the physical in rationality.

Aristotle pointed out that the health and age of the body affects intellectual function. Just as the elderly would see more clearly had they eyes of youth; so too we think with greater clarity when our bodies are in their prime.[2]

What we do with our body, and what happens to our body, influences our mental state.[3] It is clear that all cognitive activity is unconditionally dependent on certain bodily parameters, for example, loss of oxygen leads to loss of consciousness and cognitive function. Experiments show time and again that a negative environment can contribute to a negative mood, and vice versa. In a similar way we see that learning is dependent on directed attention, and knowledge on accurate information gathering by the bodily senses.

There is considerable *prima facie* evidence for a strong biochemical component to human behaviours. For example behaviours can be triggered by sensory inputs (the need to care for a sick child elicits extraordinary generosity from a mother); drug therapies can profoundly affect our mood, our behaviours, and the way we perceive the world; the dissemination of hormones in the body can also affect behaviour.

Conversely, thought seems to lead to bodily changes,[4] thoughts seem to trigger chemicals! For example, just thinking of a scene can increase our blood pressure. The mere apprehension of a stimulus can initiate behaviours, or unleash passion, triggering a biochemical cascade propelling action. This would appear to suggest that there is natural affinity between thought and biochemical processes or at least a biochemical component to the human experience of thinking. Without such connaturality, no interaction would be possible. Furthermore we see that our past behaviours influence even unintentional future behaviours, as is the case

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[2] Aristotle, *De Anima,* 408b. (Hereafter *DA*.) Aristotle. *The complete works of Aristotle*. ed Jonathan Barnes. Princeton, NJ: Princeton University Press. Volumes 1 and 2.
[3] Typified in the science of biological psychology. See for example, S. Marc Breedlove, Neil V. Watson and Mark R. Rosenweig, *Biological Psychology. An introduction to Behavioural, Cognitive and Clinical Neuroscience*, 6th ed. (Sunderland: Sinauer Associates Inc, 2010).
[4] See discussion, for example in J. M. Schwartz and S. Begley, *The Mind and the Brain* (New York: Harper, 2002), 319.

most dramatically in addiction. That this can happen even in the case of *unintended* future patterns of behaviour, seeming to suggest that our actions can create some *material* blue print for future action. Our actions seem to change us as people.

Furthermore, our genetic makeup, including temperament, exerts forces on us to act in particular ways: often a decisive influence on behaviours specific to the species, and a major influence on our temperamental behaviours over which we maintain some capacity for modification. Genetically attributable behaviour may be traced to the programmed release of specific amino acids into our developing metabolism. In other words, chemicals are ultimately a significant influence on the type of person we allow ourselves to become.

Neural studies show that illness, and impairment in specific brain areas, have cognitive consequences. It has been shown that certain cognitive processes (such as the capacity to plan and to have due regard for consequences) are impaired if there is damage to the *prefrontal cortex* (PFC).[5] It is also well documented that these neural pathways of the PFC can be interfered with by powerful emotional experience. Also, vivid memories and extreme sense input can override activity in the PFC, cutting out of the loop circuitry apparently essential for cognitive processes.[6]

Memories, initiated by electrical messaging from the senses, can have rich emotional associations and be integrated with our cognitive life. Images arising in our memories are capable of evoking not only impulsive behaviours but of initiating considered behaviours; for example sight of an animal suffering beside a road may, on the basis of certain past experiences, provoke us to stop a car, pick up the animal, and pay veterinary fees. All this suggests that concrete material

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[5] To be discussed at length in **Chapters 2** and **5**.

[6] For example Post Traumatic Stress Disorder (PTSD) deficits can be effectively treated by cognitive-behavioural therapies (CBT). See discussion: JoAnn Difede and Judith Cukor "Evidence-based long-term treatment of mental health consequences of disasters among adults" in Y. Neria et al. *Mental health and disasters* (Cambridge: Cambridge University Press, 2009), 336-339.

input to the mind is decisive in higher function. Furthermore, it is clear that there is emotional interaction with cognition. Encouragement and emotional affirmation are shown to help children learn; the provision of information may well be inadequate to help a child acquire knowledge, behaviours or habits, or the motivation to do so. [7]

It is common experience that specific memories can be very concretely associated with other specific memories created at the same time.[8] Hence, a memory can trigger very specific previous associations in the mind: for example sliced potatoes might always bring to mind Friday nights in front of TV as a child; potato scallops always bring to mind a specific fish shop; the sight of a vodka bottle evokes a particular moment in time thirty years before, etc. This is consistent with the accepted principle of neuronal development, "neurons that fire together wire together" (see **2.2.1**), that more direct connections form between associated memories and associated actions. Too often experience shows that people out of sight fall out of mind. Skills, memories, and even human relationships, can deteriorate over time. Such degradation is consistent with biochemical explanations at the synapse.

1.2.1.2 Nor are we mere bodies. Intimations of the non-material.

Learning takes time, but insight and choice, can be instantaneous. In a flash of illumination, a person may conceive a new profound and complex insight, or totally change an opinion. This suggests a fundamental difference between these manifestations of rationality. That certain intellectual processes take place in what appears to be an instantaneous way suggests that material processes are less significant in certain operations of knowing or choosing. This is consistent with the insights of Aquinas.[9] The bodily process of acquiring sense data, and presenting a

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[7] Teresa M McDevitt and Jeanne Ellis Ormrod, *Child Development and Education* (New Jersey: Merrill, 2010), 425-427. Also see Motivation. 480-515.
[8] This associative principle is central to the development of neural connectivity.
[9] Aquinas, *Summa Theologia,* ed. various (Cambridge: Blackfriars/McGraw Hill, 19650, Q.75, Art.2.

coherent image to the mind may take time, but the person grasps knowledge instantaneously.[10] For this reason, Aquinas argues it is “impossible for (the mind) to understand by means of a bodily organ.” [11]

Man can transcend the material and the concrete. He may, for example, choose to respond with habitual detachment to the material world; in the midst of constant contact with consumerism and access to all comforts and pleasures, he may keep himself detached. As an extension of this insight, it is universal experience that man has the capability of acting contrary to emotional and bodily impulses. For example, one can resist action consequent to a specific emotion such as anger or hatred. Not only can one resist emotion, one can still carry out an action out of conviction or will power when there is indifference or apathy at the level of feelings.[12]

Although man’s senses may access only sense knowledge, we see that man can develop and hold to beliefs and convictions that are not sense derived however much sense experience may be necessary to convey them.

The not infrequent occurence of altruism, of aid to others through one’s time, energy or money without tangible reward, indicates that non-material factors play a significant role in human motivation.[13] Non tangible realities can move us physically and even change us as persons.[14]

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*(*Hereafter *ST*.) Aquinas suggests that while “The body is necessary for the action of the intellect”, it is so, “not as its organ of action, but on the part of the object; for the phantasm is to the intellect what colour is to sight.”

[10] Furthermore, human beings are capable of conceptual discussion, again indicating a capacity to transcend the immediate and material.

[11] *ST*, Ia, Q.75, Art.2.

[12] Mischel’s experiments in 1972 into infant capacity for delayed gratification demonstrate the human capacity to transcend concrete incentives. Behaviours can be opposed to considered choices at times: one can find oneself following behaviours contrary to what one wishes were the case, for example in the case of addictions or a weakness of will. We are conscious of alternatives to the material and immediate. Walter Mischel, et al., "Cognitive and attentional mechanisms in delay of gratification," *Journal of Personality and Social Psychology* 21,2 (1972): 204–218.

[13] That rationality has the capacity to respond to the non material is also demonstrated in the observation that faith-based convictions or ideals that motivate behaviour. Take for example the teaching of Therese of Lisieux that we should attend to the smallest detail out of love of God:

In contrast it appears that an animal can only be motivated by sense-affecting incentive. The apparent contrast between human and animal behaviours suggests that man is capable of operating at a level transcending the immediate. There is no conclusive evidence that any animals, even primates, have the capacity to manage their own actions outside of an immediate context, nor do they appear to have any equivalent to man's capacity to direct his own actions on the basis of prior mental reflection.

1.2.1.3 A *prima facie* case exists for a profound integration of the physical and rational in the human person.

This study, in line with the Aristotelian-Thomistic view, understands human beings as "ensouled bodies", "animated flesh". Human rationality and biology are fully integrated. Possessing a non-material dimension, human beings enjoy, within limits, the capacity to make free choices.

By this view it appears incorrect to attribute agency to the body or to the mind. Rather it is the position of this study that it is the person who acts. Our somatic and rational faculties are integrated in human operations. It is the sensing, emotion-responding person who acts. The person imagines, remembers, desires, conceptualises, and thinks logically and rationally.

A strong *prima facie* case exists for a profound integration of the physical and rational in the human person:

i. It may be argued that the capacity we have to modify our habits and behaviours, and ultimately personality, derives from the material dimension to our personality. Matter by its very nature is changeable. A

"Miss no single opportunity of making some small sacrifice, here by a smiling look, there by a kindly word; always doing the smallest right and doing it all for love."

[14] Loving relationships attest to the reality of the non material. The reciprocal gift of persons in a loving relationship, a non-material form of gift that does not diminish the giver, is only conceivable in a world of non material realities.

corollary of this profound integration of body and mind is that man achieves his end in his body or not at all.

ii. Passion and reason are able to be integrated. Emotion and passion may lead to impulsive, imperfectly rational responses, yet universal experience is also that an emotion-proposed course of action can be tested against principles of reason and either pursued or rejected.

iii. We are able to inform these principles of reason by general laws to which we bind ourselves in conscience. We are capable of testing intended actions against conscience. Conscience then may be reasonably proposed to consist in a judgement based on universal principles, transcending specific memory and hypothetical action. In each judgement of conscience there are complex interplays of concrete and the universal evident.[15]

iv. The interplay of the immediate and the universal suggests a profound integration of body and rationality. Aquinas and Aristotle proposed a psychological model in which universal knowledge is derived from immediate sense knowledge.[16] They suggested that intellectual knowledge is derived from the senses. Universals are necessarily linked to experience of the particulars. Aquinas argues that the material phantasm or image facilitates the grasp of universals. Whenever we reason, we reason with reference to the particular. Even in a simple syllogism, universal terms evoke accompanying specific images and specific characteristics:

> Frankenstein's creature seeks vengeance on humankind.
> Dr Frankenstein is human.
> The creature seeks vengeance on Frankenstein.

v. Rationality appears to begin in sense knowledge but utilises rules of logic, analogy, and inductive processes to move from the specific to the general rule or conclusion. The concrete and material plays a necessary role in rationality, but rationality transcends the concrete. Reason would not be able to know universals and manipulate sense data by means of inductive and deductive reasoning were the intellect not integrated with the senses.

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[15] Refer for example to the model of the human act proposed by Aquinas. See **3.1.3.**

[16] See discussion below in **1.4.2**.

vi. It can be argued that distinctively human activity always requires involvement of the intellect. It would appear that the body can operate without the mind (although such "vegetative function" may not be described as truly human activity), but application of the rational powers appears to require bodily-dependent capacities such as imagination, sense knowledge or memory of the specific events or of concrete objects, and desires. For example, human acts can be triggered at times by simple sensory input, such as the smell of food, the picture of a loved one. Concrete symbols, such as a blood soaked flag, or a cross, can carry associations of meaning that can stir us to considered action.[17] The Thomistic view is that the point of death is that point at which bodily functions are no longer able to sustain rationality.

vii. A rational act may be conducted through the instrumental activity of the body**.** Action in and through the body involves complex neural instruction to muscles as well as monitoring of feedback from our senses and muscles. There is a profound integration of the biomechanical with higher functions of goal setting and executive direction of activity.

viii. Persons are able to express their very selves and communicate by medium of material things**.** For example, we express our love of benevolence towards others by means of material gifts. We use words, complex patterns of compression waves through the atmosphere, to convey notions of truth, beauty, and goodness.

ix. Rationality is not an end in itself. It may be argued that rationality empowers human beings to love, to unite their own will to that of another. In this view, rationality is fulfilled by generosity and gift of self.[18] In this context, reason enables us to transcend the material, in order to know and love others.

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[17] See discussion pertaining to scenarios in **3.1.2**.

[18] An advocate of this rationally founded view has been John Paul II who insisted that man is fulfilled by loving and experiencing the love of others. *John Paul II, Familiaris Consortio,* 11. "Love is the fundamental and innate vocation of every human being." See also discussion of fulfilment in my **Appendix 1. A Response to the Claims of Emergent Rationality by Non-reductive Materialism**.

x. A profound unity of hearts and minds is seen to exist in certain relationships between persons. Such profound union appears to be nourished by positive emotional engagement, attention, touch and communication. The material facilitates the transcendent. It is generally agreed that the bodily phenomenon of emotions plays a significant role in helping us empathise and connect as persons. Furthermore, love between human beings appears better able to flourish where there is contact and communication. The more present, the more personal; the more concrete our experience of the other, the more love is facilitated.

xi. Similarly, it may be argued that the capacity to choose to unite oneself to the will of another is necessarily evidence of freedom and hence of a non-material dimension to personality.[19] It may be argued that the highest expression of human existence is to be found in reciprocal relationships where fulfilment of the will of the other is the goal.

1.2.2 *Prima facie* evidence for a neuronal underpinning of virtue

I suggest that the neuroscience of virtue, understood in the Aristotelian/Thomistic sense, offers a pleasing consonance with the natural world. The development of virtue, in contrast with other ethical paradigms, is proposed as necessarily experiential: this is consistent with the explanation that developing neural structures of the human brain require experience and environment for maturity.[20]

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[19] The capacity to be able to *choose* to unite one's own will to the will of others (a capacity we see in obedient children and teenagers, diligent workers, spouses in close relationships, soldiers in battle) counters arguments asserting that human actions are predetermined by biology. Even if, in refutation of such a free will argument, one attempts to argue that the very choice to do what someone else suggests may be biologically dependent, nonetheless to commit oneself to *always* follow the will of another, for example in a committed relationship of love, effectively cuts one's actions loose from one's biology. It is absurd to argue that while some people have a biological predisposition to act in individual and specific ways (ie heeding sensible appetency), others have a biological predisposition to commit themselves to the choices of another (ie heedless of sense appetency). This would be to have a bet both ways. Hence, this is an effective refutation of biological determinacy.

[20] It is evident that there are no "child prodigies" when it comes to virtue. It is necessary to work at one's character.

Furthermore, informed by the explosion of neuroscientific knowledge in recent decades, it is reasonable to propose that several major neurobiological strands are implicated in any neurobiological component to virtue.

- Neural plasticity which permits alterations to established, or establishing, neural connections. Closely associated to plasticity are the mechanisms of synaptic strengthening.
- Mechanisms for learning, memory, habit formation, imitation, emotional management, goal election, and executive control.
- An understanding of the various discrete constituent structures of the brain, together with a mapping of neural interconnections.
- The contribution that integrated systems and complex neural mechanisms play in support of human rationality.

On the basis of advances in neuroscientific knowledge and on the Aristotelian notion of moral virtue as a habit directed towards human flourishing (see **1.6.3** and **Chapter 3**), it is reasonable to propose for investigation the following *prima facie* evidence for a neuronal underpinning of virtue:

i. Insights into neuronal development and its relationship with behaviour appear to be consistent with the notion of virtue as a preferred model for moral development. This is because <u>virtue development is experience based</u> rather than theory based. It is derived from analysis of the facts of human experience, development and flourishing, rather than from intuitive, internally consistent, principles. Hence, a study of the neuroscience of virtue is not an arbitrary choice to study one ethical system among many, but a choice well grounded in the compatibility of virtue development with neuroscientific knowledge.

ii. <u>The brain is plastic.</u> Every experience brings about functional response of some type in the brain. Structural change can accompany and underpin functional responses, in a wide array of neural processes collectively known as structural plasticity. Developmental plasticity is essentially irreversible; this plasticity with respect to processing of sensory inputs and control of motor function is now well established. It is also well established that plastic neuronal change is at work in learning and in that particular form of learning classified as habit formation. I argue that plasticity is also a central neuronal process in those specific types of habit that we call virtue. (See extensive discussion of plasticity in **2.2**.)

iii. Virtue is a form of learning. Various features of learning, for example habit formation, suggest a neurobiological basis, that learning has a material substrate in the brain. (See discussion of habit learning in **2.4**)

iv. Certain pathways of habit formation are now quite well described. All behaviours are essentially reinforcing: the more we do something the more we reinforce that behaviour. (See discussion of habit formation in **2.4**.)

v. Memory too plays a significant part in learning, and appears to operate via neurobiological mechanisms. (See discussion of memory in **2.3**.)

vi. Imitation is a form of learning from direct experience. A neural component facilitating imitation, the mirror neuron, has recently been identified. Imitation is known to play a role laying down new neural pathways. (See discussion in **2.3.6**.)

vii. There is considerable work now written on the interplay between emotion and rationality. This study focuses on the interplay of emotion, rationality and habit formation. (See discussion regarding regulation of emotion in **2.5**.)

viii. The cognitive processes at the heart of executive control are understood to be supported by areas and processes in the cortex, particularly the PFC This area of the brain maintains rich inhibitory linkages with the emotional centres of the brain. (See discussion regarding cognition and executive function in **2.7**.)

ix. "Happiness is the reward of virtue" wrote Aristotle.[21] Virtue is the facility to act in ways that complement our nature bringing us increased self-

[21] Aristotle, *Nicomachean Ethics*, 1099b16. (Hereafter *NE.*). Aristotle. *The complete works of Aristotle*. ed Jonathan Barnes. Princeton, NJ: Princeton University Press. Volumes 1 and 2.

mastery and fulfilment. This study will argue that human flourishing, including moral flourishing, has a biological basis, showing that there is a neuroscience of virtue development in which the brain has neural mechanisms that, if perfected, provide for ease of action in the moral sphere. I argue that virtue development is therefore the path of development for the human being most in accord with human nature, denoting maturity at the levels of personality and biological development.

1.3 Situating this study within contemporary approaches to the philosophy of mind.

This current study falls into the field of philosophy best described as philosophy of mind. Therefore at this introductory point it is most appropriate to situate and justify this study in the field of contemporary approaches to the philosophy of mind. This will be a three step process. First I offer a broad overview of the various currents of contemporary philosophy of mind. Second (**1.4**) I review the basic tenets of hylomorphic theory as proposed by Aristotle and Aquinas. Third, especially in **Table 1.1** and in **Appendix 1**, I summarise the spectrum of contemporary positions in philosophy of mind and offer a brief hylomorphic critique of each.

In the history of twentieth century philosophy of mind there have been a number of more significant figures and lines of development. Among these we find Ryle and his articulation of logical behaviourism, Identity Theory developed by Lewis and Armstrong, Functionalism proposed by Putnam and Fodor, Davidson's articulation of non reductive materialisms, Dennett and Churchland with respect to instrumentalism and eliminative materialism, and Block and Chalmers, among others, in the search for philosophical understandings of consciousness and qualia.

This panorama has been characterised, for the most part, by materialistic and physicalist explanations for mental phenomena in which language also has played a significant role. Recent years have been dominated by non-reductive physicalist acknowledgement of the reality of consciousness in an emergent paradigm. To some extent these currents are reactions to substance dualism, with its inability to explain causation in any rationally satisfying manner, and to behaviourism, with its reluctance to discuss matter at all.

Despite the quantity of writing and energy of debate, there is a certain same-againness evident. None of the major lines of development of philosophy of mind in the twentieth century have accorded ontological legitimacy to the non-material. The non-material has been dealt with:

i. In pragmatic fashion with no interest in metaphysical possibilities and explanations (logical behaviourism).
ii. As causally disconnected (epiphenomenalism).
iii. As immediately dependent on the material (Identity Theory, and type functionalisms).
iv. As ultimately dependent on the material (emergentism, forms of functionalism, non-reductive materialisms such as Davidson's Anomalous Monism, and mentalist emergent views).
v. Or as a fictional construct (eliminative materialists and projectivists, neurobiological physicalist explanations).

The inevitable outcome of mechanistic and materialistic approaches, and of epiphenomenal inabilities, is that contemporary philosophy of mind is generally dismissive of non-instrumental rationality and human freedom. None of the current approaches to philosophy of mind offer a way forward able to accommodate human freedom in a manner that is rationally acceptable.[22] This is the elephant standing in the philosopher of mind's lounge room because freedom cannot be easily dismissed. It is apparent that man possesses a certain freedom;

[22] This is not to say that many philosophers don't accept and advocate an emergent free will. They do; but they are unable to offer any articulation of how the limitations of animal life can have given rise to man's demonstrable capacity for universal truths and freedom. In contrast stands the Thomistic model, based on an enriched notion of causality embracing formal causality, that man enjoys participation in rationality as a principle of unity and function.

indeed, freedom must be a prerequisite for such widespread belief in the need for ethics. Either the great architects of ethics, from the times of Socrates and Confucius, have been deluded, the historical and political figures who sought to improve the lot of man were acting on false presumptions, and the teachings of Christ and Muhammad deceive over half the human race into thinking we have any control over our actions – or our moral philosophies require an adequate account of human freedom. It is time to revisit the suppositions of contemporary philosophy of mind.

This denial of human freedom in philosophy of mind is found in much of contemporary neuroscience.[23] Larry Squire writes in standard reference text, "Neuroscience is a large field founded on the premise that all of behaviour and all of mental life have their origin in the structure and function of the nervous system."[24] Another prominent neuroscientist, Nobel prizewinner Eric Kandel, is equally adamant. He writes,

> Most neuroscientists and philosophers now take for granted that all biological phenomena are properties of matter. This physicalist stance breaks with the tradition of dualism stemming from ancient Greek philosophy. The break with the tradition that mind and consciousness arise from a mysterious interaction of spirit with body actually focused the problem of consciousness for the 20th century neuroscientist. Philosophically disposed against dualism, we are obliged to find a solution to the problem in terms of nerve cells and neural circuits.[25]

The common view in neuroscience is simply that the materialist and the dualist are the fundamental categories defining attitudes to the mind-body problem: the

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[23] Neuroscientist Christof Koch substitutes "compatibilism" for freewill, the view that man has the capacity to follow his desires as determined by his chemical programming. See Christof Koch, "Finding Free Will," *Scientific American Mind*, May/June, 2012, 22.
[24] Larry Squire et al. *Fundamental Neuroscience*, 3rd ed. (Burlington, MA: Elsevier, 2008).
[25] Eric R Kandel et al. *Principles of Neural Science*, 4th ed. (New York: McGraw-Hill, 2001), 1317.

materialist says that the mind is the body; the dualist says that the mind and body are two different things.

Kandel appears not to have considered the implications of a “different substances view” nor any non Cartesian understanding of mind and body interaction, namely the integrated view of Aristotle and Thomas.

1.4 The hylomorphic underpinnings of this study.

An Aristotelian-Thomistic understanding of the human person underpins this project. This multidisciplinary investigation into the neural substrates for virtue emphasises the rational person, the ensouled body, as the subject of action. In the sections that follow I explore this concept. The sections below (**1.4.1 - 1.4.3**) set out the hylomorphic, psychological, and personalistic frameworks underpinning the philosophical reflections in this current study. In **1.4.4** I discuss the relative merits of the hylomorphic approach.

In the quotation above Kandel reveals that he does not conceive of a third possible understanding of matter, one that is neither materialistic nor dualistic: this third way will now be presented as the hylomorphic view, that matter and mind are both expressions of the same reality. The clues are of course implicit in matter itself –when a human being dies, the body itself ceases to be a body, decomposing to a mess of chemicals that no longer have a principle of unity: it is evident there was a principle of unity that held the constituent substances in order. We need a wholly different view of this type of matter, matter that is ensouled. Only while it is ensouled is there a human body; the soul, or form, makes it to be what it is. The clues are in what we see; acceptance of hylomorphism does not depend on an interpretation of qualia or an appreciation of subjective experience, nor even on the debate about the degree of freedom man enjoys. Hylomorphism provides an account of matter that not only accommodates universals and the possibility of freedom, but also what is manifested to our senses about matter itself.[26]

I look first at the key features of hylomorphic theory, the Aristotelian theory of substances, then specifically at living intelligent material substances in a review of the rational psychology developed by Aristotle and refined by Aquinas. Finally I review the evolution of the concept of personhood, in the Boethian sense as individual rational substance, through the fragmentation that followed Descartes and at recent efforts to restore the hylomorphic understanding of person. In the process I review the significance of an adequate understanding of person.

With these understandings, we then return in more detail to the principal currents of contemporary philosophy of mind **(1.5)** in order to offer the summary of current positions. In so doing I argue for the suitability of an hylomorphic solution to the mind-body problem and so prepare the way for the proposition that brain function is part-constitutive of human moral development.

1.4.1 An overview of hylomorphic theory[27].

Aristotle's studies of the *what*, *how*, and *why* of existence were further developed by Aquinas. Their metaphysics and rational psychology seek to explain what makes things, including creatures and people, to *be*, to be *what* they are, and why they *act* the way they do. It is a satisfying, rich, coherent and systematized account that integrates science, psychology, ethics and social philosophy. Some understanding of the principles of their teaching is required in order to appreciate the potential it has to accommodate human behaviour and learning, the core area of this study.

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[26] See **1.5** and **6.4.2**.

[27] According to Royce, William James is on record as accepting hylomorphism as "probably the best ultimate explanation of man", although he himself did not adopt it in his writing. James also reached acceptance of the notion of soul "in which scholastic psychology and common-sense have always believed." William James*, The Will to Believe, and Other Essays in Popular Philosophy* (1897), reprinted in *Human Immortality: Two Supposed Objections to the Doctrine*, (New York: Dover, 1956), Vol. 1, 181.

a) Substance

<u>An appreciation of causality underpins the hylomorphic notions of substantial form and prime matter.</u>

Aristotle proposed a theory of hylomorphism that non-material properties adhere together with material properties in a single substance.[28] Hylomorphism means "matter and form" ($\upsilon\lambda\eta$ meaning "lumber", later "matter"; $\mu o\rho\phi\eta$ meaning "form"); the underpinning constituents of substance. Hylomorphism underpins the Aristotelian-Thomistic notion of virtue, the core matter for this study, and best describes the approach to philosophy of mind.

To understand what something is, Aristotle argued that it is necessary to employ a notion of causality, what causes it to be what it is. Defending the unity of substance, he argued that any material being is a composite of two co-principles of substance: substantial form and prime matter, reflecting notions, respectively, of act and potency. Substantial form makes something what it is; prime matter makes it potentially other things.[29]

He proposed that form perfects matter, making something the fundamental sort of thing it is. [30] Prime matter and substantial form bestow essence and compose actual material substance, which itself will be expressed through its characteristics, or "accidents". Individual substances exist in themselves; a substance is that which can be "by itself".

Aristotle's notion of causality extends beyond activation of matter, to psychology, to learning and to acting, with significant implications throughout this study. [31]

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[28] The Shorter Oxford defines "hylomorphism" as "the doctrine that primordial matter is the first cause of the universe."
[29] James E Royce, *Man and his nature* (NY: McGraw Hill, 1961), 287.
[30] Leslie Stevenson and David L Haberman, *Ten Theories of Human Nature*, 4th ed, (NY: OUP, 2009), 94.
[31] Alan Donagan, "Thomas Aquinas on human action", in *Cambridge History of Later Medieval Philosophy*, (Cambridge: Cambridge University Press, 1982), 653. Donagan writes, "To many

The act of *esse.*

To the preoccupation with “what things are” in Aristotle’s matter and form, substance and accidents, and act and potency, Aquinas adds an overriding existential concern about “why things are”, with the distinction of essence (what a thing is) and existence (the fact of its being).[32] “Because of (this)… stress on the act of existence, rather than upon substantial form, Thomistic metaphysics is said to rise above Aristotelian metaphysics.”[33]

Aquinas wished to address squarely the challenge of explaining how things may come into existence and may cease to be. He emphasized what he called the *unity of being*. He observed that finite beings may come to be and cease to be: they do not possess being. He taught that finite things are compositions of potentiality and act in two senses, first matter and form, but also, importantly with respect to essence (what they are) and *esse*.[34] A possible being has essence, but only a really existing being has *esse*. Hence essence is “in potency to” *esse.*

Aquinas emphasized that matter and spirit differ in degree of perfection of being, not in kind. This is a particularly significant insight providing a key to the refutation of a substance dualism that overlooks any principle of actual existence, the act of *esse*, and considers only the essence of material and non-material reality.[35]

Aquinas taught that unity of being comes from *esse*, and that every being that is created must *participate* in the Divine act of existing. Aristotle too had argued for

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twentieth century philosophers, the feature of Aquinas’ theory that is most objectionable is his retention of Aristotle’s conception of causation as the exercise of a power or capacity, which allows him to think of human beings themselves, and not only of events occurring within them, as genuine causes of their actions –‘agent causes’”.

[32] Joseph Torchia OP *Exploring Personhood*. (Maryland: Rowman and Littlefield, 2008), 128.

[33] Herman Reith, *The Metaphysics of St Thomas Aquinas* (Milwaukee: Bruce, 1958), 111.

[34] “This being is distinct from that being inasmuch as it is the being of this or that nature”. Aquinas, *On the Power of God*, trans. English Dominican Fathers (Westminster, Maryland: Newman, 1952), Q.7.2. ad 9.

[35] Aquinas also differentiates between the human soul and the possibility of spiritual beings, subsistent and complete in themselves, such as angels or even God himself.

such an ultimate principle of existence. [36] “Since everything that moves and undergoes change requires an act responsible for initiating these processes, Aristotle reasons that the entire universe requires some ultimate principle of actuality.” To avoid the impossible situation of infinite regress, an unmoved mover is posited, the ultimate end, “the final cause producing motion as being loved.” [37]

The concept of participation.

Aquinas taught that substances possess being only *by participation*, that being is predicated of finite creatures by participation. [38] He wrote: “From that one being all other beings that are not their own being, but have being by participation, must needs proceed.”[39]

In summary, each actual finite being will be actualized in three ways: by a substantial form making it to be *that which it is*; by a participatory act of being, *that by which a thing is*, eg its colour, shape and smell; and, by further perfection *by its accidents* which are non essential characteristics of a substance.

Nature: the principle of operation.

Our behaviour follows upon the type of creature we are: “*operatio sequitur esse*”. Do follows be: “*agere sequitur esse*.” Observations of the operation of a being allow us to draw conclusions about its nature: “The nature of a being as such is not directly observable. We must observe its operations and then draw conclusions about its nature.” [40]

b) Soul

[36] In seeing existent reality as a dynamic act, Aquinas transcends the essentialist approaches that preceded him. He argued that the distinctive nature of human beings, with their capacity to grasp the non material, derives from their rationality which imparts a unique mode of existence. The intentionality of God is the first efficient cause, bringing things into being so his goodness might be communicated to creatures in a manifold and variegated manner. Torchia, *Exploring Personhood*, 131-2. See also *ST*, I, 47 1.
[37] Torchia, *Exploring Personhood*, 77.
[38] Torchia, *Exploring Personhood*, 129.
[39] Aquinas, *On the Power of God* Q.3. ad5. Aquinas, *On the Power of God*, trans. English Dominican Fathers (Westminster, Maryland: Newman, 1952), Q.3.5.
[40] Royce, *Man and his nature*, 25.

Soul as life principle and principle of unity.

Aristotle taught that all life forms a hierarchy and that the life principle of something is its soul. Aristotle defines soul as "the actuality of a body that has life potentially".[41] In other words, the soul activates the body.

Hence it is not accurate to think of the soul as a free standing substance. It is not a thing, but the very principle of unity of the body itself. The soul can admit no division for there is no further principle of unity. Whereas substances without souls expand through "addition"; a living thing is nourished when it "receives in its very self something that serves to maintain it".[42] "Only ensouled things truly grow."[43]

It is the soul that bestows on a substance its nature. "While it cannot be a body, it is in a body and a body of a definite kind."[44] In contrast with Plato, Aristotle affirms the explicit contribution of the body to humanness. The body is potentiality with respect to the soul, "The soul is suited to be the form of a body; the body in turn has a receptivity to ensoulment."[45]

It is better to talk of "ensouled", having distinctive ways of functioning, rather than "having a soul" as if it were a substance.[46] Body and soul make one thing (*unum*) according to Aquinas. [47]The unity of the soul and body is illustrated by the integrity of wax and the imprint it bears.[48]

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[41] *DA,* 2.1, 412a
[42] *DA,* 2.9, 135-36.
[43] *DA,* 2.9, 152-3.
[44] *DA,* 2.1, 414a.
[45] Torchia, *Exploring Personhood*, 85.
[46] Matter of course is vital to the whole understanding; forms exist only in individuated matter. Matter is the principle of individuation.
[47] Robert Pasnau, *Thomas Aquinas on human nature: a philosophical study of "Summa Theologiae" 1a75-89* (Cambridge: Cambridge University Press, 2002), 73.
[48] *DA* 2.1, 412b.

Aristotle proposes that there are three kinds of soul: the rational, sensitive, and vegetative. Adopting a teleological perspective from Plato[49] Aristotle argues that the potency of matter is limited by its form, or soul. Fullness of potentiality, for example, "human flourishing", is inherently associated with final causality, the purpose of human existence. Thus final and formal causes are related. As its form, the soul directs each living body to its true *telos*.[50]

Aquinas emphasises that the parts cannot survive without the whole. [51] The soul "perfects not only the whole but each part" of the organism, it is present as a whole in every part of the matter that it actualizes.[52] Nor, he writes in anticipation of Descartes' error, is the soul to be found in a determined location in the body, "as a sailor in a ship." [53] [54]The body itself does not remain after death;[55] as has been noted, the substance that is the being of the animal decomposes to its constituent substances.

"For living things, living is existing"[56]; "living is the mode in which living things have existence". "The soul does not merely make the body to be of a certain kind, the living kind; the soul also gives a body its very existence."[57] Hence, the decomposition of death, entails division and loss of this specific form; the prime matter is activated by other forms. "The soul itself forms that body that fits it; it does not take up one already prepared."[58] The body has no existence outside of

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[49] Torchia, *Exploring Personhood*, 6.
[50] Torchia, *Exploring Personhood*, 77.
[51] 43, *Thomas Aquinas on human nature: a philosophical study of "Summa Theologiae"* 1a75-89, 93. This is not to say that the whole cannot survive without some of its parts at times.
[52] "The whole soul is in the whole body and in each of its parts, nor is is joined bodily as bodies are joined to each other… The soul performs all its operations through its powers." Aquinas, *Summa Contra Gentiles*, trans. James F. Anderson (NY: Hanover House, 1955-7), II.72*;* cf *ST*, Ia, Q.76, Art.8.
[53] Aquinas wrote of ridiculous assumptions of those who consider the soul's being in body as in a place, like a sailor in a ship, or as if it is a point at an indivisible location. cf *In 1 Sent* 8.5.3c.
[54] *ST*, Ia Q.76, Art.1. Nor is rationality united to the body as a "*motor*".
[55] Aquinas writes, on death, "No part of the body has its proper function, whereas anything that retains its species retains the operation belonging to that species" *ST*, Ia, Q.76, Art.8. See also Pasnau, *Thomas Aquinas on human nature: a philosophical study of "Summa Theologiae" 1a75-89,* 88.
[56] Aquinas quotes Aristotle *DA*, II 4, 415b13.
[57] Pasnau, *Thomas Aquinas on human nature: a philosophical study of "Summa Theologia" 1a75-89,* 96.
[58] In *DA* I. 8.358-59.

the substance, and exists as a human body or not at all, corrupting into secondary substances[59].

<u>The human soul is the substantial form of man.</u>[60]

Aristotle argues that man, as other material substances, is composed of the two constitutive principles of matter and form: [61] "People are constituted in two substantial elements, the soul with its reasoning power (understanding and will), the flesh with its senses."[62] Man's soul is the "ultimate integral formal principle by which we live". [63] The soul is not within man causing him to act in certain ways; rather "it refers to the fact that man is capable of causing these activities, and that man is not just matter since matter of itself does not live."[64] [65]

The soul, in actualising matter, forms the body. It has no specific locus within the body. "It is really just as correct to say that matter is in the soul as to say that soul is in matter."[66] The soul is wholly there, wherever man is.[67] The soul has a virtual presence, by virtue of power exerted.

<u>Integrity of the human person.</u>[68]

Aristotle insisted that it is the person who acts, not the soul, not a part of the person: "It is surely better not to say that the soul pities, learns, or thinks, but that the man does these with the soul."[69] As the immaterial soul admits of no real division, rationality is predicated essentially: "Humans are sentient as well as

[59] Richard Taylor, "Mind and Body" in *Exploring Philosophy: an introductory anthology*, ed. Steven M. Cahn (Oxford: OUP, 2000), 102.
[60] See discussion in Torchia, *Exploring Personhood*, 135.
[61] Royce, *Man and his nature*, 282.
[62] *ST*, Ia, Q.75, Art.6 ad3; and *ST*, Ia, Q.77, Art.8.
[63] Royce, *Man and his nature*, 293
[64] Royce, *Man and his nature*, 293
[65] Torchia, *Exploring Personhood*, 149. "The soul is the primary metaphysical principle of the essence of human nature... being or *esse* provides the constitutive principle and a way of being appropriate to nature."
[66] Royce, *Man and his nature*, 316.
[67] *ST*, Ia, Q.75, Art.8.
[68] This section draws from excellent discussion in Torchia, *Exploring Personhood*, 130-150.
[69] *DA,* 408b15.

intelligent beings. By extension, then, the body which allows for sensation, is part of a being that is essentially rational."[70]

He divides the powers of the human being into reason and that which can obey reason.[71] He writes of theoretical and practical reason,[72] and of the rational and non rational aspects of the soul.[73]

Aquinas also maintained the complementarity of soul and body. He adopted the Aristotelian hylomorphic understanding of humans "as composites of the formal principle of the soul and the material substrate of the body", that the human subject is an "inextricable union comprising one substantial reality".[74]

In virtual anticipation of contemporary philosophy of mind dilemmas, he strongly rebutted the naturalism that did not distinguish between body and soul, and the ancients who asserted "that only bodies were real things; and that what is not corporal is nothing; hence they maintained that the soul is something corporeal."[75]

Adopting a Boethian line of thinking, he wrote, "In a more special and perfect way, the particular and the individual are found in rational substances, which have dominion over their own actions… actions belong to singulars. Therefore individuals of a rational nature even have a special name among other substances; and this name is person."[76] Person derives from *persona*, the Latin word for "mask"; it suggests the voice sounding through the mask of the individual actor, *per-sonare*, possibly conveying the dignity of the great person portrayed.[77] Thomas suggests that the dignity of the person derives from its spiritual, therefore

[70] Torchia, *Exploring Personhood*, 135.
[71] *NE,* 1098a5.
[72] *NE,* 1139a5.
[73] *NE*, 1192a28ff.
[74] Torchia, *Exploring Personhood*, 131-2.
[75] *ST*, Ia, Q.75, Art.1.
[76] *ST*, Ia, Q.29, Art.1.
[77] Reith, *The Metaphysics of St Thomas Aquinas*, 118.

indestructible, act of subsistence.[78] He wrote, “Person signifies what is most perfect in all nature – that is, a subsistent individual of a rational nature”[79]

Ensouled bodies; animated flesh.

Classical philosophical texts typically describe human beings as “composite realities of soul and body” but this can be more confusing than helpful. It is much truer to the thought of Aristotle and Aquinas to think of soul as the “animating principle of matter”. I suggest the term “animated flesh” even more than “ensouled body” for it better avoids any erroneous suggestion that the soul is somehow an entity in itself.

Both Aristotle and Aquinas argued that when the soul is in a state united to the body the soul and the body may *only* act in concert. This understanding is of great importance in this study. Aristotle emphasised that the highest part of the rational soul, the intellect, is inseparable from the body: “No one can learn or understand anything in the absence of sense, and when the mind is actively aware of anything, it is necessarily aware of it along with an image.”[80]Thomas too avoids both “excessive spiritualism and naive materialism regarding human nature”. Torchia sums up this feature: “Soul and body require each other: the soul depends on the body as its instrumentality in the world, and the body depends on the soul as its principle of life and activity.”[81]

The reality of ensoulment allows our thoughts to impact on our physical constitution, and conversely the body to influence our mental life. It is clear that thought is in constant and reciprocal interchange with bodily state: anxiety causes tummy ache, stress induces cancer, life meaning impacts on bodily health, hope prolongs the life of a terminally ill person… and neural pathways are instruments for higher thinking.

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[78] Reith, *The Metaphysics of St Thomas Aquinas*, 119.
[79] *ST*, Ia, Q.29, Art.3.
[80] *DA* III 8 431b.
[81] Torchia, *Exploring Personhood*, 138

Immortality of the soul.

Aristotle wrote of the human capacity for “thought and intellect”[82] and does suggest that the faculty of contemplation can exist separately from the body “as the everlasting can from the perishable”.[83] Yet ultimately, both Aristotle and Plato deemed the only basis for human individuality to be the perishable body. [84] [85] [86] Aquinas held the view that the disembodied soul enjoys another mode of existence.[87] [88] He argued that the human soul must be a substantial reality,[89] but that alone the soul does not constitute a human being. [90]

1.4.2 Rational psychology

Overview.

Rational psychology is the discipline whereby we seek to understand human nature by “diligent and subtle investigation”[91], as a preliminary to understanding what fulfils human nature and how human beings should act. A correct grasp of the Aristotelian understanding of soul is crucial if one is to arrive at an adequate metaphysical understanding of the role of matter in the human constitution, of great relevance to this current study. Aristotle writes of the nature of man in *De Anima*. Aquinas sets out his anthropology in the *Summa Theologiae* 1a 75-89. It is

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[82] *DA,* 414b19.
[83] *DA,* 413b26.
[84] Stevenson and Haberman, *Ten Theories of Human Nature*, 90-92.
[85] Aristotle argued that the disembodied soul has no memory, “It is in its separated state that the intellect is just that which it is, and it is this alone that is immortal and eternal, though *we* have no memory, as the separate intellect is unaffected, while the intellect that is affected is perishable, and in any case thinks nothing about the other.” *DA,* III 5 430a.
[86] Stevenson and Haberman, *Ten Theories of Human Nature*, 94-5. Aristotle held that the soul is a “complex property of living bodies”, a “set of capacities for a living body” and so cannot exist without a body.
[87]Torchia describes Aquinas’ view of the disembodied soul:“a mode of understanding directed towards simple intelligible objects”, by which it grasps “the singulars to which they are determined by the knowledge they acquired in this life, or by some affection, natural aptitude, or disposition of the divine order.” Torchia, *Exploring Personhood*, 149.
[88] Torchia, *Exploring Personhood*, 133. It is “…because mind (as an incorporeal substance) operates independently of body, Aquinas designates it as something subsistent.”
[89] This is in accord with the Christian belief that personal identity remains after death.
[90] *ST*, Ia, Q.75, Art.2. In a state of independence from the body he argues that the soul is able to engage in operations *per se*, as an incorporeal knowing substance. He writes of the soul as “substantial form”.
[91] *ST*, Ia, Q.87, Art.1.

immediately apparent that Aristotle and Aquinas firmly ground their discussion in material reality. Aquinas writes, for example, "It belongs to the notion of this particular man to be composed of this soul, of this flesh, of these bones."[92] [93]

In this section we look briefly at the psychology that follows from an hylomorphic notion of substance, and in particular an hylomorphic understanding of the relationship between the rational soul and the body. This is of essential significance to this study which looks in detail at the interconnection between rationality, and bodily emotion and passion. It is within rational psychology that Aristotle and Aquinas developed their understanding of virtue and its role in human action and fulfilment.

I start with the notion that human biology must be attuned to the operations of the soul.

<u>Man is endowed with a body suited to the operations of the soul.</u>

Man is endowed with a "distinctive cluster of faculties including reasoning, that are fundamental to the human way of living and functioning."[94] The soul is the principle of these operations. The most complex relationship exists between the soul and human body. "It was necessary that the intellectual soul be united to a body fitted to be a convenient organ of sense".[95] In other words, the body possesses a suitable potency.[96] Man as a type of animal uniquely capable of rational thought has a body with biology attuned to human operations: cognition, perception, belief; appetite and desire; locomotion, growth, flourishing, and

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[92] *ST*, Ia, Q.75, Art.4.

[93] Royce, *Man and his nature*, 157. Investigation in rational psychology may move inductively (*a posteriori*) from observation of experience and of what man does, to conclusions about his abilities, powers and principles of operation, to conclusions about the kind of being he is, his nature, essence and ultimate principles of being. Investigation may also proceed by reasoned analysis (*a priori*). For example, applying the principle of finality to cognition, a form possessed by the knower, we can say that this form must be for the sake of something else.

[94] Stevenson and Haberman, *Ten Theories of Human Nature*, 94.

[95] *ST*, Ia, Q.76, Art.5.

[96] Stevenson and Haberman, *Ten Theories of Human Nature*, 89. Aristotle presents the soul as the cause of life and principle of operations, but also satisfies the demand for a certain overlap with the b*ody.* "According to Aristotle, even thinking (the privileged sphere of the rational soul) involves the body drawing on the imagination and sense experience for its data."

decay. These correspond to the three powers of the human soul: the rational, sensitive, and vegetative.[97]

It is inaccurate to suggest that the soul as the life principle of the body operates through the body, as if the body were a *mere* instrument. Torchia writes, "If powers are related to the soul, it is because the soul is their cause or principle, not necessarily their subject."[98] When the soul animates the body there can be only one subject operating, the person, the ensouled body. There is no other possibility. Aquinas insists that we understand not because we are moved by our intellects, but that we are moved by our intellect because we understand, because we are rational.[99] Hence, intellect is not just another cause among physical causes.[100]

Rationality embraces the whole person but it will be argued there is a dependence of rationality upon the body as upon a material cause.[101] This carries enormous significance in this current study. All human operations, including rationality, are conducted with cooperation of the body. While the soul is always the "principle of action", in its united state, it is the person, animated body, who acts.

<u>The process of knowing.</u>

Aristotle and Aquinas insisted that the pursuit of knowledge is fundamental to the human psyche, "All humans desire to know by nature"[102] and that this pursuit of wisdom is characterised by knowledge of first causes.[103] For this task man

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[97] Royce, *Man and his nature*, 148. Aristotle and Aquinas "preferred to talk about a substantial form which was human but virtually animal and vegetative."

[98] Torchia, *Exploring Personhood*, 137. Torchia then proceeds with less clarity, open to the misinterpretation that the soul can somehow be the subject of action in embodied form: "While some operations of the soul (eg understanding and willing) are performed without the body (and corporeal organs), others (eg sensation) have the composite human being as their subject." The composite human being cannot but be the subject when the soul is embodied and therefore by necessity, all operations of the soul in an embodied state are performed with the body.

[99] *ST*, Ia, Q.76, Art.1.

[100] In a similar way, Socrates had refuted the naturalists and argued the soul to be the ultimate cause of the body's life. Plato, *Phaedo* 96a – 100e.

[101] Note enriched notions of causality in **6.4.2.2**.

[102] Aristotle, *Metaphysics* 980a. (Hereafter *M*.)

[103] *M*, 981a – 982b.

possesses non-material powers of rationality: the intellect (our power to understand).[104] [105] [106]

Knowledge starts with sense impressions. According to Aquinas, man uses his senses to grasp realities external to himself. Raw sense information informs memory, imagination and appetites, impulses and drives, emotions and passions. And at the rational level, this information may inform simple apprehension, judgements (including conscience), reasoning, rational desires, and choices. This accords with the scholastic adage: *"There is nothing in the intellect that was not previously in some way in the senses."* [107]

Motivation and action.

The intellect has being as its object; the will, which is the power of the soul to choose and to love, has that which is good for one's nature as its object. [108] Just as we can be moved by sense appetites, the will is our intellectual appetite. Aquinas defines will as a rational appetite in keeping with the rationality we find in the human soul. We seek what our bodies or our intellects perceive as good.

Our appetites sideline rational decision-making when we act impulsively to satisfy that appetition, be it hunger or the craving of a kleptomanic; alternatively our sensory appetites inform our rational choices when behaviour is consequent to the judgements we make in our will. [109] We will see this has great relevance in the action of the moral virtues.

[104] *ST*, Ia, Q.76, Art.2.

[105] For an succinct review of proofs of the immateriality of the intellect: Royce, *Man and his nature*, 91-105.

[106] *ST*, Ia, Q.76, Art.1:"The human soul is the highest and noblest of forms. Wherefore it excels corporeal matter in its power by the fact that it has an operation and a power in which corporeal matter has no share whatsoever. This power is called the intellect."

[107] Royce, *Man and his nature*, 126.

[108] *ST*, Ia, Q.76, Art.2.

[109] Royce, *Man and his nature*, 155-6: "... psychology uses a great variety of terms to describe (appetition): motivation, orexis, conation, dynamics. ... paired terms are sometimes used, such as attraction-aversion or approach avoidance."

Will is this power of rational appetition.[110] In a well balanced personality, our choices are based on an appreciation of the facts. Normally our intellect, assisted by our emotions, and with sound convictions and reasoning processes, guides the judgements and choices of our will.

Emotions and passions.

Embodied souls have emotions "*passiones animae*", essentially physical phenomena, involving "some physiological modification".[111] People are agents with desires, purposes and goals, and their actions are performed by virtue of intellect and will. People chose in accord with what they know.

Emotions and passions are closely linked to our senses, but, as we have seen, require the guidance of reason. We are a package deal; our happiness is linked with use of our reason to manage our choices, our passions and our emotions. Ultimately our actions all may be traced back to considered or impulsive choices, to well or poorly managed passions and emotions.

Human acts.

Aquinas distinguishes acts of a human being (*actus hominis*) from human acts (*actiones humanae*), genuinely moral acts. The acts of a human may not necessarily involve reason, whereas human acts are rational and voluntary - acts motivated by reason. Aquinas argues that "That over which we hold mastery can be said to be voluntary."[112] He accepts that animals can undertake limited forms of voluntary action.[113]

Virtues and vices.

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[110] *ST*, Ia, Q.83, Art.3.3.
[111] *ST*, Ia-IIae Q.22, Art.3.
[112] *ST*, Ia-IIae Q.6, Art.3.
[113] Brian Davies, "Being Human" in *The Thought of Thomas Aquinas* (Oxford: OUP, 1992), 221.

Habitual dispositions for positive human acts are known as virtues. [114] Human life is not limited simply to isolated acts, episodic and detached from the bigger perspective; this can overlook the importance of action on the basis of "*habitus*"[115], dispositions. "For Aquinas, *habitus* ... puts one's activity more under one's control than it might otherwise be."[116] The concepts of *habitus* ("an acquired quality that we change only with difficulty" according to Thomas) and connaturalisation are essential to the notion of virtue.[117]

<u>Cardinal virtues.</u>

The four cardinal virtues are the umbrella habits that accord us effective management of our thinking, and of our passions and feelings. In a well rounded personality, through these four habits we maintain a level of management over our passions, acknowledging their aptitude for the good, but not surrendering to them.

Of the four cardinal virtues, sound judgement refers to effective management of our thinking. But the other three help us manage our passions, feelings and relationships so that passions and feelings do not manage us, and so that we truly respect others. For example, without self control, our passions of desire or anger could dominate our decision-making. Without fortitude, our fears would stop us thinking clearly, and without responsibility to keep our self love in check, our decisions could neglect our duties to others.

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[114] *ST*, Ia-IIae, Q.49, Art.1: "A disposition is a state which is either a good state or a bad state for its possessor either absolutely or relatively." (Aquinas is referring to *M* 1022b10ff.)

[115] *ST*, Ia-IIae, Q.6, Art.7. cf *ST*, Ia-IIae, Q.6, Art.6.

[116] Davies, "Being Human," 225.

[117] C. S. Titus. "Moral Development and Connecting the Virtues: Aquinas, Porter, and the Flawed Saint" in Reinhard Hütter and Matthew Levering (ed.), *Ressourcement Thomism: Sacred Doctrine, the Sacraments, and the Moral Life* (Washington, D.C.: Catholic University of America Press, 2010), pp. 330-352. He writes: "A *habitus*, as an operational disposition that involves rational, volitional, and emotional qualities, is unlike the habit of tying one's shoes without looking. It requires not only continued congruous acts in theoretical and practical matters (depending on the type of quality), but also creativity in novel situations. It involves the intelligence and creativity to bring the general notion of justice, for example, to adjudicate a dispute between neighbors about a broken window. *Habitus* is a quality that disposes one to act and that becomes a second nature *(connaturalis)."*

Human fulfilment.

In the *Nicomachean Ethics* Aristotle addressed human fulfilment. He argued that human flourishing is to be found most perfectly in the life of the mind. Aristotle wrote in the *Nicomachean Ethics* of "The life of the intellect (as) the best and most pleasant life for man".[118] Both Aristotle and Aquinas held that, nevertheless, a less perfect beatitude is to be found in the practice of moral virtue as it is disposes us to rational operations, and hence to contemplation.

Further Aristotle and Aquinas regarded man as a social animal.[119] Rationality may be seen as the capacity for loving personal relationships. In this sense, intelligence and virtue are at the service of freedom and love. [120] [121]

Flashing insights into the truth of things nor the instants of choice characterize us as rational. Our rationality is a state of being. It is an abiding participation in the capacity for rational thought and choice that empowers us to know ourselves, to understand the real world in which we operate as agents, but at the same time to stand above that world, capable of altering it and of discovering in it the pleasures of loving relationships.

Aquinas argued that only God can fulfill a composite of a body and a soul with a capacity for infinite good. [122] Love of God in the will is better, in this sense, than

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[118] *NE* X 7,9; cf *NE* X 8,7 where Aristotle writes, "Among human activities that which is most akin to the divine activity of contemplation will be the greatest source of happiness."

[119] *NE* 1097b11.

[120] Davies, "Being Human," 220. Davies writes, "Intellect is that by which one recognises what is true. Will... is a matter of being drawn to things insofar as one knows them and is attracted to them".

[121] In Aquinas' worldview, the concept of personal loving relationship extended to the Divine Being. The relationship of man with the First Cause fascinated Aquinas. Torchia writes, "Any attempt to penetrate the richness of Aquinas's anthropology must address how humans stand in relation to their creator and how they exist within the larger scheme of creation." (Torchia, *Exploring Personhood*, 128.) Aquinas taught that man has what he calls "obediential potency" for elevation to the supernatural life. He linked activation of this potency with man's ultimate fulfilment.

[122] In *ST*, Ia-IIae, Q.10, Art.2 Aquinas argued that an object perceived as "universally and from every point of view" good moves the will necessarily. "The will cannot but will it." He called "beatitude" this adherence to the greatest of goods.

knowledge of God in the intellect.[123] Thomas says the human will is in a state of potency to its *summum bonum*, the ultimate Act of Being.[124] The will cannot be moved necessarily by any created finite good; it is only "our rational apprehension of an unqualified good (that)... frees us from ... attachment to any finite good". Man may only be fulfilled, ultimately, in love of God. He argued that this capacity to love is a consequence of rationality, which in turn, is disposed to perfect operation by virtue. [125]

He argued that it is the potency for a loving relationship with God as first cause and final end of the person, that bestows on each human person an intrinsic dignity. Man's fulfilment is in the activation of this potency. "...all things exist to the extent that they share in God's self-subsistent *esse*, all things desire to be like God as their final end. Accordingly to become like God is the ultimate goal and completion of all things."[126]

This lies beyond the strict scope of this study.

1.4.3 Restoring the hylomorphic notion of person.

The concept of person (**1.4.1**) within an hylomorphic understanding of reality provides a powerful alternative to the current fragmentation of approaches that characterize contemporary explorations into philosophy of mind. In this section following a brief overview of how different schools of philosophical thought have approached the concept of person, and I outline certain advantages that the notion of person offers for reaching valid conclusions about human agency including virtue development.

Overview of changing understanding of person.

[123] *ST*, Ia, Q.82, Art.3.
[124] *ST*, Ia, Q.105, Art.4.
[125] Torchia writes, "Humans differ from other finite creatures to the extent that they are able to internalise reality through their intellect and even grasp something of the infinite majesty of God." (Torchia, *Exploring Personhood*, 148.)
[126] Torchia, *Exploring Personhood*, note on 152 cites Aquinas, *Summa contra gentiles,* II, 20.

Aristotelian-Thomistic anthropology presents an integrated vision of the material and the rational in the human person. Torchia articulates the view that perceptions of personhood have moved through relatively distinct phases. Plato and Aristotle reached an understanding of humans in generic terms, as *anthropos* or *homo.* The Christian era, viewing persons as individual, unique and relational, reached a high point in the work of Aquinas. Following the Cartesian revolution and reactions to it, Torchia identifies a "steady undermining of a metaphysical understanding of a unified abiding self during the modern and contemporary periods".[127]

Essential to the Platonic and Aristotelian vision was the notion of an underlying subject. Plato identified that subject with the soul. Plato argued that the human soul has a non corporeal nature. [128] He was criticized by Aquinas for regarding the soul in the body "as a sailor in a ship"[129] from which the inescapable conclusion had to be that soul and body were distinct things unable to make one composite unity.

Addressing this dilemma, Aristotle argued that the subject possessed both physical and psychic properties. Aristotle in *De Anima* regarded people as composite individuals, "complex unities both mental and physical". [130] Crucially, as we have seen, he proposed that people are ensouled bodies: [131] "We can wholly dismiss as unnecessary the question whether the body and soul are one: it is as meaningless as to ask whether the wax and the shape given to it by the stamp are one."[132] Aristotle argued that semantics must reflect reality.[133]

The neo-Platonic early Christian era built on these understandings. In *City of God* Augustine emphasised the composite model: "Man is not a body alone or a soul

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[127] Torchia, *Exploring Personhood*, xiv.
[128] Davies "Being Human," 212.
[129] SG 2,57.
[130] Davies "Being Human," 209.
[131] Davies "Being Human," 209.
[132] *DA,* 412b6.
[133] Torchia suggests that Aristotle resolves this error at a semantic level, but it would appear that the fundamental principle he defends is metaphysical. Torchia, *Exploring Personhood*, 80.

alone. He is composed of both body and soul."[134] He insisted on an "harmonious union" of the inner spiritual and outer bodily man, and acknowledged the subjective ego: "You stood me face to face with myself..."[135]. In line with Plato and Aristotle, he proposed that will underpins personal moral responsibility.[136] The later Augustine referred explicitly to individual person of composite body and soul.

Building on Augustine's concept of "harmonious union", Aquinas argued not only for the dual properties of the one subject, "a compound whose substance is both spiritual and corporeal"[137], and that the mental and physical are notions that are not reducible to each other, but that the soul is the very principle of life. *Anima*, for Aquinas is "that which animates", "that which gives life"; it is "the root principle of life in living things within our experience."[138] There is no "medium connecting the two together". As we have seen above he argued that the soul is the form of the body. "The soul is the substantial form of the body, giving to the whole body and to each of its parts their act of existing and species. Furthermore, the whole constituted of these parts is a substantial unity."[139]

Importantly too, Aquinas took Boethius's landmark definition of person: "*rationalis naturae individual substantia*" [140] (individual substance of a rational nature) adapting it to "a person is a subsistent individual in a rational nature".[141] He argued that substance is the basis of individuality clarifying the equivocal usage in Aristotle who used substance to mean both the individual and the genus.[142] Aquinas thus more clearly reflects the autonomy of the individual.

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[134] Cf. Augustine, *De Civitate Dei*, trans. Marcus Dods (Digireads.com Publishing, 2009) ,13, 24.
[135] Cf. Augustine, *Confessions* trans. Edward Pusey (Digireads.com Publishing, 2009) VIII 7, 16.
[136] Torchia, *Exploring Personhood*, 115.
[137] *ST*, Ia, Q.75.
[138] *ST*, Ia, Q.75, Art.1.
[139] *Aquinas, In De Anima* , trans. John Patrick Rowan (St Louis and London: Herder, 1949) 10, a. 16.
[140] Boethius, *De Duabus Naturis* (n.d.), 4.
[141] *ST*, Ia, Q.29, Art.3. See earlier comments. **1.4.1.**
[142] *ST*, Ia, Q.29, Art.1.

In texts such as *Meditations on First Philosophy,* Descartes interpreted personhood in terms of consciousness. In a dualist paradigm, he identified the person with his mind or soul. He held that mental stuff (mind) and physical stuff (body) are distinct but connected, and able to influence each other. He argued that persons are identical with their minds but not with bodies. “I have a body that is closely joined to me”.[143]

The immediate successors of Descartes, Geulincx (1625-69) and Malebranche (1638-1715), rejected interaction of soul and body, and in its place advocated occasionalism, a psychophysical parallelism dependent on God’s intervention, with a denial of causality.[144] This denial of common sense helped to provoke the intellectual reaction that sought no further explanation for human behaviour in an incorruptible and immaterial mind.

In the centuries following the Cartesian revolution, the concept of person was effectively lost under pressure from empiricism.

Once we discard any metaphysical understanding of personhood and dismiss any non-material dimension we are left only with the perceptions themselves.

John Locke (1632 – 1704) argued that personal identity derives from consciousness.

> To find wherein personal identity consists, we must consider what person stands for, which, I think is a thinking intelligent being, that has reason and reflection, and can consider itself as itself, the same thinking thing, in different times and places, which it does only by that consciousness which is inseparable from thinking.[145]

[143] Rene Descartes, *The Philosophical Writings of Descartes*, trans. John Cottingham, Robert Stoothhoff, and Dugald Murdoch (Cambridge: Cambridge University Press, 1985), ii. 54.
[144] Torchia, *Exploring Personhood*, 178-179
[145] John Locke, *An Essay Concerning Human Understanding*, ed. AD Woozley (NY:New American Library, 1964), 2:27,9.

The empiricism of Locke was followed by Hume's arguments against consciousness and person. Finding his antecedents in Francis Bacon (1561-1626) and Newtonian physics, Hume (1711-1776) employed a mitigated scepticism that questioned the dogmas of metaphysics. The impact of the new science was felt everywhere, mathematics focused on efficient causality, and a demand that conclusions should be evidence based.[146] He argued that "We have no perfect idea of anything but of a perception. A substance is entirely different from a perception. We have, therefore, no idea of a substance."[147] Ultimately, he argued that human beings are no more than "bundles" of perceptions.

These reactions have led to the physicalist, the functionalist and the non reductive materialist views of the last seventy years. The physicalist understanding of the person, widely encountered in contemporary neuroscientific literature and contemporary philosophy of mind, regards people as only made of matter, for example:

> According to the Identity Theory, persons are identical with a set of physical states or events just as lightning is identical with electrical discharge, or just as the Morning Star is identical with the Evening Star.[148]

Somewhat ironically numerous commentators have pointed out that the physicalism appears as much a reaction to the inadequacies of dualism as a conviction in materialism. Of course both dualism and physicalism contrast with Aquinas's view of what people are.[149]

More recent approaches have blended physicalist and functionalist approaches. Daniel Dennett, dismissing a qualitative distinction between matter and spirit, ascribes personhood according to function and behaviour, the fulfilment of

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[146] Torchia, *Exploring Personhood*, 185.
[147] *David Hume, A Treatise of Human Nature: Being an Attempt to introduce the experimental Method of Reasoning into Moral Subjects.* (1739–40) Books I, IV, V. Cited in Torchia, *Exploring Personhood*, 185.
[148] Davies, "Being Human", 208-9.
[149] Davies, "Being Human", 208.

experimentally verifiable descriptors. He proposes six conditions for personality: rationality, intentionality, an attitude or stance towards intentionality, reciprocity, verbal communication, and consciousness in some special way (eg self consciousness).[150] [151]

Reductionist (or, more properly, eliminative materialist or epiphenomenalist) understandings have replaced teleological understandings of the person. For some, selfhood is essentially denoted by conscious experience.[152]Dennett also targets Cartesian dualism, insisting that there is "no Cartesian Theatre"[153], in other words references to the mind derive from Cartesian misconceptions.[154] His work represents a current endpoint of reductionism. See "Fictionalism" in **Table 1.1**.

Francis Crick has harnessed the neuroscience in a further strain of contemporary reductionism. He writes, "The Astonishing Hypothesis is that 'You,' our joys and your sorrows, your memories and your ambitions, your sense of personal identity and free will, are in fact no more than the behaviour of a vast assembly of nerve cells and their associated molecules."[155] See "Competition for Executive Control Accounts" in **Table 1.1**.

Searle is a proponent of non reductive approaches. He emphasises the subjectivity inherent in consciousness which he compares in some ways to "a surface feature

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[150] Daniel C Dennett "Conditions for Personhood" in *The Identities of Persons*, ed. A. O. Rorty (Berkeley: UC Press, 1976), 175-96.

[151] Michael Tooley, "Personhood" in *A Companion to Bioethics* ed. Helga Khuse and Peter Singer (Oxford: Blackwell, 1998), 120. Of the same ilk, Michael Tooley cites seventeen properties for personhood: consciousness, preferences, conscious desires, feelings, the ability to experience pleasure and pain, the ability to think, the capacity for self consciousness and rationality, a temporal awareness, memory of past actions and mental events, the ability to plan a future for oneself, momentary interests, the unification of desires over time, rational deliberation, the ability to choose between alternative courses of action based on moral considerations, character traits that change in a non chaotic manner, and the ability for social interaction and communication with others.

[152] Torchia, *Exploring Personhood*, 266.

[153] Daniel Dennett, *Consciousness Explained* (London: Little Brown and Company, 1991), 445.

[154] Torchia, *Exploring Personhood*, 266

[155] Francis Crick, *The Astonishing Hypothesis: the Scientific Search for the Soul* (NY: Scribner's, 1994), 3.

of physical systems".[156] Consciousness is simply bracketed off, too hard to explain, but material by definition. See "Biological Naturalism" in **Table 1.1**.

Chalmers also resists reductionism but his epiphenomenal approach fails to bridge the mind body divide. Nevertheless his work has highlighted the transcendent nature of consciousness.

> Even such "revolutionary" developments as the invocation of connectionist networks, non linear dynamics, artificial life, and quantum mechanics will provide only more powerful functional explanations... but the mystery of consciousness will not be removed.[157]

See "Epiphenomenalism" in **Table 1.1**.

Simultaneously, there are various other currents which have defended the "person". Bernard Williams, pursuing a non Aristotelian, relativistic, anti-utilitarian approach, argued that if there is no body there can be no person, and that human identity is necessarily bodily, although body is seen as a separate substance, not integrated to the mind.

Henry P. Stapp, Evan Harris Walkers and others, including Roger Penrose, have proposed a quantum theory explanation of consciousness. Some, among them Jeffrey Schwartz[158], have seen this as a way of preserving a spiritual dimension to the human person, but it appears essentially to be another form of non reductive materialism, in this case proposing that sub particle physics can have something to tells us about the soul.[159] Essentially it is another physicalist explanation for the mind body connection. See "Quantum Indeterminism" in **Table 1.1**.

<u>An enriched understanding of "person".</u>

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[156] Torchia, *Exploring Personhood*, 266.
[157] David J Chalmers, *The Conscious Mind: In Search of a Fundamental Theory* (NY:OUP, 1996), 121.
[158] Schwartz and Begley, *The Mind and the Brain*.
[159] See for what seems to be a surprisingly positive discussion of this theory: Torchia, *Exploring Personhood*, 268-271.

It was not until the early 20th century that there was a rediscovery of "person" through the philosophy of Jacques Maritain and others. Much of this work is inherently attuned to hylomorphic theory.

In recent decades through Karol Woytyla's (the future Pope John Paul II's) articulation of "personalism", the notion of the person as "an objective entity, which as a definite subject has the closest contacts with the whole (external) world, and is most intimately involved with it precisely because of its inwardness"[160] has gained traction. Woytyla's notion of person is founded broadly and synthetically on hylomorphic principles. He writes of the distinctive character of the person, having an "inner life", "of whose nature reason is a property"[161], and with the power of free will, of self determination. [162] He proceeds to argue that love is "always a mutual relationship between persons"[163], in fact, "the unification of persons"[164] and it is the "authentic commitment of the free will of one person (the subject), resulting from the truth about the other person."[165] He says, "Freedom exists for the sake of love."[166] Woytyla proposes a vision of human fulfilment in which our materiality and sexuality are truly integrated with rationality. He provides a philosophical defence of human rationality and freedom, and a vision of human flourishing dependent upon the integration of the spiritual and material properties of man. It is significant that Woytyla ties his discussion explicitly to Aristotle's *Nicomachean Ethics.*[167]

Furthermore, without a vision of the integration of the rational and the material, it is *not possible* to attribute to man non-material goals.[168] Charles Taylor writes:

> A self or person ... is not like an object in the usually understood sense. … We don't have selves in the way we have

[160] Karol Woytyla, *Love and Responsibility*, trans. HT Willets (NY: Farrer, Strauss, Giroux, 1981), 23.
[161] Woytyla, *Love and Responsibility,* 22.
[162] Woytyla, *Love and Responsibility,* 24.
[163] Woytyla, *Love and Responsibility,* 73.
[164] Woytyla, *Love and Responsibility,* 38.
[165] Woytyla, *Love and Responsibility,* 123.
[166] Woytyla, *Love and Responsibility,* 135.
[167] Woytyla, *Love and Responsibility,* For example: 86.
[168] See my argument in Appendix 1d.

> hearts and livers.... We are only selves insofar as we… seek and find an orientation to the good.[169]

Note these analyses also would not be possible without the hylomorphic foundation.[170]

Torchia has noted the postmodern tendency to separate human nature from moral personhood, an approach at contradiction with Aquinas's definition of person as an individual subsistent reality. Torchia writes, "A qualitative sense of personhood must rest on a fundamental metaphysical one, as the core of our humanity and individuality."[171]He notes the scepticism or even hostility of many contemporary thinkers to the claim that there is a set of universal human traits grounded in a stable abiding "nature" which all humans share (simply by virtue of their humanity.)[172] This is found, for example, in the work of Peter Singer.

In another line of investigation relevant to the task of this study, Haldane and Torchia both question the possibility of consciousness studies offering a way forward in philosophy of mind. Haldane comments, "Contemporary philosophers of mind confirm the persistence of Cartesianism in their preoccupation with the status of qualia. I remain agnostic about the possibility of a naturalistic account of qualia."[173]

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[169] Charles Taylor, *Sources of the Self: the Making of Modern Identity* (Cambridge: Cambridge UP, 1989), 34.

[170] Bewailing that "there seems no rational way of securing moral agreement in our culture", Alasdair MacIntyre also adopts both the teleological understandings of Aristotle and the Aristotelian-Thomistic understanding of human nature, in order to mount a philosophical defence of a morality founded upon the rationality of man's nature. Torchia writes, "In MacIntyre's project we find an ongoing attempt to come to grips with the fragmentation of moral conversation by means of a teleological understanding of human nature rooted in Aristotelianism and, in broader terms, in the Thomistic tradition of inquiry." MacIntyre proposes a critique of contemporary relativism and perspectivism, and is scathing of the post modern neo-Enlightenment which, failing to recognise rationality in traditions, has raised self to moral sovereign, and stripped moral rules of their teleological grounding. (Alasdair MacIntyre, *Whose Justice? Which Rationality?* (Notre Dame, Ind: UND Press, 1988), 348. Alasdair MacIntyre, *After Virtue* (Notre Dame, Ind: UND Press, 1981), 6.)

[171] Torchia, *Exploring Personhood*, 248.

[172] Torchia, *Exploring Personhood*, 3.

[173] John Haldane, "A return to form in the philosophy of mind," *Ratio* 11, 3 (1998): 253-277.

In like vein Torchia writes that personal identity is not based only on continuity of self awareness but "rooted in enduring human nature that persists in the midst of accidental changes flowing from the substantial union of soul and body. This is why humans require a metaphysical explanation that is more encompassing and penetrating than any scientific account of any biological or biochemical processes."[174]

The discussion in **1.4.1 - 3** highlights the significance of Haldane's analysis above: that the current impasse in philosophy of mind can only be broken by a metaphysical breakthrough about the nature of man. Torchia concludes, "Once we define ourselves as embodied spirits, the insolubility of the modern mind-body problem is effectively neutralised."[175] The physicalist backlash to dualism has ultimately failed to explain human nature and human behaviour. A richer understanding is needed.

1.4.4 Advantages offered by an hylomorphic notion of person.

Serious deficiencies arise in discussion of the human being or human agency when the hylomorphic notion of person is lost:

i. The concept of an underlying subject is easily compromised. Man becomes equated either to his mind, or to his physiology. To equate man to his mind implies a loss of dignity of the body. To equate him to his physiology implies a loss of dignity and a denial of any necessary distinction between human nature and animal nature.
ii. A loss of the concept of form, a loss of the notion of an animating principle for matter, opens the way to a dual substance view in which matter and man's actions can be too easily diminished in comparison to subjective perceptions and intentions, and in which it becomes impossible to explain satisfactorily psychic causality of the physical (or better to say "non-

[174] Torchia, *Exploring Personhood*, 139.
[175] Torchia, *Exploring Personhood*, 271.

material causality”). Ultimately this line of thinking leads, as in the work of Hume, to a denial of the very principle of causality.

iii. A loss of this integrity of mind and matter also makes it very difficult to account for the interaction between thought and emotion, or to account for choice and election of action. Ultimately too, it diminishes the dignity of human sexual relationships, expressed bodily.
iv. A lack of understanding of the potential of the hylomorphic explanation for the human person has led, in neuroscientific circles, to the assumption that all theories of a non physical component to the human person have a substance dualism at their core.
v. We have seen that explanations for the interaction of the material and the rational resort either to some form of non reductive physicalism or epiphenomenalism. These non reductive approaches assume there to be no metaphysical difficulty in accounting for rationality within such frameworks. They are unable however to provide a satisfactory physicalist or epiphenomenalist explanation for the hylomorphic conclusion that rationality must be considered as a spiritual power because it permits the possession of truths which are universal, not just particular. (See Appendix 1.)
vi. The lack of a satisfying rational psychology opens the door to empiricist, behaviourist, and functionalist approaches, in which a richer metaphysical explanation can be dismissed as inaccessible, irrelevant, or simply too hard.

And this, I suggest, is precisely what has happened.

An Aristotelian-Thomistic understanding of person provides:

i. An effective response to physicalist understandings that deny the possibility of human freedom. (See **1.3** and **Table 1.1**).
ii. A scientifically coherent alternative to dualist understandings for the interaction of body and mind. (In the process I will draw attention to the simplistic understanding of non-materialism, considering all proponents as dualists, by many in contemporary neuroscience.)

iii. A satisfying epistemology that accounts for the interaction of human being with the material world.
iv. A metaphysical basis for human dignity. Human dignity is founded not in our rationality, as such, but in the fact that we have a rational soul. [176] As persons we are unique, having our own personal dignity, and we are at the same time, relational. This is the core of Aquinas' doctrine of the person.[177]

1.5 An hylomorphic critique of 20th century currents in philosophy of mind.

In this section I argue for the legitimacy of an hylomorphic approach to philosophy of mind. In the light of the preceding understanding of the human person, it is possible now to offer a critique of 20th century currents in philosophy of mind and to argue that a philosophy of mind founded upon an hylomorphic notion of the human person offers distinct advantages.

By offering an understanding of how the material and non-material can coexist and interact as properties of a single substance, hylomorphism provides a robust foundation for a philosophy of mind and a framework for criticism of other approaches to brain and mind, and of freedom and virtue.[178] The integration of material and non-material properties offered by hylomorphism stands in constrast to one-or-the-other understandings of the material and mental offered by what

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[176] *ST*, Ia, Q.75, Art.1.
[177] Torchia, *Exploring Personhood*, 139-140. Torchia writes,"Aquinas's understanding of humans as substantial unities of soul and body implies that the soul (as an act of the human composite) cannot be confined to (or localised in) some part of the body (eg the brain) or bound up exclusively with physiological processes (eg brain wave activity, consciousness, or receptivity to feelings of pleasure or pain.)... rationality is not viewed as a behavioural characteristic, in Aristotelian terms, an accidental property. Rather it assumes a definitional significance, as a means of designating those who are spiritual and intellectual beings by their very nature, regardless of the quality of their rational output."
[178] Raymond Tallis and Peter Hacker each criticise reductive materialism as predicated on the same assumptions as dualism, that it is "crypto-cartesianism", because it conceives only of substances either material or non-material. (P. M. S. Hacker and Raymond Tallis, "Are Persons Brains? The Challenge of Crypto-Cartesianism - P. M. S. Hacker and Raymond Tallis" Youtube. Accessed 22.10.12.) Arguably however the same criticism could be levelled at Tallis' own non reductive emergent view. Hacker's pure Wittgensteinian silence is more difficult to buttonhole. In contrast however, the hylomorphic theory of substance opens a new Pacific of possibilities.

can be seen as the three basic approaches to philosophy of mind: dualism, reductionism, and eliminativism.[179]

John Haldane's writings on the advantages of an hylomorphic approach to philosophy of mind emphasize the necessity for a metaphysics that permits material and non-material properties to be integrated. He argues that beneath thought and action we must discern the acting person: "A correct account of the nature of persons will include, as essential aspects, accounts of the nature of thought and of action, since these are the primary modes of activity of those beings whose nature is that of persons."[180] His work in this field offers an approach and credibility for the hylomorphic underpinnings of this study.

Hylomorphism offers a number of advantages over competing ontologies utilised in philosophy of mind debate.

i. Progress on the knotty mind-body question is possible once we accept the hylomorphic premise that "do follows be", that actions follow upon the nature of the entity. Hylomorphism offers an understanding of the nature of persons, and of the metaphysical priority of person over thought and action.[181]
ii. The perennial difficulty for philosophers of mind to explain how mental phenomena could possibly cause physical events appears overcome using an hylomorphic framework.[182]

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[179] Georges Rey, *Contemporary Philosophy of Mind*. (Cambridge MA: Blackwell, 1997).
[180] Haldane, "A return to form in the philosophy of mind", 49.
[181] The application of the concept of person to philosophy of mind has some history. In 1958 P.F. Strawson argued that the concept of person is more basic than that of a person's mind or body, observing, "We routinely attribute to the very same thing, persons, both material and mental properties: I walk, and sleep, as well as think and feel." (For reference see: Kirk Ludwig, "The Mind-Body Problem: An Overview" in *The Blackwell Guide to Philosophy of Mind,* eds. Stephen P Stich and Ted A Warfield (Cambridge MA: Blackwell, 2003), 17.
[182] Descartes proposed matter and spirit, body and mind, to be irreconcilable realities, separate substances, though causally interacting. On the other hand hylomorphism proposes that matter and spirit differ in degree not in kind; Aquinas says they differ in their degree of perfection of being, and that they are properties of the substance, not substances in themselves. Although D. M. Armstrong argues that the "considerable difficulty and confusion which surrounds the philosophical theory of properties" poses a challenge for the "one substance view" which includes hylomorphism, nevertheless the one substance view of hylomorphism is not only rigorously articulated but is consistent with the facts of human experience. See D. M. Armstrong, "Mind body

iii. A further nagging problem for philosophers of mind has been to offer an explanation for mental responses to the environment. Hylomorphic philosophers argue that it is that we possess the object itself in our intellect, a conformity of mind to thing; we do not "perceive visual experiences, we have them" as Putnam says in the Dewey lectures.[183] Haldane too recognises the fertile ground here for hylomorphism to offer a clear understanding of the intersection of mental and physical.[184]

iv. Causality, since Descartes, has been a central issue in the mind-body problem. Again hylomorphism offers a way forward with its rich understanding of causality and the distinction it offers between efficient and formal causation.[185]

v. Haldane argues that an hylomorphic understanding of substance permits an effective critique of both dualism and materialism as flawed philosophical notions.[186] (See also **6.4.2**)

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problem: philosophical theory," in *Oxford Companion to the Mind,* 2nd ed., ed. Richard L Gregory (Oxford: OUP, 2004).

183 Hilary Putnam, "Sense, Nonsense and the Senses: An Inquiry into the Powers of the Human Mind," *Journal of Philosophy* 91 (1994): 445-517 at 453-4.

184 Haldane argues that a well articulated hylomorphic account protects realism from falling into conceptual relativism because it offers an understanding of how perceptions are grasped objectively. He draws on the hylomorphic notion of form, that which "makes something to be what it is", "informing" of the kind of thing something is. Form is act; the hylomorphic notion of prime matter is pure potentiality. Matter makes individuals of the same form distinct; where there is universality there is no matter. Concepts in the intellect are particular types of forms. Concept and substantial form "though distinct in the modes of their actualisation, *in esse naturale* as opposed to *in esse intentionale*, are specifically alike." Haldane argues that thought is *intrinsically* related to its object because it shares the same form.

185 Haldane argues that formal causation in knowing must not be confused with efficient causation, which is the pathway for material causation. Yes there is efficient causality acting on the organ of sense but the result is a formal change. We take in formal causes under the material conditions of changes of sense and therefore with particularised qualities. See below: **6.4.2.2.**

186 In discussing current attribute dualists who suggest that the higher region of the brain is a physical substance "with some non-physical properties", Haldane argues that "a proper understanding of substantiality should lead one to reject the idea that a wholly physical particular could be the bearer of intrinsic attributes that are non-physical. The error of the Cartesian is to suppose that non-physical attributes imply an exclusively incorporeal substance as bearer." Hylomorphism is equally effective against the fundamental tenets of materialism whether it takes the form of eliminative materialism, behaviourism, identity theory, central state materialism, functionalism, anomalous monism or any of the other forms of non reductive materialisms. "If thought is a non physical activity as I have argued that it is, then the intellectual powers are not physical; nor, therefore, can the substance to whose nature the powers belong." Haldane, "A return to form in the philosophy of mind," 58.

vi. An hylomorphic analysis urges a radical departure from philosophy of mind's dead-end preoccupation in recent years with consciousness and the notion of qualia. It is not the way we feel about reality that gives us a non physical dimension, it is a reflection of our nature itself. An hylomorphic analysis permits a return to being away from both epistemological and metaphysical idealism.[187]

vii. The hylomorphic ontology is very much in keeping with, and provides an explanation for, our intuitions of being, our observations of human freedom, of human action and causation, and of teleological motivation.[188] The hylomorphic approach is in keeping with the widespread acceptance of human freedom. Without an understanding of substance that integrates the material and non-material as properties, neural explanations for consciousness, intentionality and qualia must remain as mechanistic and deterministic. It is time for a radical return to the ontological basis of subjective experience.

Table 1.1 An hylomorphic critique of 20th century currents in philosophy of mind (in endpapers) classes the principal currents of philosophy of mind according to categories of irrealism, conceptual reductionism, conceptual anti-reductionism, and ontological antireductionism. These categories, adapted from Ludwig, provide a convenient framework for analysis on a spectrum of physicalism:[189] from radical physicalist, through reductive and non reductive materialism, to ontological solutions. Hylomorphism, described by Haldane as "non physicalist, non dualist, dual aspect" theory is situated in the last of the four categories. [190]The subcategorisations are substantially my own. In the right hand column I offer a

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[187] "Contemporary philosophers of mind confirm the persistence of Cartesianism in their preoccupation with the status of qualia. I remain agnostic about the possibility of a naturalistic account of qualia." Haldane, "A return to form in the philosophy of mind," 57.

[188] It appears that some accept substance dualism, a dualism of the classical property or event variety, in order to uphold teleological motivation. Yet, "the dual aspect monism... of hylomorphism will offer the same advantages." John Bickle, "Philosophy of Mind and the Neurosciences" in *The Blackwell Guide to Philosophy of Mind,* ed. Stephen P Stich and Ted A Warfield (Cambridge MA: Blackwell, 2003), 333.

[189] Malo describes physicalism as the theory whereby everything supervenes in the physical realm. Antonio Malo, "Three theories about freedom" pre publication manuscript, 145.

[190] Ludwig, "The Mind-Body Problem: An Overview," 21.

brief hylomorphic critique for the various lines of thought. For the purposes of refutation, the various subcategories tend to group into recurring themes, broadly though not exclusively: eliminativist, behaviourist and functionalist, reductive and non-reductive emergent, and dualist. If hylomorphism is correct, then we have a solution to the major objection to my thesis: that it cannot relate propositions about the brain to propositions about choice and virtue.

Also by this approach I wish to suggest the incisive potential for an hylomorphic contribution to philosophy of mind and to further justify the position adopted by this current study. It is beyond my scope to offer more a more detailed critique but I do wish to demonstrate that hylomorphism exposes significant weaknesses of irrealism, conceptual reductionism, and conceptual anti-reductionism, and of dualistic forms of ontological antireductionism.

Also in the endpapers is found **Appendix 1. A Response to the Claims of Emergent Rationality by Non-reductive Materialism**. The paradigm of emergent rationality requires a more detailed philosophical response. I argue that acceptance of this position, popularised by both neuroscientists and philosophers, reveals an incorrectly framed inquiry from the start, and that acceptance must lead to a denial of the eudaimonic dimension of virtue.

1.6 Situating this study in current approaches to ethics.

The Aristotelian-Thomistic view of human moral development proposes that human personality, if it is to flourish, requires the development of intrinsic qualities of self management. This study proposes that these qualities, in ways essentially described by Aristotle and Thomas, have a neural substrate.

As the field of the morality of acts, moral behaviour and moral character is broadly described as moral philosophy or ethics, it is appropriate that I briefly situate this study in the spectrum of current approaches to ethics.

During the early period of the second half of the 20th century, the prevailing view was that ethics classified conveniently into two broad groups: [191]

i. Consequentialist ethical theories developed from the utilitarian doctrines of Bentham and Mill. These are essentially teleological approaches in which the ethical nature of an action is derived from the contribution of the action to the well being of human beings. [192]
ii. Deontological (duty based) theories, including ethical systems where moral obligation is primarily derived from a religious or from a purely rational framework. Many of these theories take Kant as their philosophical founder. Kant argued, captured in his “Categorical Imperative”, that ethics derives from “a universal and impartial law of rationality”.

Many commentators now add virtue ethics as a third fundamental category; it is increasingly regarded as a “serious rival” for traditional moral theories of utilitarianism and deontology. [193]

This study, seeking out the neuroscientific aspects of the development and practice of virtue, is situated in the field of virtue ethics.

1.6.1 Some reasons for the growing stature of virtue ethics.

The legitimisation of virtue ethics as an alternative ethical approach is the result of a number of factors. A 1958 paper by Elizabeth Anscombe’s is regarded as the forerunner of this philosophical revival. [194] Her call for a return to the notion of human flourishing founded on the development of virtue was a turning point. She argued forcefully that without a clear psychological understanding, ethics must be unproductive, that we must “stop doing moral philosophy until we get our

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[191] A view reflected in G. E. M. Anscombe, “Modern Moral Philosophy” in *Virtue Ethics*, ed. Roger Crisp and Michael Slote (Oxford: OUP, 1997), 26-44, and articulated in J. Rawls *A Theory of Justice* (Cambridge Massachusetts: Harvard University Press, 1971.)

[192] Roger Crisp and Michael Slote, “Introduction” in *Virtue Ethics,* ed. Roger Crisp and Michael Slote (Oxford: OUP, 1997), 1-25..

[193] Daniel Statman, “Introduction to Virtue Ethics,” in *Virtue Ethics: A Critical Reader*, ed. Daniel Statman (Washington DC: Georgetown University Press, 1997), 2.

[194] Anscombe, “Modern Moral Philosophy”, 26-44.

psychology straight".[195] Anscombe also took specific issue with modern moral ethicists in the utilitarian tradition for allowing worthy ends to justify means that are unjust.[196]

In the decades since Anscombe's paper, virtue ethicists have argued that virtue ethics offers distinct and inherent advantages over deontological and consequentialist approaches.

i. It has been argued that virtue ethics holds "explanatory primacy", that deontological or teleological ethical systems focusing on moral analysis of actions beg investigation into the qualities of character that give rise to such actions. One virtue ethicist, Gary Watson, sums up this view, "Action appraisal is derivative from appraisal of character... .Basic moral facts are about quality of character." [197] [198]
ii. Virtue based approaches have gained ground for their positivity and flexibility, and for their ability to offer solutions in the myriad of ethical

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[195] Anscombe wrote of "... (the current) huge gap, at present unfillable as far as we are concerned, which needs to be filled by an account of human nature, human action, the type of characteristic a virtue is, and, above all, of human "flourishing". And it is the last concept that appears the most doubtful. For it is a bit much to swallow that a man in pain and hunger and poor and friendless, is flourishing, as Aristotle himself admitted."
Anscombe, "Modern Moral Philosophy", 44
[196] Anscombe, "Modern Moral Philosophy", 44
[197] Gary Watson, "On the primacy of character," in *Virtue Ethics: A Critical Reader,* ed. Daniel Statman (Washington DC: Georgetown University Press, 1997), 58.
[198] This conviction builds on the Aristotelian principle introduced above: "do follows be". At the core of this issue is what Statman calls the "meta-ethical" ethical difference between deontological and virtue ethics. Virtue theory refers to the ethical approach in which "the basic judgements in ethics are judgements about character". Virtue ethicists insist that being is prior to behaviour. The primacy of character view is well illustrated by Swanton's reference to a passage in CS Lewis emphasising the integrative function of virtue: "What is the good of telling... ships how to steer so as to avoid collisions if, in fact, they are such crazy old tubs that they cannot be steered at all? What is the good of drawing up, on paper, rules for social behaviour, if we know that, in fact, our greed, cowardice, ill temper, and self-conceit are going to prevent us from keeping them? I do not mean for a moment that we ought not to think, and to think hard, about improvements in our social and economic system. What I do mean is that all that thinking will be mere moonshine unless we realise that nothing but the courage and unselfishness of individuals is ever going to make any system work properly. It is easy enough to remove the particular kinds of graft or bullying that go on under the present system: but as long as men are twisters or bullies they will find some new way of carrying on the old game under the new system. You cannot make men good by law: and without good men you cannot have a good society. That is why we must go on to think... of morality inside the individual." C. S. Lewis, *Mere Christianity* (London: Fontana, 1955), 68-9. Christine Swanton, *Virtue Ethics: A Pluralistic View* (Oxford: OUP, 2003).

dilemmas that can occur in real life. According to Macintyre, Aristotle sees virtues as effective and explanatory of outcomes in the real world. [199] Swanton praises virtue ethics for "taking seriously the richness of the moral domain, its sensitivity to context and situation, its scepticism about the codifiability of ethics".[200] [201]

iii. It is argued that virtue ethics is more compatible with the dignity of the human person. The inability of both duty based and consequentialist systems to offer approaches that accommodate the dignity of human autonomy has also been pointed out, in that there is an manifest gulf, a schizophrenia, between justification and motivation. It is argued that we are diminished as human beings if we take external principles as our motivation.

iv. Reflecting human dignity, virtue ethics is oriented towards personal relationships. It is argued that in deontological and consequentialist approaches the person disappears under the tyranny of principles; genuine relationships become impossible.[202]

v. Christine Swanton argues that virtue ethics provides an enriched account of automony, an automony that even allows an agent to act apparently sub-optimally, yet, satisficing rationality, in such a way that such behaviour can be a legitimate expression of one's character. (Swanton picks up the economics term originally coined by Herbert Simon denoting a rational approach that stops looking for alternatives once one that is "good

[199] Alasdair Macintyre, "The Nature of the Virtues," in *Virtue Ethics,* ed. Roger Crisp and Michael Slote (Oxford: OUP, 1997), 136.
[200] Swanton, *Virtue Ethics: A Pluralistic View*, 9.
[201] Virtue ethicists argue that utilitarianism and deontology share an obsession with principles as the guide of human behaviour, and that such principle based guidance is too abstract and at times contradictory to be effective. In contrast, virtue ethics proposes moral character as key factor. It is an agent based ethical system.
[202] See discussion with reference to the views of Stocker and Toulmin, in Statman, "Introduction to Virtue Ethics," 6-7.

enough" is found.[203]) Results and consequences are avoided as the ultimate measure for the rightness or goodness of an action.[204]

vi. Beyond simple effectiveness in understanding human behaviours, it is argued that virtues are constitutive elements of human wellbeing.[205] Slote argues that in duty based ethics, the agent's actions are directed to the well being of others but not of self. He argues that this reduces agents to the status of tools to help others, and that this ultimately devalues the moral agent and undermines the Kantian principle that every individual is of intrinsic and equal value. [206]

vii. Virtue ethics provides a view of ethical activity that is perfectly integrated with a naturalistic view of man. [207]

viii. It is argued that virtue based approaches are superior to rule or end based approaches in the way they can accommodate an ethic of care. Carol Gilligan, Nell Noddings, and Annette Baier have developed a "relational ethics" that sits well with virtue ethics.[208]

ix. An ethic of virtue is also most compatible with a rich human psychology that recognizes the contribution of positive human emotion in human decision making and action. Aristotle viewed virtue as "a disposition in which both reason and emotion are well ordered". [209] Anscombe had drawn attention to the "lack of an adequate philosophy of psychology" in Kant and Hume.[210] Cottingham argues:

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[203] Herbert Simon, "A behavioural model of rational choice," in *Quarterly Journal of Economics* 69, (1955): 99-118. Cited in Swanton.
[204] Christine Swanton, "Virtue Ethics and Satisficing Rationality," in *Virtue Ethics: A Critical Reader,* ed. Daniel Statman (Washington DC: Georgetown University Press, 1997), 82-98.
[205] Statman, "Introduction to Virtue Ethics," 6-7.
[206] Statman,"Introduction to Virtue Ethics," 5.
[207] See Statman, "Introduction to Virtue Ethics," 15, for elaboration of this view.
[208] See Statman, "Introduction to Virtue Ethics," 17, for elaboration of this view. Canadian philosopher, Donald De Marco, drawing on the Augustinian tradition of virtue, holds that the capacity to truly love others and to be happy is a consequence of character with a well rounded development of virtues, that it is the presence of virtue that makes the effective expression of love possible. Donald DeMarco's *Heart of Virtue* develops this idea masterfully. He describes virtues as the channel by which love is delivered to others; good intentions are insufficient. Augustine says that charity contains all the cardinal virtues. Cf. D. DeMarco, *The Heart of Virtue* (San Francisco: Ignatius, 1996); Augustine, *Epistle* CLXVII PL33, 738.
[209] Swanton, *Virtue Ethics: A Pluralistic View*, 8.
[210] Anscombe, "Modern Moral Philosophy".

"one of the key insights of virtue theory is that the good life consists in a structured pattern of living... whose fundamentals have to be rooted in a civic culture, a culture in which the right pathways of emotion and action have been laid down in infancy and fostered by long habits of training and upbringing."[211]

The bottom line is that virtue ethics appears more compatible with reflections on aspects of character such as emotion, subjectivity and human relations. [212] Furthermore, as will be seen, in this study I am arguing that virtue ethics is not only compatible with the psychology of emotion, but shares common ground with the neuroscience of effective self management and emotional control.

x. Virtue ethics seems to offer <u>a better understanding of principles of education</u> founded on human psychology. For example, the core of moral motivation is not rules, nor do rules play a key role in moral education. "According to virtue ethics, education through moral exemplars is more effective than education focussed on principles and obligations, because it is far more concrete."[213] (See **6.5**.)

However, when all is said and done virtue ethics resists direct comparison with alternative approaches to ethics. Gary Watson argues:

> To think that an ethic of virtue ... is opposed to duty is a category mistake. Duties and obligations are simply factors to which certain values, for example, fidelity and justice, are responsive. They do not compete with virtue for moral attention... . One's virtues may enable one to endorse, apprehend, correctly apply, or disregard some principle of action. [214]

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[211] John Cottingham "Religion Virtue and Ethical Culture," *Philosophy* 69, (1994):163-80.
[212] Statman, "Introduction to Virtue Ethics," 8.
[213] Daniel Putnam, "Virtue theory in ethics courses", *Teaching Philosophy* 15, (1992): 51-6. See discussion in Statman, "Introduction to Virtue Ethics", 13.
[214] Watson, "On the primacy of character", 60.

The ten reasons above will be further validated by a successful description of the biological bases of virtue. In this study I am arguing not only that neural development harmonises with the development of virtue, but also that virtue ethics constitutes an ethical account that is more attuned to human nature than are the more theoretical accounts of Western ethics.

1.6.2 Within virtue ethics there exists a spectrum of significantly contrasting approaches.

We have looked briefly at advantages offered by virtue ethics as an ethical system. Now we look at the range of approaches within virtue ethics, a field in which there are numerous approaches but one nevertheless in which "... the similarities between species of virtue ethics are more important than their differences." [215]

Various historical approaches to the notion of virtue.

Contrasting understandings of the notion of virtue are not a new phenomenon. Macintyre writes of three contrasting historical attitudes towards virtue. He suggests that: Homer understood virtues as means to empower a person to fulfil a social role; Aristotle and Aquinas focused on virtue as "a quality the exercise of which leads to the achievement of the human telos"; and, Franklin offered a utilitarian account of the virtues as keys to earthly and heavenly success.[216]

According to an alternative view:[217] Socrates, Cicero and Kant share a stoic emphasis on the dignity of virtue, with emphases on piety and courage; Aristotle and Aquinas offer a rich and realistic understanding of virtues as psychological habits; and, Hume transforms virtue into a useful tool to achieve social-political ends.

Divisions according to judgements about character.

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[215] Swanton, *Virtue Ethics: A Pluralistic View,* 4.
[216] Macintyre, "The Nature of the Virtues", 118-140.
[217] Nafsika Athanassoulis, "Virtue Ethics," in *Internet Encyclopedia of Philosophy,* http://www.iep.utm.edu/virtue/ (accessed 15 November 2010).

As we have seen above, virtue ethicists will all agree that aretaic judgements (judgements about character) are prior to judgements about rightness or wrongness of actions. Again there is a spectrum of approaches.

The moderate view is some actions are always abhorrent, and hence that character need not be prior to action. Slote argues "the ethical status of acts is not entirely derivative from that of traits, motives or individuals...."[218] Alderman and Soloman present a more unitary view, either reducing deontic concepts to aretaic concepts, or with Anscombe and Williams, arguing that deontic concepts should be ignored completely. There is also the moral worth view proposed by Audi, whereby virtue "is the sole ground of moral goodness, even though it is not the ground of moral rightness or of obligatory conduct."[219] Similarly, Hursthouse argues that an action is right if it is carried out by a virtuous character. [220]

<u>Divisions according to universality.</u>

Universality provides another lens for assessment of the various contemporary approaches to virtue ethics. Aristotle conceives virtues as human excellences contributing towards a form of flourishing that is perfective of human nature. Aristotle's vision of the rational life is embraced by some contemporary virtue ethicists, such as Foot, Hursthouse, Taylor and Nussbaum; others seek to shrug off Aristotelian metaphysics.[221] Originally MacIntyre claimed virtues are culture specific, but later adopted the Aristotelian position.[222]

<u>Divisions of virtue ethics according to deontological and consequentialist considerations.</u>

The relationship of the various contemporary approaches of virtue ethics to deontology and to consequentialism is complex.

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[218] Michael Slote, *From Morality to Virtue*, (NY: OUP, 1992), 89.
[219] Robert Audi, "Acting from Virtue", *Mind* 104, (1995): 449-71.
[220] Statman, "Introduction to Virtue Ethics," 6-7.
[221] Gregory Velazco y Trianosky, "What is virtue ethics all about?" in *Virtue Ethics: A Critical Reader,* ed. Daniel Statmand (Washington DC: Georgetown University Press, 1997), 47.
[222] R. Hursthouse, "Virtue Theory" in *Ethics in Practice*, ed. Hugh La Follette (Malden MA: Blackwell, 2007), 53.

Virtue ethicists adopt either a teleological view, that virtues permit human flourishing, or a non teleological account, that virtues are worthy in themselves. Rawls understands virtues to be "strong and normally effective desires to act on the basic principles of right",[223] yet virtue ethics stands against this conventional wisdom that would align virtue ethics with deontology. Velazco y Trianosky argues that, in fact, an ethics of virtue and an ethics of duty are radically different approaches to ethical questions, yet each may be either in a teleological or non teleological (deontological) form.[224] Furthermore, these teleological accounts may also be considered from the perspective of consequentialist principles. Trianosky argues that as many virtue ethicists maintain a form of utilitarianism when they argue for the usefulness of the virtues, they are thus teleological in orientation.[225]

Typical of this approach is that adopted by Von Wright: "Virtues... are needed in the service of the good of man. This usefulness of theirs is their meaning and (natural) purpose". [226] Julia Driver also adopts a consequentialist view, viewing a moral virtue as "a character trait (a disposition or cluster of dispositions) which, generally speaking, produces good consequences for others."[227] Other virtue ethicists while teleological may give more importance to intention rather than causality.

Watson suggests that we should consider an ethics of virtue as at once teleological and nonconsequentialist.[228] He points out that Aristotle is regarded by Rawls as teleological, yet he may just as readily be seen as deontological, opposed to consequentialism. He suggests that following Socrates who regarded virtue as the primary constituent of human flourishing, Aristotle saw virtue, human

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[223] Rawls, *A theory of Justice*, 436.
[224] He argues that in a teleological approach, "the rightness of actions or the virtuousness of traits depends on their causal relation to the good". Gregory Velazco y Trianosky, "What is virtue ethics all about?" 47.
[225] Statman, "Introduction to Virtue Ethics," 10-11.
[226] G. H. von Wright *The varieties of goodness*, (London: Humanities Press, 1963), 140.
[227] Julia Driver "The virtues and human nature", 122.
[228] Watson, "On the primacy of character", 57.

excellence, as constitutive of, not instrumental to, human flourishing.[229] This is an important distinction.

It is in this sense that Anscombe, too, is non teleological, while seeking to retain a close connection between virtue and human good. [230] Swanton defends the non utilitarian character of virtue ethics comparing it, for this purpose, with deontological ethics. [231] She too maintains a strong connection between virtue and human flourishing. Others, like Slote, are of a radical non-teleological orientation and prefer not to link virtues to wellbeing. Slote consciously adopts an agent based ethics that regards virtues as admirable traits not tied to the promotion of further good, [232] arguing that it is the intrinsic features of virtue that make it attractive, and even that the "contribution" of virtues to an agent's wellbeing should be disregarded.[233]

Alasdair Macintyre, although adopting a teleological position, offers a meeting point for teleological and non teleological approaches. He insists that virtue is not a means to enjoyment, rather fulfilment and enjoyment are *integral* to the very exercise of virtue. [234]

Virtue empowers from within and cannot be understood as a means to be utilized in the pursuit of happiness. Macintyre's understanding is that virtue empowers us to do things which will bring in themselves fulfilment.

> A virtue is an acquired human quality the possession and exercise of which tends to enable us to achieve those goods which are <u>internal</u> (the outcome of which is a good for the

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[229] Watson, "On the primacy of character", 62.
[230] Gregory Velazco y Trianosky, "What is virtue ethics all about?"
[231] Statman, "Introduction to Virtue Ethics," 11.
[232] Swanton, *Virtue Ethics: A Pluralistic View,* 19-25.
[233] Statman, "Introduction to Virtue Ethics," 10-11.
[234] Macintyre, "The Nature of the Virtues", 135. Macintyre writes, "As Aristotle says, the enjoyment of the activity and the enjoyment of achievement are not the ends at which the agent aims, but the enjoyment supervenes upon the successful activity in such a way that the activity achieved and the activity enjoyed are one and the same state. Hence to aim at the one is to aim at the other; and hence also it is easy to confuse the pursuit of excellence with the pursuit of enjoyment *in this specific sense*."

whole community) to practices and the lack of which effectively prevents us from achieving any such goods.[235]

1.6.3 This study is situated under the umbrella of eudaimonist virtue ethics.

The current study subscribes to a moderate Aristotelian eudaimonist approach in which virtues, acquired and exercised for their own sake, are constitutive elements of human flourishing and wellbeing, denoted sometimes by the Aristotelian term *eudaimonia*.

While, as we have seen, virtue ethicists adopt either a teleological view, that virtues enable human flourishing, or a non teleological account, that virtues are worthy in themselves, Aristotle adopts the teleological position. According to Aristotle, it is the promotion of human flourishing, eudaimonism, that makes a trait a virtue. In line with Aristotle, Statman asks, "If the virtues are not derived from the notion of flourishing, where are they derived from?"[236] He argues that Aristotle takes for granted the virtues really are virtues and that the goods they promote are really worth having. Rejecting the extremes that a non teleological approach imposes, Statman argues that Aristotle held "to quite a moderate version of virtue ethics (if at all)".[237]

Within the range of positions adopted by teleological virtue ethicists with respect to end, Rosalind Hursthouse and Christine Swanton offer finely nuanced accounts illustrating the richness of current scholarship. Of the two, the approach of Hursthouse is the more Aristotelian. She combines eudaimonism with "naturalism, the view that what makes a trait of character a virtue is its being partially constitutive of non-defectiveness in human beings". She sees virtue as a trait "that makes a human good *qua* human", serving also the flourishing of the

[235] Macintyre, "The Nature of the Virtues", 135.
[236] Statman, "Introduction to Virtue Ethics," 26.
[237] Statman, "Introduction to Virtue Ethics," 26.

species. Hursthouse sums up, "A virtue is a character trait that a human being needs for *eudaimonia*, to flourish and live well."[238]

Swanton argues that Aristotle fails to make a satisfactory link between the demands of the world and the flourishing of the virtuous person. She suggests that he insufficiently develops an account of flourishing. "We do not, in Aristotle, understand virtues via an account of flourishing - we understand flourishing via an account of the virtues."[239]

Each however provides an effective answer to The Thesis of Non Aretaic Value, the assertion that the base level goods of flourishing are prior to virtue and that therefore virtue is derivative. Swanton does so explicitly, herself drawing on Aristotle, arguing that the base level goods of flourishing must be considered more broadly than goods as such. She argues that Aristotle regarded the field of virtues as pertaining to pleasures, friends and small details, not necessarily good or evil in themselves, etc, in other words "being", itself.

Ultimately Swanton argues that virtue is a responsiveness to being, that the appropriate responsiveness of a human being is virtuous, and that it is human nature that imparts to the goods of flourishing their value; hence their value is intrinsically related, but not prior, to virtue itself. [240] Ultimately, she says, the complexity of virtue is derived from the complexity of human nature itself. [241]

These views sit most comfortably with the notion that virtues are a flourishing at both the organic and personal levels, the approach that this study has taken. These explorations into a biophysical basis for *eudaimonia* will be taken up again in **6.2**.

1.7 An overview of the potential benefits of this study.

[238] Rosalind Hursthouse *On Virtue Ethics,* 167.
[239] Swanton, *Virtue Ethics: A Pluralistic View,* 9.
[240] Swanton, *Virtue Ethics: A Pluralistic View,* 55.
[241] Swanton, *Virtue Ethics: A Pluralistic View,* 10.

The object of this study is the accord between the acquisition of moral virtues, understood as good habits enabling human flourishing, and neuroscientific knowledge of how the human being develops. This study argues that virtue development is fitting and proper to the development of mature human beings. As such it brings together ethics and neuroscience with a view to drawing practical, albeit brief, conclusions in the field of moral education.

It is hoped that outcomes from this study will include the following.

<u>Contributions to medical science</u>.

i. This review of mechanisms of plasticity and learning, of goal election, habit formation, cognitive processing, moral activity and emotional regulation, cross referenced to physically identifiable characteristics of virtue, will draw conclusions at the macro level about the systems, mechanisms, processes and brain structures underpinning virtue.
ii. Among various conclusions, new insights will be offered into the role of deep cortical structures, such as the *basal ganglia* (BG), in the operation of the virtues. The view will be offered that the operation of virtue should be considered as a "macro" system within the brain.

<u>Contributions to ethics</u>.

i. This endorsement of a virtue based approach to living has the potential to contribute to the debate evaluating the contrasting approaches to ethics.
ii. In particular, this understanding at the biological level of the operation and development of virtues promises to emphasise the necessity for virtue, and therefore virtue ethics, for effective moral education and human flourishing.

<u>Contributions to philosophy of mind</u>.

i. Insights into neuroscience in the light of an hylomorphic approach to philosophy of mind offer the possibility of effective critiques of other current writing on the topic.

ii. In particular it is hoped that this study contributes to effective responses to non-reductive and reductive physicalist approaches, and to dualistic understandings of one form or another.

Contributions to Aristotelian-Thomistic philosophy.

i. The attempt to reconcile Aristotelian-Thomistic understandings with current neuroscientific knowledge has the potential not only to enrich neuroscience by offering it a coherent template for human nature and activity, but also to enrich and contemporize this philosophical tradition.
ii. Among other conclusions, it is hoped that discussion about the nature of various cardinal virtues yields insights into the unity of the virtues, ie the integration of the four cardinal virtues in each human action.
iii. Furthermore it is hoped that this investigation into the nature of virtue, in the light both of neuroscience and the Aristotelian/Thomistic tradition, assists in clarifying the relationship between rationality and virtue, and therefore in delineating what could be termed "the biological dimension" of virtue.

Contributions to education.

i. The discussion of neuroscientific development will lead to numerous conclusions about optimum pedagogical methods.
ii. Brief and practical conclusions will be drawn with respect to parenting.

1.8 Conclusion

This study investigates the neural bases for moral virtue in the Aristotelian-Thomistic understanding, and whether or not this neural basis is integral to the notion of fulfilment or *eudaimonia*.

My starting point in this chapter has been to establish a *prima facie* case for the profound integration of the physical and the rational in the human person. I have noted the effectiveness of an hylomorphic psychology in reconciling these realms and the contribution that hylomorphism has the potential to make to philosophy of mind. Having situated this study in the spectrum of contemporary approaches to philosophy of mind, I then apply an hylomorphic critique to contemporary philosophy of mind in order to demonstrate the explanatory power of such an approach. I respond to the notion of "emergent rationality" that is prevalent in contemporary philosophy of mind.

I then consider the place of this study within current approaches to ethics. The comparative advantages offered by virtue ethics are noted and I situate this study within the spectrum of approaches to virtue ethics itself, placing it under the broad heading of eudaimonist virtue ethics. Finally I offer an overview of expected outcomes to arise from this study.

Chapter 2

Neural Mechanisms and Systems.

I saw the hideous phantasm of a man stretched out, and then, on the working of some powerful engine, show signs of life, and stir with an uneasy, half vital motion. Frightful must it be; for SUPREMELY frightful would be the effect of any human endeavour to mock the stupendous mechanism of the Creator of the world.

Preface to the 1831 Edition
Frankenstein; or, The Modern Prometheus
Mary Shelley

2.1 Overview.

In this chapter I focus on particular areas of current neuroscientific research which, I suggest, are most relevant to the biological structures underpinning virtue.

I focus first on the umbrella category of mechanisms underpinning brain plasticity, the anatomical restructuring of the brain in the process of learning, through the impact of environment or as a result of passive or freely elected experience. Plasticity is of central interest in this study because virtue is a manifestation of conscious experiential learning. I review the numerous cellular, molecular and genetic systems and mechanisms of neuronal structural plasticity, and suggest that mechanisms of structural plasticity underpin the formation of virtue, understood as good habits. “Neuroplasticity is the key bridging process” for learning. [242] Plastic anatomical changes are at the neuronal basis of a range of phenomena, including habitual actions,[243] and the attention, motivation and goal election required in conscious learning.

I then present current research into learning and memory. It is argued that, as virtue development is a form of memory and learning, mechanisms of plasticity

[242] Pontifical Council for the Sciences. Working Group on Neuroplasticity and Education. *Final Statement. October 2010*. http://www.casinapioiv.va/content/dam/accademia/pdf/sv117.pdf. (accessed 2 November 2012).
[243] Typical of the literature: Graybiel, “Habits, Rituals, and the Evaluative Brain,” 359-87.

such as *long term potentiation* (LTP) and other processes for synaptic strengthening, as well as other mechanisms such as myelination that serve to consolidate pathways, will be involved. Recently identified mechanisms for imitation associated with what are known as mirror neurons, discovered by Italian researchers in the early 1990s, are outlined as field that promises significant insights into forms of imitative learning that occur in the early stages of virtue development.

Then I review studies representative of major themes of current neuroscientific research in a number of areas. My focus is on the brain's capacity to develop establish or consolidate pathways for behaviours and for the cognitive-emotional regulation of those behaviours. Mechanisms of plasticity accord a degree of permanence to the neurobiological changes in each of these areas and hence to the behaviours supported by those neural bases.

- Currents of contemporary research into the <u>role of the BG</u> are reviewed. The BG have been understood for decades as having a role in the formation of motor habits, but now also their contribution to decision making and motivation is recognised.
- I then consider the <u>neural bases for emotional control.</u> Emotional control is central to a life of virtue. Virtue, as will be seen below, was understood by Aristotle and Aquinas to empower us to manage our emotional lives.
- Then the focus moves to current research into <u>goal directed behaviours and reward activation</u>. Virtue consists not just any habitual action, but in consciously elected *good* habits. Reward pathways provide a key mechanism for positive goal election which is a necessary aspect of the process of the development of virtue.
- The final section in this chapter will review strands of current research in the vast field of <u>cognition and executive function</u>**.** I will consider neural bases for cognition and executive function including consideration of consequences, planning, goal election and executive direction. Virtue, as

understood by Aristotle and Aquinas, is a characteristic of rational life, and therefore it is essential that any proposal for the neural bases of virtue encompass conscious executive direction, decision making, planning, assessment of consequences, all in the light of the underpinning Aristotelian anthropology discussed in **Chapter 1**.

This selection of areas of focus has been progressively refined at the draft stage of writing in the light of the analysis I develop in **Chapter 5.**

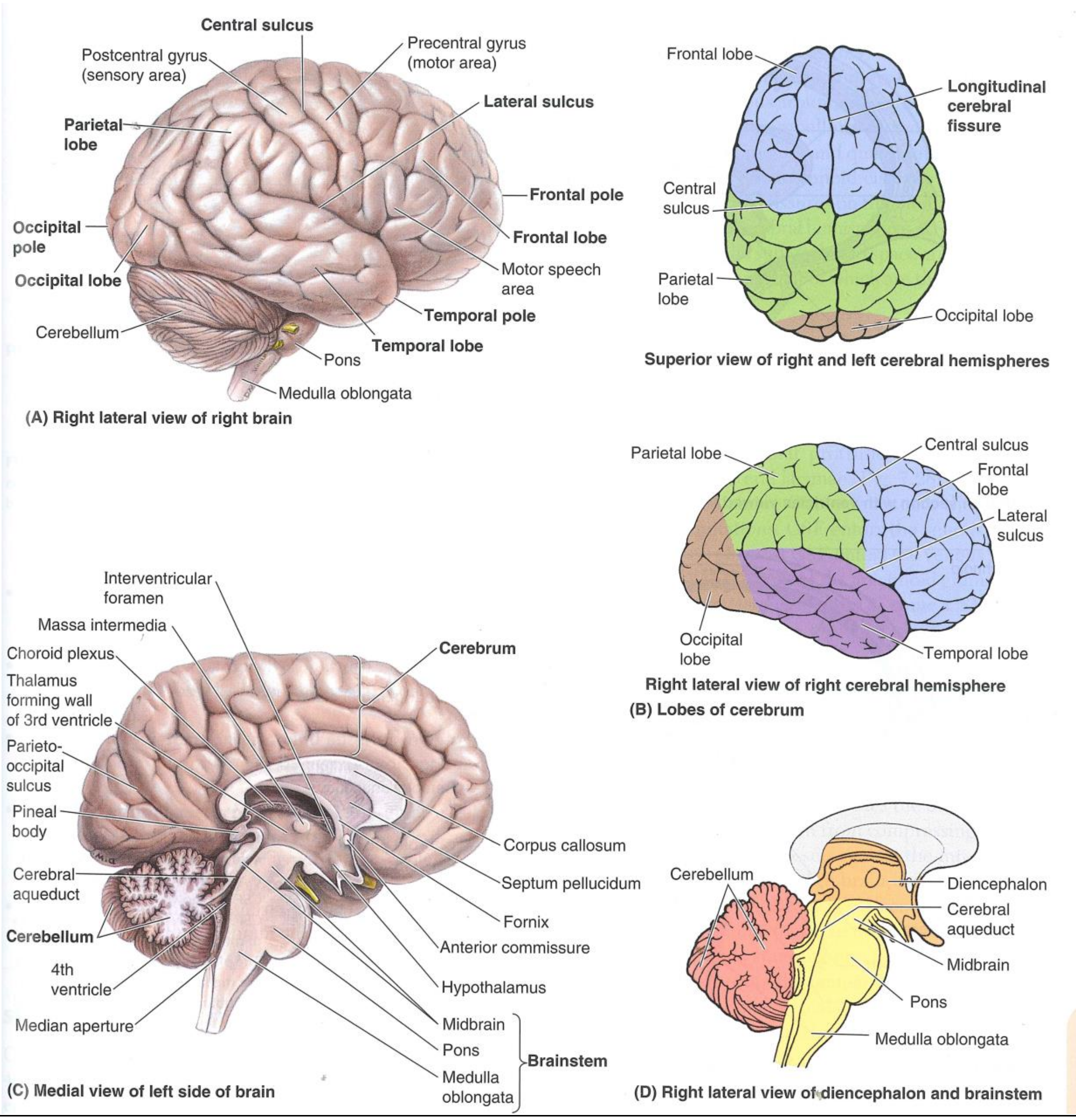

Figure 2.1 Gross anatomy of the human brain.
Source: Moore, K.L.et al. *Clinically oriented anatomy.* Philadelphia: Wolters Kluwer, 2010. 879.

Specific neuroscientific content essential to the argument of the thesis is included within this study proper. Familiarity with the fundamentals of contemporary neuroscience is treated as assumed knowledge so I recommend that readers with a non scientific background refer to **Appendix 2. A Brief Introduction to Neuroscientific Concepts and Terminology.**[244]

2.1.1 Rationale for the structure adopted.

In this section my selection of the above areas of investigation is discussed and justified.

My argument is summarised as follows. New imaging techniques and a consequent increasing weight of studies argue that it is possible to identify specific areas, pathways, systems and mechanisms in the brain that, at the neural level, support behaviour. Moreover the Templeton grants provide a rule-of-thumb confirmation that areas of investigation in this study are consistent with the contemporary attempts of others. Furthermore a simple analysis of the human act identifies a number of key systems that one would expect to find implicated in habitual behaviours. Finally, several arguments are proposed with a view to justifying the inclusion of the BG as an important area of investigation in this study.

2.1.1.1 Imaging the brain.

Although there is no literature detailing the neural substrates for virtue, rigorously defined, it is a fortuitous time to be attempting such a task. A wealth of data and enriched understanding of brain structure and function have come to light in the past two decades directly as a result of new imaging techniques. Neuroscientist Antonio Damasio wrote in 2005, "More may have been learned about the brain and the mind in the 1990s, than during the entire previous history of psychology

[244] My more detailed and broader review of fundamental neuroscience, prepared as introductory work on this thesis, is also available on request.

and neuroscience."[245] These imaging techniques not only permit high resolution studies of brain activation in real time, but they offer insights into previously unrecognised contributions of deep brain regions, and the data may be applied to an understanding of virtue as good habit, simplistically speaking.

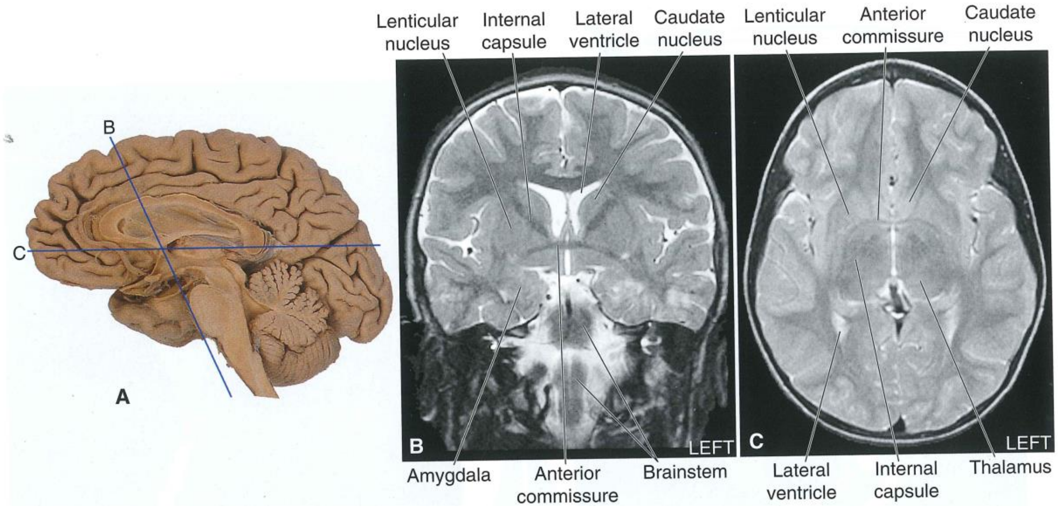

Figure 2.2 Examples of high resolution magnetic resonance images. These are T_2 weighted images in which white matter (myelination) appears darker than grey matter.
Source: Nolte, John. *The human brain. An introduction to its functional anatomy.* 6th ed. Philadelphia: Mosby, 2009. 116. Obtained by courtesy of Dr Joachim F. Seeger, University of Arizona College of Medicine.

The implications for a greater understanding of human behaviour are far reaching. Pontifical Academy of the Sciences gathering of experts in Human Neuroplasticity and Education in October 2010 concluded:

> The methods of brain and cognitive sciences have reached a stage such that we can now objectively monitor the developmental trajectory of the child's brain and document how this trajectory is being shaped by parenting, education, and other environmental influences.[246]

[245] Quoted in: David Rock, "Recent insights on the brain that change everything", *Quiet leadership: Help people think better, don't tell them what to do*, prepublication draft (New York: Harper Business, 2006).
[246] Pontifical Council for the Sciences. Working Group on Neuroplasticity and Education. *Final Statement. October 2010*.

These imaging advances have allowed more precise temporal and spatial identification of brain areas implicated in specific function and processes than has ever been possible before, and have led to a surge in understanding of plasticity in the brain, of localised functionalities, of connectivities, and of the scale of cortical networking.

See **2.1.3.e.** for caveats regarding neuroimaging. Principal neuroimaging technologies in use are summarised in **Appendix 3 Neuroimaging Technologies.**

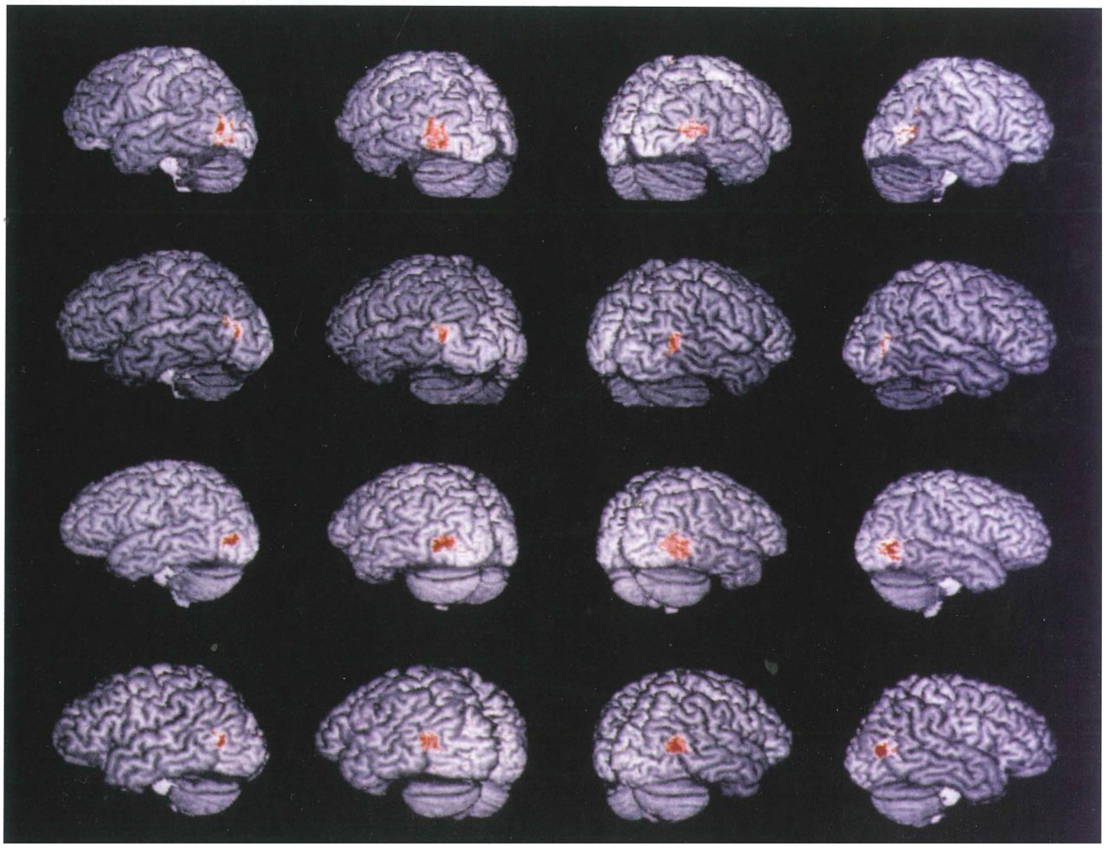

Figure 2.3 **An example of the use of combined PET and MRI imagery to detect areas of increased cortical activity in specified tasks**. Imaging demonstrates changes in blood flow on the lateral surface of the occipital lobe as subjects attend to moving visual (as opposed to stationary) stimuli. The four images in each row are of the same subject. PET scanning after intravenous injection of $H_2{}^{15}O$ mapped blood flow, and T_1-weighted MRI scans permitted reconstruction of the surface of each brain. Data was then coregistered. **Source**: Watson, J.D.G. et al. Cerebral Cortex 3:79 (1993). Cited in Nolte, John. *The human brain. An introduction to its functional anatomy.* 6th ed. Philadelphia: Mosby, 2009. 136.

2.1.1.2 *Prima facie* confirmation for the broad direction of this investigation: Projects recognised in the 2009 Templeton Positive Neuroscience Awards.

In 2009 the Templeton Foundation fund offered substantial grants, the Positive Neuroscience Awards, for research into the neural bases for virtue. [247] Impelled by this support there has been an explosion of research focussing explicitly on the neural bases of virtue. Topics of the projects chosen by the recipients of the first round of grants are broad and disparate:

- The effect of specific genes on the neurotransmitter *dopamine* (DA) which is understood to be a factor in resilience.
- The neural processing of attention in schizophrenics and meditators.
- The relationship between social support and genetic action.
- The effects of meditation on the structure and function of the *ventromedial prefrontal cortex* (VMPFC), hippocampus, and amygdala, brain regions part of the neural circuit critical for deactivating conditioned fears.
- Neural connectivity in musicians.
- Whether heroically altruistic people show greatest sensitivity to fearful expressions, more amygdala activation, and enhanced amygdala-prefrontal connectivity.
- The neural bases of trained resilience following intense stress.
- Activity in the reward areas of the brain when subjects share the positive emotions of others.
- The relationship between the activity of nerve fibres transmitting gentle touch, empathy and bonding.

[247] Templeton Report; News from the Templeton Foundation, http://www.templeton.org (accessed 8 July 2009) The Templeton Positive Neuroscience Award, funding "methodological rigorous projects that apply the tools of neuroscience" in four categories. One category of grants is for research identifying "the neural bases of the cognitive and affective capacities that enable virtues such as discipline, persistence, honesty, compassion, love, curiosity, social and practical intelligence, courage, creativity and optimism".

- Brain regions for empathy and altruism.
- A study of the impact of genotype, and hormonal, and neural differences in nurturing behaviour of fathers.
- The relation of reward systems of the brain to intrinsic reward.
- A study of the possibilities of altering the response of one's amygdala.
- A study of the neural processes supporting positive thought and affiliation to others.
- A study of the cooperation of various neural regions in the processing of emotion.

The areas of interest in these projects are broadly in accord with those selected in this chapter. However it is noticeable that Templeton projects appear to lack a rich understanding of virtue that could assist in directing their search. The work of **Chapters 3** and **4** will directly focus on provision of a coherent underlying definition of virtue to assist in identification of neural bases.

Several observations are relevant:

- The Templeton list provides insights into current thinking about the neural bases of virtue. There is agreement that the neural bases of virtue are identifiable and that they are multifaceted.
- All subheading themes which are the focus of **Chapter 2** are represented in this current list, except, tellingly that of **2.4** focussing on the role of the BG. It is possible this is so because the classic definition of virtue as good habit has been overlooked. It is proposed that an Aristotelian-Thomistic anthropology and definition of virtue can greatly assist the search for the neural bases of virtue.
- Furthermore without an Aristotelian-Thomistic understanding of the intrinsic relationship of virtue to human flourishing, the neural features of virtue may well remain elusive for they will have lost a connection with biological development. This current study proposes that the neural bases

of virtue, in the light of Aristotelian thought, denote not only the holistic but also the biological flourishing of the organism.

It is hoped that his current study seeking neural bases consistent both with rational psychology and the neuroscience will add substantially to the endeavour of identifying the neural bases of virtue.

2.1.1.3 The human act provides insight into the function of virtue.

A further key to this task is the enriched understanding of the human act offered by Aristotle and Aquinas. In a simplified model of any human act, there are four steps leading to rational action: desire, emotion, reason, and choice/action. Such a division provides a starting point for productive analysis with the purpose of identifying neural correlates. Virtue must essentially be understood as the stable disposition to act well, ie to carry out these four steps well. (See **3.1.3** for elaboration of these points.)

- Desire corresponds to the motivation underpinning acts. Aristotle argues that, when a creature acts virtuously, it is motivated by the desire of acting for its own natural good. Aquinas writes similarly, "a good habit is one which disposes to an act suitable to the agent's nature".[248] Hence the motivational pathways, the pathways of reward activation, appear implicated in our search for the neural bases of virtue. A further feature at this point may be the pleasure that Aristotle argues accompanies the exercise of virtue.[249]
- A second key to understanding the neuroscience of virtue is to understand the neuroscience of emotion. A classical understanding of virtue is that it assists us to manage our emotional lives; hence, the neural bases for emotion, and for the cortical regulation of emotional pathways, appear implicated.

[248] *ST*, Ia, Q.54, Art.3.
[249] *NE*, 1104b.

- Next we apply the understanding that human acts, and hence virtuous acts as a subset of human acts, must be guided by reason. Aquinas wrote, "the habits of the moral virtues are caused in the appetitive powers, according as they are moved by the reason".[250] The various pathways of the brain that contribute to planning, memory, logic and cognition, are relevant here.
- Furthermore all human acts require the exercise of choice. The co-constituent of man's rationality is the will, man's capacity for choice.[251] In fact, Aristotle proposed that virtue is the "habit of choosing". The neural bases of executive action, goal election and attentional systems appear implicated in the neuroscience of virtue.

Add to these constituent steps of the human act, the understanding that virtue is a stable and easily repeated behaviour. So, it is necessary to investigate the neuroscience of habit formation. Further, it will be argued in **Chapters 3** and **4** that the four cardinal virtues have distinctive roles each with specific neural basis. Hence distinction at the neural level, of the four cardinal virtues, will be also require discussion.

2.1.1.4 Insights into the basal ganglia.

The brain regions and pathways associated with the BG, linking habit formation and volition, appear to offer a significant key to understanding the neural bases of virtue. Research into the BG sheds light on procedural memory and habit learning, and recent studies of cortical plasticity and the role of BG-thalamo-cortical loops with their widespread cognitive-emotional interaction offer understanding of processes of planning, goal selection, self regulation, attention and motivation.

[250] *ST*, Ia-IIae, Q.51, Art.3.
[251] The term "co-constituent" is used a number of times in the course of this thesis, denoting the relationship to virtue of both rationality and biophysical processes.

a) Pathological insights into dysfunctional basal ganglia: Huntington disease, Obsessive Compulsive Disorder, Parkinson disease, and *Encephalitis Lethargica.*

Pathological studies into Huntington disease, *Obsessive Compulsive Disorder* (OCD), Parkinson disease, and *Encephalitis Lethargica (EL),* assisted by new imaging technologies, argue for an expanded role attributable to the BG. Consistent with this view, this study presents the BG as an important player in the complex interplay of multiple brain regions active in reward and emotion processing, motor instruction, and goal election. Prior to this study there appears to be no literature identifying a decisive role of the BG in the formation and exercise of virtue.

An important source of knowledge about the brain, and particularly about subcortical structures is obtained through autopsy seeking causes for abnormal behaviours in the years preceding death. A number of conditions are linked to diseases of the BG. Although loss of motor control is the most obvious manifestation in each case, behaviour change associated with the illness provides insight into the breadth of function of the BG. In many cases dysfunction in the BG has been associated with a significant loss of emotional regulation, executive capacity, and capacity to read social cues.[252]

In *The Exceptional Brain*, Robert Kaplan, a clinical professor of psychiatry, documents the trajectory of BG diseases of the BG on Woody Guthrie (Huntington Disease), Howard Hughes (OCD), and Adolf Hitler (Parkinson Disease). His broad brush conclusions throw into relief the cognitive contribution of the BG, thereby adding weight to the view that the BG play an integral role not only in motor function but also in the development of conscious and volitional habits.

The most significant conclusions may be summarized:

[252] Robert M. Kaplan, *The Exceptional Brain* (Sydney: Allen and Unwin, 2011).

- Huntington disease is characterised by uncontrolled movements, not uncommonly accompanied by symptoms of psychological dysfunction: increased moodiness, anger, loss of self control, depression, substance abuse, absence of personal hygiene and loss of sexual inhibition. Psychoses are evident in up to 12% of cases. [253] Huntington disease is caused by neural degeneration in the BG as a result of a gene mutation. Huntington is characterised by severe degeneration of the putamen and caudate in the BG and of the frontal cerebral cortex, and is associated with an excess of, or supersensitivity to, DA in the *substantia nigra* (SN).[254] That Huntington is associated with changes in personality and psychological health argues for a broader attribution to the BG than that of movement control.
- OCD is associated with obsessional behaviours. Untreated OCD can develop a psychiatric or psychotic dimension, a loss of touch with reality. OCD is caused by dysfunction in the caudate nucleus and irregularities in the BG (with some frontal cortex contribution) of DA and *5-hydroxytryptamine* (5-HT) more commonly known as serotonin. The repetitive nature of activity appears caused by excessive DA release. Anxiety manifests as a comorbidity when this compulsivity is associated with lack of 5-HT control over DA release. [255] Kaplan describes OCD as "an anxiety disorder". That this disease of the BG may often be successfully treated by cognitive therapies,[256] possibly suggests that the caudate possesses plasticity, and that the caudate has a cognitive role. [257] In any case, intractable cases of OCD can be successfully resolved by operating to disconnect the pathway between the thalamus and the *prefrontal cortex* (PFC), the striato-thalamocortical pathway. That OCD is associated with changes in personality and psychological health argues for a broader attribution to the BG than that of the mediation of repetitive behaviours.

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[253] Kaplan, *The Exceptional Brain*.
[254] Kathryn L. McCance and Sue E. Huether, *Pathophysiology,* 6th ed. (Missouri: Mosby Elsevier, 2010), 568, 570.
[255] McCance and Huether, *Pathophysiology*, 662.
[256] As documented by Schwartz and Begley, *The Mind and the Brain.*Schwartz is a recognised authority on OCD therapies.
[257] Kaplan, *The Exceptional Brain*, 253-256.

- Parkinson disease is a common movement disorder resulting from degeneration of the BG. Some 50% of sufferers of Parkinson disease also show cortical and executive function deficits in addition. Parkinson can also be associated with the development of OCD. Both these comorbidities attest to the cognitive contribution of the BG. When the DA inhibitory influence in the BG is diminished, the tremors of Parkinson disease develop. [258] [259]

Furthermore, *encephalitis lethargica* (EL) the mysterious sleepy sickness epidemic early in the 20th century, appears to have been a disease of the BG. Amongst the alarming effects were a loss of will, and at times an insensitivity to situations requiring will power.[260]

b) A role for the basal ganglia in volitional habits.

The pathways and mechanisms of addition (**2.6.6**) and insights into the cognitive consequences of diseases of the BG provide important insights into the development of volitional habits. The fact that addictions develop not only from the intake of substances (for example, nicotine and alcohol), but also from behaviours (for example morally negative behaviours such as viewing pornography, and morally neutral behaviours such as computer gaming and distance running). A subject may find himself addicted against his will because of ignorance of addictive behaviours (video gaming, for example), but an addiction

[258] McCance and Huether, *Pathophysiology*, 569, 572; Carol Mattson Porth, *Essentials of Pathophysiology*, 3rd ed. (Philadelphia: Wolters Kluwer, 2011), 912.

[259] Often Parkinsonian patients manifest the disease on one side only. Kaplan points out that Hitler demonstrated a dominance of the right hemisphere long before his Parkinson became obvious in the last years of the war. Any exaggerated dominance of one hemisphere brings with it clear deficits. Hitler manifested extreme emotional reactions in keeping with right hemispheric dominance of affectivity. This is further in keeping with underdeveloped left hemisphere, a poorly developed capacity to step back and reflect, or to appreciate timing (consider the debacle following the German invasion of Russia). It is clear that the greater the integration of the various neural areas the greater the capacity to flourish. That Parkinson is associated with changes in personality, psychological health and emotional regulation argues for a broader attribution to the BG than that of motor control. See Kaplan, *The Exceptional Brain*, 253-256.

[260] Paul Foley, "The Encephalitis Lethargica Patient as a Window on the Soul" in *The Neurological Patient in History* ed. L. Stephen Jacyna and Stephen T. Casper (Rochester, NY: U of Rochester Press, 2012), 184-214.

may also result from the subject knowingly indulging in an activity that he knows will become harder and harder to resist. This raises the distinct likelihood that positive behaviours may also be pursued with intention that such behaviours become facilitated.

Of course not all activities become addictive; no amount of washing up or making our beds will give us an addiction to washing up or making our beds. Yet it is universal human experience that activities frequently performed in childhood induce not only a capacity to perform that activity in adult life, but also a tendency to do so (to make one's bed on rising, to wash glasses rather than leave them in the sink, etc). Such tendencies are not addictions, but are rather what we could call volitional habits.

It is possible to propose that these volitional habits may be mediated by plasticity in the upper cortex but this explanation in isolation appears less than adequate. It fails to take into account the demonstrated role of the BG in mediating repetitive behaviours arising from addiction, OCD, Tourette Syndrome, and in its demonstrated contribution to consciously directed movement, a role that has become dysfunctional in Huntington, Parkinson and EL. There is a very strong case to be made that the BG are integrally involved in the development of volitional habits (**2.4**):

- We know that, without dependency on the PFC, the BG are integral to non-volitional habits, addiction and compulsions (OCD, Tourette Syndrome, etc). It does not logically follow that just because the BG are integral to non-volitional habits that they are not *also* implicated in volitional habits. In fact, given recent knowledge of pathways, interdependence, and the cognitive contribution of lower cortical structures, I suggest the weight of evidence has dramatically shifted towards this latter view.
- The role of the BG is now increasingly understood in both cognitive operations, and in reward based activity, and therefore in emotional

management and goal setting. The role of the BG in instructing cortical areas, in clarifying motor and reward messages to cortical areas, is now also better understood. (See especially **2.4** and **2.6** for references.)

- We now know that reward representations in the cortex, in the *orbitofrontal cortex* (OFC) and PFC (see **2.6.5**) are linked to the reward representations in the BG. Horvitz, for example, draws attention to the sustained activity in cells of the striatum in anticipation of reward as a mirror of reward coding in the OFC.[261] Such cortical management of striatally based behaviour patterns is consistent with the action of virtue.
- We also know that these volitional, reward based responses are mediated in the ventral striatum, and that in time these transform to reward independent, overlearned experiences mediated in the dorsal striatum.[262] Sustained volitional behaviour in the face of a lessened significance of reward is consistent with the action of virtue.

A mechanism for volitional habits appears present here. This appears to be a neural pathway integral to the support of virtues in the brain. It remains to be demonstrated whether the BG be implicated in the full range of habitual behaviours that arise through virtue, or only in simpler procedural, but *volitional and virtuous*, behaviours, such as habitual routines of work and courtesy, respect, and positive self talk.

In conclusion, it may be seen that there is *prima facie* evidence for the selection of the key subheadings of **Chapter 2**: mechanisms of plasticity, mechanisms of learning, memory and imitation, understandings of particular neural structures with a particular focus on the BG, neural bases for emotional control, goal directed behaviours and reward activation, and cognition and executive function.

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[261] Jon C. Horvitz, "Stimulus-response and response outcome learning mechanisms in the striatum," in *Behavioural Brain Research* 199 (2009): 133.

[262] Lovinger offers an excellent overview of current knowledge of plasticity in the dorsal striatum. David M. Lovinger, "Neurotransmitter Roles in Synaptic Modulation, Plasticity and Learning in the Dorsal Striatum," *Neuropharmacology*. 58(7) 2010: 951–961.

2.1.2 Search information.

Information about my search for relevant neuroscientific studies is set out in **Table 2.1** in the endpapers. My focus was to obtain studies representative of current knowledge. By preference I sought recent studies and recent, review studies. Of the studies yielded by these literature searches, I deemed many inappropriate for selection because they were irrelevant to this project, too narrow in scope, anecdotal and pertaining to limited samples, or superseded by later studies. I obtained a number of other studies first identified as references in studies that I had selected in the search process. In addition material was obtained from numerous recently published texts and monographs. Several prominent authors in the fields of plasticity were contacted in an effort to locate all relevant studies. In my final stage of writing and editing, I checked for new information and included content from some 25-30 new studies.

Consequently material obtained from close study of some 110 papers and approximately 30 recently published texts and monographs has been integrated into the discussion of this chapter.

2.1.3 This neuroscientific investigation carries some caveats.

Although the goal of associating complex psychological phenomenon with neural substrate is still very much a field in its infancy, this study draws on a growing tradition of highly credentialed contemporary literature which links function with specific processes, mechanisms, pathways and areas of the brain.

Much about neural processes remains currently undescribed so it is necessary to be somewhat measured in conclusions. While likely biological mechanisms have been identified, the basis of the interface between biological molecular processes and conscious learning and memory is still conjectural. For example it is not understood how modifications of neuronal connections form a representation of reality to the person. What has become clear is that the brain operates as a highly complex network, with sophisticated, concurrent signalling and reciprocal interactions between multiple brain regions and systems, attuned to the orchestration of outputs at the service of the acting person.

As is evident in **Chapters 2, 3** and **5** this approach aligns with the methodology of much contemporary neuroscientific research in seeking to identify brain regions and pathways which are actively implicated in specific activities (eg executive, cognitive, attentional, limbic, sensory regions and pathways). While it is true that rigid localisation theories of the brain have given way to a broader focus on pathways, on integrated and flexibly acting brain regions, and on some appreciation of the complexity of networking in brain, it is also clear that specific areas and pathways demonstrate direct and at times critical involvement in particular functions.

There are contrasting schools of thought with reference to the anatomo-functional model, a form of localisation, that has arisen as a consequence of more precise imaging. Desmurget et al. propose that their data calls into question what they see as a fashion of *functional localisation* that has penetrated even our most complex human faculties. (See also **2.2.6.**) They cite an extensive list of papers that they argue have taken the concept of localisation to an unwarranted degree, including the work of Anderson et al. in 1999 who placed our moral sense in the PFC, Azari et al. who argued that religious experience is built into our nervous system within a restricted fronto-parietal network, and Bartel's and Zeki's thesis that romantic and maternal love engages the medial insula and the anterior cingulated cortex. They argue that the brain is not "a rigid mosaic of independently encapsulated modules." [263]

Furthermore, philosopher Martha Nussbaum uses the very notion of plasticity to argue against precise localisation of function, and to oppose the view that we "include a particular physiological process as a necessary element in a definition of

[263] M. Desmurget et al. "Contrasting acute and slow growing lesions: a new door to brain plasticity (Review)," *Brain* 130 (2007): 898-914.

a given emotion type".[264] Yet she uses the word plasticity in a slightly unusual manner in relation to the vast contemporary literature on physiology of the brain, suggesting that plasticity is opposed to a view that specific processes, pathways and locations may be identified with any certainty in the brain.

These are however the dissenting voices. Although "functional localisation" is by no means a universally accepted position, a judicious acceptance of the notion of "localisation" may be found in the vast majority of relevant current studies. Certainly the old localisation theories are now discredited but new imaging approaches and advances in molecular biology are helping us identify when information about processes, pathways and locations is reliable or when greater caution should be applied.

a) The brain is constantly in a state of change.

The brain changes physically and constantly in response to input from within and outside the body. In addition to this passive process, the individual has the capacity to self-manage change. In other words every choice we make, wherever we direct our attention, every move we make, every word we speak, in short, every input from our environment, works change in our brains on a functional and often structural basis.

This study takes the position, aligned with a great majority of current neuroscientific studies seeking neural bases for processes, that this state of constant change does not preclude the possibility of detecting patterns of neural activation.

b) Our appreciation of the complexity of brain networking is at a rudimentary level.

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[264] Martha C. Nussbaum, *Upheavals of Thought* (Cambridge: Cambridge University Press, 2001), 115.

The complexity of the human brain is a result not only of the vast numbers of neurons and glial cells (some 100 billion neurons and perhaps twice that number of glial cells), nor simply of the number of synaptic interconnections between neurons (estimated at an average of several thousand per neuron), but also of the pathways and networking that integrate the various brain regions. For example, the significance of certain subcortical areas reciprocally connected to the cortex is being increasingly understood. Sub-cortical areas that had been thought, only two decades ago, to be mere relay stations for motor commands are now understood to play integral roles in cognitive function. The complex contribution of the cortico-striatal-thalamocortical pathways, as a further example, have been a rich field of research in recent years.

As scanning technologies have improved, localisation theories of the brain have given way to an understanding of the flexibility, complexity and integration of neural networking. In **5.3** I will be discussing the extension of neural networking and collaboration of systems in the brain. Within this context much contemporary neuroscientific research seeks identify brain regions which are actively implicated in specific function.[265] It remains clear that specific areas demonstrate direct and at times critical involvement in particular functions. Conclusions in this study will be required to respect principles of functional integration and of specific function.

c) The basis of the interface between molecular processes and conscious processes, such as learning and memory, is still conjectural.

[265] A corollary of this point is that there is a lack of universal agreement about language and terminology from one author/researcher to another. This seems to arise principally because knowledge in this field is expanding faster than the conventions of discussion. By the term "consolidation" of pathways I will refer to changes in the anatomical characteristics of the neurons with the result that neuronal activity is facilitated; by "hard wiring" I will understand the anatomical structures of neurons, the subunits of all nerve pathways, a meaning is often found in the literature. Note however, there is no universal agreement on this usage. Some authors use the term to refer to neurons established before birth, or in critical stages of development, others distinguish "hard wired" by which they mean not experience dependent, from what they call "soft wiring", by which they refer to experience dependent[265]. In a similar way, "hardwired" is sometimes opposed to "plastic". Note usage in Doidge, *The brain that changes itself*, 95.

Although various convincing hypotheses (eg LTP) are proposed for the molecular mechanisms of memory with the support of a growing body of evidence, and while the manner by which networked neurons may mediate memory and learning is supported by plausible computer modelling, the actual processes are not described. Currently there is no neuroscientific understanding of the relationship between neural mechanisms and mental representations.[266] The position of this study, based on the integrity of rational and the biological in man according to Aristotle and Aquinas, is that mental and biological events are coincident manifestations of the one phenomenon. (Refer to **Chapter 1** discussion.)

In line with the abundant current research into plasticity, memory and learning, we will seek to identify processes, mechanisms and pathways that are implicated and, at times critically so, in the functioning of the person.

d) Our experimental knowledge of brain function is derived from animal as well as human studies.

It is necessary to be cautious in transferring conclusions in animal studies to the human domain. Nevertheless "clinical findings strikingly parallel animal experimentation data," indicating that function and structure can be highly phylogenetically conserved.[267]

e) Our capacity to study neuronal activity in real time and with precision is uneven and still developing.

The "voodoo correlations" and "neurotrash" line of criticism popularised by Raymond Tallis, in rubbishing practically every attempt to relate localised brain function to human behaviour, goes beyond what is broadly acceptable in the

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[266] Daniel J. Siegel, *Neurobiology of We*, (Sounds True Audio Lectures, 2008).
[267] See for example discussion in A. V. Kalueff, "Neurobiology of memory and anxiety From genes to behaviour. (Review) "*Neural Plasticity,"* Hindawi Publishing Corporation (2007): ID 78171, 6.

neuroscience community.[268] Of more weight however are the tightly argued criticisms of Edward Vul et al.[269]

Neuroimaging has definite limitations. Educator and neuroscientist John Geake comments: [270]

- We must always bear in mind that brain structure is extremely complex, and function, non linear.
- The vast functional interconnectivity of the brain means that mappings of structure to function, the neural bases of specific tasks,[271] are not straight forward activities.
- The data is limited by the imaging method chosen.
- Neuroimaging data is a statistical comparison of indicators of neural activation against a baseline that has been set by the researcher, and that, as “most of the brain is involved in any cognitive task”, changes in statistical parameters will change the apparent results. Imaging data defining areas of heightened neural activity in a given task certainly must not be interpreted to mean that other areas of the brain may not be implicated in that activity.[272]
- The mere fact that an area of the brain is implicated in a given activity does not provide direct insight into the contribution that area makes.

Johnson et al. reflect this wariness. They argue that imaging depends upon choices of the researcher: “thickness of brain slices, level of clarity and detail, techniques for filtering signal from noise, and choice of individuals to be sampled”; and they caution that there is rarely a 1:1 correspondence between region and function.

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[268] See above, **1.5**.
[269] Edward Vul et al. “Puzzlingly high correlations in fMRI studies of emotion, personality and social cognition” *Perspectives on Psychological Science* 4, No 3 (2009).
[270] Geake criticizes some forms of “educational neuroscience” seeing it fraught with dangers of oversimplification, and typified by the fads such as brain gym exercises and neuromyths of left brain and right brain thinking that overlook the abundant interconnection between the hemispheres. Nevertheless, despite this balanced skepticism, he concludes that neuroscience can do much to inform our understanding of learning.
John G. Geake, *The Brain at School* (Berkshire: McGraw Hill, 2009).
[271] John G. Geake, *The Brain at School* (Berkshire: McGraw Hill, 2009), 36.
[272] Geake, *The Brain at School*, 29.

They cite a celebrated misuse of *functional magnetic resonance imaging* (fMRI) study of swinging voters prior to USA presidential elections to illustrate the problem of reverse inference and that because brain regions may be activated by many different processes, it may not be possible to draw conclusions about specific mental states, motivations and cognitive processes.[273]

f) Cross disciplinary studies involving neuroscience are uneven in quality.

New fields such as neuroethics,[274] and even neurotheology, have flourished, along with some intelligent to absolutely shonky writings and therapies blending brain science with educational, business and even entertainment.[275] Usma Goswami has offered a telling review of "brain based" learning packages, too many of which, the author argues, are "scientifically spurious applications".[276]

A growing number of commentators in this field focus on fulfilment through relationships, finding evidence for this position in the neuroscience itself. For example, neuroscientist Daniel Siegel pioneers a field he calls "interpersonal neurobiology", or the "neurobiology of we".[277] Despite the jargon, Siegel's approach broadly accords with cognitive management of emotion, and with the view that attention and plasticity are linked. Unfortunately, and this is a common

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[273] S. B. Johnson et al. "Adolescent maturity and the brain: The promise and pitfalls of neuroscience research in adolescent health policy," *Journal of Adolescent Health* 45, (2009): 216-221.

[274] Daniel J. Siegel, *Mindsight* (Melbourne: Scribe, 2009), 267.

[275] A sample of recent books: Andrew Newberg and Mark R. Waldman, *Born to Believe* (NY: Free Press, 2006); Bob Garrett, *Brain and Behaviour* (Los Angeles: Sage, 2011). Note also the spread of "neurolinguistic programming", "auditory therapy", brain building Nintendo, etc.

[276] Usma Goswami, "Neuroscience and education: from research to practice?" *Nature Reviews Neuroscience* (on line 12 April, 2006), 7.

[277] In *Mindsight* Siegel advocates "mindsight", the capacity to reflect on the internal workings of our minds, to monitor and modify "the flow of one's thoughts within the Triangle of Wellbeing" made up of relationships, mind and brain. He describes it as a kind of focused attention giving insight into our mental processes so that we can "name and tame" emotions we are experiencing, and develop a greater capacity to move beyond "reactive emotional loops", having greater freedom of choice in our action plans. There are three principles: wellbeing is a learnable skill; we can change the physical structure of our brains so we are more resilient, compassionate, empathetic; relationships are necessary to sculpt a brain. Daniel J. Siegel, *Mindsight* (Melbourne: Scribe, 2009).

problem faced by intuitive approaches, an impoverished anthropology fails to offer sure guidance to the applications of science.

…

My investigation will respect these caveats. My intention is to propose, by means of an integrative analysis of current research into brain function, a highly plausible model for the biological bases of virtue, the accuracy of which could be laboratory tested in the future. By highlighting the expansive trend in plasticity studies, and by making cross disciplinary links, I hope to stimulate interest in what I see as an important field for further exploration.

2.2 Plasticity.

Neuroplasticity refers to the ability of neurons to change their function, chemical profile (amount and types of neurotransmitters produced), or structure in response to learning, environment or experience.[278]

The phenomenon of plasticity is of particular interest in this study because it is widely accepted that it provides the underlying mechanisms for learning and memory. Processes of learning and memory, in turn are central to the development of virtue, particularly habit formation, of ready attention, and of the associated goal directed behaviours that underpin purposeful action.

Plasticity may be categorised as functional or structural. It is also described as developmental, or activity/environmentally dependent plasticity. Note that these categories are not exclusive of each other. Much developmental plasticity is driven by timely environmental inputs, and structural change is perhaps always accompanied by functional change.

[278] Definition taken from: Clifford J. Woolf and Michael W. Salter, “Neuronal Plasticity: Increasing the Gain in Pain,” *Science*, (June 2000): 1765-1768.

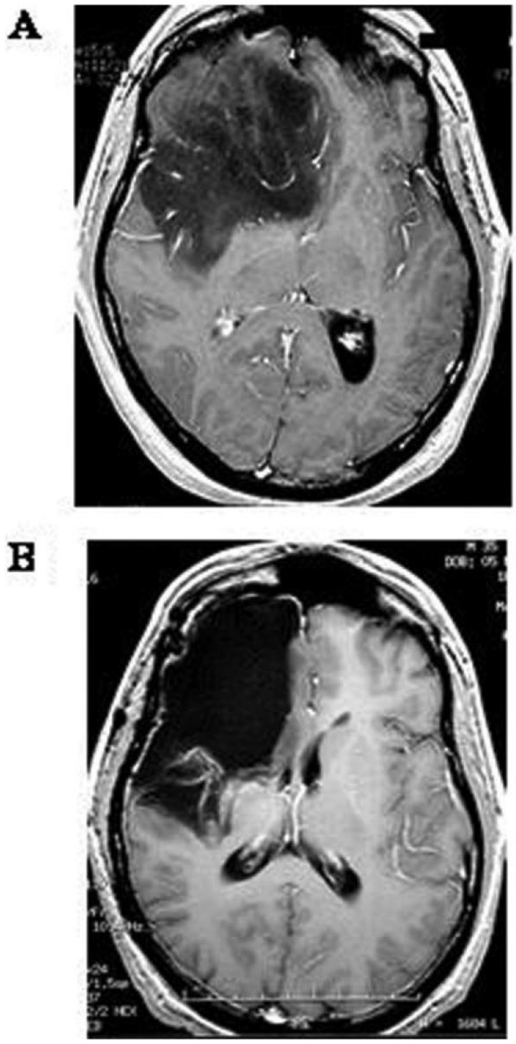

Figure 2.4 The astonishing capacity for structural change in the brain, for reengineering connectivities and function. Pre- and post-operative T_1-weighted MRI show removal of total glioma and resection of right paralimbic system. Despite post-surgical hemiparesia, within three months the patient had completely recovered.
Source: Desmurget, M. et al. "Contrasting acute and slow growing lesions: a new door to brain plasticity (Review)." *Brain,* 130 (2007). 903.

2.2.1 Historical considerations.

Plasticity, as a term in neuroscience, was first used by William James in 1890 in reference to the potential for humans to modify their behaviour. Remarkably, he linked plasticity to habitual behaviours. He wrote:

> Plasticity [. . .] means the possession of a structure weak enough to yield to an influence, but strong enough not to yield all at once. Each relatively stable phase of equilibrium in such a structure is marked by what we may call a new set of habits.

> Organic matter, especially nervous tissue, seems endowed with a very extraordinary degree of plasticity of this sort; so that we may without hesitation lay down as our first proposition the following, that the phenomena of habit in living beings are due to the plasticity.[279]

In 1895 the great Spanish neuroscientist Ramon y Cajal offered the hypothesis that learning could be based on the selective strengthening of synapses, now recognised as a central mechanism for plasticity. He predicted both experience-induced, plastic change to neuronal pathways and also genetically-driven, developmental plasticity,[280] and that association learning might involve morphological and functional changes at the synapse. He wrote in 1904 of "the formation of new pathways through ramification and progressive growth of the dendritic arborization and the nervous terminals."[281] He argued, "The organ of thought is, within certain limits, malleable and perfectible by will-directed, mental exercise" and that "mental practice" must strengthen neuronal connections and create new ones.[282]

At the heart of plasticity is the distinction, described by Jerzy Konorski in 1948, between, on the one hand, the neuronal reaction to an incoming impulse, in other words the neuron's excitability, and, on the other, the permanent functional transformations and the corresponding anatomical changes, plastic changes that arise in particular systems of neurons as a result of appropriate stimuli.[283]

The following year Donald Hebb, another giant in the field of neuroscience, described what has become known as the Hebbian principle: "Cells that fire

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279 William James, *The Principles of Psychology* (1890), 68.
280 Alvaro Pascual-Leone et al. "The Plastic Human Brain Cortex," *Annual Review of Neuroscience* 28 (2005): 379.
281 Santiago Ramón y Cajal, *Textura del Sistema Nervioso del Hombre y de los Vertebrados*, 2 vols. (Madrid Moya, 1899 and 1904), 296.
282 From Doidge, *The Brain that changes itself,* 202.
283 From Kandel, *Principles of Neural Science*, 340.

together wire together"[284] and its corollary "Cells that fire out of sync lose their link".[285] Hebb postulated conditions under which synapses change on the basis of activation: "When an axon of cell A is near enough to excite a cell B and repeatedly or persistently takes part in firing it, some growth process or metabolic change takes place in one or both cells such that A's efficiency, as one of the cells firing B, is increased."[286]

With repeated firing, nerve cells become firmly connected. In this way, neuronal pathways are self reinforcing. Furthermore whichever cell is triggered first, connected neurons tend to fire in concert, as one unit. Donald Hebb had successfully described the principle underpinning activity-dependent plasticity: that changes in synaptic strength correspond to changes in neuronal morphology.

Arden and Linford explain, "On the macro level: the more often we do something, the more likely we are to do it again."[287] This principle is at the basis of much experience dependent plasticity whereby cells that excite other cells cause those cells to become linked in their firing characteristics. This study proposes that experience dependent plasticity at the neuronal level as the fundamental mechanism for reinforcement of behaviours through repetition.

When we speak of activity dependent plasticity, we are referring first of all to electrical activity within the neuron. "Structural plasticity in the mature brain is guided by neuronal activity."[288] Synaptogenesis, neurite outgrowth and other forms of structural change are driven by electro-chemical processes associated with neuronal activity.

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[284] D. O. Hebb,. *The organisation of behaviour*. (New York: Wiley, 1949).
[285] Mark F. Bear et al. *Neuroscience. Exploring the Brain,* 3rd ed (Philadelphia: Lippincott Williams and Wilkins, 2007), 717.
[286] Hebb, The organisation of behaviour. 62.
[287] John B. Arden and Lloyd Linford, *Brain-based therapy with children and adults* (New Jersey: John Wiley and Sons, 2009), 21.
[288] Markus Butz et al. "Activity dependent structural plasticity (Review)," *Brain Research Reviews* 60 (2009): 287-305.

Plasticity was first documented by Timothy Bliss and Terje Lomo in their 1973 discovery of LTP as a stable modification of synaptic strength. That dendritic length and branching complexity could be altered by experience was documented in the late 70s by Fiala et al. and by Pysh and Weiss. Later Eric Kandel was awarded the 2004 Nobel Prize for his identification in the 1960s and 70s of the Hebbian mechanism as a basis of memory and learning in the sea slug *Aplysia.*[289]

It is now accepted that plasticity is present in all parts of the mature brain.[290] Pioneer in plasticity studies, Alvaro Pascual-Leone, writes: "Plasticity is an obligatory consequence of all neural activity (even mental practice), and environmental pressures, functional significance, and experience are critical factors."[291]

Lashley had suggested in 1950 that the brain is equipotent, able to compensate for any lesion, and yet, while this view is not borne out empirically, in the last two decades there has been a growing recognition of the enormous plasticity of the brain.[292] "Synaptic plasticity may be the rule throughout the brain, rather than the exception," comments one study.[293] [294] Norman Doidge, psychiatrist and popular science writer, calls plasticity "one of the most extraordinary discoveries of the twentieth century".[295]

2.2.2 Plasticity is categorised as functional or structural.

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289 Source for this section unless otherwise attributed: Byrne, John H. "Learning and memory: basic mechanisms" in *Fundamental Neuroscience*. 3rd ed. Larry Squire et al.,Chapter 49. Burlington, MA: Elsevier, 2008.

290 Butz, "Activity dependent structural plasticity (Review)," 287-305.

291 Pascual-Leone, Alvaro, "The Plastic Human Brain Cortex," 395.

292 For clinical observations of remarkable plasticities in action: Desmurget, "Contrasting acute and slow growing lesions: a new door to brain plasticity (Review)," 898-914. See also Doidge, *The Brain that changes itself.*

293 J. A. Blundon and S. S. Zakharenko, "Dissecting the components of LTP," *The Neuroscientist* 14 (2008): 6.

294 Cf Desmurget, "Contrasting acute and slow growing lesions: a new door to brain plasticity (Review)," 908. The authors comment: "Massive brain lesions within almost any area of the brain, including the supposedly untouchable eloquent areas, can often be effectively counterbalanced by adjacent and remote changes in neural organisations ... (revealing) astonishing plasticity."

295 There has been an evolving appreciation, in contrast with the most rigid forms of localisation theory, that elements of the human CNS have a potency for plastic change, and not infrequently repeated plastic change. Doidge, *The brain that changes itself.*

Functional plasticity is essentially any change in the transmission characteristics of a neuron *without* change to the anatomical connection between neurons. Usually this term is used in contrast to structural plasticity, even though structural changes themselves will normally lead to detectable changes in function. Functional plasticity usually takes place through temporary changes to synaptic strength. This may be for example, owing to a change in number and availability of post synaptic receptors, alteration to presynaptic release of neurotransmitter, and alteration of the thickness of synapse. This short term synaptic plasticity is a virtually ubiquitous form of plasticity in the brain. Another example would be the phenomenon whereby in certain conditions the frequency of firing patterns can up-regulate response thresholds in particular cells, habituating the neuronal response.

Structural plasticity is the anatomical remodelling of neural pathways. Typically it may involve changes to numbers of synapses and neurons, or changes to branching and connectivity patterns. As noted above structural changes bring about an altered function.

Sometimes, but not always, structural change may also be a consequence of functional changes. For example, genetically induced structural changes may themselves be triggered by certain firing patterns. Structural changes are always mediated by intracellular chemical signalling and often lead on to changes in extra cellular signalling at the synapse.

Note however that the distinction between functional and structural changes is increasingly blurred. Neuronally associated functional change often implies structural changes in some form or other. For example, we can now witness and measure *in actu* the rapid growth or retractions of dendritic spines, and the discharge of single neurons. These phenomena bring about not only molecular but also morphological changes at the synapse, changes such as synaptogenesis, vesicle transport and receptor mobility.

Plasticity may also be subtractive, when neurons or synapses are eliminated. It may be reactive (after pharmacological intervention or surgery) or spontaneous (experience dependent). It is competitive, as demonstrated in countless studies; for example, visual topographic representations, rerouted to the auditory cortex, will compete for neural "real estate" at that location even when auditory input is present.[296]

The brain's capacity to lock in new behaviour has been dubbed, "the forgotten fourth aspect of plasticity".[297] William James's linkage of habit with plasticity has already been noted. As this study is of the habits of virtue, durable changes established in character, I will focus principally on structural plasticities. It is highly consistent with an Aristotelian-Thomistic, ensouled-body anthropology that changes in our very character should be thus reflected in our biological constitution. Recall too that James emphasised the "stability" of the new state, the potential for us to *be* in a new way. This sits most comfortably with Aristotelian descriptor of virtue, to be seen in **Chapter 3**, as "that which makes us who we are".

2.2.3 The big picture: synaptic strengthening as the net result of structural plasticity.

At their essence, all structural plasticities involve modifications to neural pathways either directly (direct modifications of neuronal pathways or adjustments to the anatomy of the neuron itself) or indirectly (through changes to the amount and types of neurotransmitter or neuromodulator produced).

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[296] For example: M. Merzenich, "Seeing in the sound zone," *Nature.* 404 (2000): 820-821.
[297] Along with memory, learning and the capacity to reorganise to take up function of impaired areas. Cf Doidge, *The brain that changes itself*, 276; M. V. Johnston et al. "Plasticity and injury in the developing brain," *Brain and Development* 31 (2009): 1-10.

Neuronal function in almost all its aspects is dependent on intracellular signalling initiated at the cell surface. The cell's response to neurotransmitters, growth factors and other signalling molecules depends on receptors and pathways that relay messages to intracellular compartments, and to the enzymes, ion channels and proteins in the cytoskeleton that mediate the effects of transmitters. The variety of ion channels and the flexibility of mechanisms regulating these channels, such as G-proteins, [298] second messengers, and cognate protein kinases that phosphorylate ion channels,[299] greatly enhance the scope for modulating neuronal function. Responses are further modified through localisation and concentration of signal activity and by history of prior activity. It is believed that protein phosphorylation and the regulation of gene expression by intracellular signals are the most important mechanisms for neuronal plasticity.[300]

Ultimately, synaptic strengthening will be the net result of both direct and indirect forms of modification of pathways. These permanent anatomic changes are mediated through gene expression.[301]

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[298] G-protein linked signals are of particular interest to plasticity studies for they offer rich possibilities of modulation of cell function and plasticity. Their slower time frame for operation allows modulation of distant cell processes. Diffusion of second messengers extends messaging through cell body and to nucleus altering gene expression, and to other cells via, for example, NO. G-protein pathways can elicit a coordinated cell response to synaptic release, resynthesis of transmitter, excitability of membrane, gene expression, etc. G-protein linked signals, operating over the span of fractions of a second to many minutes, are capable of diverse modulation and amplification. Typically these G-protein linked signals rely on the generation of a second messenger within the cell that in turn activates proteins, including *protein kinases* (PKA and PKC), which modify processes in the cell. For introduction see Thomas L. Schwartz, "Release of neurotransmitters" in Larry Squire et al. *Fundamental Neuroscience*, 3rd ed. (Burlington, MA: Elsevier, 2008), Chapter 8.

[299] Protein phosphorylation and dephosphorylation are important in regulation of cell function, mediating signals from neurotransmitters, neuropeptides, growth factors, hormones, and other signalling molecules. This process provides the most common post-translational modification in eukaryotes, capable of rapidly modifying functions of enzymes, proteins and channels without adjustment of expression. This mechanism also contributes to long term alteration of cells by changing the complement of proteins. It is often dependent on a second messenger such as cAMP (essentially the second messenger intracellular surrogate for the neurotransmitter which is the first messenger) and Ca^{2+}, or by extra cellular ligand such as nerve growth factor. See Bear, *Neuroscience. Exploring the Brain,* 162.

[300] Source for intracellular signalling: Howard Schulman, and James L. Roberts, "Intracellular signalling" in Larry Squire et al. *Fundamental Neuroscience*, 3rd ed. (Burlington, MA: Elsevier, 2008), Chapter 10; Bear, *Neuroscience. Exploring the Brain,* 157-163.

[301] Genes are in a sense *third* messengers. Extracellular signals (neurotransmitters, hormones, drugs, growth factors, etc) are most influential at the point where transcription is being initiated.

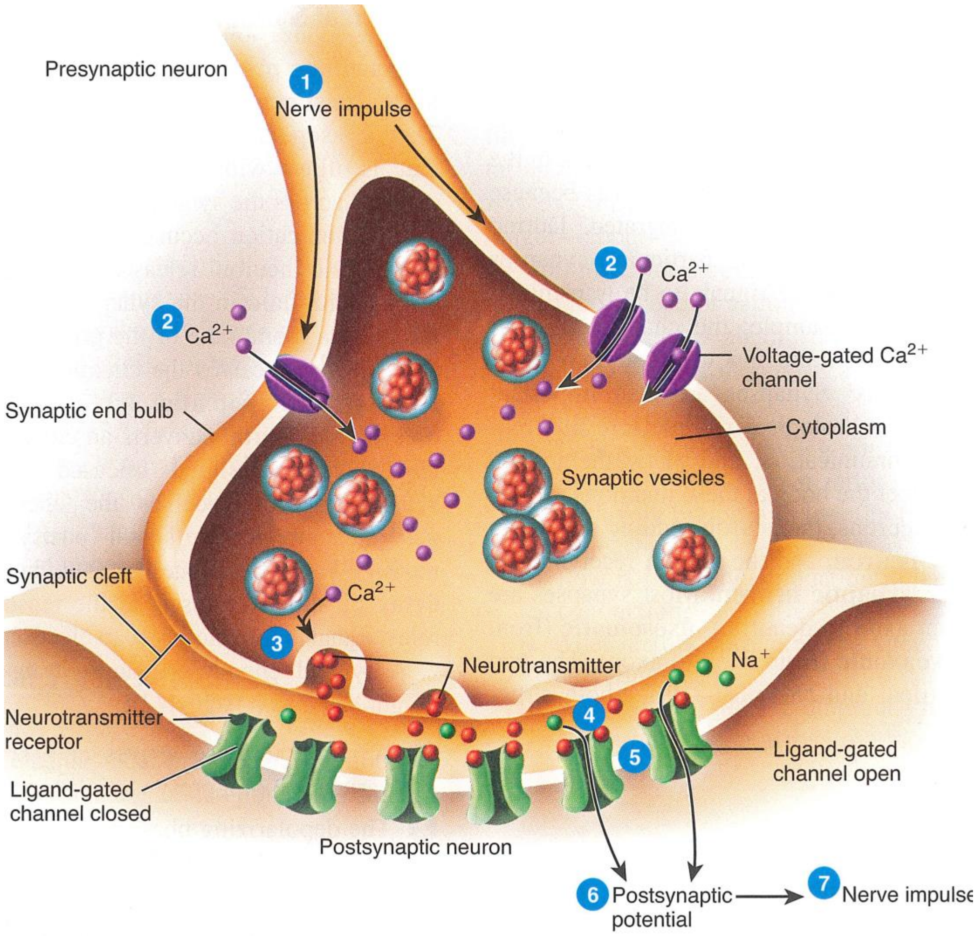

Figure 2.5 Signal Transmission at the chemical synapse. 1.Nerve impulse arrives at synaptic knob. 2. Voltage gated Ca^{2+} enters cell. 3. Ca^{2+} triggers exocytosis of synaptic vesicles. 4. Neurotransmitter suffuses across synaptic gap. 5. Neurotransmitters bind to ligand gated channels allowing Na^{+} to flow into post synaptic neuron. 6. Postsynaptic potential develops.7. Action potential triggered in axon on post synaptic neuron. **Source**: Tortora, Gerard J. and Derrickson, Bryan. *Principles of Anatomy and Physiology*, 12th ed. New Jersey: Wiley, 2009. 442

2.2.4 Developmental plasticity.[302] [303]

Critical to nuclear transcription is the role of the catalytic subunit of PKA that phosphorylates the activator protein CREB on entering the nucleus. Evidence is growing that some forms of long term memory require new gene expression. Intracellular signalling also affects nuclear gene expression. Schulman and Roberts, "Intracellular signaling."

[302] For an introduction: A. Siegal and Hreday N. Sapru, *Essential neuroscience*, revised ed. (Philadelphia: Lippincott, Williams and Wilkins, 2006), Chapter 2.

[303] Unless otherwise attributed in this section: Eric I. Knudson, "Early experience and sensitive periods" in Larry Squire et al. *Fundamental Neuroscience*, 3rd ed. (Burlington, MA: Elsevier, 2008), Chapter 22. Note that some draw a distinction between critical periods when changes are in a tight window and are "wholly or partially irreversible" and sensitive periods as "a time period when exposure has a stronger effect on development." Yoav Ben-Shlomo and Diana Kuh, "A life course approach to chronic disease epidemiology: conceptual models, empirical challenges and interdisciplinary perspectives," *International Journal of Epidemiology* 31, (2002): 285-293.

Many developing neural circuits demonstrate periods of development, known as sensitive or critical periods when their ability to adjust to experience is heightened; they are refined by means of changes in synaptic connectivity.[304] Critical periods or sensitive periods are those finite windows of opportunity for the development of specific sensorimotor faculties.[305] The term is less precisely used for broadly indicative times of greater responsiveness in the development of neuronal systems, for example the window of opportunity for the development of the prefrontal cortical pathways, understood to extend to the early 20s in males.

In critical periods a failure to experience appropriate inputs can lead to permanent impairment of perception or behaviour. Studies of the temperament of rats, for example, provide useful insights into this form of plasticity: attentive mothering is conducive to important behaviour changes that are increasingly understood at the cellular level. The interactions that a newborn rat experiences with its mother in the first week after birth profoundly influence its response to stress as an adult.[306]

In sensitive periods changes are far more readily induced than in maturity; for example, a new language may still be learned as an adult although more arduously and only with focused attention. For other changes the opportunity is lost; for example the window for imprinting may open and close within space of hours. Circuit changes occurring in sensitive periods differ from those in adulthood in magnitude, persistence, and behavioural conditions upon which changes are dependent.

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[304] Veronica A. Alvarez et al. "Distinct Structural and Ionotropic Roles of NMDA Receptors in Controlling Spine and Synapse Stability," *Journal of Neuroscience* 27 (2007): 7365.

[305] For example, the time outside of which the development of cortico-optic pathways is not possible.

[306] The primary mechanism at work is the experience dependent expression level of the GR gene in the hippocampus. Attentive mothering causes a demethylation of a GR gene, thereby a stable increase in GR gene expression in the hippocampus, and a resulting decrease in basal levels of glucocorticoids which at high circulatory levels, lead to anxiety and fearfulness. Also the animal is thereby made capable of tighter regulation of hormonal release in response to stressors. This leads the animal to be calm, adventurous and able to react without anxiety and fear to stressors. Rats that, in these first two weeks, were groomed extensively and where the mother facilitated access to milk are less fearful and less reactive to stressors even as adults. Cross fostering shows the source of these traits to be experiential.

2.2.4.1 Sensitive periods in humans.

Appropriate and adequate environmental inputs are crucial for sound development.[307] [308] This is true for affective and sensory development.[309] Sensitive periods can intersect with the development of moral behaviour. We have seen above the importance of attentive mothering. Positive modifications of an infant's behaviour effected by sound parenting practices, arguably lay the foundations for later virtuous self-directed behaviours.

Rene Spitz broke new ground with his 1945 studies of deprived children suffering from what he called "hospitalism". He found that these children, often with only one carer for eight or more children, were affectively impaired.[310] In the 1990s various researchers followed the longitudinal progress of Romanian orphans raised with little affection and sensory stimulation whilst in orphanages in their early infancy. On leaving the orphanages, the children were found to be impaired in all domains. Despite making up physical size relatively quickly, infants who had been in the orphanages past six months of age were found to have lasting cognitive deficits. Those adopted after the age of two suffered profound deficits. Further studies link postpartum depression in mothers with affective deficits expressed neurobiologically and behaviourally. Infants of depressed mothers tend

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[307] Bear, *Neuroscience. Exploring the Brain,* 701.

[308] Arden and Linford, *Brain-based therapy with children and adults*, 15. This text also contains a table overview of major brain and functional changes in the period between birth and eight years on page 17. Experience in early life is decisive in fundamental human capacities such as stereoscopic vision, visual acuity, and binocular coordination; and high level capabilities such as social behaviour, language (the most studied sensitive period in humans), ability to perceive forms and faces. These sensitive periods are subject to the same principles at work in other animals. Development of the brain proceeds "in phylogenic order", with the development of the senses themselves preceding the higher processing pathways for these senses.

[309] For an overview of the dynamics of attachment, and neural development of the affective potential in infancy: A N. Schore, "Effects of a secure attachment relationship on right brain development, affect regulation and infant mental health" *Infant Mental Health Journal* 22, Nos 1-2 (2001):7-66.

[310] Dennis Coon, *Essentials of psychology*, 7th ed. (Pacific Grove: Brooks/Cole , 1997), 115.

to show a overactivation of areas of the right frontal lobe, and underactivation of the left, in comparison with the norm.[311]

The apt times for development of the child and adolescent brain may also be understood as arguably a "sensitive period". Human grey matter reaches a maximum at 10-12 years of age in parietal lobe, 11-12 in frontal lobe, and 16-17 in temporal lobe. White matter maturation continues throughout childhood and adolescence and within the association areas of the neo cortex has been noted to continue to myelinate through the third and into the fourth decade of life. Myelination the subicular and presubicular regions, and volume of the hippocampus to which these regions connect, continue to grow even into adulthood.[312] When habits of self control, respect and reflection are not acquired in these formative years it can be a steeper road in adulthood to motivate oneself to develop, for example, a habit of study, or a habit of getting up early. If, instead of positive behaviours, the maturing person develops negative traits such as laziness or a habit of venting anger, the challenge of substituting new behaviours can be daunting and all-too-difficult.

For summary, refer to **Table 2.2 Systems for sensitive periods of development** in endpapers.

2.2.4.2 Mechanisms of developmental phases.

The period of early development involves, on a grand scale, plastic change in particular systems of neurons during as a result of appropriate stimuli. An understanding of the mechanisms at work in these early stages is helpful.

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[311] Schore, "Effects of a secure attachment relationship on right brain development, affect regulation and infant mental health" 7-66.

[312] F. M. Benes et al. "Myelination of a key relay zone in the hippocampal formation occurs in the human brain during childhood, adolescence and adulthood," in *Arch. Gen. Psychiatr*. 51 (1994): 477-484.

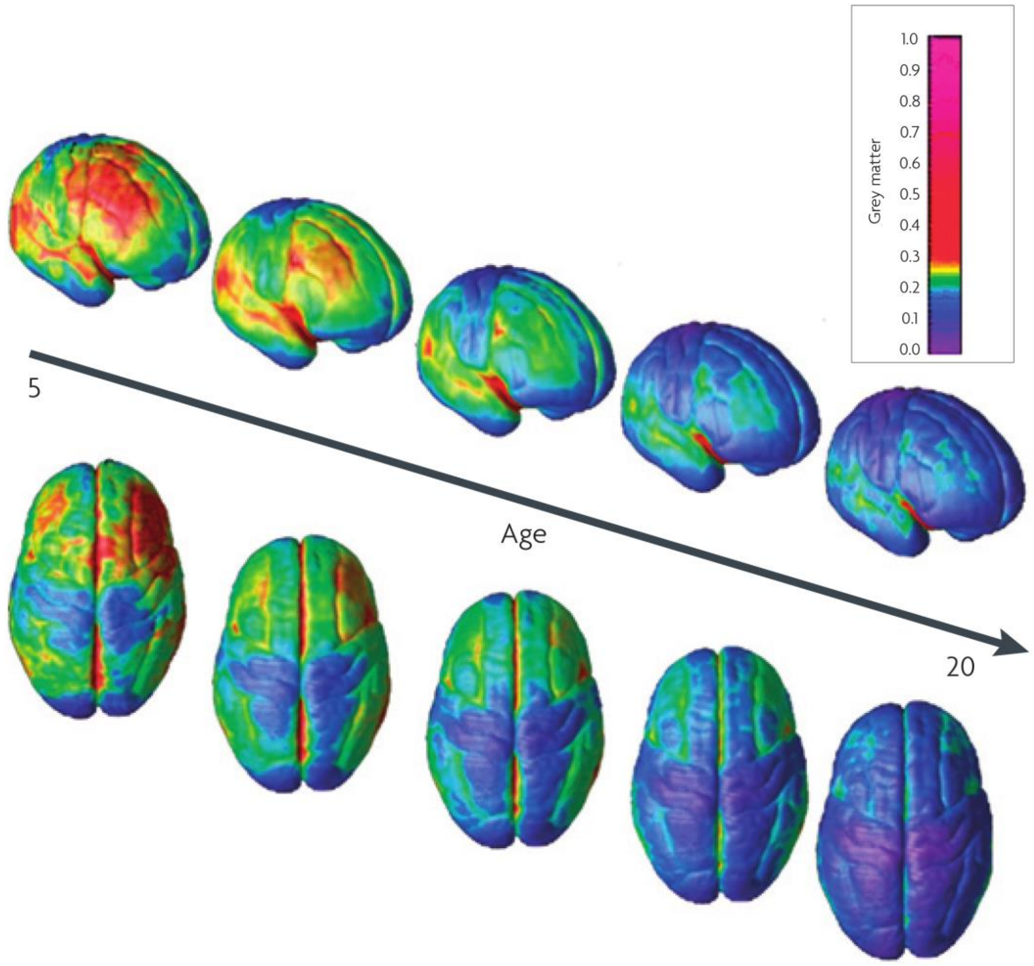

Figure 2.6 **The developing cortex.** The images are generated from a longitudinal MRI study of 13 children scanned biennially over an 8-10 year period. Predominance of blue corresponds to grey matter loss, and increasing myelination, commencing in primary sensorimotor areas and spreading to PFC and lastly to temporal cortex. **Source**: Gogtay, N. *et al.* "Dynamic mapping of human cortical development during childhood through early adulthood." *Procedings of the National Academiy of Science*, USA, 101 (2004): 8174–8179. Citation in Blakemore, Sarah-Jayne. "The social brain in adolescence." *Nature Reviews Neuroscience,* 9 (2008): 267-277.

a) Experience tuned development.

Developmental plasticity typically involves axonal overdevelopment, activity dependent synaptic pruning, and staged synaptic reorganisation. Experience tunes both excitatory and inhibitory connections in a largely non reversible manner and according to Hebbian principles.[313] It seems that the same mechanisms controlling

[313] The opening of critical and sensitive periods depends on pathway maturation. Information involved (from lower circuits) must already be sufficiently reliable, circuit connectivity sufficiently mature, and mechanisms enabling plasticity must be active: for remodelling of axons and dendrites, elaboration of new synapses, adjustment of synapse performance, changes in gene expression.

synaptogenesis during circuit development also underpin circuit remodelling and the establishment of new synapses. For example, neurotrophins such as *brain derived neurotrophic factor* (BDNF) can also play an essential role in anatomical remodelling. LTP and *long term depression* (LTD) have a role in developmental learning and *N-methyl-D-aspartate* (NMDA) receptors are integral to the mechanisms of plasticity at work. (See **2.2.5.1**) When appropriate experience is received and brain circuitry commits to specific linkages, the sensitive period ends. Importantly, once a specific circuit is formed it is much more difficult for altered experience to induce new connections.[314]

b) The role of axons.

The growth cones of neurons, christened by Ramon y Cajal as "soft battering rams", are the axonal tips that grow towards target synapses.[315] [316] Since his work detailing the growth and connectivity of major classes of nerve cells, much insight has been gained into the mechanisms for axonal guidance and for achieving specificity in neuronal connections. Growth cones are actively guided.[317] Sperry from the 1940s showed that there is a highly specific targeting mechanism. In the vicinity of the target field axon development is very accurate, with selection of target cell very precise. Programming in neurons seems to be for specific targets; it has been shown that surgically transferred motorneurons still reached their target. Formation of connections with target cells depends on three factors: the directed growth of axons to the target fields, the selection of target cells, and importantly for the purposes of this study, electrical activity.

[314] See Knudson, "Early experience and sensitive periods," 530.

[315] Marianne Bronner-Fraser and Mary E Hatten, "Neurogenesis and migration," in Larry Squire et al. *Fundamental Neuroscience*, 3rd ed. (Burlington, MA: Elsevier, 2008), 351.

[316] Bear, *Neuroscience. Exploring the Brain,* 699 and Alex L, Kolodkin and Marc Tessier-LaVigne, "Growth cones and axon pathfinding," in Larry Squire et al. *Fundamental Neuroscience*, 3rd ed. (Burlington, MA: Elsevier, 2008).

[317] Accurate axonal guidance depends on various mechanisms such as scaffolding on other axons, use of other extracellular matrices and guidepost cells. The growth cone of the axon, both a sensory and a motor structure, responds to the received guidance cues from outside the cell in the form of large soluble molecules such as netrins, semaphorins, laminins, and cadherins. Four types of guidance mechanisms seem to operate: contact attraction, chemoattraction, contact repulsion, and chemorepulsion.

c) Synapse formation and elimination.

Synapse formation and elimination is a core developmental process. [318] The development of the nervous system is directed by the expression of particular genes at specific times and in specific places but external factors such as nutrients, sensory stimuli and social experience also play a major role in development. Mechanisms exist for neuronal differentiation, for axonal targeting of destination cells, and for regulation of synaptic formation. It is known too that deprivation of normal environmental conditions has profound repercussions on maturation of the nervous system and on behaviour. Of particular interest in this study is the role that physical and social interaction with the environment, and subsequent electrical activity, play in modifying or reinforcing the neural structures once they are formed.

In the human frontal cortex, maximum synaptic density is reached at one year with the numbers coming down to adult levels at approximately 16 years of age.[319] While programmed cell death, in contrast to the case for other animals, plays a lesser role in human brain development, synaptic elimination seems to be more prevalent in humans and primates. [320] The gradual decline in synaptic density proceeds into late adolescence suggesting substantial changes to connectivity up to age 20. DA is believed to play a key role in cortical information processing around puberty.[321] The changing neuromodulatory effects of DA appear to impact on refinement of excitatory and inhibitory inputs of layer III pyramidal neurons during adolescence.

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[318] Although the features in common between synapse formation and synaptic plasticity are not well described it is evident that synaptic connectivity in the CNS is plastic in response to environmental inputs. "Neuronal activity is also important for certain aspects of synapse formation, but exactly how it participates and whether it employs mechanisms shared with those governing synaptic plasticity remain intriguing questions." Steven J. Burden, Dennis D. M. O'Leary and Peter Scheiffele, "Target selection, topographic maps and synapse formation," in Larry Squire et al. *Fundamental Neuroscience*, 3rd ed. (Burlington, MA: Elsevier, 2008), 433.

[319] Arden and Linford, *Brain-based therapy with children and adults*, 87-90.

[320] Peter R Rapp and Jocelyne Bachevalier, "Cognitive development and aging," in Larry Squire et al. *Fundamental Neuroscience*, 3rd ed. (Burlington, MA: Elsevier, 2008).

[321] Arden and Linford, *Brain-based therapy with children and adults,* 87-90.

One recent study shows that children's plasticity of brain seems attributable to a number of mechanisms: neuronal overproduction and programmed cell death (apoptosis) of excessive neurons; overproduction of synapses (approximately twice adult levels in the cortex at age 2) and deletion of immature synapses; and from activity dependent processes that allow for ongoing stabilisation and modification of synapses. By means of these forms of plasticity, children are enabled to learn new skills quickly or recover from brain injury. Synaptic proliferation and pruning are controlled by intrinsic mechanisms and environmental factors.[322] Developmental plasticity is evident through adolescence. Neuroimaging evidence suggests that elimination of synapses has a causal role for changes in social cognitive processing in the PFC, particularly for decreased activity during adolescence in the *medial PFC* (mPFC) and *post central gyrus* (pSTS), a process in which the *anterior cingulated cortex* (ACC), the inferior frontal gyrus, the amygdala and the anterior insula also play a role.[323]

Synapse elimination is a normal aspect of development of the organism and may be viewed as a fundamental process for plasticity. [324] Synapse elimination is essentially a response of the organism to environment. Lichtman and Colman have argued that synapse elimination allows the organism to be more adapted to its specific environment.[325]

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[322] Butz, et al. "Activity dependent structural plasticity," 287-305.
[323] Sarah-Jayne Blakemore, "The social brain in adolescence," *Nature Reviews Neuroscience* 9 (2008): 267-277.
[324] Bear, *Neuroscience. Exploring the Brain,* 707.
[325] Citation from Juan C. Tapia and Jeff W. Lichtman, "Synapse Elimination," in Larry Squire et al. *Fundamental Neuroscience*, 3rd ed. (Burlington, MA: Elsevier, 2008), 469-491. Lichtman writes, "This process may tune the nervous systems of higher animals to the particular environment of each individual animal."[325] They proposed that the loss of connections is due to the greatly duplicated neurons present in mammalian and vertebrate nervous systems. Noting that vertebrate *neuromuscular junctions* (NMJs) initially contain large numbers of fan-in (multiple innervation of single target muscle cell) and fan-out (innervation of multiple target cells) neural pathways, they suggested that the purpose of synapse elimination may be to trim away this redundant multiple innervation of target cells to a situation of multiple unique connections: generating non redundant circuits from a situation of much less specific innervation initially.

Rather than ridding the nervous system of connectivity "mistakes", synapse elimination appears to *sharpen specificity* based on the cues that promote selective synapse formation. The number of axons converging on postsynaptic cells, and number of postsynaptic cells contacted per axon decreases. There is a removal of inputs due to branch trimming. Remaining inputs compensate, adding in part new synapses. Although innervation from multiple sources is eliminated there is an increase in the number of presynaptic terminals linking the surviving axon to the target. Trophic substances appear to contribute to this process. [326] The end result is that new structures more than compensate for the loss. There is no net weakening of synaptic input to target cells. Such synapse elimination is now understood to be central to the maturing CNS through adolescence and into adulthood. Clarification of pathways appears associated with this period of increasing self control.

Typically in neonatal vertebrates axons of neurons fan out to many target cells and connect weakly. In adulthood, axons disconnect from many target cells, there is a lessening of fanning out, and numbers of synapses on each target can increase. Some two thirds of axonal branches in the corpus callosum of newborn monkeys are eliminated in this way, and a similar process has been shown to take place in the human corpus callosum, and in cortico-spinal axons also. This process is linked to experience, and hence is a mechanism of plasticity. [327]

Synapse elimination may play a role also in memory. Bailey and Chen demonstrated that long term habituation of the gill withdrawal reflex also features synaptic elimination. Habituated animals exhibited a pruning of synaptic terminals associated with long term habituation, with a 35% reduction on average from 1300 per neuron to 800 per neuron.[328] It has been suggested that "the most important form of adult plasticity must certainly be memory." [329] It is possible

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[326] Charles T. Leonard, *The Neuroscience of Human Movement*. (St Louis: Mosby, 1998), 126.
[327] Bear, *Neuroscience. Exploring the Brain,* 707.
[328] C. H. Bailey and M. Chen, "Morphological basis of long-term habituation and sensitisation in *Aplysia*," *Science* 220 (1983): 91-93.
[329] Tapia and Lichtman. "Synapse Elimination," 488.

that learning may involve selection of synaptic pathways already in existence rather than construction of new circuits. Plasticity can be both in elimination of some circuits and an alteration of the strengths of existing connections.

Plastic change is not simply about maintaining adaptability, it is also concerned with locking in changes. Hence, synaptic elimination seems closely associated with critical periods and also with the durability of memory. Tapia and Lichtman argue that input elimination provides an answer both for the inability for change after a certain point in critical periods, and also for the indelibility of memory. "Input elimination is an attractive means of assuring indelibility because by eliminating competing (ie asynchronously firing) inputs, a circuit becomes sheltered from disruption by different activity patterns." [330]With respect to memory, the authors note that "the permanent loss of axonal input is an attractive mechanism for information storage." [331]

2.2.5 Other synaptic factors.[332]

There is a growing understanding of homeostasis of the neuron, the maintenance of the overall synaptic weight in the neuron by means of plastic changes and of the associated phenomena of homo-and heterosynapic changes. Butz et al. argue that forms of structural plasticity, rather than following Hebbian or anti-Hebbian principles, [333] contribute to the homeostasis of the neuronal network. Homeostatic neural plasticity refers to the capacity of neurons to compensate for

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[330] Tapia and Lichtman. "Synapse Elimination," 488.
[331] Tapia and Lichtman. "Synapse Elimination," 488.
[332] Material in these paragraphs draws on: M. Chistiakova and M. Volgushev, "Heterosynaptic plasticity in the neocortex (Review)," in *Experimental Brain Research* 199,3-4 (2009):377-90; and Butz, "Activity dependent structural plasticity," 287-305. Chistiakova and Volgushev have focused on homosynaptic and heterosynaptic complementarity. They argue that *homosynaptic* changes are synaptic changes of transmission as a result of the specific induction related to learning. Changes at other synapses on a given neuron that are non involved in the original induction related to learning are called *heterosynaptic* changes. The authors argue that evidence suggests that these changes are complementary processes. Further they suggest that heterosynaptic plasticity may assist in synaptic homeostasis, the maintenance of the overall synaptic weight of a neuron, and in ensuring that certain memories are given greater permanence.
[333] Anti Hebbian plasticity "causes synapses to decrease in strength when there is simultaneous pre- and postsynaptic activity". It is believed to predominate in fibres to cerebellum Purkinje cells. P. Dayan and L.F. Abbott, *Theoretical neuroscience* (Cambridge, MA: MIT Press, 2002).

network activity by regulating their own excitability. This is a neuron centric view in which synaptic remodelling, involving an interdependent complex of functional and structural plastic changes, maintains desired levels of neural activity. Wolff and Wagner noted in 1983 that activity dependent plasticity restores neural homeostasis.

Chistiakova and Volgushev explain that nonassociative, or heterosynaptic, plasticity of specific synapses may result in a neuron as a result of back propagation, where other synapses in the same neuron have experienced Hebbian-type associative, or homosynaptic plasticity by well understood processes of Ca^{2+} influx (fast large amplitude influx leading to LTP; slower low amplitude to LTD) in response to intracellular tetanization. (See **2.2.5.4**.)

2.2.5.1 NMDAR and AMPAR mediated plasticities.

a) NMDA plasticities.

NMDA mediated plasticities, associated with LTP and LTD, are a burgeoning area of current research. The NMDA receptor is one type of ionotropic glutamate receptor.[334] It was first described by Moriyoshi in 1990. Significantly, this pathway seems linked to development, learning, and memory, and to neuronal recovery from injury.[335]

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[334] See discussion in M. Neal Waxham, "Neurotransmitter receptors" in Larry Squire et al. *Fundamental Neuroscience*, 3rd ed. (Burlington, MA: Elsevier, 2008). Unless otherwise noted, Waxham is the source of information in this section.

[335] Enzymes triggered by this process then sensitize the cell to subsequent stimuli through both retrograde signalling and modification of post synaptic proteins, as well as triggering genetic manufacture of new synaptic proteins through the second messenger CREB in association with BDNF. Some hallucinogenic compounds block the NMDA ion channel, but require it open to work, hence are called open channel blockers. NMDA receptors are dependent for opening on both appropriate binding of glutamate and on depolarization of the membrane (having a Mg^{2+} dependent block at resting potential), and they permit Ca^{2+} permeability. Normally these receptors prevent calcium entry, but the arrival of an action potential at the synapse leads to glutamate binding that allows calcium influx and depolarises the cell.

NMDA receptors are implicated in LTP and LTD processes and numerous variations this category of plasticity are now identified: "many forms of activity dependent regulation of synapses demonstrated both *in vitro* and *in vivo* require activation of NMDA-type glutamate receptors. These receptors are among the first molecules to accumulate at the sites of nascent synapses where NMDARs become stable synaptic components." [336]

LTP results, described as "an experience dependent, long lasting increase in chemical strength of neurotransmission that is a crucial mechanism in learning and memory".[337] The precise timing of neuronal plasticity in response to diverse environmental stimuli seems to be a function of the interaction of neurotransmitter and growth factor-signalling pathways. In most structural synaptic plasticities intracellular calcium and gene expression appear implicated. Calcium influx is understood to be a trigger for LTP.[338]

Corlew et al. (2008) suggests that postsynaptic NMDARs trigger classical forms of LTP and LTD, and that *presynaptic NMDARs* (preNMDARs) mediate *spike timing-dependent LTD* (tLTD) at some synapses with some evidence also of LTP. "NMDARs were first discovered as postsynaptic receptors at glutamatergic synapses, and have since been shown to be involved in many aspects of synaptic transmission, dendritic integration, synaptic and neuronal maturation, and plasticity throughout the brain." [339] Corlew et al. place emphasis on preNMDAR regulation of probability for presynaptic release and short-term plasticity.

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[336] Alvarez, "Distinct Structural and Ionotropic Roles of NMDA Receptors in Controlling Spine and Synapse Stability," 7365.

[337] LTP: Definition of Ronald W. Oppenheim and Christopher S. Von Bartheld, "Programmed cell death and neurotrophic factors," in Larry Squire et al. *Fundamental Neuroscience*, 3rd ed. (Burlington, MA: Elsevier, 2008), 456.

[338] Butz, "Activity dependent structural plasticity," 289. Hebbian and anti-Hebbian mechanisms (filtering out unwanted noise allowing only preferred spiking patterns to emerge) seem to be at the core of structural plasticities and synaptic potentiation in the form of LTP and LTD.

[339] R. Corlew, et al. "Presynaptic NMDA Receptors: Newly appreciated roles in cortical synaptic function and plasticity," *The Neuroscientist* 14 (2008): 6, 609.

Another focus for current research in this field is the role of NMDARs in the stabilisation of glutamatergic synapses.[340] Alvarez et al. note that NMDARs perform a regulatory function in the neuron via various pathways and at many levels and that NMDAR presence is essential for spine density and regulation of the number of active excitatory synapses. The authors find that "through ionotropic and structural signalling, NMDARs regulate the rapid dynamics of spine morphology."[341]

Studies by Markram and Sakmann at the Max Planck Institute have demonstrated NMDA related plasticity as a result of pre and post synaptic interaction: precise timing of backpropagating *post synaptic potential* (PSP) following *excitatory postsynaptic potential* (EPSP) leads to a strong depolarisation. This leads to glutamate ejection from NMDA receptors, thus allowing Ca^{2+} influx, a cascade of intracellular messaging, and release of growth signalling factors associated with structural plasticity and consequent LTP.[342]

b) Interplay with AMPARs**.**

Studies are unveiling the role of presynaptic NMDARs and their interplay with *α-amino-3-hydroxyl-5-methyl-4-isoxazole-propionate receptors* (AMPARs), establishing necessary conditions for plasticity.[343] NMDARs have been found at "silent synapses", immature synapses lacking AMPARs but with the potential to acquire them by means of NMDAR mediated LTP. [344] Although LTP and LTD are

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[340] Alvarez, "Distinct Structural and Ionotropic Roles of NMDA Receptors in Controlling Spine and Synapse Stability," 7365-7376.

[341] Alvarez, "Distinct Structural and Ionotropic Roles of NMDA Receptors in Controlling Spine and Synapse Stability," 7372. The authors note that *in vitro* studies of rat hippocampal pyramidal neurons demonstrate that the absence or loss of NMDARs seems not to affect synapse formation nor spine growth, but does increase the motility of spines, and can lead to loss of spines and loss of synapses. These NMDAR dependent spine changes are triggered by electrical stimulation with specific patterned features.

[342] H. Markram et al., "Regulation of Synaptic Efficacy by Coincidence of Postsynaptic APs and EPSPs," *Science* 275, (1997) 213-215. Cited in Waxham, "Neurotransmitter receptors."

[343] Corlew, "Presynaptic NMDA Receptors: Newly appreciated roles in cortical synaptic function and plasticity," 609-625.

[344] Alvarez, "Distinct Structural and Ionotropic Roles of NMDA Receptors in Controlling Spine and Synapse Stability," 7365.

regulated by many mechanisms, AMPA receptor trafficking, the insertion or removal of the *AMPA receptor* (AMPAR) at the synapse, on the basis of evidence from animal studies linking AMPAR trafficking in the rodent barrel cortex to experience dependent plasticity, and AMPAR trafficking to fear conditioning in hippocampus, appears to account for postsynaptic expression involved in LTP and LTD.[345] Kessels and Malinow argue that AMPA trafficking is the mechanism underlying the formation of neuronal pathways, and behaviour modification itself.[346]

Blundon and Zakharenko reviewed the evolution of understanding of LTP and its cellular locus. They described this as an unresolved area for understandings of plasticity. New imaging demonstrates that LTP has both pre- and post- synaptic components although most current studies focus on post-synaptic contributions. "LTP is not a unitary phenomenon, even at a single synapse, but rather is a group of plasticities." [347] NMDA-LTP develops rapidly, is expressed postsynaptically, and is needed for short term memory retention.

The role of zinc at the cortical synapse, and on NMDARs and AMPARs has also become a field of active investigation.[348] That zinc seems to play a role in cortical plasticity is suggested by animal studies showing that rats on zinc deficient diets are more aggressive and have poorer memories at maturity, and monkeys raised by mothers on zinc deficient diets manifest poorer memories and learning. Zinc deprivation during development appears to have a negative effect on DNA

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[345] Kessels, Helmut W. and Malinow, Roberto. "Synaptic AMPA Receptor Plasticity and Behaviour" in *Neuron* 61(2009): 342-3.
[346] Kessels and Malinow, "Synaptic AMPA Receptor Plasticity and Behaviour," 340.
[347] Blundon and Zakharenko, "Dissecting the components of LTP," 600. In contrast to the work of Corlew (above), Blundon and Zakharenko place more emphasis on *presynaptic NMDARs* (preNMDARs) as the source of LTP.NMDA-independent LTP develops more slowly, is expressed presynaptically, and allows longer term retention. The mix of these two pathways depends partially on frequency of the stimulus. Essentially by this second pathway, "calcium-triggered activation of certain protein kinases" leads to the redistribution of AMPARs (and/or enhancement of their properties) in dendritic spines and eventually increases the sensitivity of dendritic spines to glutamate, boosting the response of functional synapses and converting "silent synapses" into functional synapses.
[348] Amy S. Nakashima and Richard H. Dyck, "Zinc and cortical plasticity," *Brain Research Reviews* 59 (2009): 347-373.

synthesis. Although the exact function of zinc in the cortex is not clear, vesicular zinc (about 20% of the zinc present in the CNS) has a wide ranging impact on postsynaptic function. A consensus of numerous studies is that zinc can inhibit LTP in specific neural locations. At postsynaptic locations zinc has various potential effects including inhibition of NMDA, kainite and *γ-Aminobutyric Acid* (GABA) receptors, potentiation of AMPA receptors, increasing glutamate present in the synapse via mechanisms involving glial cells, modulation of internal cell signalling thus also affecting protein synthesis and plasticity.

2.2.5.2 DA and the GPCR receptor.

Of particular interest in this study is the mechanism of DA mediated plasticity, the neurotransmitter most directly associated with the reward systems in the brain. DA, as well as most neuropeptide transmitters, binds only to the *G-protein-coupled-receptor* (GPCR) metabolic receptor. Second messenger pathways are established which may trigger gene transcription. This is one reason why DA is an effective mediator of plasticity. [349] Neuroleptic drugs used in the treatment of neuropsychiatric disorders block DA receptors creating imbalances in the dopaminergic system.

Evidence links NMDARs and D1 Dopamine receptors as critical in certain plasticities.[350] Scott and Aperia show that striatal culture exposure to NMDA promoted recruitment of D1 receptors to the plasma cell membrane via vesicular transport and also by lateral movement in the membrane. An imbalance of D1 and D2 receptors leads to glutamatergic imbalance altering behaviour. For example, hypofunction of the glutamatergic system appears to lead to schizophrenia.

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[349] For an overview of neurotransmitter receptors see: Waxham, “Neurotransmitter receptors” ; and John H. Byrne, “Presynaptic potentials and synaptic integration,” in Larry Squire, et al. *Fundamental Neuroscience*, 3rd ed. (Burlington, MA: Elsevier, 2008) Chapter 11. Unless otherwise stated, the source for this section.

[350] L. Scott and A. Aperia, “Interaction between N-Methyl-D-Aspartic Acid Receptors and D1 Dopamine receptors: an important mechanism for brain plasticity (Review),” *Neuroscience* 158 (2009): 62-68.

Metabotropic receptors are also associated with electrical-signalling-induced plasticities. The study of *post synaptic potentials* (PSPs) reveals a mechanism for long term plastic changes in neuronal and synaptic structure. [351] [352] Slow PSPs are the indirect effect of transmitter binding to metabotropic receptors.[353]

2.2.5.3 Neurotrophic factors.[354]

The presence or absence of *neurotrophic factors* (NTFs) or neurotransmitters can promote neural growth. [355] Following groundbreaking work, from the 1930s, by Viktor Hamburger and Rita Levi-Montalcini into into p*rogrammed cell death* (PCD) or apoptosis, came the identification of NTFs.[356] This led in turn to the neurotrophic hypothesis: "Neurons compete for limiting amounts of target derived survival promoting (trophic) agents during development."[357]

The presence or absence of NTFs can play a decisive role in a number of mechanisms in the nervous system including the fate of cells, axons, neurite growth and branching, dendrite development, synapse development and regulation, stabilization and plasticity, in LTP, and in learning and memory. Poo and his team discovered that neurotrophins can have a regulatory function in

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[351] Byrne, "Presynaptic Potentials and synaptic integration" Chapter 11.
[352] For a clear introduction to synaptic transmission: Laurie Lundy Ekman, *Neuroscience Fundamentals for Rehabilitation,* 3rd ed. (St Louis: Elsevier, 2007), Chapter 3.
[353] A typical pathway involves the K^+ metabotropic channel which is normally open. The transmitter binds to the receptor activating the G protein to interact with AC adenylyl cyclise. As a result the synthesis of cAMP is increased, PKA protein kinase A is activated, the channel protein is phosphorylated, and the channel closes. These PSPs are generally slow and persistent because of activation of second messenger systems. This pathway provides long term modulation of the ionotropic pathway, altering both the membrane potential and the biochemical state of the postsynaptic cell.
[354] Principal source for this section: Oppenheim and Von Bartheld, "Programmed cell death and neurotrophic factors," 452.
[355] Wolff et al. in 1979 documented that neurotransmitter GABA may also act as neurotrophic agent. See Butz, et al., "Activity dependent structural plasticity," 288.
[356] Bear, *Neuroscience. Exploring the Brain,* 707.
[357] Kristin Scott, "Chemical senses: taste and olfaction," in Larry Squire, et al. *Fundamental Neuroscience*, 3rd ed. (Burlington, MA: Elsevier, 2008), 452.

synaptic plasticity through the neurotrophins BDNF and NT-3 that have fast and major effects on the strength of synapses.[358] In 2003 Chao noted that*:*

> Neurotrophins and other NTFs also play a role in modulating long term changes in functional and anatomical plasticity in the developing and mature brain by altering long term potentiation, synaptic connectivity, and responses to stress, inflammation and trauma.[359]

There are multiple families of NTFs:

- CNTF and LIF of the neuropoietic cytokine family possess widespread neurotrophic acivity.
- The GDNF family (GDNF, neurturin, artemin, and persephin) relate to the TGF ▯ gene family impacting on enteric, dopaminergic and motor neurons.
- *fibroblast growth factors* (FGFs) may have role in injury.
- And NTFs themselves, which have a role in determination of stem cells, neuronal migration and survival, axonal growth and regulation of synaptic competition and plasticity, LTP, response to injury, regeneration and adult neurogenesis.

NTFs interact with two major classes of receptors:

- the trk (tyrosine receptor kinase) family of receptors;[360]
- the receptor p75NTR.

It is believed that interaction between neurotransmitter and growth factor-signalling pathways plays an important role in neural plasticity in response to

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[358] M. M. Poo, "Neurotrophins as synaptic modulators," *Nature Reviews Neuroscience* 2 (2001): 24-32. Cited in Oppenheim and Von Bartheld. "Programmed cell death and neurotrophic factors," 461.

[359] M. V. Chao, "Neurotrophins and their receptors: a convergence point for many signalling pathways," *Nature Reviews Neuroscience* 4 (2003):299-309. Cited in Oppenheim and Von Bartheld, "Programmed cell death and neurotrophic factors," 461.

[360] The Trk receptor kinases and the trk family members, trkA, trkB, and trkC, transduce neurotrophic signals setting up pathways that are inhibitory to apoptopic mechanisms. Deprivation of neurotrophins can lead trigger pro-apoptopic mechanisms that promote cell death.

diverse environmental stimuli.[361] BDNF is an important mediator of plastic change. It is active in synaptogenesis,[362] and appears to play a role in converting short term memories to long term memories; blocking of BDNF during exercise prevents exercise induced increase in *cAMP response-element binding protein* (CREB) mRNA levels. CREB activation, via *cyclic AMP* (cAMP) pathways,[363] leads to expression of cFos and Jun which in turn effect the expression of genes bringing about LTP and long term memory. Some studies suggest that self-perpetuating loops are established.[364]

2.2.5.4 Other chemical signalling systems.

a) Ca^{2+}.

Ca^{2+} plays a key role in the mechanisms of plasticity.[365] Calcium channels are found in all neurons. Ca^{2+} is an important second messenger in neurons influencing neurotransmitter release, synaptic plasticity, neurite outgrowth during development and gene expression. The variety of ion channels and ionic mechanisms make possible complex patterns of action potentials within single neurons as well as complex synaptic computations.[366]

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[361] Oppenheim and Von Bartheld, "Programmed cell death and neurotrophic factors," 452. "Secretion of neurotrophins requires activity dependent stimulation patterns that may specifically strengthen active synapses."

[362] S. Vaynman and F. Gomez-Pinilla, "Licence to run. Exercise impacts functional plasticity in the intact and injured central nervous system by using neurotrophins," *Neurorehabilitation and Neural Repair* 19, No 4, (2005): 283-95. BNDF affects the action of synapsin I, the protein by which synaptic vesicles are tethered to the actin cytoskeleton. In the event of high frequency stimulation a ready availability of vesicles sustains synaptic transmission but when synapsin I is inhibited neurotransmitter release is reduced and transmission may be breakdown. Studies linking genetic compromise of the synapsin I gene to learning difficulties suggest that presynaptic molecules such as synapsin I contribute to the phenomenon of perforated synapses (believed through their multiple dendritic contacts to enhance transmission), and suggest that synapsin I regulates neuronal formation including neurite development, axonal elongation and synaptogenesis.

[363] AMP is agonist for AMPA channels.

[364] Vaynman and Gomez-Pinilla, "Licence to run. Exercise impacts functional plasticity in the intact and injured central nervous system by using neurotrophins," 283-95.

[365] Schwartz, "Release of neurotransmitters," 160.

[366] Ca^{2+} processes affect short term synaptic plasticity. We speak of dependent plasticity whereby the performance of synapses varies according to frequency of stimulation and record of prior activity. Usually, repetitive high frequency stimulation (known as a *tetanus*) is initially dominated by a growth in successive PSP amplitudes. This is a process known as *synaptic facilitation* (or

Ca^{2+} can be associated with memory and learning. Significantly, excess Ca^{2+} is toxic to the neuron, a feature linked to neurodegenerative disorders and to cell death in hypoxic brain injury. The glutamate receptor, mGluR1**,** has been linked to long term synaptic plasticity at many sites in brain especially LTP in hippocampus, and LTD in cerebellum.

b) ACh.

ACh is the agent of plasticity in the neuromuscular synapse. Initially various motor neurons may input a single muscle fibre, but stimulation accelerates the pruning of inputs to one source. AChR elimination precedes loss of the synapse as the first step in the process. The presynaptic terminal then disassembles and the axon retracts. It has been shown that when α–bungarotoxin blocks some of the ACh receptors the process is triggered.[367] ACh has been described as "a brain chemical essential for learning".[368] Nicotinic ACh is the major neurotransmitter acting at neuromuscular junctions in the *peripheral nervous system* (PNS) and is a mediator of memory in this pathway. ACh at muscarinic receptors plays a role in neuromodulation in the CNS, specifically in selection of objects of attention, and is thus an important contributory factor for learning and thus plasticity.[369] Aspartate and glutamate, the biogenic amines, and neuropeptides also have significant links to pathways of plasticity. There are numerous other currents of investigation.[370]

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synaptic depression where the second stimulus is lessened the closer it is to the first as a result of a depletion of available vesicles; autoinhibition, or receptor desensitization). By paired pulse facilitation the second pulse can be twice the amplitude of the first as registered across the synapse, typically within a second. *Augmentation* over seconds replaces facilitation. *Potentiation* is a third phase of growth in amplitude, evident over minutes (also concept of *post-tetanic potentiation*). Residual Ca^{2+} seems to lead to facilitation, augmentation and potentiation. It seems this is not simply due to residual Ca in active zones but possibly to an overloading of the Ca removal processes. For more detail: David A. McCormick, "Membrane potential and action potential" in Larry Squire, et al. *Fundamental Neuroscience*, 3rd ed. (Burlington, MA: Elsevier, 2008), 125.

367 Bear, *Neuroscience. Exploring the Brain,* 707.

368 Doidge, "The brain that changes itself," 43.

369 Lundy Ekman, Laurie. *Neuroscience Fundamentals for Rehabilitation.* 3rd ed. St Louis: Elsevier, 2007. p60

370 Kessels and Malinow, "Synaptic AMPA Receptor Plasticity and Behaviour," 344. It is suggested also that release of NE following emotional arousal may promote synaptic plasticity.

c) Other chemical signalling.

Other chemical signalling is also conducive of plasticity. As we have seen above, certain chemical signalling, most commonly in the forms of neurotransmitters, neuromodulators such as enkephalins, and growth factors, affect function at the synapse and are candidates to mediate plasticity. *Endocannabinoid* (EC), DA and calcium signalling mediate plasticity in the form of LTD and LTP as revealed in the corticostriatal pathway. Wickens explains that DA "plays a crucial role in determining the magnitude and direction of plasticity." He notes that EC signalling and *spike timing dependent plasticities* (STDP) are also significant in mediating presynaptic LTD.[371]

d) Desensitization.

Desensitization, a simple mechanism of plasticity, is common in the GPCR receptors. There are two known mechanisms for desensitisation. The first is rapid, from seconds to minutes, and involves receptor phosphorylation. The second may take either minutes or hours, and involves the physical removal of receptors, a process that involves endocytosis. As a down-regulating mechanism it may be either reversible or irreversible.

2.2.5.5 Astrocytes at the synapse.

In a 2008 review, Stevens looked at the emerging understanding of the complex role of astrocytes in mediating synaptogenesis, synaptic elimination, and structural plasticity using chemical and physical signals. Advances in imaging provide graphic insights into the speed of spine and synapse formation, and the morphology of the astrocytes themselves. Astrocyte envelopment of a synaptic terminal, a dendritic spine, is shown to take place over some 12 minutes; single

[371] Wickens, "Synaptic plasticity in the basal ganglia,"119-128.

astrocytes may associate with multiple neurons and over 100,000 synapses, actively signalling and providing stability to each.[372] Releasing trophic factors and "gliotransmitters", exhibiting rapid reaction to environmental cues, and expressing many of the same surface molecules, receptors and channels as do neurons, astrocytes are now seen as critical in developing neural pathways in the brain.

2.2.5.6 Structural considerations.

a) Dendritic spines.[373]

Dendritic development provides important insights into experience based plasticity. Rapid changes in arbor development are possible in response to synaptic inputs or growth factors. Slower changes link to gene transcription. Dendritic growth and branching is influenced by a variety of extra cellular signals. NTFs (eg NGF, BDNF, NT-3, NT-4) act through Trk receptors in regulating arborisation, increasing length, branching, and the number of primary dendrites.[374]

Synaptic inputs, by increasing calcium influx rapidly, may enhance rates of branch addition and stabilization. Slower phase calcium signals may signal the nucleus for gene transcription. Such activity induced genes can then have profound effects on dendritic arbor structure and function. This dynamic morphological remodelling allows individual neurons to constantly adapt and respond to external stimuli.

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[372] Stevens, "Neuron-astrocyte signalling in the development and plasticity of neural circuits," 278-288. It seems that Ephrin/Eph signalling plays a role in regulating the morphology of spines, possibly in stabilising immature filipodia into mature spines.

[373] For the mechanisms and process of dendritic arbor development: Hollis Cline, et al. "Dendritic development," in Larry Squire, et al. *Fundamental Neuroscience*, 3rd ed. (Burlington, MA: Elsevier, 2008), 1141.

[374] L. Ciani and P. C. Salinas, "Signalling in neural development: WNTS in the vertebrate nervous system: From patterning to neural connectivity," *Nature Reviews Neuroscience* 6 (2005): 351-362. Authors note that Notch signalling activates gene transcription and can restrict length of dendrite, positively promote branching and increase dendritic complexity. The Slit guidance proteins and the Robo receptor are also involved in signalling. Ciani and Salinas documented the role of WNT signalling (secreted proteins with a role in neuronal cytoskeleton. Cadherins and □□ catenin also seem to be important mediators of dendritic morphogenesis.

Bestman et al. (2008) demonstrated that processes of selective stabilization and elaboration of branches toward appropriate target areas, leading to circuit refinement, are present in developmental stages and also underlie the refinements occurring in the mature nervous system.[375]

Synaptic strength and dendritic development are interrelated. Synaptic and structural plasticity seems to be a result of signals received by the dendrite. Work by Luo in 2002 suggests that synaptic strength and dendritic arbor development share the same molecular regulatory pathways.[376] Synaptic inputs and neurotransmitters actively play a significant role in controlling dendritic arbor development. NMDA and AMPA receptor function is linked to dendritic branch specialisation: hence synaptic strengthening and structural stability seem linked. Engert and Bonhoeffer (1999) showed that LTP inducing stimuli increase both synaptic strength and spine formation.[377] As it does for synaptic strengthening, sensory input has striking effects on dendritic development.[378] In a calcium dependent process, afferent input through AMPA receptors stabilizes synapses and increases arborisation. There is evidence that waves of calcium in the developmental stages of neurons may underpin normal brain development and plasticity.[379] Calcium/calmodulin dependent protein kinases (CaMKs) and MAPKs appear to be mediators of calcium dependent dendritic growth.[380] [381]

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375 J. Bestman, et al. “Dendrite Development,” in *Dendrites*, ed. Stuart, Spruston, Hauser (Oxford: Oxford University Press, 2008).

376 L. Luo, “Actin cytoskeleton regulation in neuronal morphogenesis and structural plasticity,” *Annual Review of Cellular Developmental Biology* 18 (2002): 601-635. Cited in Cline, et al. “Dendritic development.”

377 F. Engert and T. Bonhoeffer, “Dendritic spine changes associated with hippocampal long term synaptic plasticity,” *Nature* 399 (1999): 66-70. Cited in Cline, et al. “Dendritic development.”

378 W. C. Sin, et al. “Dendrite growth increased by visual activity requires NMDA receptor and Rho GTPases,” *Nature* 419 (2002): 475-480. Cited in Cline, et al. “Dendritic development.”

379 S. I. Firth, et al. “Retinal waves: mechanisms and function in visual system development,” *Cell Calcium* 37 (2005): 425-432. Cited in Cline, et al. “Dendritic development.”

380 Different types of neurons all have characteristic arborisation. Dendritic trees also vary according to spatial extent and type of afferent input. The orderly arrangement of dendrites is governed by three factors: self avoidance (no overlapping with dendrites of own neuron) leading to maximal dispersion and unambiguous signal processing; tiling (no overlap of dendrites of neurons of same type); co-existence (overlap of dendritic tress of different types of neurons). In development, dendrites interact with other neurons and glia and this affects arbor development in both extent and timescale. It is evident that dendrites have mechanisms whereby they recognise

b) Dendritic processing facilitates plasticity and cortical control.

The phenomenon of retrograde impulse spread into dendrites, whereby action potential actively back propagates into dendrites, can have many functions and effects. [382] Importantly for this study, it creates conditions for synaptic plasticity by depolarising spines. Permanent changes at the spine in response to stimuli greatly enhance the potential for plasticity in the neuron. It is the synaptic regions of dendritic areas of the neuron that exhibit the plastic changes involved in learning and memory. [383] "Spines add a dimension of local computation to dendritic function that is especially relevant to mechanisms for learning and memory." [384]

c) The speed of morphological change.

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neighbouring dendrites. Many of these signals remain to be identified, although *Downs Syndrome cell adhesion molecule* (Dscam), originally identified as an axon guidance receptor, provides insights into *Drosophila* dendrite self avoidance. *Drosophila* studies give insight into mechanisms of dendrite development, revealing for example, the genetic basis for characteristic arborizations. For example, Lohmann et al (2005) documented that synaptic inputs, by increasing calcium influx rapidly may enhance rates of branch addition and stabilization. Dendro-dendritic interactions regulate the shape and organisation of dendritic fields. Dendrite development involves both growth and retraction. See C. Lohmann, et al. "Local calcium transients regulate the spontaneous motility of dendritic filopodia," *Nature Neuroscience* 8 (2005): 305-312. Cited in Cline, et al. "Dendritic development."

[381] Additional source for this section: Cline, et al. "Dendritic development."

[382] For example, dendritic information processing can enhance the signal to noise ratio, enable the neuron to enter into oscillatory activity, and can provide parallel processing pathways. The net result is that in the dendritic tree various modes of information processing are evident: logic operations, motion and coincidence detection, oscillatory activity, lateral inhibition, network control of sensory processing involving attenuation, filtering, amplification, and segregation, and motor control. Standing oscillatory activity along neural pathways has been associated with neural mechanisms offering improved cortical control.

[383] Gordon M. Shepherd, "Complex information processing in dendrites," in Larry Squire, et al. *Fundamental Neuroscience*, 3rd ed. (Burlington, MA: Elsevier, 2008), 267. The apical dendrite of the CA1 pyramidal neuron: "Most of the input to the oblique dendrites is believed to be involved in the generation of LTP, a candidate model for learning and memory."

[384] A decrease in stem diameter increases input resistence of spine head and therefore the necessary EPSP amplitude affecting subsequent response and also degrading connectivity to parent dendrite. Spines themselves may also have active properties because of either voltage gated channels or voltage dependent synaptic receptors such as for NMDA. Information processing based on coincidence detection and response implies simple logic operations are inherent at the level of the dendrite and spine suggesting the possibility of cognitive contributory role. Shepherd, "Complex information processing in dendrites," 267.

Tiny dendritic spines seem related to cognitive function: studies of mental retardation and different hormonal exposures show that spine morphology is greatly altered in cortical neurons. The dimensions of the spine stem determine quality of the connection to dendritic branch, thereby providing a mechanism for learning and memory. [385]

The time required for a synapse to develop is remarkably short. [386] It is calculated that the presynaptic terminal forms in 10-20 minutes, and that the complete process from initial contact to a functional synapse requires only one to two hours. Once the target is reached, cell adhesion molecules bring the cells together at the synapse in a rapid process. This data is of significance in studies of plastic change.

Yasumatsu et al. (2008), with ongoing physical measurement of cultured rat hippocampal CA1 pyramidal dendritic spines via two photon imaging over the space of several days, demonstrated that generation and elimination of spines took place more frequently than had been previously believed, and that this took place both with and without synaptic activity. The authors suggested that enlargement of a spine, being a virtually instantaneous process unlike the 20 mins required for spine generation, can provide a mechanism for short term memory. They note that large spines with long necks, found more often in the cortex than the hippocampus, are resistant to activity dependent shrinkage and they suggest that this supports the current view that the neocortex is responsible for longer lasting memories.[387]

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[385] Shepherd, "Complex information processing in dendrites," 267.

[386] Elaine N. Marieb and Katja Hoehn, *Human anatomy and physiology*, 8th ed. (San Francisco: Pearson, 2010).
p424

[387] N. Yasumatsu, et al. "Principles of Long-Term Dynamics of Dendritic Spines," *Journal of Neuroscience* 28(50) (2008): 13592-13608. The study showed that spines demonstrate a native instability but that statistically spine volume correlates to age and life expectancy. Close analysis showed also that dendritic filipodia are constantly emerging. They find a correlation between the "savings function" quantified by Ebbinghous in 1885 to model retention of memories, and the curve of volume decay for small spines.

Further corroboration is found in the studies by Conde and Caceres highlighted the extremely dynamic internal structures of axons and dendrites and speed with which change plastic structural change occurs.[388] (See **2.2.5.6. e**) They showed that microtubules grow and disassemble rapidly, especially at times of synaptogenesis and that growth cone motility may be regulated by microtubule-associated-protein 1B (MAP1B). In a 2003 study of mice genetically engineered to express differently fluorescing proteins, Walsh and Lichman were able to obtain images of retraction of the axon from one motor neuron and replacement by another over the space of four days. The dramatic substitution of one axonal tip for the other appears to takes place in less than a day.[389]

d) Plasticity as a consequence of neurogenesis.

Neurons in the human organism are normally established at birth, yet in adult humans neural stem cells persist in regions near ventricular layers, including hippocampus, regarded as a key region for memory and learning.[390] The signals triggering development of neural stem cells are not yet clear but environment may well play a key role. For example, rats raised in enriched environments show more proliferation and survival of hippocampal stem cells. Conversely, stress seems to inhibit stem cell proliferation and viability in the hippocampus. Hippocampal stem cells appear to play a significant role in permitting the plasticity inherent in memory processes.

e) Microtubule assembly.

Another recent line of research focuses on the contribution of microtubules to structural plasticity. Conde and Caceres reviewed understanding of the regulation of microtubule assembly, organisation and dynamics in axons and dendrites, and

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[388] Cecilia Conde and Alfredo Caceres, "Microtubule assembly, organisation and dynamics in axons and dendrites (Review)," *Nature Reviews Neuroscience* 10, (May 2009): 319-332.
[389] M. K. Walsh and J. W. Lichtman, "In vivo time-lapse imaging of synaptic takeover associated with naturally occurring synapse elimination," *Neuron* 37, (2003):67.
[390] Bear, *Neuroscience. Exploring the Brain,* 693.

supported the view that microtubules are "key determinants of neuronal polarity" [391] with a potential contribution to plasticity. Their very dynamic instability, an ability to grow and disassemble rapidly, lends weight to this view. Assembled as dense parallel arrays, bundles, microtubules have been shown to play a key structural role, required for both growth and maintenance, in both dendrites and axons.[392] The regulated assembly of microtubules is evident at synaptogenesis. The authors suggest that this process and also the regulation of growth cone motility may be managed by microtubule-associated-protein 1B (MAP1B).[393]

2.2.6 Use-induced plasticities.

The projects of Michael Merzenich continue to demonstrate the vast possibilities for plastic change in the brain induced by activated pathways. [394] For example his work with ferrets has demonstrated the capacity for the auditory cortex A1 to wire for visual cues in the same way that V1 normally establishes a rectinotopy (a topographic map of the neuronal inputs from the retina) and what are called "orientation columns" with pinwheels of groups of specific neurons. Acknowledging the insights of Aristotle, he says "This is an important extension of issues addressed by Aristotle, John Locke, Charles Bell, Johannes Muller and others. Each of these added a progressively more convincing and more complete argument that the sources of input signals to the brain, and the activations of specific brain regions by those signals, underlie sensory qualities and functions."[395]

The well known London taxi driver study revealed that the human hippocampus is capable of responding to experience/environment by mechanisms of plasticity. London taxi drivers are required to master what is commonly known as "The Knowledge", a police city navigation test that requires typically two years of study.

[391] Conde and Caceres, "Microtubule assembly, organisation and dynamics in axons and dendrites (Review)," 319.
[392] Conde and Caceres, "Microtubule assembly, organisation and dynamics in axons and dendrites (Review)," 321.
[393] Conde and Caceres, "Microtubule assembly, organisation and dynamics in axons and dendrites," 329.
[394] Merzenich, "Seeing in the sound zone," 820-821.
[395] Merzenich, "Seeing in the sound zone," 820-821.

The volumes of the posterior hippocampi of 16 experienced (mean of 14.3 years driving) London taxi drivers were shown not only to be significantly larger than those of control subjects but also to be correspondingly larger in proportion to the amount of years of taxi driving although the increasing volume was only reflected in the right hippocampus suggesting that the left and right hippocampi have differing roles in spatial navigation. This study suggests that this posterior hippocampal region is utilised to store spatial representation of the environment, and that the hippocampus is capable of plastic change in response to the demands of experience.[396] This is in line with current understanding of the hippocampus; that it codes for the storage of explicit memory.

Somewhat analogously a 2005 study by Lazar et al. demonstrated that meditation influences experience dependent cortical plasticity. Cortical thickness in brain regions for attention and sensory processing were thicker than matched controls for the twenty participants in the study with extensive meditation experience, mediation understood as cultivated attention to present moment stimuli without cognitive elaboration. Thicker cortical regions included the PFC and right anterior insula, mostly in the right hemisphere, that responsible for sustaining attention. The study did not reveal the source of the greater thickness. Possibilities included enhanced dendritic arborisation, glial volume or increased vasculature but all would support increased neuronal function.[397]

The 2007 study by Desmurget et al. highlights the swiftness and comprehensive extension of plastic response after trauma. The authors review the literature on recovery from stroke and from *low grade glioma* (LGG), a slow growing tumour. They note that LGG recovery after surgery is in most cases complete within a year and that tumour invasions cause the brain to initiate a major reorganisation of the

[396] E. A. Maguire, et al. “Navigation-related structural change in the hippocampi of taxi drivers,” in *Proceedings of the National Academy of Sciences of the USA* 97, 8 (2000): 4398-403. Two different independent analysis techniques were used, one utilising *voxel based morphometry* (VBM) in structural MRI scans of the whole brain, and a second involving an established pixel counting approach focusing on the hippocampus itself. The non drivers manifested a larger anterior hippocampal region.
[397] S. W. Lazar et al. “Mediation experience is associated with increased cortical thickness,” *NeuroReport* 16, (2005) 1893-1897.

neural functions, hence most LGG patients present as normal or only slightly impaired despite substantial tumours.

They also record the phenomenon of acute functional remapping, the cause of which is unclear. They demonstrate that function control can transfer within 15-60 mins of the resection to other adjacent regions, perhaps taking up “latent intracortical connections”.[398] They suggest that a gradual learning process mediates brain plasticity, with the soon to be eclipsed areas instructing intact regions via indirect and direct pathways. This theory would account for remarkable adjustments as slow growing lesions develop and also for subsequent recovery after resection.[399]

2.2.7 Exercise induced plasticity.

A form of use-induced plasticity is exercise induced plasticity. It also appears to follow pathways mediated by chemical signalling. Energy intake and expenditure serve to co-regulate plasticity in the adult hippocampus, which, along with the temporal lobe structures, is a brain area essential in learning, memory and mood regulation. [400] It has been shown in animal studies that “enhancement of somatic metabolism by wheel running or caloric restriction improves central neuroplasticity,”[401] and that in contrast, a high caloric diet, excessive energy intake, serves to reduce plastic and learning in the hippocampus by reducing the presence of BDNF. [402]

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[398] Desmurget, et al. “Contrasting acute and slow growing lesions: a new door to brain plasticity,” 908.

[399] Desmurget et al. “Contrasting acute and slow growing lesions: a new door to brain plasticity,” 898-914.

[400] Alexis M. Stranahan and Mark P. Mattson, “Impact of Energy Intake and Expenditure on Neuronal Plasticity,” *Neuromolecular Medicine* 10, 4 (2008): 209-218.

[401] Stranahan and Mattson, “Impact of Energy Intake and Expenditure on Neuronal Plasticity,” 209.

[402] Stranahan and Mattson, “Impact of Energy Intake and Expenditure on Neuronal Plasticity,” 209.-218. The words of the Roman lyric poet Horace appear prophetic: “Clogged with yesterday’s excess, the body drags the mind down with it.”

BDNF, including exercise induced transcription of BDNF, is seen as a facilitator of neuronal excitability and function at the synapse. Vaynman and Gomez-Pinilla have reviewed the literature on exercise induced up-regulation of BDNF promoting repair and neurotrophic support. Exercise studies draw attention to the increase in levels of molecules such as the *insulin-like growth factor* (IGF), *fibroblast growth factor 2* (FGF-2) and BDNF in regions of the brain, most particularly the hippocampus. "Exercise can activate specific neural circuits to modify the way that information is transmitted across cells at the synapse…."[403] The authors demonstrate that exercise raises neurotrophic factor levels in regions of the adult brain improving learning and memory.[404]

Animal studies have shown repeatedly that exercise improves cognitive function especially in tasks dependent on the hippocampus. Studies also show that BDNF is also exercise induced in the cerebral cortex, the cerebellum and the spinal cord. BDNF is known to mediate synaptic plasticity, and facilitate learning and memory mechanisms.[405]

2.2.8 Plasticity induced by transcranial stimulation.

There is considerable current focus on the various techniques of transcranial stimulation and the resultant plasticities that are evident. A leader in these fields is Alvaro Pascual Leone.

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[403] Vaynman and Gomez-Pinilla, "Licence to run. Exercise impacts functional plasticity in the intact and injured central nervous system by using neurotrophins," 283.

[404] Vaynman and Gomez-Pinilla, "Licence to run. Exercise impacts functional plasticity in the intact and injured central nervous system by using neurotrophins," 283. Hippocampal culture studies show that depolarising activity leads to the overexpression of mRNAs for the pro-BDNF and other precursor protein. BDNF, however, is the growth factor that shows greatest induction in the hippocampus. Levels of BDNF present in the hippocampus correlate directly to learning efficiency and memory with BDNF blocked rats showing no exercise induced improvement in performance on the Morris water maze task and rats with laboratory reduced BDNF levels in the hippocampus demonstrating impaired spatial learning and memory.

[405] Vaynman and Gomez-Pinilla, "Licence to run. Exercise impacts functional plasticity in the intact and injured central nervous system by using neurotrophins," 283.

A recent study co-authored by Pascual Leone reviews the current knowledge of *transcranial direct current stimulation* (tDCS) making the observation that studies demonstrate that tDCS is responsible for long term synaptic change brought about by protein synthesis, and that these changes are reversible and feature similarities to LTP and LTD. The authors suggest that tDCS is distinct from other transcranial electrical stimulation and transcranial magnetic stimulation in that it will not produce the rapid depolarisation and hence action potentials in neurons. It is likened to a neuromodulatory intervention.[406]

A further study focuses on non invasive *repetitive transcranial magnetic stimulation* (rTMS) and the manner in which it has been applied to induct changes in neuronal response and short term *primary motor cortex* (M1) plasticity at the synapse. rTMS creates a sustained excitation of neurons after the original burst of TMS has stopped. That LTP and LTD longer term effects are present is not clear. On the other hand *paired associative stimulation* (PAS) protocols are shown to induce LTP and LTD like effects in the human M1. PAS induced plasticity is enhanced if attention is paid to the area under stimulation, and the paper suggests that this is possibly through attention-dependent activation of the ascending cholinergic pathways. It is suggested that PAS induced plasticity shares common circuitry with motor learning. [407]

Summaries of the numerous systems and mechanisms of plasticity operating at the cellular and molecular level are offered in **Table 2.3** and **Table 2.15**. [408]

2.3. Neural bases for learning and memory.

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[406] M. A. Nitsche, et al. "Transcranial direct current stimulation: State of the art 2008," *Brain Stimulation* 1, 3 (2008): 206-23.

[407] U. Ziemann, et al., "Consensus: Motor cortex plasticity protocols," *Brain Stimulation* 1, 3 (2008): 164-182.

[408] Arguably plasticity involves both systems and mechanisms. Systems involve coordination of various brain areas (eg VTA release of DA to striatum effecting cortical regulation) and cellular mechanisms (eg second messenger plasticities).

Learning and memory are the key processes by which environment and experience alter behaviour. Learning is the process of acquiring knowledge about environment or experience. Memory is the process of storage and retrieval of that knowledge leading into some form of response: subconscious, conscious but impulsive, or conscious and deliberate.

While some authors distinguish between mechanisms of learning and memory, at other times the words are used synonymously. They form two overlapping categories: habituation, sensitisation and conditioning leading to increase or decrease in the strength and efficacy of synapses; and activity-dependent regulation of gene expression leading to physical changes at the synapse bringing about pre and post synaptic alterations in membrane potential (the mechanisms accounting for the long term synaptic plasticity of the various forms of LTP and LTD).

It is of specific interest to this study that implicit and explicit memory makes possible the learning of perceived behaviours. Alvarez et al. write, “The formation of memories and the acquisition of new behaviours are thought to occur through the activity-dependent regulation of synaptic connections in the brain.”[409]

Both the ease of practice that is associated with virtue, and the motivational rewards inherent in the practice of virtue, argue for the implication of mechanisms of non-declarative memory. (See also **2.3.6.1.b**.) Furthermore it is reasonable to propose that during the process of acquisition of virtue when effort is more conscious, that declarative memory plays a more significant role. (See below **2.3.5 Skill related learning** for brief discussion of the progression from declarative to non-declarative memory during skill acquisition, a process having common features with virtue acquisition to the extent that both involve automatisation of behaviours.)

[409] Alvarez, et al. “Distinct Structural and Ionotropic Roles of NMDA Receptors in Controlling Spine and Synapse Stability,” 7365-7376.

In this section, I focus also on imitation, as one of the core processes for learning from the environment and from the example of others. The neural bases for this are now increasingly well described. This provides some explanation for the ease of acquisition of virtuous behaviours by children, and also for the human capacity for empathy.

Tables 2.4 Systems for learning, **2.5 Memory systems**, and **2.6 Systems for imitation and empathy** capture the complexity of learning, memory and imitation and summarise a *prima facie* association with the development and exercise of virtue. Higher brain function is supported by complex systemic interaction distributed across multiple brain areas.

2.3.1 Learning and memory.

a) Learning.

Learning may be subclassified as associative and nonassociative learning.

Associative learning is a broad category of learning that involves formation of associations. It subdivides into:

i. classical (Pavlovian) conditioning, also known as reward conditioning, or appetitive classical conditioning. It was first described by Ivan Pavlov and it involves a conditioned stimulus (eg a bell) associated with an unconditioned stimulus (eg food) provoking a response (eg salivation). The response will continue after a time of conditioning by the conditioned stimulus even if no longer accompanied by the unconditioned stimulus. In a similar way, a shock to the foot eliciting limb withdrawal will produce aversive conditioning.
ii. The second type of associative learning is known as instrumental, or operant, conditioning by which an organism associates consequences with its own behaviour, and over time thereby alters the probability that a

certain behaviour will be expressed. (See **2.6.4 Reinforcement in basal ganglia learning.**)

Nonassociative learning comes in three broad forms:

i. habituation whereby when a stimulus is delivered repeatedly, there is a reduction in response to it;
ii. dishabituation which is the restoration or recovery of a response that had been habituated owing to the presentation of another, typically strong, stimulus;
iii. finally there is sensitization, the enhancement of a response evoked by a strong stimulus.

b) Memory.[410]

The various forms of memory and the brain areas implicated in each may be classified in the following way:

i. Working memory resides in the neocortex. One theory is that immediate memory, the memory that holds information in the brain for a few seconds, for example allowing us to maintain the flow when we read, is based on reverberating circuits.[411]
ii. Long term memory may be either declarative or nondeclarative.
    - Declarative memory (explicit memory). The median temporal lobe and the medial diencephalon are involved in both forms of declarative memory. Explicit memory may be either
        - Episodic (narrative event memory)
        - Semantic (factual)
    - There are three forms of non declarative memory (implicit memory):[412]

[410] Unless otherwise noted the source for this section is: Byrne, "Learning and memory: basic mechanisms".
[411] Saladin, *Anatomy and Physiology*, 5th ed., 473.
[412] Marieb and Hoehn, *Human anatomy and physiology*, 8th ed., 458-459.

- procedural: skills and habits dependent upon the BG in conjunction with cerebellum and neocortex (riding a bike, playing an instrument)
- emotional memory: emotional associations dependent upon the amygdala (the association of rewards or punishment with particular cues).
- motor memory: conditioned reflexes drawing upon the cerebellum. [413]

2.3.2 The five major memory regions of the brain.[414]

The major memory regions of the brain are the hippocampus, amygdala, striatum, cerebellum, and cerebral cortex. Each contributes in a unique way to memory; each has its own memory system, the capacity to benefit from experience that is presented to it in its specific role in the brain. We know too that each of these regions is the foundation for and is integrated with a much larger network of diverse brain areas with which it cooperates in the processes of memory.

Behaviour is typically the product of the contributions of multiple memory systems. For example, the declarative memory of sporting coach's instructions, modulated in the hippocampus, is complemented by repetition learning of motor skills founded in the striatum. In turn, other memory systems may operate in parallel: the amygdala could modulate hippocampal and striatal memory systems when sporting emotional arousal becomes involved. Systems can influence plasticity in other areas. For example, it is thought that amygdalar projections promote synaptic plasticity in linked areas such as the hippocampus, parahippocampal region, and certain cortical areas. There are examples too of collaboration between cerebellar and hippocampal systems.

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[413] John Nolte, *The human brain. An introduction to its functional anatomy*, 6th ed. (Philadelphia: Mosby, 2009), 617.

[414] For distinct forms of memory systems and the story of their discovery, the principal source of material that follows: Joseph R. Manns, and Howard Hichenbaum, "Learning and memory: brain systems," in Larry Squire, et al. *Fundamental Neuroscience*, 3rd ed. (Burlington, MA: Elsevier, 2008), 488.

a) The <u>hippocampus</u> supports declarative memory, the conscious recollection of events and facts. It is believed that the hippocampus initially acts as a retrieval system for information in widespread areas of neocortex. Scoville and Milner in 1957 documented the case of H.M., suffering seizures from the age of 10, and treated in 1953 with major removal of tissue from medial temporal lobe, leading to profound memory impairment with practically no capacity for new learning. His case demonstrated how the hippocampus codes for long term explicit memory.[415] [416] [417] A current hypothesis is that the hippocampus codes explicit memory and that if, for some reason, the action of the hippocampus is impaired or blocked, there will be no coherent recall of the episode.[418]

b) The <u>amygdala</u> is associated with emotional memory. While the amygdala as a whole has a general role in memory modulation for emotion laden content, the *basolateral amygdala complex* (BLA) and *central nucleus of the amygdala* (CEA) have significantly different roles. [419] The BLA includes the lateral, basolateral, and basomedial nuclei, and draws input from widespread cortical areas, and from the sensory nuclei of the thalamus. There are reciprocal connections to hippocampal and striatal memory systems. The amygdala seems able to mediate the creation and consolidation of memories that are made more vivid, accurate and longer lasting by emotional overlay. Many studies show that BLA mediates a system for coding memory strength by importance measured from a subjective position. [420] We remember important events more than trivial

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[415] Cited in Arden and Linford, *Brain-based therapy with children and adults*, 3.
[416] For the role of LTP in hippocampus see: H. Eichenbaum et al. "The medial temporal lobe and recognition memory," *Annual Review of Neuroscience* 30 (2007): 123-152.
[417] Bear, *Neuroscience. Exploring the Brain,* 693.
[418] Siegel, *Neurobiology of We*.
[419] J E. LeDoux, "Emotion circuits in the brain," *Annual Review of Neuroscience* 23 (2000): 155-184.
[420] J. L. McGaugh, "The amygdala modulates the consolidation of memories of emotionally arousing experiences," *Annual Review of Neuroscience* 27, (2004): 1-28. Such events cause release of *epinephrine* (Epi) and glucocorticoids by adrenal glands leading onto release of norepinephine in amygdala, increasing its activity and thereby consolidating memory in other parts of the brain

events. This region is seen as important in tagging memories with emotional "markers", but not in maintenance or call up of memories, which perhaps is more the work of the hippocampus.

Memory of facts is improved when facts are learned in connection with an emotion, unless intense arousal is involved.[421 422]

c) The striatum, a major constituent of BG, plays a role in reward and motivation, motor control. It organises somatosensory and motor representations in a topographic manner, and connects also to other regions of the BG and also thalamus (projecting back to premotor and motor cortex and prefrontal association cortex). It draws cortical inputs from many areas of cerebral cortex. There are few projections to brain stem motor nuclei and none to the spinal motor apparatus "which suggests the system operates mainly to modify cortical motor representations rather than control behaviour through direct motor inputs".[423] The dorsal striatum lays down memory for motor habits, actions and outcomes, playing a key role in much *stimulus-response* (S-R) habit learning.[424 425]

d) The cerebellum receives direct input from spinal cord and brain stem and indirect sensory and motor input from various areas in cerebral cortex via

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(direct by connections to striatum, hippocampus or cortex; and indirect by connections with nucleus basalis which innervates much of cortex).

[421] A Bechara, et al., Emotion, Decision Making and the Orbitofrontal Cortex. Cerebral Cortex March 2000: 10: 295-307. See L. Cahill et al."The amygdala and emotional memory," *Nature* 377, (1995): 295-296. The authors demonstrated that not only is decision making and working memory distinct in the PFC but that the emotional mechanism by which emotion can bias decisions is different from the mechanism whereby emotion enhances memory.

[422] Furthermore, the cognitive contribution of sleep has been demonstrated. Memories are consolidated by both Hebbian and non-Hebbian synaptic strengthening. Sidarta Ribeiro, "Sleep and plasticity," *Pflugers Arch*iv 463, 1 (2012): 111–120.

[423] Manns and Hichenbaum, "Learning and memory: brain systems," 1165.

[424] M. G. Packard and J. L. McGaugh, "Inactivation of hippocampus or caudate nucleus with lidocaine differentially affects expression of place and response learning," in *Neurobiology of Learning and Memory* 65, (1996): 65-72.

[425] Further studies reviewed and providing insight into the mechanisms of memory: A. Pasupathy and E. K. Miller, "Different time courses of learning related activity in the prefrontal cortex and striatum," *Nature* 433, (2005): 873-876. B. J. Knowlton, et al. "A neostriatal habit learning system in humans" in *Science* 273 (1996): 1399-1401.

pontine nuclei in brain stem. It projects to spinal cord, brain stem, hypothalamus, and thalamus, the thalamic targets in turn projecting onto cortical motor and non motor areas especially in the frontal lobe. Cerebellar memory is involved not only in motor reflex learning, but also in mental processing involving precise timing.

e) The cerebral cortex contains motor and sensory areas, association areas, integrative centres such as the PFC with its focus on motor planning, higher order cognition, and working memory, the general interpretive area and the speech centre. The cortex plays a role in many forms of memory. The networks of the major learning systems include cerebral cortex, although certain forms of learning can bypass cerebral cortex, for example, eyeblink conditioning mediated by the cerebellum whereby eye blink is associated with another conditioning stimulus. An engram or memory trace is the location or physical representation of memory in the brain: "The sum total of changes in the brain that first encoded an experience and that then constitute a record of that experience".[426] Various brain regions are involved in the representation of even a single event.[427]

2.3.3 Mechanisms of memory. [428]

In both implicit and explicit memory, memory follows three stages:

- Learning or acquisition
- Short term memory (with associated rapid decay of the neural response)

[426] Larry Squire and Eric R. Kandel, *Memory: From Mind to Molecules* (NY: HPHLP, 1999), 73. Lashley's pioneering studies in the 1920s failed in their attempt to prove that all areas of the cortex contribute to memory, but he did add to the understanding that memories are distributed. In 1949, Hebb suggested that engram could be distributed in the brain, and that the neurons involved in sensation could be also be implicated in representation. Hebb suggested that engrams based on one modality would be represented in that modality. Animal studies verify this. See also Bear, *Neuroscience. Exploring the Brain,* 733 and 751.
[427] Squire and Kandel, *Memory: From Mind to Molecules*, 73.
[428] Source in this section unless otherwise cited: Bear, *Neuroscience. Exploring the Brain,* 738-745.

- And finally *intermediate term memory* (ITM) converting to *long term memory* (LTM) after persistent repetition. In contrast to earlier phases, this final phase features protein synthesis. [429]

These stages are underpinned by distinct neural regions and processes.

In summary, vertebrate and invertebrate studies reveal the following principles.[430] It is commonly acknowledged that forms of activity induced plasticity are at the core of memory. Memory operates through cellular and molecular mechanisms that alter membrane excitability and synaptic strength ultimately at the level of the individual neuron, and in complex interconnected circuits of large numbers of neurons. There are changes in existing neural circuits for both short and long term forms of learning and memory, mediated possibly by multiple cellular mechanisms within individual neurons. Cellular changes are mediated to some extent by second-messenger systems. Learning and memory often correlate to changes in membrane channels. New protein synthesis is involved in long term memory but not in short term memory. LTP and LTD are forebrain mechanisms for or associated with memory storage and are regarded as evidence for plasticity.[431]

2.3.3.1 Declarative memory storage.

The current understanding is that the hippocampus acts as a retrieval system for information in widespread areas of neocortex. It is widely held that the temporal neocortex is the site of long term memory storage. The hippocampus has links to the medial temporal lobe. Temporal lobe association areas (the source of highly processed sensory information) project to the parahippocampal and rhinal cortex, then to the hippocampus, and then, via the fornix, to the thalamus and hypothalamus. These medial temporal structures are regarded as critical for declarative memory consolidation. There is the possibility that memories are temporarily stored locally here before transfer to the neocortex.

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[429] Tully, Tim et al. "Targetting the CREB pathway for memory enhancers." In *Nature Reviews Drug Discovery*. (2 April 2003): 267-277.
[430] Byrne, "Learning and memory: basic mechanisms," 1132.
[431] Byrne, "Learning and memory: basic mechanisms," 1132.

There is evidence that specific memories can be widely distributed in the brain. For example, memories formerly evoked by a stimulation of a later removed section of the temporal cortex have been shown to be evoked, after excision, by electrical stimulation of a third location. A further example: human fMRI studies show that extrastriate cortical area is implicated in attentive memory of material for which the subject has a fascination, eg cars for car buffs.[432]

Memory in the cortex supports perceptual learning and repetition priming and is regarded as "highly plastic in that its representations can be altered after experience"[433] as a result of alterations in synaptic connectivity and membrane excitability. Lynch writes, "There is no doubt that consolidation of memory requires some form of synaptic remodelling."[434] Butz et al. accord with this view, and referring most of all to long term memory, states that this remodelling is structural and that the strengthening of existing synapses occurs in the Hebbian sense during memory formation.[435]

2.3.3.2 Non-declarative, or procedural memory storage.

The striatum is the seat of habit learning and procedural memory, forms of non-declarative memory. That H.M. could learn new habits despite loss of declarative memory demonstrates that the bases for these memories are distinct. Monkeys with striatal lesions exhibit impaired procedural memory. Striatal disease in

[432] Macaque monkey studies show that high order visual areas such as the *inferotemporal cortex* (IT) provide storage for certain declarative memory. Well documented cases of cerebral impairment demonstrate that the diencephalon and medial temporal lobe, and thalamus are interconnected serving memory consolidation. Much of our knowledge of the role of hippocampus in memory from the study of rats. It is shown to be important in spatial memory by studies involving the Morris water maze. O'Keefe proposed that the hippocampus creates a topographic map of the environment. Others suggest hippocampus is associated with working memory. Cohen et al developed a model of the role of the hippocampus in "relational memory", linking spatial representation to things happening at the time of the experience. Bear, *Neuroscience. Exploring the Brain,* 738-745.
[433] Manns and Hichenbaum, "Learning and memory: brain systems," 1174.
[434] M. A. Lynch, "Long term potentiation and memory," *Physiological Review* 84, (2004): 117. The word "consolidation" suggests the author is referring to long term memory.
[435] Butz, et al., "Activity dependent structural plasticity," 295.

humans, for example Huntington disease, exhibits analogous manifestations. Parkinsonian patients, with degeneration of SN, also exhibit impaired procedural memory. [436]

2.3.3.3 Working memory, a form of short term memory, storage.

Working memory is different from both declarative and procedural memory. It is used for holding information required for an immediate need (eg shorter term recollection of a phone number). Working memory is now shown to be linked to planning and problem solving, as demonstrated by the Wisconsin card test. [437]

Many areas of the brain, besides the hippocampus, appear implicated in working memory. The PFC is closely interconnected to medial temporal and to hippocampus and seems implicated in working memory. Monkey performance on delayed response tasks (lifting lid on container previously demonstrated to contain food) in 1930s first demonstrated PFC implication in working memory. Nevertheless, working memory also seems linked to cortical areas outside PFC. The *lateral intraparietal cortex* (area LIP) for example seems implicated in guiding eye movements requiring some vision specific working memory.

It is believed that working memory involves some form of synaptic facilitation, perhaps accompanied by tetanic stimulation, rapid repetition of signals at the synapse resulting in an accumulation of Ca^{2+} at the synaptic knob. This increases the likelihood of further neurotransmitter release and action potential in the neuron across the synapse. Forms of working memory over longer timeframes may involve post-tetanic stimulation, whereby release of neurotransmitter remains facilitated when there has been a recent history of neuronal stimulation. The resulting Ca^{2+} build up lowers the thresholds for subsequent action potentials.[438]

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[436] Bear, *Neuroscience. Exploring the Brain,* 753.
[437] Bear, *Neuroscience. Exploring the Brain,* 755.
[438] Saladin, *Anatomy and Physiology*, 5th ed., 473.

2.3.4 LTP as an underpinning mechanism for memory. [439]

LTP leads to persistent, long lasting changes in the strength of synaptic connections, as measured by the amplitude of the EPSP in immediate downstream neuron. We have seen above that LTP was first identified in 1973 by Bliss and Lomo in the hippocampus of the rabbit. LTP is a form of plasticity linked to information storage in several regions of brain; Hebbian LTP with its quality of associativity seems clearly linked to retrieval of information. There is a large and increasing body of evidence that LTP is indeed the substrate for some forms of learning.

LTP is found in the hippocampus, cerebellum, neocortical regions, and also in subcortical centres such as the amygdala. It is present in at least 17 pathways in the brain, not from the hippocampus to other brain areas, but also, not involving the hippocampus, in cortico-cortical pathways and from various areas of the cortex, the thalamus, the amygdala, the subiculum, the dentate gyrus, and the striatum. It seems reasonable to expect that plasticity in the hippocampus facilitating encoding for explicit memory, in the striatum for reward and procedural activities, in amygdala coding for emotional experiences, and in the cortex associated with long term memory and cognitive regulation of behaviour play a significant role at the developmental stage of virtue

LTP is present in a variety of neural synapses and even in the same synapse under different conditions it may utilise different pathways. Often but not always, [440] LTP is linked with Donald Hebb's classic dictum of plasticity, that the synaptic strength of existing synapses joining cells will increase as those cells are active.

[439] Source in this section unless otherwise cited: Lynch, "Long term potentiation and memory," 87-136.

[440] An example of non Hebbian LTP: in the synapse at the mossy fibre CA3 junction in the hippocampus, and at the parallel fibre-Purkinje synapse in the cerebellum.

All forms of LTP seem suited to rapid learning but the localised nature of synaptic changes makes LTP hard to detect *in situ*. It has been possible to show that synaptic enhancement is linked to memory in studies of amygdala circuits that mediate fear. Saturation or blocking the mechanisms of LTP has demonstrated that learning itself has been blocked. Whitlock has shown that learning in rats does induce hippocampal LTP.[441] Pastalkova has also shown that inhibition of PKMz in hippocampus distrupts LTP maintenance and eliminates spatial learning.[442] Learning may involve weakening of synaptic strength also.

As the explanation for memory consolidation the case for LTP has not been proven to the satisfaction of all. [443] While some studies show that saturation of LTP impairs spatial learning, others have not been so conclusive.[444] In a recent study of conscious cats, the CA1 neurons exhibited persistent reversal of previously induced LTP when exploring a novel and non-stressful environment. In other words, the links between LTP and memory were not completely clear. It is suggested that close linkages may be present between LTP and spatial learning in some but not all synaptic connections where one or the other is present.[445] In general there is an apparent inconsistency in at least some of the data from various research centres, raising the question, Lynch suggests, as to whether experimentation requiring genetic manipulation is entirely reproducible.[446] [447]

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[441] J. R. Whitlock, et al. "Learning induced long-term potentiation in the hippocampus," *Science* 313(2006): 1093-1097.
[442] E. Pastalkova et al. "Storage of spatial information by the maintenance mechanism of LTP," *Science*. 313 (2006): 1141-1144.
[443] Since the mid 1990s there has been great progress over the previous decade in understanding the mechanisms of memory and learning, and in particular of the afferent pathways of the hippocampus. Advances in research instruments (development of techniques for knockout and overexpression of particular genes, and of probes for analysis of cell signalling and gene transcription) have contributed to this progress.
[444] Lynch, "Long term potentiation and memory," 87-136.
[445] Lynch, "Long term potentiation and memory," 120.
[446] Lynch, "Long term potentiation and memory," 117.
[447] There appear to be multiple mechanisms and multiple second messenger pathways operating for the induction, expression, and maintenance of LTP. The mechanisms have highly conserved across species. There is agreement that LTP induction depends on increase in cellular concentration of ions in pre and/or post synaptic cells, but the exact role of Ca^{2+}varies. Numerous pathways seem to modulate or control Ca^{2+}. For example, calcium influx occurs through ionotropic GluRs, expecially the N-methyl-D-aspartarte receptor (NMDAR) as well as through *voltage gated calcium channels* (VGCCs). The Ca^{2+} phosphatases pathway leads to LTD but the Ca^{2+} protein kinases pathway leads to LTP. Since the 1980s much work has been invested in identifying the

Nevertheless there is now much evidence that forms of memory stimulate synaptic activity linked to LTP. It has been shown too that when LTP is inhibited, some forms of memory are inhibited by the same agents. However, the multiple pathways in the brain, and the multiple forms of memory, suggest that to consider LTP as the exclusive pathway for memory is simplistic.[448] Butz et al. find considerable evidence that synaptogenesis is found in the close vicinity of synapses characterised by LTP but that "due to methodological limitations experimental data directly indicating that structural plasticity is involved in learning are rare". [449]

LTP and LTD are closely associated mechanisms of plasticity. Butz et al. affirm that LTP promotes spine maturation and stabilisation while LTD leads to the weakening of spines and synapses. The evidence suggests that learning and memory are a result of the complementary actions of functional plasticities and of the structural changes that hardwire them. Furthermore, while there is constant synaptic rewiring in limbic areas, this is less evident in sensory and motor areas although, significantly for this study, there is evidence also of synaptogenesis in motor skill learning.[450] Recent research is focusing on the detailed workings of LTP and LTD through studies of gene transcription associated with enhanced spatial memory .[451] Other research is exploring the relationship of LTP and LTD to homeostasis,

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signalling cascades that lead to expression of LTP and consolidation of memory. Both are seen as dependent on calcium, CaMKII, and protein synthesis. Recently the recycling of AMPA receptors has become an area of study. Further studies reviewed and providing insight into the mechanisms of memory and in particular for the role of LTP and LTD: L. Stenho-Bittelet al. "Calcium release from the nucleus by InsP3 receptor channels," *Neuron* 14, (1995): 163-167; M. Fisher et al. "Rapid actin-based plasticity in dendritic spines" *Neuron* 20, (1998): 847-854; M. Ito, "Cerebellar long term depression: Characterisation, signal transduction, and functional roles," in *Physiology Review* 81.3 (2001): 1143-1195. R. Malenka and M. F. Bear, "LTP and LTD: an embarrassment of riches," *Neuron* 44, (2004): 5-12.

[448] Lynch, "Long term potentiation and memory," 119.

[449] Butz, et al., "Activity dependent structural plasticity," 295.

[450] Butz, et al., "Activity dependent structural plasticity," 293.

[451] M. Costa-Mattioli, "Switching memories on and off," *Science* 322, 5903 (2008): 874-875. The author demonstrates the key role that a reduction of the translation initiation factor elF2x plays in laying down long term memories and in converting short term memories to long term memories. elF2x has been shown to suppress protein synthesis yet stimulate synthesis of CREB2. He demonstrates that mice in which the activity of elF2x had been reduced genetically (elF2x$^{+/S51A}$ mice) show conversion of short term memory to long term memory. The studies showed that

and to homosynaptic/heterosynaptic change, in relation to the mechanisms of learning. Homosynaptic changes are the synaptic changes of transmission as a result of the specific induction related to learning, and heterosynaptic changes are changes at other synapses (on the same neuron) non involved in the original induction related to learning. [452]

2.3.4.1 Further factors for the synaptic facilitation involved in memory.

Other current work is detailing the mechanisms underlying the cortical representations of the environment in the in the sensory cortex. Fromke, Merzenich and Schreiner demonstrate by means of in vivo whole cell recording that plastic changes to the receptive field of the auditory cortex are effected by means of electrical stimulation of the nucleus basalis in conjunction with auditory stimulation of the adult rat primary auditory cortex. They suggest this neuromodulation of the auditory cortex by the cholinergic nucleus basalis may be a key mechanism for receptive field plasticity, and in particular for heightened attention to novel or meaningful stimuli.[453]

The work of Yasumatsu et al. (2008) indicates structural plasticity among dendritic spines as an additional mechanism for learning. [454] Spinogenesis and LTP are closely linked; LTP correlates to shrinkage of hippocampal spines.

It has been shown by Leuner et al. (2006) that hippocampal dentate gyrus neurons undergo ongoing replacement; this has been suggested as a further mechanism

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eIF2x$^{+/S51A}$ mice in water mazes showed superior ability, indicating enhanced spatial memory, and also in memory of auditory and visual stimuli on behavioural tests involving prediction of foot shocks and nausea. Hippocampal slices from eIF2x$^{+/S51A}$ mice showed long lasting LTP, in contrast with the normally expected short lasting changes (not gene based, protein mediated).

[452] Chistiakova and Volgushev, "Heterosynaptic plasticity in the neocortex (Review)." Chistiakova and Volgushev find that nonassociative, or heterosynaptic, plasticity of specific synapses may result in a neuron as a result of back propagation, where other synapses in the same neuron have experienced Hebbian-type associative, or homosynaptic plasticity by well understood processes of Ca^{2+} influx (fast large amplitude influx leads to LTP; slower low amplitude to LTD) in response to intracellular tetanization.

[453] Robert C. Froemke, Michael M. Merzenich, and Christoph E. Schreiner, "A synaptic memory trace for cortical receptive field plasticity," *Nature* 450 (2007): 425-429.

[454] Yasumatsu, et al., "Principles of Long-Term Dynamics of Dendritic Spines," 13592-13608.

for learning and memory. The rich expression of BDNF in the hippocampus, a factor in neurogenesis, has already been noted above. The significance, for virtue development, of mechanisms of plasticity in the hippocampus has been noted above. Fascinatingly also, it has been noted that newly integrated neurons pass through a process of changing neurotransmitter excitation, from GABA to glutamatergic, with evidence that plasticity is most pronounced in the first four months after mitosis.[455]

2.3.4.2. The neuroscience of memory enhancement.

Mechanisms of memory enhancement have also been documented. Tully et al. (2003) review the literature on what they call a "chemistry of brain plasticity" identifying gene targets for memory enhancement. Most drugs of this nature involve both the cholinergic system and neurohumoral signalling, a slower form of signalling that takes place between the CNS and peripheral tissue influencing motivation and emotion. This form of signalling contrasts with the fast action of neurotransmitters. [456]

2.3.5 Skill related learning.

Skills, to the extent they are intentionally acquired sequences of actions, share common ground with voluntarily acquired habits. Skill studies demonstrate consistently that automaticity brings efficiency. This efficiency is one of the major benefits offered by the development of good habits. For example, Romero et al. (2008), in a study typical of this field, investigated changes in EEG in 10 subjects aged 19-22 learning a pseudo-arithmetic task.[457] Subjects responded faster with

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[455] Stranahan and Mattson, "Impact of Energy Intake and Expenditure on Neuronal Plasticity," 209.-218.
[456] T. Tully et al., "Targetting the CREB pathway for memory enhancers," *Nature Reviews Drug Discoveries* 2, 4 (2003): 267-77.267-277.
[457] EEGs offer greater temporal specificity, at some loss, with respect to fMRI, of spatial resolution.

practice. The data suggest that there was a shift in method of processing from mechanical counting towards reliance on memory.[458]

In addition to conclusions about the efficiency of habit formation, I will discuss the possibilities for retention of voluntary deliberation within a paradigm of habit development. In **2.4** I will discuss the neural bases of habits as forms of learning. And I will be discussing the development of automaticity through the modification of *action-outcome* (A-O) learning to S-R learning (**2.4.7.2**).

2.3.6 Neural systems of imitation and learning.

A further area of significant current research involves the neural bases of imitation and empathy. These insights offer an understanding of the remarkable facility whereby infants effortlessly imitate parents possibly in behaviours and attitudes as well as in simple facial expressions, and bear out the sad truth of Jefferson's observation: "Man is an imitative animal."[459]

Meltzoff and Moore (1977) found that within an hour of birth imitation of facial expression is apparent.[460] It is suggested that these processes of imitation provide a neural account for the ease by which external example, for example by parents, is adopted during sensitive periods. Hence it is a field of research clearly of interest in a study that seeks the neural bases for training in virtue.

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[458] Stephen G. Romero, et al. "Electrophysiological markers of skill-related neuroplasticity," *Biological Psychology* 78 (2008): 221-230. The authors also discussed theories of stages of learning with respect to skill acquisition within the paradigm of the Adapted Control of Thought Theory, a theory of skill acquisition which moves from facts that must be rehearsed, the declarative stage, the "what" of knowledge, to a "how to", the procedural stage, in which strategies are refined and focused for the specific task. They contrasted this model with Logan's Instance Theory of Automatisation and Rickard's Component Power-Law Theory of Automatisation that hold there to be a strategic switch between methods of processing, from a multi-step algorithm, to streamlined processes relying on memory recall.

[459] Thomas Jefferson, *Notes on the Stateof Virginia*, Ch 18. http://xroads.virginia.edu/~hyper/jefferson/ch18.html; accessed 17.12.12. The context: "The whole commerce between master and slave is a perpetual exercise of the most boisterous passions, the most unremitting despotism on the one part, and degrading submissions on the other. Our children see this, and learn to imitate it; for man is an imitative animal."

[460] A. Meltzoff and M. Moore, "Imitation of facial and manual gestures by human neonates," *Science* 198 (1977): 75-78.

The discovery of mirror neurons led to an understanding of the underlying mechanisms. Pellegrino et al. (1992), Gallese et al. (1996), and Rizzolatti et al. (1996) documented mirror neurons in the premotor cortex of macaque monkeys. Mirror neurons which are associated with particular actions trigger when those actions are observed in others and also when the actions are performed by the subject. I will look here at several representative studies in this burgeoning field.

Iacoboni et al. (1999) tested by means of fMRI imaging whether these mirror neurons could be found in human subjects. The authors tested the theory that imitation occurs through a mechanism, “the direct matching hypothesis”, whereby an observed action is directly mapped to the motor cortex in a study in which human subjects were asked to observe finger movements. In data matching results already obtained in monkey studies, they found that the imitation mechanism was present in the left frontal operculum area (Broca’s area) and the right anterior parietal cortex. The result was also compatible with the fact that Broca’s area is the motor area for speech, and imitation is critical in the development of speech. The mechanism was noted as apparently present mostly in the right hemisphere.[461]

Researchers were soon turning their attention to a complex derivative of simple imitation, the development of empathy. A study by Carr et al. (2003) tested the ideas of Theodore Lipps, who had suggested that “inner imitation” played a critical role in the development of empathy, against the developing knowledge of mirror neurons.

From the starting point that the fronto-parietal network in conjunction with the superior temporal cortex is critical for human action representation and imitation, the authors wished to investigate whether the limbic system also received action representations to allow emotional processing, and hence empathy, to take place.

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[461] M. Iacoboni et al. “Cortical Mechanisms of Human Imitation,” *Science* 286, 5449 (1999): 2526-2528.

The study showed that the amygdala and insula were also actively involved but the authors suggested that explicit representational content might not be present, and that it might be important to differentiate between the various brain regions implicated in the various emotions, eg disgust in the anterior insula and fear in the amygdala.[462] Following this view there are two principal mirror networks: the parietal lobe and premotor cortices, and that of the insula and ACC.

Hurley (2008) incorporated the provocative word "mind-reading" into the title of a study that sought to develop a model for perception, action and cognition: "a model of subpersonal architecture for control, mirroring and simulation, above the neural, but below the conscious."[463] This approach was not atypical of the cross disciplinary psychology/cognitive neuroscientific explorations into the function of mirror neurons. Hurley argued, "Human mirror systems may be part of the mechanisms for understanding observed actions and intersubjective empathy" and that "direct resonance... provides a fundamental similarity between yourself and other agents that enables the understanding of another's actions as instrumentally structured." ... a "plausible neural basis" for understanding others.[464]

Casebeer linked mirror neurons and *Theory of Mind* (TOM), by which neuroscientists refer to our ability to understand the thoughts of others in order to assess consequences of our actions. He suggested an integral role for mirror

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462 L. Carr, M. Iacoboni, et al. "Neural mechanisms of empathy in humans: a relay from neural systems for imitation to limbic areas," *PNAS* 100, 9 (2003): 5497-5502.
463 S. Hurley, "The shared circuits model (SCM): How control, mirroring, and simulation can enable imitation, deliberation, and mindreading," *Behavioral and Brain Sciences* 31 (2008): 1-58. The proposed model seeks to explain, imitation, deliberation and mindreading via five layers: 1. Sensorimotor feedback and motor control; 2. Predictions of sensory feedback from motor control, thus improving control and adding to perception of the world; 2+4 Predictions interact with monitored inhibition of output; 3. Mirrroring that generates inputs, enabling imitative learning, among other benefits; 3+4. Mirroring and inhibition allowing for management of one's own acts; 5. Consideration of possible observed action, and the development of hypotheses about acts possible towards others.
464 Hurley, "The shared circuits model (SCM): How control, mirroring, and simulation can enable imitation, deliberation, and mindreading," 9. See reference for quotation.

neurons in moral behaviour: “Mirror neurons might bootstrap full-blown TOM into existence through an inner simulation of the behaviour of others.”[465]

Rizzolati et al. (2009) reflected on this role of mirror neurons as direct, non-cognitive media for grasping the intentions of others. [466] As we know our own reasons for action, we can infer information about the action observed and about the actor. Mirror mechanisms are also active in relation to visceromotor emotion-related behaviours. Rizzolati writes, “The role of the mirror mechanism is to provide a direct understanding of the actions and emotions of others.”[467] This carries profound implications for the capacity of an infant to absorb emotional responses for better or for worse from its parents.

I find these ideas most powerful and compatible with the view that I will present of mirror neurons as core mechanisms in the capacity for infants and children to grasp their parents example of appetitive responses.

2.3.6.1 Neural systems for affective feelings.

Affection also plays a role in empathy. The OFC which is at the apex of a limbic circuit connecting the VMPFC, AC gyrus, amygdala and temporal pole, plays a major role processing appreciation of moral consequences of behaviour and the “interpersonal signals necessary for the initiation of social interactions betweenindividuals”.[468] [469] Activation of the OFC produces warm and loving feelings.[470] The OFC can overwhelm consciousness with these feelings.[471]

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[465] William D. Casebeer, “Moral cognition and its neural constituents,” *Nature Reviews Neuroscience* 4 (2003): 844.
[466] G Rizzolatti et al., “Mirror neurons and their clinical relevance,” *Nature Clinical Practice Neurology* 5, 1 (2009): 24-34.
[467] G Rizzolatti et al., “Mirror neurons and their clinical relevance,” 33.
[468] Schore, “Effects of a secure attachment relationship on right brain development, affect regulation and infant mental health,” 7-66.
[469] S. D. Pollak, “Early adversity and mechanisms of plasticity Integrating affective neuroscience with developmental approaches to psychopathology,”*Development and Psychopathology* 17, (2005): 747.
[470] Arden and Linford, *Brain-based therapy with children and adults*, 103.

Left and right OFC appear to differ in function: the right decodes mental states of others and is associated with empathy with others; the left reasons about mental states. The right OFC and right anterior insula cortex are components of a pathway that integrates bodily responses with attentional and emotional states.[472]

Balbernie suggests that limbic circuits require use-dependent stabilisation directly reflecting the infant's social environment.**[473]** He suggests that the right limbic system is key to complex attachment dynamics and interpersonal coping.[474] Right brain development in early childhood is shaped by the dynamics of attachment. Mother to child, and child to mother attachment relationships are now known also to be critical in the infant's development of self regulatory pathways during the first three years when right brain development is dominant. [475]

The work of Schore (2001) highlights developmental aspects of the OFC areas. He linked attachment and positive maternal affect to initial reward stimulation in the infant's brain. Once these initial pathways are established, they appear to contribute to mechanisms for mature affect regulation. For example, during positive interactions, mother-infant facial communication generated DA mediated arousal and elation in the right brain of the infant. DA inputs mediated reward and emotional response. These DA inputs established a pattern of "burst firing" as

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[471] J. B. Nitschke et al., "Orbitofrontal cortex tracks positive mood in mothers' viewing pictures of their newborn infants," *NeuroImage* 21 (2003): 583-592.

[472] Schore, "Effects of a secure attachment relationship on right brain development, affect regulation and infant mental health," 7—66. Schore cited the work of Critchley.

[473] In a review of literature concerning the significance of caregiver input during the first three years, years of "optimal plasticity", Balbernie focused on the role of the OFC, the area he suggested governs attachment. He argued that the OFC is a "zone of convergence between cortex and subcortex" governing "the ability to generate self awareness and personal identity". R. Balbernie, "Circuits and circumstances. The neurobiological consequences of early relationship experiences and how they shape later behavior," *Journal of Child Psychotherapy* 27, 3 (2001): 237-255.

[474] Balbernie, "Circuits and circumstances. The neurobiological consequences of early relationship experiences and how they shape later behavior," 237-255.

[475] Allan N. Schore, "Attachment, Affect Regulation, and the Developing right Brain: Linking Developmental Neuroscience to Pediatrics," *Pediatrics in Review* 26, No. 6 (2005): 205.

opposed to “pacemaker like firing”. [476] Schore called this “caregiver induced organisation of the infant’s brain.” [477] There is a sequential maturing and function of the various limbic and orbitofrontal areas. Schore noted that the limbic circuit comprising OFC, AC gyrus, amygdala and temporal pole was described by Brothers in 1997. Schore described the OFC as the “hierarchical apex of the limbic system”, crucial in control of behaviour in relation to emotion, and with a major role in processing “interpersonal signals necessary for the initiation of social interactions between individuals”.[478]

2.3.6.2 Neuropeptides and mechanisms of trust.

Trust studies have demonstrated the role of oxytocin in promoting plasticity. The role of trust in attachment, as well as in economic transactions, has been studied. Kosfeld et al. (2005) focused on the role of oxytocin in the development of trust, in a search for possible biological bases of trust between human beings. Their study, in line with the view that oxytocin increases affiliation and social attachment in non-humans, demonstrated that the neuropeptide was shown to increase trust and social benefit also in humans. A single dose of oxytocin was nasally administered in a double blind study involving 194 male students participating in a trust game. [479]

2.4 Habit formation and the role of the basal ganglia.

For summary table of the integrated contribution of the basal gangia with respect to habit formation refer to **Table 2.7 Systems for habit formation**.

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[476] Schore, “Effects of a secure attachment relationship on right brain development, affect regulation and infant mental health,” 23. This corresponds to the observation of Leknes and Tracey with respect to the effects of phasic DA signaling. S. Leknes and I. Tracey, “A common neurobiology for pain and pleasure,” *Nature Reviews Neuroscience* 9, (2008): 314-320.
[477] Schore, “Effects of a secure attachment relationship on right brain development, affect regulation and infant mental health,” 24.
[478] Schore, “Effects of a secure attachment relationship on right brain development, affect regulation and infant mental health,” 7-66.
[479] M. Kosfeld et al., “Oxytocin increases trust in humans,” *Nature* 435 (2005) 673-676. Oxytocin receptors are found in various regions of the human brain including the amygdala.

2.4.1 The basal ganglia and related structures.

The *basal ganglia* (BG) are the largest nuclei of the brain. They occupy a considerable volume of the cerebrum.[480] These cerebral nuclei lie buried deep within the telencephalon, which in its origin is the secondary brain vesicle in the embryo which will later develop into the cerebral hemispheres. These bilateral nuclei consist of grey matter and are found lateral to the thalamus and above the midbrain. The BG are also known, more correctly, as the *basal nuclei*.[481] At times one finds that the striatum (the input nucleus of the BG also known as the neostriatum) is also used synonymously with BG.[482]

Following Da Cunha, a typical division of the BG is:

- dorsal striatum[483]
    - caudate nucleus
    - putamen
- ventral striatum alternatively known as the *nucleus accumbens* (NAc)
- *globus pallidus* (GP)
    - *internal segment* (GPi)
    - *external segment* (GPe)
    - *ventral pallidum* (VP).[484]

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[480] Rod R. Seeley, et al., *Anatomy and Physiology* (NY: McGraw Hill, 2008), 455.

[481] Gerard J. Tortora and Bryan Derrickson, *Principles of Anatomy and Physiology*, 11th ed. (New Jersey: Wiley, 2006), 493. Authors suggest that basal nuclei is a more accurate terminology as ganglion properly refers to neural feature of the PNS.

[482] John H. Martin, *Neuroanatomy: Text and Atlas*, 3rd ed., (NY: McGraw, 2003), 327.

[483] Henry H. Yin and Barbara J. Knowlton, "The role of the basal ganglia in habit formation (Review)," *Nature Reviews Neuroscience* 7 (2006) point out that the heterogeneous structure of the dorsal striatum suggests regions may be functionally specialised. Caudate is an area of the "associative striatum" receiving inputs from association cortices. Yet putamen is of the sensorimotor striatum. These areas in rodents, respectively *dorsomedial striatum* (DMS) and *dorsolateral striatum* (DLS) are functionally dissimilar, and it has been suggested that the DMS is functionally linked to hippocampus (perhaps more A-O linked, with DLS more S-R linked).

[484] Claudio Da Cunha, et al. "Learning processing in the basal ganglia: a mosaic of broken mirrors," *Behavioural Brain Research* 199 (2009), 158.

Nomenclature in this area can be a little confusing.[485] The GP and putamen together form the lentiform nucleus, with together with the caudate nucleus forms the corpus striatum[486].

Neuroanatomists are not in definitive agreement about which brain centres to include within the BG.[487] There is broad agreement that at least the caudate nucleus, the putamen and the GP should be included in the BG proper.[488] At times the associated motor nuclei of diencephalon (especially within the thalamus) and mesencephalon, the midbrain, are included within the BG.[489]
The BG are functionally linked to the nearby SN (which sends axons to caudate nucleus and midbrain) in midbrain, and to the *subthalamic nuclei* (STN) which interconnect with the GP.[490] Associated BG structures include:

- *Substantia nigra* (SN)
    - *Substantia nigra pars compacta* (SNpc)
    - *Substantia nigra pars reticulata* (SNr)
- *Ventral tegmental area* (VTA) (closely associated with the NAc)
- STN.[491]

Table 2.7 summarises the brain areas, pathways and mechanisms associated with habit formation and the association of habit formation with the development and exercise of virtue.

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[485] Squire et al., *Fundamental Neuroscience*. 3rd ed., lists as *intrinsic* nuclei of the BG: GPe, STN, SNpc, and VTA.
[486] Tortora and Derrickson, *Principles of Anatomy and Physiology*, 11th ed. 493.
[487] For example, some authors consider that the striatum is composed of caudate nucleus and putamen, others include within the corpus striatum what is known as the lentiform (the GP together with the putamen) and the caudate nuclei.
[488] Saladin, *Anatomy and Physiology*, 5th ed., 534.
[489] Frederic H. Martini, *Fundamentals of Anatomy and Physiology*, 6th ed., (San Francisco: Pearson, 2004), 486.
[490] Tortora and Derrickson, *Principles of Anatomy and Physiology*, 11th ed., 493-494.
[491] Da Cunha, "Learning processing in the basal ganglia: a mosaic of broken mirrors," 158.

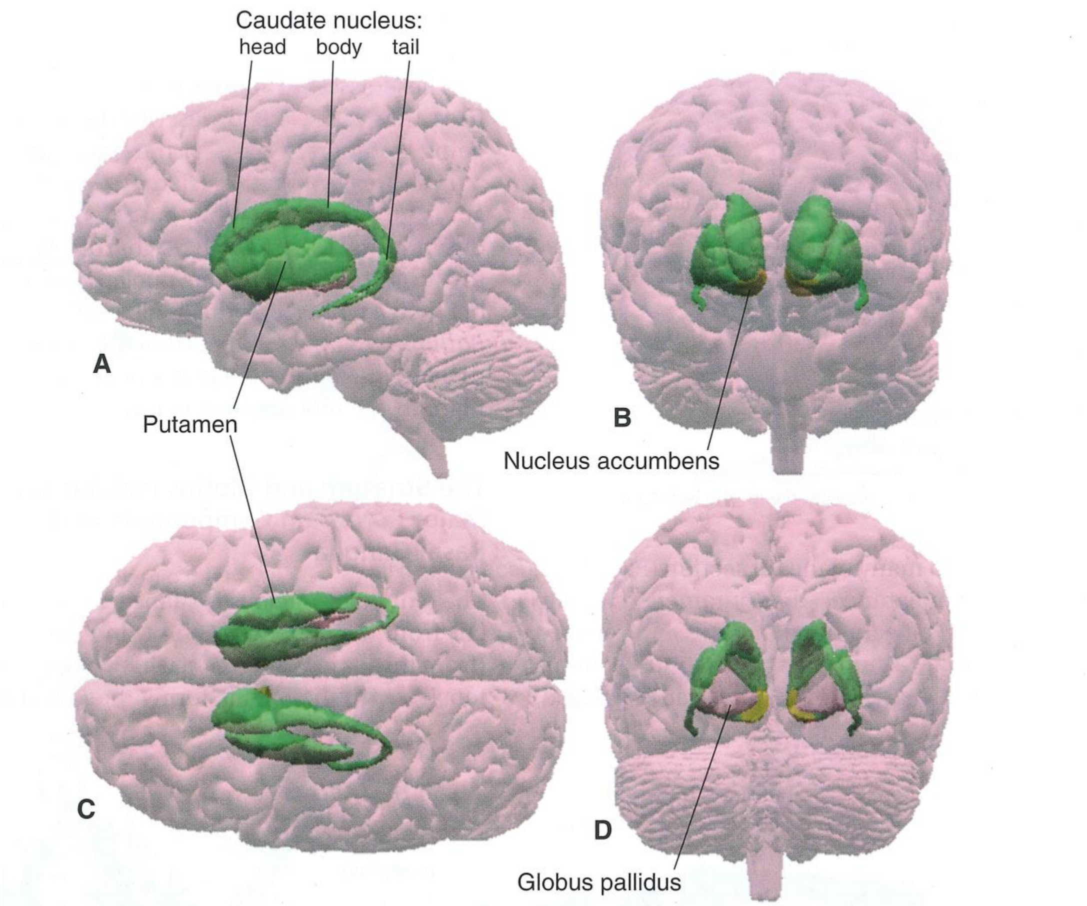

Figure 2.7 **Location of the basal ganglia.** A 3D construction of the striatum and GP within a translucent CNS. Note proximity to OFC and MPFC.
Source: Nolte, John. *The human brain. An introduction to its functional anatomy.* 6th ed. Philadelphia: Mosby, 2009. 478.

2.4.1.1 A key functional division of the basal ganglia.

a) The ventral pars

The ventral pars, a psychic area,[492] is constituted by the NAc and the VTA. The NAc receives afferents from the limbic domain and DA from VTA. It is known to participate in emotions.[493] The ventral pars is a key component of "mesolimbic" pathway which is active in reward situations playing a major role in motivation.[494]

[492] Nomenclature adopted by Nicola Beretta, et al. "Synaptic plasticity in the basal ganglia: A similar code for physiological and pathological conditions," *Progress in Neurobiology* 84 (2008): 345-346.
[493] Martin, *Neuroanatomy: Text and Atlas*, 3rd ed., 329.
[494] M. Di Filippo et al., "Short term and long-term plasticity at corticostriatal synapses: implications for learning and memory," *Behavioural Brain Research* 199, 1 (2009): 108-18.110.

In a ground breaking human study, MJ Keopp et al. (1998) used a radioligand C-labelled raclopride, binding to D2 receptors and therefore evident through [^{11}C] RAC-PET imaging,[495] to demonstrate DA release in the ventral striatum correlating with performance level in playing a video game. Eight subjects played a game where they were required to navigate a tank receiving a monetary incentive. DA release was then compared with baseline levels determined by viewing a blank screen revealing at least a two fold increase in extra cellular levels of DA present in the ventral striatum. DA release in this situation was interpreted as the equivalent to that in animal studies in relation to anticipatory or appetitive phases of motivated behaviour where DA release assists in learning predictors for rewarding outcomes.[496]

b) The dorsal pars.

The dorsal pars, a motor area, is made up of dorsal striatum and SN.[497] This region receives afferents from associative and sensorimotor domains. The caudate nucleus receives information from cortical sensory, motor and integrative areas[498]. Caudate is an area of the "associative striatum" and receives inputs from association cortices. The putamen is regarded as an area of the sensorimotor striatum. [499] DA neuromodulation inputs to this region from the SNpc. This region is involved in learning and movement initiation. Putamen neurons are active in anticipation of body movements, neurons of the caudate nucleus are active prior to eye movements, and the GP plays a role in regulation of muscle tone.[500]

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[495] PET imaging using the radioligand C-labelled raclopride which binds to D2 receptors.
[496] M. J. Keopp, et al., "Evidence for striatal dopamine release during a video game." Nature 393 (1998) 266-268.
[497] Nicola Berretta et al. "Synaptic plasticity in the basal ganglia: a similar code for physiological and pathological conditions," 343-62.
[498] Martini, *Fundamentals of Anatomy and Physiology*, 6th ed., 486.
[499] Yin and Knowlton, "The role of the basal ganglia in habit formation," 468.
[500] Tortora and Derrickson, *Principles of Anatomy and Physiology*, 11th ed., 493.

The dorsal striatum lays down memory for motor habits, actions and outcomes, playing a key role in much S-R habit learning.[501]

Monkey studies by Pasupathy and Miller (2005) found that memory in the striatum may instruct the PFC with respect to S-R situations.[502] Human studies in 1996 reported by Knowlton et al. showed that early Parkinson patients who suffered degeneration of neurons in SN and consequent loss of input to striatum, suffered loss of probabilistic classification learning. Their loss of declarative memory was impaired rather by hippocampal and diencephalic impairment.[503]

2.4.2 An overview of the contribution of the basal ganglia.

Understanding of the role of the BG has progressed dramatically in the past two decades.

Until recent years, the sub-cortical location of the BG had greatly impeded effective studies of its function. Studies, for example those that have shown that damage to the BG leads to tremor, muscle rigidity and involuntary movements, relied on pathological examination. Initially the role of the BG was considered to be that of a relay station, facilitating unconscious actions such as arm swings or laughter, or inhibiting muscular activity. [504] [505] The role of the BG was seen less of initiating movement but rather of providing the pattern and rhythm for muscular

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[501] Squire et al., *Fundamental Neuroscience*, 3rd ed. Studies of the rat in a T maze by Packard and McGaugh in 1996 showed that initially rats seek reward using "place" strategies, guided by surrounds using the hippocampus, but overlearning replaced this with a response strategy based on the striatum. Suppression of striatum returns the rat to use of place strategies.

[502] Squire et al., *Fundamental Neuroscience*, 3rd ed.

[503] Squire et al., *Fundamental Neuroscience*, 3rd ed. The Richfield et al. study in 1987 demonstrates the close linkage between these functions with respect to reward, motivation and habitual behaviours. The authors documented a striking case of bilateral damage to the caudate nucleus, an integral part of the dorsal striatum, to a 25 year old woman, resulting in similar manifestations to those caused by prefrontal trauma. Her resulting personality change involved alterations in "affect, motivation, cognition, and self-care". Behaviour included "vulgarity, impulsiveness, easy frustration, violent outbursts… hypersexuality and minor criminal behaviours." Treatments seemed ineffective. The formation of replacement positive habitual behaviours did not occur.

[504] Tortora and Derrickson, *Principles of Anatomy and Physiology*, 11th ed., 493-494.

[505] Alexander P. Spence and Elliott B. Mason, *Human anatomy and physiology,* 3rd ed. (Menlo Park: Benjamin/Cummings, 1987), 345.

movement.[506] In conjunction with limbic system, the BG was known to play a role in regulation of emotional responses and in initiation and termination of attention, memory.[507]

The work of Middleton and Strick (1994) provided decisive evidence of the non-motor contribution of the BG to higher cortical activity by the identification of efferent pathways from the BG to the PFC, providing evidence of an integral role for the BG in higher cortical activity.

An elegant series of experiments in 1994 was successful in documenting the neural pathways between the BG and the PFC. Using three cebus monkeys, Middleton and Strick effected transneuronal retrograde transport of the McIntyre-B strain of the *herpes simplex virus type 1* (HSV1) from area 46 of the PFC to the GP and to the dentate nucleus of the cerebellum, and so were able to conclude that neurons in these subcortical areas project to the PFC, and that they were distinct from neurons projecting from motor areas of the cerebral cortex.[508] The authors chose area 46 of the PFC, an area implicated in spatial working memory, in the direction of behaviour, and also in planning of future behaviour.[509]

In this way they were able to demonstrate that outputs from both the BG and the cerebellum have a role in higher cognitive function. In contrast to the theory that the role of the BG was merely to funnel widespread cortical outputs to the primary motor cortex, the authors proposed the existence of non-motor loops through the BG, parallel to motor loops, but with a cognitive function.[510]

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[506] Martini, *Fundamentals of Anatomy and Physiology*. 6th ed, 486.
[507] John W. Hole Jnr., *Human Anatomy and Physiology,* 2nd ed. (Dubuque: WBC, 1981).
[508] Frank A. Middleton and Peter L. Strick, “Anatomical evidence for cerebellar and basal ganglia involvement in higher cognitive function,” *Science* 266, 5184 (1994): 458-61.
[509] Middleton and Strick, “Anatomical evidence for cerebellar and basal ganglia involvement in higher cognitive function,” 458-61.
[510] Middleton and Strick, “Anatomical evidence for cerebellar and basal ganglia involvement in higher cognitive function,” 460. This study provided experimental evidence for the proposal in 1986, by Alexander et al., of the existence of distinct non-motor loops that influence higher order function. Middleton and Strick identified pathways from the BG via the thalamus to the DLPFC, to the lateral OFC and the ACC. They argued that the implication of the BG in higher cortical activity is supported by evidence of cognitive deficits as well as motor difficulties associated with BG

The role of the BG in procedural learning and the implicit learning (learning not consciously recognised) that is present in *stimulus response* (S-R) associations, as well in the development of habits and addictions is well documented.[511] Yin and Knowlton have argued that the distinct networks of the BG "are the neural implementations of actions and habits, and that an understanding of these networks can illuminate findings from different levels of analysis, from the cellular and molecular mechanisms of synaptic plasticity to the conditions that favour habit formation and the development of compulsivity in various clinical disorders."[512]

However the role of the BG in cognitive processes has become increasingly better understood. It is now clear that the BG play an important role in regulation of the function of the cerebral cortex, with all regions of the cortex projecting to the BG and via the thalamus projecting back to the cortex.[513] It seems that the BG play a major role in selection of patterns of cortical activity, and ultimately of selection and reinforcement of chosen motor programs.[514] There is now recognition that the BG play a significant role not only in "starting, stopping, and monitoring the intensity of movements executed by the cortex"[515] but in cognition, in direction of attention, in planning, and in motivation. Furthermore the BG are acknowledged to have a key role in control and modulation of social behaviours and may be integral to a progressive evaluation process of behaviours.[516] It is now argued that the BG play a key role in control of "voluntary behaviour"[517], perhaps in overlaying deliberate cognitive agendas onto habituated actions.

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dysfunction in Parkinson's and Huntington's diseases. They also made reference to the work of R.L. Sturb in 1989, and J.L.Cummings in 1993, showing that focal lesions of the GPi led to reduced performance of working memory and rule based learning, normally indicators of dysfunction of the frontal lobe.

511 Graybiel, "Habits, Rituals, and the Evaluative Brain," 359-87.

512 Yin and Knowlton, "The role of the basal ganglia in habit formation," 464.

513 Ole H. Petersen, *Human physiology (*Oxford: Blackwell, 2007), 205.

514 Petersen, *Human physiology,* 205.

515 Marieb and Hoehn, *Human anatomy and physiology*, 7th ed., 443.

516 Graybiel, "Habits, Rituals, and the Evaluative Brain," 379.

517 Yin and Knowlton, "The role of the basal ganglia in habit formation," 464.

Wickens (2009) states that, by that time "It is increasingly recognised that the basal ganglia contribution to movement is in some way *secondary* (italics mine) to a contribution to intentional behaviour, learning and decision making".[518] Furthermore, the implication of the BG in complex drug seeking behaviours is now increasingly understood. This role suggests that habits and behaviours mediated in the BG are not be limited to simple motor sequences, but that BG pathways are likely to be integral to the pursuit of complex, purposeful, behaviour patterns. [519]

It is now recognised that the BG are the region of the brain with major involvement in skeletal motor management, for example with a key role in motor activity controlling motor coordination and steadiness. [520] [521] [522]Unlike the motor cortex (connecting directly to motor neurons) the BG act on descending pathways in a fashion similar to the cerebellum in subconscious facilitation of habits, and automatic actions utilising procedural memory, but also, and this is significant, with deliberate attention, and limbic modulation of cognition and action.[523] It is an area critical for learning, cognition and behavioural control. It is suggested that the BG play a significant role in key areas of interest in this current study of the neural correlates for virtues understood, at the simplest level, as good habitual behaviours.

2.4.3 Connectivity to the basal ganglia.

This section summarises inputs and outputs of the BG. Gradually the contributions of specific areas in and pathways involving the BG have been identified.[524]

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[518] Wickens, "Synaptic plasticity in the basal ganglia,"119.
[519] Beretta, Nicola et al. "Synaptic plasticity in the basal ganglia: A similar code for physiological and pathological conditions" in *Progress in Neurobiology* 84 (2008): 345-346.
[520] Marieb and Hoehn, *Human anatomy and physiology*, 8th ed., 453.
[521] Martin, *Neuroanatomy: Text and Atlas*, 3rd ed., 330.
[522] The new understanding of the contribution of this brain region may be summed up as follows: "It is well known that the cortico-striatal network controls functionally heterogeneous decision making processes, including goal directed actions, susceptible to reward feedback, and stimulus linked actions, largely automatic or habitual." Beretta et al., "Synaptic plasticity in the basal ganglia: A similar code for physiological and pathological conditions," 349.
[523] Martin, *Neuroanatomy: Text and Atlas*, 3rd ed., *327.*
[524] Tortora and Derrickson, *Principles of Anatomy and Physiology*, 11th ed., 493-494.

a) Inputs

Afferent pathways, input pathways to the BG, are from all regions of the cortex, from the VTA, the *intralaminar nuclei* (ILN) of the thalamus, and the SNpc.

- The striatum is a key target of excitatory major projections from the entire cortex, and is "constantly informed about most aspects of cortical function".[525] The ventral striatum is the target of inputs from the limbic cortex, the hippocampus and the amygdala.[526] Processing of motor commands takes place here and in the GP, with output across to thalamus and then back to cortical motor areas.[527]
- The putamen receives input from motor and somatosensory cortical areas. [528]
- The caudate nucleus receives information primarily from the association cortex.
- The close association of the BG to the thalamus is most significant. Principal input to the BG is glutamatergic from cortex and thalamus. It should be noted that the BG and the thalamus are intimately interconnected by these major neural highways. Almost all sensory input to the cerebral cortex passes through the thalamus. The thalamus also features sensory nuclei. Also the thalamus assists in maintenance of consciousness.[529] The thalamus is also known to play a key role in focusing attention, a process involving the ILN receiving input from the frontal cortex, as well as brain stem, and projecting back to the BG. It has been noted that lesions of the ILN eliminate awareness.[530] It must be understood that the thalamus is not a simple relay station but itself, along

[525] Nolte, *The human brain. An introduction to its functional anatomy*, 5th ed., 469.
[526] Nolte, *The human brain. An introduction to its functional anatomy*, 5th ed., 469. OCD, schizophrenia and severe anxiety are associated with dysfunction of limbic-striatal circuitry.[526]
[527] Martini, *Fundamentals of Anatomy and Physiology*, 6th ed., 486.
[528] Nolte, *The human brain. An introduction to its functional anatomy*, 5th ed., 469.
[529] Gail W. Jenkins, et al. *Anatomy and Physiology*, 2nd ed. (New Jersey: Wiley, 2010), 425.
[530] Squire et al., *Fundamental Neuroscience*, 3rd ed.

with the BG, is a centre for integration of subcortical motor inputs and feedback from the motor cortex.[531]

The BG are a region of great biochemical diversity, exhibiting almost all the neuroactive agents.[532] Neuromodulatory inputs include:[533]

- DA from VTA and SNpc
- Serotonergic from the raphe
- GABAergic from GP and SN
- ACh, EC, *nitric oxide* (NO), and adenosine.[534]

SNpc DA afferents target associative cortex connections in the caudate. VTA DA afferents in a similar way target projections to the ventral striatum.

As DA is a principal moderator of plasticity, DA release in the striatum and BG is evidence of inhibitory limbic plastic modification of BG activity.

b) Outputs

Efferent pathways project from output nuclei of the BG: the GPi, the VP, and the SNr.

- Projections are inhibitory and target the thalamic nuclei (including the *ventrolateral nucleus* (VL), ventral anterior nucleus, medial dorsal nucleus).
- The BG-thalamocortical loop. Neuromodulation effects a decisive modulatory effect back on the cortex via these pathways. Hence the BG exert a major modulatory effect on glutamatergic cortical outputs.[535]

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[531] Kaas and Stepniewska, "Motor cortex," 167.
[532] Martin, *Neuroanatomy: Text and Atlas*, 3rd ed., *327.*
[533] Wickens, "Synaptic plasticity in the basal ganglia,"121.
[534] Di Filippo et al., "Short term and long-term plasticity at corticostriatal synapses: implications for learning and memory," 112-113.
[535] Da Cunha, "Learning processing in the basal ganglia: a mosaic of broken mirrors," 158.

- Projections of striatum, GP and SNr are GABAergic are inhibitory. 95% of neurons in striatum are GABAergic *medium spiny neurons* (MSNs)[536]. Note that the BG contain inhibitory GABAergic neurons, spiny in the striatum and aspiny in the pallidum, requiring strong and coherent excitatory cortical inputs from almost all cortical areas to become active. [537] Basal forebrain projections also innervate the hippocampus and amygdala, also in an inhibitory manner.
- Outputs of the BG directly impact on motor control by affecting activity of motor areas in the cortex[538]. BG components involved in motor control are the GP and the SN.[539]
- The ventral striatum organises somatosensory and motor representations in a topographic manner, and outputs to the GP which in turn outputs to the VLo in the thalamus, a part of the VL. The VLo in turn outputs to the premotor and motor cortices and to the *supplementary motor area* (SMA) in the cortex.[540] There are few projections to brain stem motor nuclei and none to the spinal motor apparatus. Again, this is very significant and "suggests the system operates mainly to *modify cortical motor representations* (my italics) rather than control behaviour through direct motor inputs".[541]
- Some projections to brainstem motor structures such as the pedunculopontine nucleus exercising control over locomotion[542], and to the superior collicus controlling neck and eye movements.[543]

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[536] Da Cunha, "Learning processing in the basal ganglia: a mosaic of broken mirrors," 159.
[537] Yin and Knowlton, "The role of the basal ganglia in habit formation," 464.
[538] Nolte, *The human brain. An introduction to its functional anatomy*, 5th ed., 469. Excitatory outputs of the BG facilitate muscle movement at the beginning of a voluntary movements while inhibitory outputs inhibit muscle activity in antagonist muscles. Also it has been shown that the BG inhibitory outputs decrease muscle tone, for example eliminating unwanted movement in muscles at rest. Hence persons with BG dysfunction typically manifest increase muscle tone when at rest, leading to uncontrolled movements. (Seeley et al., *Anatomy and Physiology,* 496-7.)
[539] Jon H. Kaas and Iwona Stepniewska, "Motor cortex" in *Encyclopedia of the Human Brain*, Vol 3, ed. V. S. Ramachandran (San Diego: Academic Press, 2002), 159.
[540] Squire et al., *Fundamental Neuroscience*, 3rd ed.,
[541] Squire et al., *Fundamental Neuroscience,* 3rd ed.,
[542] Petersen, *Human physiology,* 205.
[543] Squire et al., *Fundamental Neuroscience,* 3rd ed.,

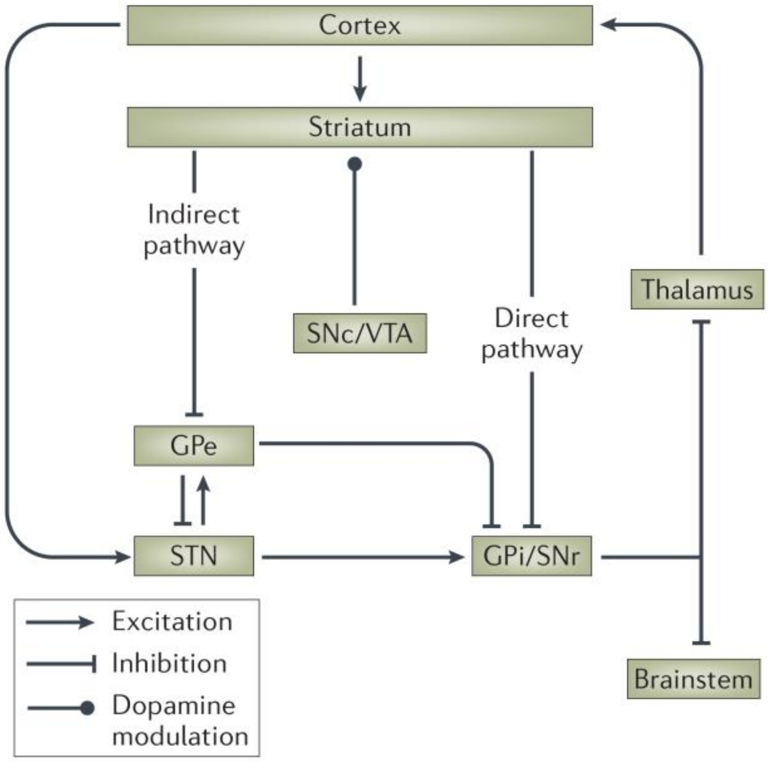

Figure 2.8 **The main connections of the BG.** The direct pathways from the striatum are associated with disinhibition on the cortex, and the indirect with inhibition. Note that this is a simplification of the limbic, associative, sensory and motor functionalities of the basal ganglia. All pathway loops however follow the cortico-striatal-GP-thalamic sequence. **Source**: Yin, Henry H. and Knowlton, Barbara J. "The role of the basal ganglia in habit formation (Review)." *Nature Reviews Neuroscience* , 7 (2006): 465.

2.4.4 Loops.

Through the major cortical-BG loops incorporating the thalamus, rich neuromodulation of the BG especially by DA reward circuitry, in turn modulates cortical activity. This activity further reflects the integral role of the BG in cortical, goal elective and reward focused activities and its involvement in habit formation and motor management.

Loops are extensive neural pathways bridging and connecting distinctive areas of the brain. Multiple parallel anatomical loops link the basal ganglia, thalamus, and cortex. There are four categories of functional loops involving the BG: the skeletomotor, the oculomotor, the PFC loop, and the limbic loop.[544] There are multiple versions of cortico-BG-cortical loop: most prominent are the cortical association areas-caudate loop, the putamen-sensorimotor cortex, and the limbic-NAc loops.[545] These loops define the function of the various areas of the BG. It is the caudate that is mainly implicated in modulation of cognitive cortical function.[546] There are also loops involving the ILN of the thalamus connecting with the BG but little is yet known of their function.[547]

The cerebral cortex and BG appear to be essential components in the cognitive processes of generating anticipatory behaviour. [548] The skeletomotor loop and the oculomotor loop also appear to facilitate programming and effecting specific goal directed behaviours. BG pathways are also important for motor skill learning.[549] Only a small proportion of the BG loops appear to have a motor management function.[550] Under certain conditions plastic change occurs in these pathways. [551] The most direct motor loop involves excitatory inputs to putamen from cortex, and may serve to "funnel the activation of widespread cortical areas" onto the SMA.[552] One recent study finds, "Increased corticostriatal transmission leads to increased thalamocortical activity, and an increased likelihood of behavioural response expression."[553] Neurons of the "indirect" pathway, inhibited by DA,

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[544] Martin, *Neuroanatomy: Text and Atlas*, 3rd ed., 330 and *347.* The limbic loop involves the BG in regulation of emotional responses in conjunction with limbic system. This loop begins both in the cortical limbic association area and in the hippocampal formation, thence to the ventral striatum into the VP and medial dorsal nucleus of the thalamus. The cortical target for the limbic loop is the anterior cingulate gyrus and orbitofrontal gyrus.
[545] Nolte, *The human brain. An introduction to its functional anatomy*, 5th ed., 468.
[546] Nolte, *The human brain. An introduction to its functional anatomy*, 5th ed., 473.
[547] Nolte, *The human brain. An introduction to its functional anatomy*, 5th ed., 470.
[548] A. Floyer-Lea and P. M. Matthews, "Distinguishable Brain Activation Networks for Short- and Long-Term Motor Skill Learning," *Journal of Neurophysiology* 94 (2005): 516.
[549] Floyer-Lea and Matthews, "Distinguishable Brain Activation Networks for Short- and Long-Term Motor Skill Learning," 516.
[550] Bear, *Neuroscience. Exploring the Brain,* 464. Motor loops are both excitatory and inhibitory.
[551] Horvitz, "Stimulus-response and response outcome learning mechanisms in the striatum," 131. In the case of tonic, not phasic, DA output, LTD is likely to result in these cells.
[552] In this "direct" pathway, excitatory cortical inputs to the putamen link by inhibitory connections to the GP. Unsignalled neurons in the GP are spontaneously active and therefore inhibitory on the thalamus. These now inhibited GP neurons then refrain from inhibitory action on the thalamus. The end result of this process is that excitatory thalamus neurons increase activity in the SMA. Bear, *Neuroscience. Exploring the Brain,* 466.
[553] Horvitz, "Stimulus-response and response outcome learning mechanisms in the striatum," 131.

project to the GPe, and thence via strong excitatory outputs to the SNr and the GPi output nuclei.[554]

BG research is increasingly focusing on the interaction between the loops, such as limbic loop mediation of the motor loops, and on possible mechanisms. For example it is shown that dendrites connect the loops with all loops projecting back to SNpc, possibly converging on DA neurons in this area.[555] In addition during the past decade significant further pathways connecting the BG and other brain centres have been identified. Cerebellar-BG connections have now been established, as have the hippocampal-BG pathways mentioned above.[556] Haber et al. (2000) documented their discovery of abundant connections between striatum and midbrain.

2.4.4.1 Frontal lobe-basal ganglia loops provide a key to complex goal directed behaviours.

Various regions of the cerebral cortex have closed loops (loops which finish back in the brain area where they began): lateralPFC, orbitalPFC, and the premotor cortex. These closed loops allow recursive feedback. Daw et al. (2005) suggested that it is by means of this recursive processing that the PFC is able to link complex anticipated behaviours with rewards and then "cache" chunked steps to achieve desired outcomes in the rapid plasticities of the striatum in a "caching reinforcement learning system".[557] Koch explains the interaction of the BG and the PFC in this process: "the BG learns each fork in the road whereas the PFC puts together the whole route."[558]

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[554] Di Filippo et al., "Short term and long-term plasticity at corticostriatal synapses: implications for learning and memory," 109. The indirect pathway thereby reinforces inhibition as thalamic neurons in the frontal cortex are excitatory unless inhibited by GPi and SNr.
[555] Martin, *Neuroanatomy: Text and Atlas*, 3rd ed., 330. Note also that Joel and Weiner have proposed interaction between parallel circuits.
[556] Yin and Knowlton, "The role of the basal ganglia in habit formation," 470.
[557] N. D. Daw et al., "Uncertainty based competition between prefrontal and dorsolateral striatal systems for behavioural control," *Nature Neuroscience* 8, (2005): 1704-1711. Cited in Christopher Koch, "Consciousness" in Larry Squire, et al., *Fundamental Neuroscience*, 3rd ed. (Burlington, MA: Elsevier, 2008), Chapter 53.
[558] Koch, "Consciousness", 1220.

The fact that representations of habits in the BG are not goal dependent, empowers the PFC to pursue *complex* (my italics) goal directed behaviours utilising these habits. This conclusion is consistent with the findings of Pasupathy and Miller (2005) who noted in that changes in activity in the lateral PFC during visuomotor rule learning induce immediate changes in the dorsal striatum, whereas reflection of changes in the opposite direction were much slower. It is suggested that this allows the PFC, which holds the complete model of an anticipated activity, to capture quick "reward related snapshots" of anticipated actions. [559]

2.4.5 The role of the basal ganglia in motor learning.

a) Motor learning as a form of memory.

Motor learning may be understood as a form of memory. There are multiple memory functions performed by areas of the striatum. The striatum organises somatosensory and motor representations in a topographic manner; the dorsal striatum lays down memory for motor habits, actions and outcomes, playing a key role in much S-R learning; also emotional memory is also interconnected with the BG (via limbic pathway) and is believed to further modulate the basal-cortical motor management processes.

As we have seen above in **2.3.2** there are multiple memory systems and brain sites involved in memory. Memory representations are understood to depend on cellular and molecular processes that alter synaptic strength; protein synthesis and gene translation are involved in long term memory. The view that the BG is identified with implicit procedural memory has been increasingly modified over the past two decades.[560]

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[559] Koch, "Consciousness," 1220.

[560] We have seen that memories are commonly classified as non declarative (or implicit) for more or less unconscious procedural, motor or emotional memories, or declarative (or explicit) for

There is no question that the striatum plays a key role in mediating the procedural memories underpinning behavioural habits.[561] When implicit learning is emphasised in a probabilistic learning task, the striatum is more active, but for explicit learning, the medial temporal lobe is more active.[562] Since early 1990s, PET and fMRI studies have demonstrated that the striatum is critical in encoding motor programs.[563] This is confirmed by studies of impairments as a result of striatal dysfunction. Although the cerebellum seems involved in early stages of motor sequence learning, the striatum seems critical for retention of sequences. Implicit knowledge is now believed to be stored in the motor cortex and associated parts of the BG along with cerebellum.[564]

However the traditional division of multiple memory systems between hippocampal dependent learning and striatum dependent learning is regarded as no longer fully satisfactory. Poldrack and Packard argued that hippocampus (place) and dorsal striatum (response learning) are two competing learning systems (corresponding, in human studies, to declarative learning mediated in medial temporal lobe, and non-declarative learning in the striatum). But other results suggest that the hippocampus and the striatum *cooperate* (my emphasis) in a functional circuit, contrary to the former view that they compete.[565] It appears that the implicit and explicit are not totally independent systems of learning, in line with recent findings that the hippocampus is closely coordinated with the striatum, despite its involvement in flexible, non-repetitive activity.[566] All this is consistent with a greater involvement of the BG in explicit cognitive activity

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conscious memories, for example of facts and episodes. There has been a growing realisation that storage of these different forms of memory not only takes place in different parts of the brain but memory and learning processes are highly interconnected and interdependent between various regions.

561 Bear, *Neuroscience. Exploring the Brain,* 751.

562 Yin and Knowlton, "The role of the basal ganglia in habit formation," 470.

563 Julien Doyon, et al., "Contributions of the basal ganglia and functionally related brain structures to motor learning," *Behavioural Brain Research* 199, (2009): 62-63.

564 Stephen Wise and Reza Shadmehr, "Motor control" in *Encyclopedia of the Human Brain*, Vol 3, ed. V. S. Ramachandran (San Diego: Academic Press, 2002), 137-157.

565 Yin and Knowlton, "The role of the basal ganglia in habit formation," 470.

566 Yin and Knowlton, "The role of the basal ganglia in habit formation," 470.

than had previously been thought and of a model of brain function where discrete areas and systems are more comprehensively integrated than had previously been thought.

The implication of the PFC in motor memory is also now apparent. As studies unveil the underlying processes of motor learning, higher levels of cortical involvement, of the significance of various regions of the BG at various stages in the process, and the role of cortical-BG interconnections, are all apparent. Motor learning principally involves the cortico-basal-thalamic pathways mediated by plasticity in the BG synapses, the cortico-cerebellar loop through the dentate nucleus and ventral-posterior lateral nucleus of the thalamus, the hippocampus in early stages of learning, and the "functional interplay... between cortico-striatal, cortico-cerebellar, and limbic systems in this form of learning" [567]

For a long time it was thought that the BG and the cerebellum played the principal roles in procedural motor memories, memories that either retained reflex responses, or explicit sequences that had become automatised: the cerebellum had been understood to play a role in the reflex responses to stimuli that characterise classical conditioning, and the oldest hypothesis involving the BG was that implicit memory resided in the BG, and explicit in the *medial temporal lobe* (MTL).[568] This view has been modified in recent years. It is now believed that long term storage of explicit motor knowledge is in the PFC and associated parts of the BG, while storage of intermediate term explicit motor knowledge is in the MTL.[569]

b) The learning process: from the explicit to the automatized.

The BG are implicated in goal directed motor activity, and in those same motor activities after they are automatized. During the period of acquisition, both

[567] Doyon, et al., "Contributions of the basal ganglia and functionally related brain structures to motor learning," 62.
[568] Recent evidence for the importance of the cerebellum in motor learning has been provided in both lesion (Baizer et al. 1999; Doyon et al. 1997, 1998) and imaging (Doyon et al. 2003) studies.
[569] Stephen Wise and Reza Shadmehr, "Motor control" in *Encyclopedia of the Human Brain*, Vol 3, ed. V. S. Ramachandran (San Diego: Academic Press, 2002), 137-157.

implicit procedural habits and virtue facilitated behaviours move from the explicit to the automatised. Both are acquired by a process initially involving attentive, voluntary and repetitive action and explicit knowledge.

Procedural memories are learned gradually by a process that relies on reinforcement; this can be the foundation for habits after further overtraining. Once acquired these habits show great resistance to change. The BG become increasingly involved in the process of learning as actions become more automatic. In the early stages of learning, attention to action and to the requisite explicit knowledge is required. Predictably, as new skills are being learned PET studies show increased blood flow indicating greater synaptic activity in the PFC. As a skill becomes learned and unconscious, the posterior parts of the cerebellum, [570] the non primary motor cortex, and the *posterior parietal cortex* (PPC) are most involved.

Note that the BG are involved in both early stages and in completed procedural learning. Wise and Shadmehr state that the findings of these PET studies "support the hypothesis that prefrontal cortex-basal ganglionic modules subserve voluntary movement, whereas the motor cortex-basal ganglionic modules (along with cerebellum and PPC) underlie the more automatic movements of the same kind."[571]

c) The comparative roles of the cerebellum and the basal ganglia.

There are four essential components to the motor systems controlling skeletal muscles: the cortical and subcortical nuclei (primary motor and premotor cortices, and the brain stem) with their descending pathways, the motor neurons

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[570] Floyer-Lea and Matthews, "Distinguishable Brain Activation Networks for Short- and Long-Term Motor Skill Learning," 517. The authors note the mechanisms of motor skill learning. Doyon and Ungerleider (2002) documented the role of the striatum in the long-term storage of well-learned movement sequences. Hoshi et al.(2005) documented input from the cerebellum to the putamen (posterior striatum) via the cerebello-thalamo-striatal pathway showing that these two areas are far more interconnected, and therefore interactive, than has been long thought.
[571] Wise and Shadmehr, "Motor control," 153.

themselves and the interneurons, the BG, and the cerebellum. These last two input to the thalamus that in turn inputs the primary and premotor cortices.[572] In other words, all executive muscular commands are modulated by the BG and the cerebellum. The work of Doyon et al. (2009) into the neural substrates of procedural memories further demonstrated an extended role for the BG both before and after automatisation.

The authors draw a distinction between *motor sequence learning* (MSL) and *motor adaptation* (MA) by which we change our behaviours to compensate for changes in the environment.[573] MSL requires a learned sequence of movements, which, among other methods of acquisition, may be "learned implicitly through repeated practice".[574] Acquisition of skills follows several phases: fast learning stage, a slow stage, through to the automatized stage when movements are effortless and carried out with much reduced attention. It is shown that motor sequence learning requires repetition but then "continues to develop over time after training has ended".[575] The authors suggest that the striatum is not necessary for retention and execution of MA tasks, and that the cerebellum and BG play inversely complementary roles in MSL and MA tasks.[576]

These results are consistent with the view that the cerebellum is active in establishing new patterns of behaviour but that once these patterns are committed to memory, it becomes inactive. On the other hand, the BG continue to mediate the representation for the behaviour. [577]

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[572] Martin, *Neuroanatomy: Text and Atlas,* 230.
[573] Doyon, et al., "Contributions of the basal ganglia and functionally related brain structures to motor learning," 61-75.
[574] Doyon, et al., "Contributions of the basal ganglia and functionally related brain structures to motor learning," 62.
[575] Doyon, et al., "Contributions of the basal ganglia and functionally related brain structures to motor learning," 67.
[576] Doyon, et al., "Contributions of the basal ganglia and functionally related brain structures to motor learning," 70. Interestingly the authors note that sleep appears to play a significant, and perhaps necessary, role in consolidation of some forms of memory.
[577] Doyon, et al., "Contributions of the basal ganglia and functionally related brain structures to motor learning," 67,69, 70. Doyon et al document a dual task paradigm to investigate the relative roles of the BG and cerebellum. In a fascinating knitting experiment, eight experienced knitters were scanned as they performed a familiar knitting action, a new "Continental" method, and a

d) **Numerous brain areas are implicated at both acquisition and completion stages of this learning process.**

Motor skill learning is a highly complex neural process involving plastic change in very many brain areas and pathways.[578] Procedural learning pathways involve sensorimotor messaging to the association cortex and thence to BG and on to thalamus and premotor cortex. The premotor cortex has a key role in the acquisition of motor skills involving repetition and patterns of activity, coordinating the muscles involved via the primary motor cortex. One author describes the premotor cortex as "the memory bank for skilled motor activities." [579] Memory formation in this region is triggered by ACh release from the basal forebrain. The premotor cortex has involvement also in planning complex voluntary actions that require fine coordination.

The work of Floyer-Lea and Matthews (2005) confirmed this remarkably complex interplay of brain areas in both short and long term learning. They sought to study the distinct brain networks mediating fast, short-term and slow, long-term motor learning of the same motor task.[580] Their research found that short-term motor skill learning was associated with some plasticity in the cortical network specific

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control movement of knitting needles. fMRI imaging demonstrated that the cerebellum and BG were initially involved in learning the new method, but that once learned, the cerebellum became inactive with the long lasting representation of the behaviour involving only the BG and associated motor cortical regions.

[578] While it is totally incorrect to equate motor skill learning to the acquisition of virtue, it is suggested that the behaviours automatized in various simple potentially virtuous actions, for example of greeting others courteously, or of coughing into a handkerchief, rely in part, for the neural basis on such motor learning. I write of these actions "potentially virtuous" for the habitual intention with which the action is performed is also highly relevant.

[579] Marieb and Hoehn, *Human anatomy and physiology*, 8th ed. 437.

[580] The authors designed an experiment for the performance of a finger pressure sequence learning task carried out by twenty two right handed subjects (subdivided into a short term and long term group; each almost equally divided between men and women; with age range, 20–34 years.) fMRI results of initial training session after exposure to the exercise, were compared with results after the second training session after exposure, and with results over a three week training period. Their results reflected the 1995 findings of Karni et al. who had suggested distinct plasticity mechanisms for altered brain motor representations with short- and long-term learning. Floyer-Lea and Matthews, "Distinguishable Brain Activation Networks for Short- and Long-Term Motor Skill Learning," 512-518.

for the learned movements. They suggested that increased traffic in a subcortical circuit (cerebellar dentate, thalamus, and putamen) could be a critical element in development of greater movement automaticity with short-term learning. They confirmed the implication of the putamen in processing movement timing, and suggested that the motor cortex–putamen circuit could be crucial in encoding movement sequences. [581]

They found that long-term learning involved pronounced plasticity in the primary somatosensory and motor cortex and increased activation in the loop between motor cortex and basal ganglia "after a motor sequence is practised extensively."[582]

e) Emotion and procedural memory.

Further evidence of the highly integrated nature of brain systems is apparent in studies which demonstrate that procedural memory consolidation appears associated with the reward systems of the brain. DA release from the SN is believed to trigger memory formation in the BG. Monkey studies, documented by Romo and Schultz (1990) and Montague et al. (1996) confirmed that striatal neurons are conditioned by DA (reward) signalling. [583]

Doyon et al. note evidence for emotional facilitation of memory in the BG.[584] Processes of cellular consolidation of limbic dependent memory traces, also appear to consolidate motor memories. They note the synthesis of proteins in the

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[581] Floyer-Lea and Matthews, "Distinguishable Brain Activation Networks for Short- and Long-Term Motor Skill Learning," 512-518.

[582] Floyer-Lea and Matthews, "Distinguishable Brain Activation Networks for Short- and Long-Term Motor Skill Learning," 516-517. These findings should be considered with the results of an automaticity study by Poldrack which showed the association loop decreased in activity with shift to sensorimotor-cortico-BG networks.

[583] Cited in Marieb and Hoehn, *Human anatomy and physiology*, 8th ed., 459. In contrast, declarative memory pathways involve sensory input carried to the association cortex, information is then sent to the medial temporal lobe, including the hippocampus and proximate temporal cortical areas that link to the PFC and the thalamus. ACh from the basal forebrain released into the PFC and the medial temporal lobe is believed to trigger memory formation.

[584] Doyon, et al., "Contributions of the basal ganglia and functionally related brain structures to motor learning," 68.

motor cortex after training enables motor skill learning. This seems to indicate that processes of system consolidation, as demonstrated in the cortico-hippocampal circuit, are also applicable to the circuitry for motor sequence learning.[585]

2.4.6 Habit formation, a particular form of learning.

Against this review of procedural learning, it is enlightening to look in more detail at habit formation.

By way of introduction to this section, a parenthesis about the nature and features of habits in their relationship to the BG is warranted. Habits are well characterised: they are learned, (ie a result of mechanisms of experience dependent plasticity), they are robust after they are fixed by repetition, there can be a lack of behavioural flexibility, they allow for virtually unconscious performance, they demonstrate insensitivity to outcome devaluation and contingency degradation, they tend to manifest as an ordered sequence elicited by a specific context or stimulus, and may be either cognitive or motor.[586] Habits have similar features to, but are distinct from, *fixed action patterns* (FAPs) in animals; symptoms of Tourette syndrome, and OCD.[587] One OCD circuit has been documented. Not surprisingly it is a cortico-subcortical pathway and is implicated also in drug addiction. The focal nature of tics suggests an origin in specific sites in the striatum and in specific cortico-basal ganglia subcircuitry. In general habits are recognised now as systems with distinct brain substrates. Computational approaches, pioneered by Sutton and Barto in the 90s, have added a powerful instrument to studies in this area.

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[585] Doyon, et al., “Contributions of the basal ganglia and functionally related brain structures to motor learning,” 68.

[586] For this list of characteristics I have drawn on a number of sources including: Yin and Knowlton, “The role of the basal ganglia in habit formation,” 475.

[587] Unless otherwise indicated, content in this section attributed to: Graybiel, “Habits, Rituals, and the Evaluative Brain,” 359-87.

Classically habits have been seen to fall in the domain of procedural learning as opposed to declarative learning. Compulsive habits manifest similar neural programs of development to addictions (**2.6.6**). They may be acquired either by behavioural routines and rituals that have been learned, through innate mechanisms, or though neurological or neuropsychiatric illness or addiction. The skilled procedural actions of a morning routine, or of driving to work, also have much in common with habits as such.

Graybiel points out that proceduralisation, movement sequences, can occur in both cortical and subcortical, widely distributed brain regions where they exhibit many neural parallels to habit learning, most significantly:

- dynamic involvement of neocortex and striatum,
- shift from anterior/ventral regions of striatum to caudal zones as the proceduralisation is acquired,
- with a corresponding shift from anterior/ventral cortical regions to more posterior zones.

The line between compulsive habit formation and a cortically integrated facility for behaviour is indistinct.

Graybiel argues that BG-mediated habits fall somewhat ambiguously between voluntary, conscious, higher-order, deliberative behavioural control, and lower-order control almost inaccessible to consciousness.[588] She suggests that habits affect not only behaviours but cognitive activity. In taking the above position, she seeks to resist what she sees as a narrowing of the definition of habit.[589]

[588] Graybiel's work sits comfortably with Schwartz's work on management of OCD by cognitive therapies and is effectively a call for greater recognition of the close interdependence of habit and cognitive processes. Schwartz and Begley, *The Mind and the Brain.*

[589] Graybiel refers to increasing evidence that habitual behaviours involve pathways connecting the neocortex with the striatum and related areas of the BG, and that this circuitry in the BG underpins disorders where repetitive thoughts and behaviours surface. She argues that this circuitry "can iteratively evaluate contexts and select actions and can then form chunked representations of action sequences that can influence both cortical and subcortical brain structures." It is this shift from evaluation to performance, she says, that characterises acquisition of habits.

In keeping with this broadened understanding, Tang et al. (2007) document a significant contribution that habit formation makes to the wellbeing of the organism. They studied the striatal neuronal output in 26 rats during the formation of a motor habit. Rats were surgically implanted with 12 microwires, each for single neuron recording. The aim of the study was to observe changes in output by striatal neurons related to vertical head movement during the process of motor habit acquisition.[590] They were able to demonstrate a growing efficiency of neuronal activity in the course of learning: "Our data suggest that the striatum may shift from facilitating acquisition of efficient movement with a large population of neurons early in training to modulating or maintaining habitual movement with stronger firing by fewer neurons after overtraining, consistent with evidence that lesions of the striatum impaired formation (Yin et al., 2004) and expression (Packard and McGaugh, 1996) of a habit."[591]

In other words, habit learning provides the organism with a way of producing movement that is more efficient at the neuronal level, and therefore conducive to the flourishing of the organism. (See **6.2.1.2**.)

2.4.7 Plasticity in the basal ganglia and related structures.

It is appropriate, having reviewed the anatomy and role of the BG, that we now turn our attention specifically to plasticity in this region. Within the argument of this study is that various mechanisms of plasticity constitute the material underpinnings for learning, including habit formation, in the brain. It is activity dependent plasticity, the "long lasting change in the functional efficacy of synaptic connections that is induced by certain patterns of brain stimulation"[592] that most interests us; and this is totally consistent the view that repeated behaviours assist in the formation of both habits and virtue itself.

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[590] Chengke Tang et al., "Changes in activity of the striatum during formation of a motor habit," *European Journal of Neuroscience* 25, (2007): 1212.
[591] Tang et al., "Changes in activity of the striatum during formation of a motor habit," 1223
[592] Wickens, "Synaptic plasticity in the basal ganglia,"121.

Although an understanding of the internal workings of the BG is very much a work in progress,[593] nevertheless, much progress has been made in unravelling the complexities of BG plasticity, and in identifying component regions and their role in facilitating implicit learning.

There are numerous and distinct forms of plasticity that underpin learning and cognitive processes mediated by the striatum when specific behavioural tasks are being learned. These forms include LTP, LTD, shorter forms of intrinsic plasticity (such as lateral inhibition and modification of neuronal membrane properties) and STDP, which "encodes salient information in neuronal networks".[594]

2.4.7.1 Forms of basal ganglia plasticity.[595]

i) The reward signal DA is believed to be the principal mediator of striatal plasticity. DA has been shown to strengthen synapses in the striatum

[593] As recently as 2006 one research team wrote: "At present we remain ignorant of the detailed mechanisms that underlie habit formation at all levels of analysis.... We do not yet understand how synaptic plasticity in the basal ganglia alters the outputs of the networks, and we do not have direct evidence linking such plasticity to well-defined learning." Yin and Knowlton, "The role of the basal ganglia in habit formation," 475. Furthermore, Di Filippo et al. write, "The integrative significance of the intrastriatal networks is still far from being completely elucidated." Di Filippo et al., "Short term and long-term plasticity at corticostriatal synapses: implications for learning and memory,"109.
[594] STDP in the striatum seems to operate in reverse to other brain areas. It has been demonstrated that in most cases, if where STDP is present, LTP is a consequence if the EPSP follows the presynaptic response (brief high Ca^{2+} influx owing to activation of NMDA receptors); LTD is produced if the presynaptic response follows the EPSP (low level Ca^{2+} influx). The importance of this form of the plasticity in the striatum has been recognized for some two decades. Di Filippo et al., "Short term and long-term plasticity at corticostriatal synapses: implications for learning and memory,"114.
[595] Beretta et al. summarise the significance of plasticity in the BG and associated pathways: "It is well known that the cortico-striatal network controls functionally heterogeneous decision making processes, including goal directed actions, susceptible to reward feedback, and stimulus linked actions, largely automatic or habitual." They go on to argue that these processes hinge on "distinct learning rules and, accordingly, distinct forms of plasticity", and that it is variations in synaptic plasticity and at times the absence of synaptic modification in the dorsal striatum that are implicated in procedural learning, stimulus response association, habit formation and motor control. Beretta et al., "Synaptic plasticity in the basal ganglia: A similar code for physiological and pathological conditions," 349.

that are currently active, producing synaptic strengthening shown to relate to operant learning. [596]

ii) <u>In ventral pars</u>, [597] LTD and LTP plasticities are present in various forms, by specifically different induction mechanisms, featuring changes both pre- and post-synaptically, and even on the same synapse mediated by different receptors. ACh, DA, EC, GABA, glutamate, opioid, and nicotinic plasticity are all present, some in a wide variety of forms. "LTD/LTP induced modification of firing discharge (change from single spike to burst) could control alertness, volition, responses to natural rewards, and drugs sensitisation." [598]

It is possible that the striatum plays a key role in reward related memory.[599] Two classes of striatal neurons have been identified in signalling reward related events, in each case utilising DA, but it should be recognised that the mechanisms underlying "striatal neuroplasticity and reward-related behaviours and learning are still far from being elucidated."[600]

Plasticity in the form of LTD and LTD, "probably the two main forms of synaptic plasticity",[601] is found at corticostriatal-MSN synapses. [602] MS neurons seem much more susceptible to LTD than LTP owing to their very negative resting membrane potential.[603] Now "almost all forms of

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[596] Horvitz, "Stimulus-response and response outcome learning mechanisms in the striatum," 129-140.

[597] For source material and more detail: Beretta et al., "Synaptic plasticity in the basal ganglia: A similar code for physiological and pathological conditions," 356. Plasticity in the dorsal and ventral striatum exhibits distinctive characteristics.

[598] Content in this subsection drawn principally from Beretta et al., "Synaptic plasticity in the basal ganglia: A similar code for physiological and pathological conditions," 345-356.

[599] Di Filippo et al., "Short term and long-term plasticity at corticostriatal synapses: implications for learning and memory,"116.

[600] Di Filippo et al., "Short term and long-term plasticity at corticostriatal synapses: implications for learning and memory,"115.

[601] Di Filippo et al., "Short term and long-term plasticity at corticostriatal synapses: implications for learning and memory,"114.

[602] Originally LTD and LTP were identified as isolated phenomena. Now, it is known that "the neuronal processing within BG loops in physiological or pathological conditions does not rely on the expression of one single form of synaptic modification, but on a milieu of long-term synaptic potentiation and depression". Beretta et al., "Synaptic plasticity in the basal ganglia: A similar code for physiological and pathological conditions," 356.

[603] Beretta et al., "Synaptic plasticity in the basal ganglia: A similar code for physiological and pathological conditions," 356.

Hebbian plasticity have been demonstrated at excitatory coticostriatal synapses onto striatal projecting neurons and some seem to be expressed by striatal interneurons".[604]

Intrinsic plasticity has been observed in striatal MSNs: "Synaptic output can also be modulated by enduring changes in neuronal intrinsic excitability resulting from changes in voltage gated ion channels function."[605] The result is an amplification or attenuation of the EPSP amplitude. This form of plasticity changes the probability of PSP and duration, and secondly mediates metaplasticity, the capacity to induce consequent plasticity at the synapse. Thirdly it may be involved in efficient tuning of output in relation to repeated synaptic inputs. The complexities of intrinsic plasticity are under current study.[606]

Plasticity in the NAc reinforces spatial memory, consolidates links between emotion and context cues in relation to planning in the PFC and motor behaviours, plays an underlying role in natural reward processes, and also provides the neural basis for craving after drugs of abuse.[607] Note that the link to drug seeking shows that habits in the BG need not be simple motor sequences, but may involve the pursuit of complex purposeful behaviour patterns. Limbic DA inputs are from the VTA.

Plasticity in the VTA establishes a reward memory with respect to behaviours caused by natural incentives (food, water, sex) or dysfunctional processes such as those caused by drugs of abuse (craving, sensitisation, dependence).

iii) <u>The dorsal pars</u> features links to associative and sensorimotor cortical areas especially in medial and lateral areas. Activity in the dorsal region is modulated by DA from SNpc. The role of LTP and LTD in movement

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[604] Di Filippo et al., "Short term and long-term plasticity at corticostriatal synapses: implications for learning and memory,"110.

[605] Di Filippo et al., "Short term and long-term plasticity at corticostriatal synapses: implications for learning and memory,"114.

[606] Di Filippo et al., "Short term and long-term plasticity at corticostriatal synapses: implications for learning and memory,"114.

[607] Beretta et al., "Synaptic plasticity in the basal ganglia: A similar code for physiological and pathological conditions," 345-356.

initiation and learning in this area have been well described. [608] In the dorsal pars LTD is the dominant form of plasticity in the cortico-striatal pathway, in various forms, at D2 receptors.[609]

Plasticity is evident in the SN**.** Postsynaptic LTD in SNpc has been identified. This is independent of NMDAR but dependent on Ca2+ intracellular signalling. Tetanic stimulation of subthalamus has been shown to lead to LTP in SNpc, suggesting that the subthalamus can thus play a role in motor activity. The relationship between movement and plasticity in SN DA neurons has not yet been described.

Plasticity in STN appears significant in motivation for natural rewards and for craving for drugs. Plasticity in this nucleus has a major role in motor function control.

2.4.7.2 DA: principal mediator of plasticity in the basal ganglia.

DA was initially hypothesised to mediate reinforced learning by strengthening synaptic connections in the striatum in the presence of a reward. In complement to information in the preceding section, the following mechanisms associated with DA are apparent.

- In the early 80s Schultz and colleagues demonstrated that rewards elicited phasic DA midbrain responses by strengthening synaptic connections in the striatum. Later electrophysiological response to reward stimuli of DA cells in the SN and the VTA was documented, and DA-invoked plasticity in the striatum detected *in vitro.*
- Recent experimental data shows that the rapid onset of phasic activity seems to be a key mechanism of DA mediated plasticity and seems to be present in both *stimulus-outcome* (S-O) and A-O learning.[610] Sustained

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[608] Di Filippo et al., “Short term and long-term plasticity at corticostriatal synapses: implications for learning and memory,”115.

[609] LTP may also be induced by *high frequency afferent stimulation* (HFS) protocol, and involves activation of NMDA, D1, M_1, ACh and mGlu receptors. LTD and LTP, as in the ventral pars are modulated by DA. It is thought that resistance to plasticity may be a third code for BG neurons.

[610] Horvitz, “Stimulus-response and response outcome learning mechanisms in the striatum,” 129-140. DA phasic responses to reward predicting stimuli are shown to be sustained some hundreds

reverbatory loops appear to facilitate appropriate motor action by maintaining activity in the cortical movement related cells. It is suggested that DA mediated binding assists in establishing behavioural sequences. [611]

- LTD and LTP both are mediated and triggered by DA release, although LTP is inhibited by activation of D2 receptors (mainly present in the indirect pathway). Hence DA release is more likely to lead to LTP in direct pathway and LTD in indirect. Higher levels of DA favour induction of LTP.[612]
- Cannabinoid and adenosine receptors also play a part in striatal LTD.[613] Wickens notes that DA and EC signalling mediate plasticity in the form of LTD and LTP, with intracellular calcium signalling also significant. DA "plays a crucial role in determining the magnitude and direction of plasticity"[614].
- Learning in the striatum is driven by novelty.[615] Schultz and others suggest that phasic DA release is triggered by rewards that are unpredicted. It has been shown that there is a steady tonic low level of DA release "to run the motor programs already set up"; phasic DA release seems to be a "learning signal" [616] that induces plasticity. The phasic release of DA appears implicated in instrumental learning, Pavlovian conditioning, and various forms of associative and reinforcement learning.[617].

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of milliseconds beyond responses to salient non reward events. Note that Horvitz refers to A-O goal directed learning as R-O.

[611]High frequency stimulation leads to LTD, but "when DA is applied in brief pulses coinciding with the time of pre-synaptic stimulation and post synaptic depolarisation of the striatal cell, corticostriatal synapses show potentiation rather than depression." He pays tribute to the work of Reynolds. D1 receptor blockade has been shown to prevent self stimulation of the SN in rats. DA is shown to strengthen synapses in the striatum that are currently active. The authors focuses only on D1 synapses and consequent LTP. Horvitz, "Stimulus-response and response outcome learning mechanisms in the striatum," 130.

[612] "According to Hebb's rule, LTP occurs when presynaptic and postsynaptic neurons are depolarized at the same time. LTP can be induced in the striatum by repeated activation of the cortical terminals." Heterosynaptic associative LTP is induced when multiple cortical neurons and MSN depolarise concurrently. Reverberation may serve to keep neurons in the loops depolarised. High frequency firing of the cortical neurons may also lead to LTD at the synapses. Da Cunha et al. speculate that "LTP and LTD of synapses associating different cortical inputs with the same MSNs may build the memory trace of associative learning mediated by the basal ganglia."Da Cunha, "Learning processing in the basal ganglia: a mosaic of broken mirrors," 163.

[613] Da Cunha, "Learning processing in the basal ganglia: a mosaic of broken mirrors," 163.

[614] Wickens, "Synaptic plasticity in the basal ganglia," 119.

[615] Horvitz, "Stimulus-response and response outcome learning mechanisms in the striatum," 129-140.

[616] Da Cunha, "Learning processing in the basal ganglia: a mosaic of broken mirrors," 163.

[617] Da Cunha, "Learning processing in the basal ganglia: a mosaic of broken mirrors," 163.

- "Depotentiation", the reversal of an LTP that has already been established, has been identified as a further form of synaptic plasticity. It is now believed too that DA mediated binding may assist in establishing behavioural sequences, and that sustained reverbatory loops appear to facilitate appropriate motor action by maintaining activity in the cortical movement related cells. [618].
- DA timing is significant. Precisely timed pulses of DA "coinciding with the time of pre-synaptic stimulation and post synaptic depolarisation of the striatal cell-corticostriatal synapses show potentiation rather than depression" that would normally be the case with high frequency stimulation.[619] Furthermore, DA mediated corticostriatal synaptic strengthening seems to work to maintain the movement direction coding in the frontal cortex until the trigger stimulus occurs.[620]
- DA synapses are normally found on the neck of spines with the excitatory synapse on the head of the same spine. [621]

2.4.7.3 Insights from plasticity within the hippocampus

Hippocampal studies of plasticity shed further light on the nature of plasticity in the BG. Beretta et al. note the differences of plasticity between the BG and and the hippocampus.[622] Hippocampal plasticity is dependent upon synaptically

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[618] Horvitz, "Stimulus-response and response outcome learning mechanisms in the striatum," 137.
[619] Horvitz, "Stimulus-response and response outcome learning mechanisms in the striatum," 130.
[620] Horvitz, "Stimulus-response and response outcome learning mechanisms in the striatum," 135-136.
[621] Wickens' calculations show that DA able to act on all excitatory synapses concurrently. The action of DA is mediated by G protein coupled receptors; six types of DA receptors have been identified falling into two camps: D1 and D2. Both present in the BG. Wickens, "Synaptic plasticity in the basal ganglia,"121.
[622] The paper notes that the hippocampus has proven itself ideal for plasticity studies *in vitro* owing to its highly organised structures and layers. Applications of the same approaches to the BG have brought challenges; this region manifests distinct cell layers; and the dendrites of MS projection neurons (composing 95% of neuron population in striatum and NAc) are not polarised, and they synapse onto both internal and external axons with both excitatory and inhibitory contacts. Also the striatum features a highly interconnected neuronal plexus with the result that synaptic responses are easily contaminated by complex receptor inputs. Source material and more detail: Beretta et al., "Synaptic plasticity in the basal ganglia: A similar code for physiological and pathological conditions," 345-356.

released glutamate, whereas striatal plasticity involves DA activity, release of ECs and ACh.[623]

Beretta et al. note that the groundwork for synaptic plasticity studies in BG, and in all vertebrate CNS, was laid by Bliss and Lomo, who, as we have seen, detected *in vivo* LTP in the hippocampus following on repetitive excitation. "Activity dependent synaptic potentiation occurs within milliseconds, can persist for hours or days and is expressed as a persistent increase in the size of the synaptic component of the evoked response, recorded either from individual neurons or from a larger cell population."[624] Bliss and Lomo's work was complemented by Schwartzkroin and Wester (1975) who used brain slice preparations to demonstrate LTP under controlled in vitro conditions. Plasticity in both areas obeys the Artola-Brocher-Singer rule: "induction of LTP or LTD depends on the ability of the postsynaptic membrane to reach different sequential threshold for LTD and LTP induction." This observation possibly reflects progressively higher levels of postsynaptic free calcium.

2.4.8 Initial reflections on the possible role of the basal ganglia in virtue acquisition.

With cortical, limbic and motor interconnections providing a capacity for reflective action, reward based goal reinforcement, and the development of habitual action, the BG, noted by Di Filippo as the "brain centre for habit formation",[625] appear highly implicated in the neural underpinnings of virtue.

The neuronal processes of habit formation are of relevance to this study. Habits, acquired in the BG, are the result of experience driven plasticity in basal ganglia-

[623] Beretta et al., "Synaptic plasticity in the basal ganglia: A similar code for physiological and pathological conditions," 353.
[624] Di Filippo et al., "Short term and long-term plasticity at corticostriatal synapses: implications for learning and memory,"109. Di Filippo is the source of other citations in this paragraph.
[625] Di Filippo et al., "Short term and long-term plasticity at corticostriatal synapses: implications for learning and memory,"109.

based circuits.[626] The pathways that facilitate habitual behaviours, highly interconnected with limbic and cognitive areas of the brain, would seem to have much in common with pathways related to the development of good habits, virtues. Both begin with simple goal-oriented behaviours, both are experience acquired, requiring consolidation by repetitive action, both require interconnection to motor, motivational, cognitive and executive areas. During acquisition there is a movement from attentive explicit behaviour to the automatised. Both show great resistance to change once acquired.

Not only are the implicated limbic, cortical and basal-thalamic regions, (brain regions supporting motivation, automatisation of action, and executive goal direction) functionally required for both habit and virtue formation, but the efficient interconnection of these brain regions is shown to be present in the brain.

The BG with their thalamic pathways to both the limbic system and the cortex are a crucial piece in the puzzle, and it is only in little more than the last decade that the complex involvement of the BG in cognitive and motivational processes has become apparent. The cognitive connection is particularly important in the case of virtue. As will be seen in **Chapters 3** and **4**, motivation in virtuous action is a complex interplay of initial reward incentives (for example in the case of a child developing a virtue), previously established pathways for patterns of behaviour, and what we could call a cognitive evaluation of goal. In particular, Graybiel's reflections on habit, described above, emphasize that this evaluative component is potentially present via pathways involving the BG.

Di Filippo writes, "It is widely accepted that animals, including humans, shape their behaviour on the basis of experience and that motivation is characterised by action, either to increase the probability of an outcome (appetitive motivation), or

[626] Graybiel, "Habits, Rituals, and the Evaluative Brain," 361.

to reduce it (aversive motivation)" [627] These motivations shape our actions via the mediation of the BG pathways. Reward and motivation will be discussed below (**2.6**).[628]

At the heart of the capacity of the brain to wire for habit and ultimately virtue are mechanisms of plasticity. Beretta writes, "It is widely accepted that the complexity and adaptability of neuronal communication, which is necessary for integrative and higher functions of the brain, is amply represented by plastic changes occurring at the synaptic level. Therefore long term modifications of synaptic efficacy between neurons have been considered the cellular basis of learning and memory."[629]

Virtues, it will be seen are stable capacities for habitual action... they empower the owner to act in the world effectively. Da Cunha captures this notion: "Since the output of the basal ganglia is almost exclusively to frontal cortex and brainstem motor nuclei, the memories encoded by this system must be expressed as actions. This explains the procedural nature of these memories."[630]

2.5 Neural bases for emotional control.

In this section we overview representative current research into emotional self-regulation. This will shed further light on role of the cortico-limbic connections of the BG, and on the possibilities for pathways of the emotional self-regulation that characterises virtue in the Aristotelian vision.

Since the 1930s the cerebral cortex has been acknowledged to play an inhibitory influence on emotional behaviour. In the last fifteen years much has been written

[627] Di Filippo et al., "Short term and long-term plasticity at corticostriatal synapses: implications for learning and memory,"115.
[628] For an overview of the neurobiology of appetitive and aversive responses, see Leknes andTracey, "A common neurobiology for pain and pleasure," 314-320.
[629] Beretta et al., "Synaptic plasticity in the basal ganglia: A similar code for physiological and pathological conditions," 343.
[630] Da Cunha, "Learning processing in the basal ganglia: a mosaic of broken mirrors," 163.

about the pathways of emotional control, in particular distinguishing the cognitive pathways allowing cortical modification of limbic responses, and the direct cognitive-bypass routes, the "quick and dirty" routes, that manifest impulsive reactions of rage, flight, etc.[631]

2.5.1 Theories of emotion.

An initial overview of emotion, drawn principally from psychology, is appropriate.[632]

According to the James-Lange theory of emotion, from the start of the twentieth century, the physiological changes *are* the emotion... we feel sad because we cry, for example. If we remove the physiological changes, we remove the emotion. Although this seems counter intuitive, it does place emphasis on the integration of mind and body, and recent studies have, in fact, shown that faking emotions can produce emotion. For example, Strack, Martin, and Stepper documented in 1988 that most people rate cartoons funnier if they hold a pen in their teeth, thus forcing a smile, rather reading the cartoon while holding the pen in their lips and preventing a smile.

Walter Cannon in 1927 and Philip Bard proposed a more subtle model, known as the Cannon-Bard theory, whereby emotional experience is understood to be able to occur independently of bodily changes.[633] Cannon proposed a special role for the thalamus. According to the Cannon-Bard theory the thalamus and hypothalamus, possibly inhibited by the cerebral cortex, are responsible for emotional responses to stimuli. Subsequently it is apparent that these areas and the sympathetic nervous system do have involvement in certain aspects of emotional response and control.

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[631] For popular accounts of the direct pathways see: Daniel Goleman, *Social Intelligence* (Sydney: Random House, 2007); and Rita Carter, *The Brain Book* (London: DK Books, 2009).
[632] Background sources: Richard J. Gerrig et al., *Psychology and life* (Sydney: Pearson, 2009); David G. Myers, *Psychology*, 7th ed. (NY: Worth, 2004); Lorelle Burton et al., *Psychology*, 2nd ed. (Milton, Qld: Wiley, 2006).
[633] Bear, *Neuroscience. Exploring the Brain,* 564.

Other more recent theories have modified, and continue to modify these two fundamental attitudes towards emotion.

In the 1930s Papez proposed a circuit responsible for emotion, with emotion governed by the hypothalamus. The circuit involved a circular loop connecting hypothalamus to thalamus, to ACC to hippocampus. He proposed that the ACC is responsible for emotional experience. Links to the neocortex provide for a rich emotional life. The hippocampus is no longer given the prominence in emotion accorded to it by Papez. Nor does it seem that there is a single system responsible for emotion. [634]

The Schachter-Singer theory allows for self-knowledge of the degree of one's emotional arousal through observation of one's own physiological changes.[635] In 1999, Antonio Damasio, aided by these direct insights into the emotional brain, proposed a model to distinguish between observable behaviours, the emotions, and the private experiences of feelings.[636]

2.5.2 Emotion and memory.

Context and emotional state are known to modify memory.[637] Memory reciprocally affects emotional state. Joseph LeDoux, a pioneer in the neural bases of emotion, says, "My work is as much about memory and plasticity as emotion."[638]

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[634] Bear, *Neuroscience. Exploring the Brain,* 569-571.
[635] Real time imaging is now available that has allowed identification of areas of the brain active during emotional arousal.
[636] A. Damasio, *The feeling of what happens* (NY: Harcourt Brace, 1999), Ch 12.
[637] The work of Baddeley and Godden in Cambridge elegantly illustrates the role of context in memory recall. Mood state is a particular form of context. See: Squire and Kandel, *Memory: From Mind to Molecules,* 73.
638 Quoted in Bear, *Neuroscience. Exploring the Brain,* 576.

Recent studies have further explored the area of the interconnection of emotion and memory.[639] Kalueff has reviewed the literature on the interplay between memory and anxiety, and mechanisms of plasticity linked to anxiety, focussing especially on the role of neurotransmitter systems and neuropeptides in regulation of memory and anxiety processes.[640]

The author notes that brain synaptic plasticity is now known to be modulated by both neurons and glial cells with glial Ca-binding protein S100B, and PACAP (pituitary adenylate cyclase-activating polypeptide), noted as regulators of synaptic plasticity. The connection of the latter with the expression of neurotrophins is noted.[641]

LeDoux studies the area of the amygdala involved in the storage of emotional memories, the lateral nucleus. Importantly he has described how subcortical sensory inputs to the amygdala can drive emotional responses that *precede* cortical awareness.[642] We can react emotionally before rationally assessing the situation.

2.5.3 Human brain areas associated with regulation of emotion.

[639] Work of Gordon Bower in Stanford illustrates this connection: subjects in a sad mood are more likely to recall negative experiences and vice versa. See: Squire and Kandel, *Memory: From Mind to Molecules,* 73.

[640] The inhibitory GABA channels are the primary Cl channels, and have long been regarded as anxiolytic. GABA and GABAergic genes now seen as key mediators of learning and memory in anxiety, and in specific in the amygdala and hippocampus, regions of the brain involved in memory and anxiety. The role of ras-associated binding proteins, such as Rab3a, essential for vesicle trafficking, is discussed. Also the role of protein kinase C(PKC) γ has been studied: expressed in the limbic system, it is a modulator of neurotransmitter release and excitability in neurons; in its absence memory and anxiety are reduced. Kalueff, "Neurobiology of memory and anxiety From genes to behaviour (Review)".

[641] Kalueff, "Neurobiology of memory and anxiety From genes to behaviour (Review)".

[642] D. Pare et al., "New vistas on amygdala networks in conditioned fear," *Journal of Neurophysiology* 92, (2004): 1-9.

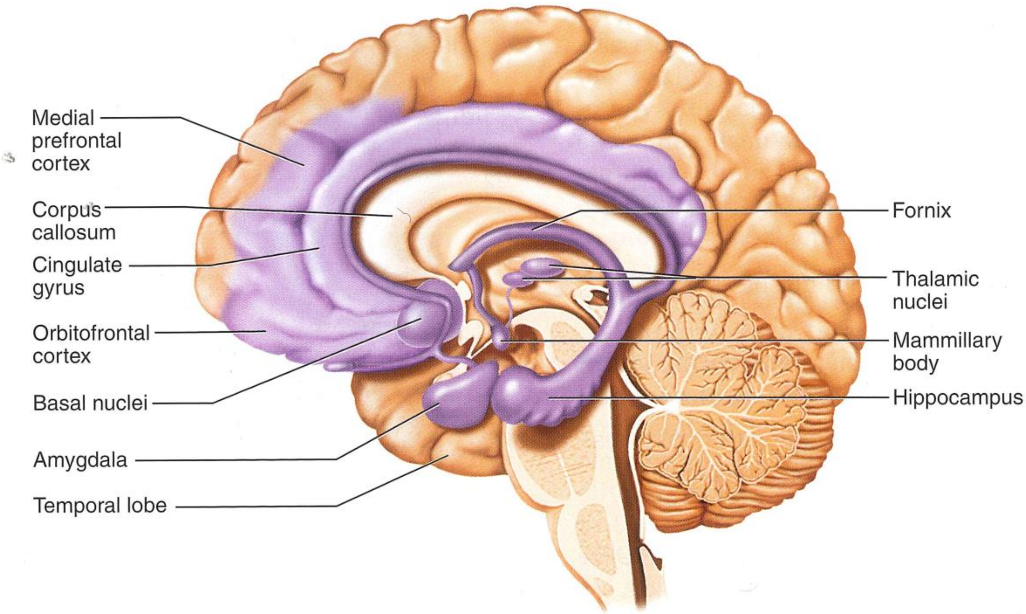

Figure 2.9 a. **Areas associated with the limbic system.** **Source**: Saladin, Kenneth S. *Anatomy and Physiology*. 6th ed. NY: McGraw Hill, 2012. 537.

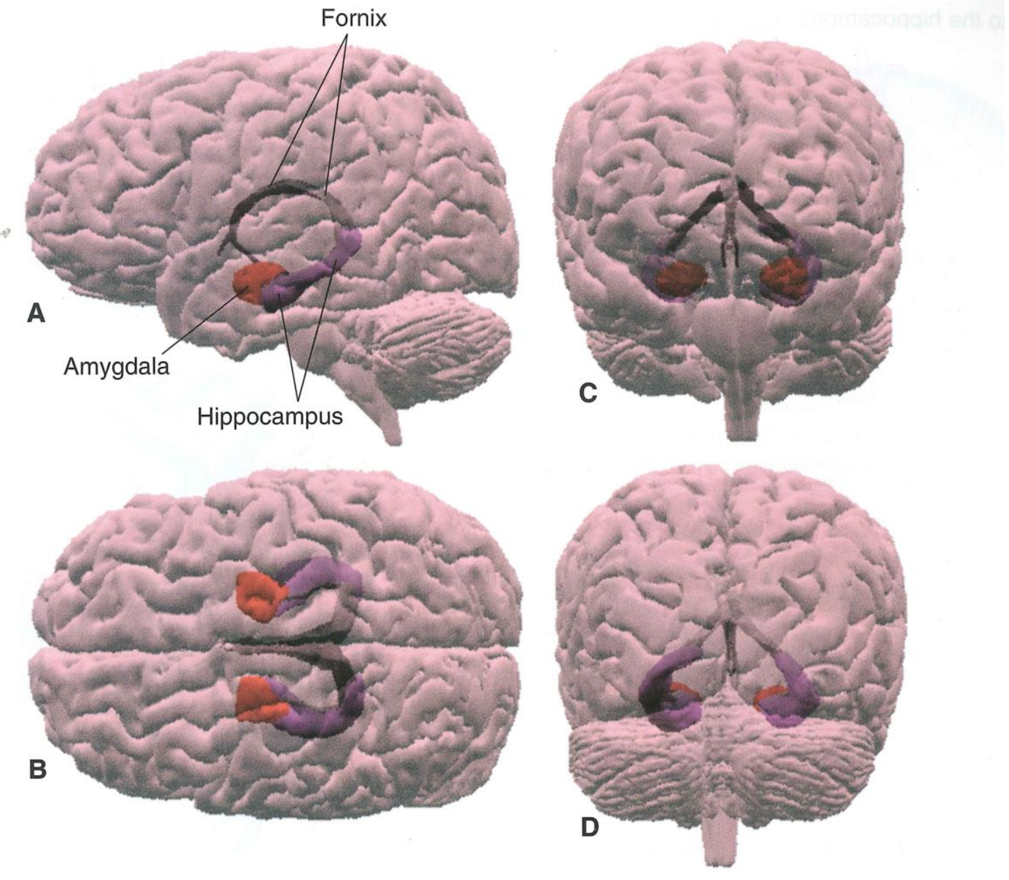

Figure 2.9b **Location of key limbic areas.** A 3D construction of the hippocampus, fornix and amygdala within a translucent CNS. **Source**: Nolte, John. *The human brain. An introduction to its functional anatomy.* 6th ed. Philadelphia: Mosby, 2009. 595.

Emotion is processed in the brain primarily in regions including several parts of the PFC, namely *dorsolateral prefrontal cortex* (DLPFC), *ventromedial PFC* (VMPFC), OFC, as well as the amygdala, hippocampus, ACC, and insular cortex.[643]. The limbic cortex is found "on the medial brain surface, in the cingulate gyrus and medial frontal lobe, and on the orbital surface of the frontal lobe".[644]

Neuroimaging (see **Appendix 3**) shows that distinct subregions of the PFC have specific function in relation to emotion regulation. fMRI imaging, which detects brain activity with resolution down to 1mm^3, can show areas that are active but not necessarily all areas necessarily involved. The limbic cortical areas, those areas of the cortex adjacent to the limbic area, have been identified as the DLPFC, the VMPFC, and the OFC. These areas now believed to be a "cerebral association area for the control of behaviour".[645]

It appears that there are brain circuits for specific emotions, for example, implicating the insula in disgust, the amygdala in fear, and the PFC in conscious representations of emotion. The hypothalamus also carries out a number of functions associated with emotion, the basic drives for thirst and feeding. It directs motor patterns associated with various emotional responses such as pain, pleasure, sexual arousal, and rage and it has a role in coordination of autonomic functions affected by emotional arousal. It also coordinates release of a number of hormones such as oxytocin.[646]

The amygdala plays a key role in particular emotional experience. The nuclei of the amygdala "mediate the effects of sensory stimuli on emotional behaviour"; "through interconnections with other cortical and subcortical structures it

[643] R. J. Davidson, "Affective style, psychopathology, and resilience: Brain mechanisms and plasticity," *American Psychologist* 55, 11 (2000): 1196-1214. The author is the Awardee for Distinguished Scientific Contributions in 2000 from the American Psychological Association.
[644] Martin, *Neuroanatomy: Text and Atlas*, 3rd ed., 40.
[645] Guyton and Hall, *Textbook of Medical Physiology*, 11th ed., 738.
[646] Martini, *Fundamentals of Anatomy and Physiology*, 8th ed., 475.

controls emotional expression and behaviour."[647] The amygdala is particularly active in mediating early attachment relationships, and reaction to stress and non conscious emotional memories.[648] Building on studies by Jerome Kagan who had demonstrated that traits such as timidity and shyness persisted from childhood into adulthood, Schwartz et al. (2003) conducted fMRI scans of some of these inhibited babies, now in early adulthood. The scans showed that the amygdala of this group tended to be overactive, reflecting fear and anxiety, in the presence of novelty.[649]

The interconnections between the limbic cortical areas and the limbic areas themselves are becoming increasingly well defined. The amygdala is now known to receive neuronal signals from all limbic cortical areas, and from the temporal, parietal and occipital cortex (most especially the auditory and visual association areas).[650] Efferent connections return to these cortical areas as well as to the hippocampus, the septum, the thalamus and the hypothalamus. The anterior cingulate gyrus has anterior connections to the amygdala and posterior connections to the hippocampus.[651]

Of the neurotransmitters in the brain, the amines - DA, 5-HT and *norepinephrine* (NE) - have been shown to play a role in modulating the individual's emotional responses.[652] These are critical to the brain's excitatory and inhibitory mechanisms of control: NE from the locus ceruleus is usually excitatory, DA (inhibitory in the BG, and possibly excitatory elsewhere in the cortex) is critical in the body's reward systems (see **2.6.1**), 5-HT from the raphe nuclei released in the

[647] H. Wagner and K. Silber *Physiological Psychology* (London: Bios, 2004), 190.
[648] Arden and Linford, *Brain-based therapy with children and adults*, 3, 36.
[649] C. E. Schwartz, et al., "Inhibited and uninhibited infants grown up: Adult amygdalar response to novelty," *Science* 300, (2003): 1952-1953.
[650] Arthur C. Guyton and John E. Hall, *Textbook of Medical Physiology*, 11th ed. (Philadelphia: Elsevier Saunders, 2006), 737.
[651] Nolte, *The human brain. An introduction to its functional anatomy*, 5th ed., 641.
[652] R. A. Depue and P. F.Collins, "Neurobiology of the structure of personality: Dopamine, facilitation of incentive motivation, and extraversion," *Behavioral and Brain Sciences* 22, 3 (1999): 514.

hypothalamus and limbic structures is known to inhibit aggression, and ACh from the gigantocellular neurons of the reticular excitatory area is excitatory.[653] [654]

2.5.3.1 Involvement of prefrontal cortex in emotional regulation.[655]

Here we look at the implication of the cortical areas in management, or more properly, inhibition of emotion.[656] Pollak points out that most emotion studies take a top down approach because of the fact that damage to PFC leads to poor emotional regulation.[657]

Nevertheless, recent studies in emotion regulation do note the interdependence of brain areas and integration of systems. For example, Salzman and Fusi found in 2010 that the "functional and the electrophysiological characteristics of the amygdala and the PFC overlap and intimately depend on each other. Thus, the neural circuits mediating cognitive, emotional, physiological, and behavioural responses may not truly be separable and instead are inextricably linked."[658] Furthermore Ray and Zald (2012) argue that PFC-limbic interaction is more

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[653] Bear, *Neuroscience. Exploring the Brain,* 581.

[654] Guyton and Hall, *Textbook of Medical Physiology*, 11th ed., 730.

[655] For an overview of the role of the PFC in executive function: Earl Miller and Jonathan Wallis, "The prefrontal cortex and executive brain functions" in Larry Squire, et al., *Fundamental Neuroscience*, 3rd ed. (Burlington, MA: Elsevier, 2008).

[656] Some authors prefer to consider the PFC as involved in inhibition of emotion; it is noticeable that Damasio is seeking to move away from the suggestion that it is the role of the PFC to neutralise emotion. Rather he writes of the importance of a rich emotional life. To this point we have been considering the contribution of the cortical areas to the management of emotion. There is a growing realisation that emotional pathways also assist rationality. The contribution of emotion to rational decision making which is under considerable current philosophical scrutiny introduces an interesting further dimension that will be developed in **Chapters 3** and **4**. This philosophical interest finds recent happy concordance in the neuroscience. Damasio, for example, has argued that the brain uses emotion to direct judgments. A.R. Damasio "The somatic marker hypothesis and the possible functions of the prefrontal cortex." *Philosophical transactions of the Royal Society of London. Series B: Biological sciences*, 351, (1996): 1413-1420.

[657] Pollak, "Early adversity and mechanisms of plasticity Integrating affective neuroscience with developmental approaches to psychopathology," 745. Damage in areas of the PFC is assocated with reduced emotional control.

[658] C. Daniel Salzman and Stefano Fusi, "Emotion, Cognition, and Mental State Representation in Amygdala and Prefrontal Cortex," *Annual Review of Neuroscience* 33, (2010): 173–202. This study provides an excellent overview of amygdalic connectivity.

reciprocal than the conventional top-down models would suggest,[659] as the ventral and dorsal PFC are in rich *reciprocal* communication with the amygdala.[660]

The complexity of pathways implicated in emotional regulation is being progressively revealed. A major *magnetic resonance imaging* (MRI) study of 1900 14 year old teenagers noted seven cortical and subcortical networks implicated in inhibition of activity and six networks implicated in failed inhibitions.[661]

There has been a growing body of knowledge about the role that the PFC, and its constituent implicated areas, play in managing emotion. Specific areas of the PFC implicated in emotional processing have been identified, with specialised roles attributed to them. Barbas and Zikopoulos noted, “The three distinct prefrontal sectors, namely the lateral, orbitofrontal and medial, are interconnected, and provide the basis for interaction of pathways underlying cognitive and emotional processes.” [662]

Davidson explains that the PFC "represents emotion in the absence of immediately present elicitor, playing an important role in assessing affective consequences of actions, and in persistence of emotion.” [663] Particular sections of the PFC seem to play a major role in regulation of the duration of emotion, and the suppression of negative emotion once elicited, essentially an affective working memory. These areas work together to generate information and behaviour related to emotion.

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[659] Rebecca D. Ray and David H. Zald, “Anatomical insights into the interaction of emotion and cognition in the PFC,” *Neuroscience and Biobehavioural Reviews* 36 (2012): 479-501.
[660] Ray and Zald, “Anatomical insights into the interaction of emotion and cognition in the PFC,” 479-501.
[661] R. Whelan, et al., (IMAGEN Consortium), “Adolescent impulsivity phenotypes characterized by distinct brain networks,” in *Nature Neuroscience*, on line. (October 2012).
[662] H. Barbas and B. Zikopoulos, “Sequential and parallel circuits for emotional processing in primate orbitofrontal cortex” in *The Orbitofrontal Cortex*, ed. David H. Zald and Scott L. Rauch (Oxford: OUP, 2006), 57.
[663] Davidson, “Affective style, psychopathology, and resilience: Brain mechanisms and plasticity,” 1196-1214.

He states that individual affective and regulatory differences are attributable to "asymmetries" in the PFC and in the contribution of the amygdala.[664] As a general rule, the left hemisphere appears to play a greater role than the right in cortical regulation of emotion. Pronounced right frontal asymmetry in young adults, evident in electroencephalography (EEG) scans showing disproportionate activity of right over left against controls, is associated with negativity and withdrawing behaviours. Even sad and crying infants show greater EEG activity in the right hemisphere. Happy infants show more left frontal EEG activity. [665] Left and right side damage to the PFC areas reveals the differing function of these areas. Left side damage leads to greater incidence of depressive symptoms, as it normally plays a role in positive affect. [666] The right hemisphere of the brain tends to favour the immediate, limbic response prior to cerebral modification. [667]

The VMPFC appears to play a key role in predicting positive and negative affective consequences.[668] Both the experience of pain and witnessing the pain of others leads to activation of the mPFC and the insula, as well as the lateral cerebellum.[669] Morgan and colleagues in 1994 documented a study of 36 rats designed to evaluate the role of the mPFC in the phenomenon of fear extinction by means of classical fear conditioning. The mPFC is a region commonly understood to play a role in emotional reactivity and autonomic regulation. The study demonstrated that the mPFC plays a significant role for fear extinction in rats.[670] [671]

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[664] Davidson, "Affective style, psychopathology, and resilience: Brain mechanisms and plasticity," 1196-1214.
[665] Arden and Linford, *Brain-based therapy with children and adults*, 220-221. See also Schore, "Effects of a secure attachment relationship on right brain development, affect regulation and infant mental health," 7-66.
[666] Davidson, "Affective style, psychopathology, and resilience: Brain mechanisms and plasticity," 1196-1214.
[667] Davidson, "Affective style, psychopathology, and resilience: Brain mechanisms and plasticity," 1196-1214.
[668] Davidson, "Affective style, psychopathology, and resilience: Brain mechanisms and plasticity," 1196-1214.
[669] Nolte, *The human brain. An introduction to its functional anatomy*, 6th ed., 605.
[670] Maria A. Morgan, Lizabeth M. Romanski and Joseph E. LeDoux, "Extinction of emotional learning: contribution of the medial prefrontal cortex," *Neuroscience Letters* 163, 1 (1993): 109-113.
The study showed that rats with lesions in the mPFC (created by insertion of electrode and current to the specific brain area) took on average some 80% longer period than control rats to return to

The ACC, within the mPFC, has been called the "major outflow of the limbic system, also involved in evaluating pain and distress vocalisation" [672] The ACC also plays a role in directing attention, inhibited impulsive behaviours, and in generating goal-directed behaviours.[673] It appears to play a role in analysing conflicting options.[674]

The OFC is the limbic gateway to the cortex. Balbernie suggests that it is through the OFC that the limbic system and the cortex interact. This view is now widely accepted and as such the OFC plays a central role in cortical regulation of emotion,[675] and is activated when we are making decisions on the basis of emotion laden information.[676] Brain imaging studies have also shown that the OFC plays a role in the brain's reward systems, [677] consistent with the view that OFC functions pertain to the emotional component underlying and individual's reaction to events in the environment.[678] Imaging studies of orphans (See **2.2.4.1**) revealed abnormalities consistent with the behaviours that appear to follow upon being raised in environments of social deprivation, in particular, the manifestation of an underactive OFC in comparison with normal children.[679]

The PFC, and especially the OFC, receives inputs related to emotion from various brain locations including amygdala, thalamus, VTA, and olfactory system. Major connections from the OFC include to the hippocampus, the amygdala and the

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established criteria for fear extinction to the conditioned stimulus, demonstrating that the mPFC plays a significant role for fear extinction in rats.

671 Morgan et al., "Extinction of emotional learning: contribution of the medial prefrontal cortex," 109-113.

672 M. I. Posner and M. K. Rothbart, "Developing mechanisms of self regulation," *Development and Psychopathology* 12, (2000): 429.

673 Markowitsch, H, et al., "Brain circuits for the retrieval of sad and happy autobiographic episodes," *Cortex* 39, (2003): 643-665.

674 Arden and Linford, *Brain-based therapy with children and adults*, 88.

675 Balbernie, "Circuits and circumstances. The neurobiological consequences of early relationship experiences and how they shape later behavior," 237-255.

676 Arden and Linford, *Brain-based therapy with children and adults*, 226.

677 Wagner and Silber, *Physiological Psychology*, 193.

678 M. Roesch and G. Schoenbaum, "OFC as gateway," in *The Orbitofrontal Cortex*, ed. David H. Zald and Scott L. Rauch (Oxford: OUP, 2006), 202.

679 Arden and Linford, *Brain-based therapy with children and adults*, 8.

hypothalamus. Damage to the left OFC of Phineas Gage, appears to have been a significant factor in his reduced inhibition and heightened irresponsibility.[680]

Arden and Linford described clinical therapies for neuroplastic remodelling of the frontal lobes. They reported that as affect regulation in the PFC improves, the OFC can effectively inhibit activation of subcortical areas such as the amygdala.[681]

Conscious regulation of emotion utilizes both the DLPFC and VMPFC. It is believed that the DLPFC recruits input from the VMPFC (which includes the OFC) when there are conflicting emotional situations.[682] It has been shown that the DLPFC, interacting with *ventrolateral PFC* (VLPFC) and ACC, is active in choosing not to follow "prepotent behaviour" or in choosing a novel behaviour.[683] Studies to determine volitional control of behaviour have found that impairment in monkeys is analogous to that in humans. Monkeys seeking reward by moving a joystick in a particular way in specific response to a visual cue are shown to be greatly impaired if there be damage to the VLPFC and orbital PFC. [684]

Recent papers analysing regulation dysfunction by Bennett (2011), and Heatherton and Wagner (2011), offer insights into pathways for cortical regulation of emotion. Both studies confirm the role of DA induced cortical plasticities in cortical regulation and the contribution of cortico-striatal circuits. Bennett reports that modulation of the prefrontal-limbic network (including ACC, amygdala and hippocampus) is principally through the hypothalamus, BG and midbrain.

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[680] Phineas Gage, in 1848, suffered the loss of much of his medial PFC. His behaviour changed, becoming irreverent and profane, socially inappropriate, and unable to plan. Frontal damage leads to disinhibition, emotional impairment, difficulty in planning, and impaired working memory.
[681] Arden and Linford, *Brain-based therapy with children and adults*, 31-40.
[682] Arden and Linford, *Brain-based therapy with children and adults*, 88.
[683] Tatia M. C. Lee, et al., "Regulation of human behaviours (Review)," Future Neurology 2, 2 (2007): 190. The lateral PFC is activated by cognitive tasks, the VLPFC by tasks requiring information in working memory, and the DLPFC when information must be manipulated. Anterior areas of PFC may have a role in information transfer between these other areas.
[684] Tomita et al., showed that disconnecting the PFC from temporal cortex prevented in monkeys the activation of stored memories.Although there is a need for some caution in drawing direct parallels between monkey and human PFC function some limited conclusions are possible: that monkeys with PFC damage are impaired on conditional learning tasks, show emotional impairment, and are impaired at object recognition. H. Tomita, et al. "Top down signal from prefrontal cortex in executive control of memory retrieval" *Nature* 401, (1999): 699-703.

Dysregulation of this network gives rise to major depression disorders.[685] Dysregulation tends to follow one of three pathways: the hypothalamic-pituitary-adrenal (HPA) axis, through the BG, and consequent to modulatory change in the midbrain VT and Raphe nucleus.

The high levels of cortisol evident in adolescent suicidal patients are attributable to failure of the glutocorticoid receptor inhibiting release of corticotrophin releasing factor and adrenocorticotrophic hormone. Epigenetic causes attributable to abuse lead to decrease in the glutocorticoid receptor. Suicidal patients are also characterised by reduced grey matter in the ACC and increased grey matter in the amygdala linked directly to reduced or increased formation of synaptic spines.

Later life depressive mood appears related to dysfunction in the caudate that disrupts the DLPFC-subcortical connectivity normally involved in goal election and suppression of negative thoughts. Furthermore another loop (the OFC, subgenual ACC, ventralmedial striatum and amygdala) normally associated with goal directed behaviour, is disrupted by hyper activity most probably as a result of hyperintensities in the caudate. In schizophrenia reduced levels of DA in the PFC (and high activity in the amygdala) are associated with depression and increased levels in the striatum are associated with positive affect.[686]

Heatherton and Wagner found two independent pathways mediating frontal regulation of emotion: a more successful frontal-striatal pathway, and a frontal-amygdalic pathway that was less successful in regulation.[687]

Another recent area of investigation into cognitive control has involved self regulation of amygdalic activation. Twenty-eight right-handed, medically- and

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[685] M. R. Bennett, "The prefrontal-limbic network in depression: Modulation by hypothalamus, basal ganglia and midbrain," *Progress in Neurobiology* 93, (2011): 483.
[686] M. R. Bennett, "The prefrontal-limbic network in depression: Modulation by hypothalamus, basal ganglia and midbrain," 470.
[687] Todd F. Heatherton and Dylan D. Wagner, "Cognitive Neuroscience of Self-Regulation Failure," Trends in Cognitive Science 15, 3 (2011): 132–139.

psychiatrically-healthy male volunteers (age 28.0±9.0 years), were used. Participants were given real-time fMRI neurofeedback and demonstrated most clearly the capacity to downregulate activity in the left amygdala while contemplating positive autobiographical memories.[688]

Attentional processes in the brain predispose for emotional self regulation. A 2001 study by Beauregard et al. had 10 young adult males with an average age of 23.5 years watch erotic films but in contrasting scenarios. In the first they were asked to watch naturally, in the second, they were asked to suppress sexual responses. In the first, fMRI imaging detected increased activity in right temporal pole, right amygdala and hypothalamus. In the second, no increased activity was detected in these areas but in the DLPFC and ACC.[689] Posner and Rothbart state, "Top down mechanisms, such as attention, may serve as models of how neural activity may be increased or decreased in networks to establish processing priorities".[690] Beyond the PFC areas already mentioned (DLPFC, VMPFC, ACC, the insular cortex, and the OFC) Pollak and Eslinger note that the integrated systems of emotional control further involve the cognitive management of areas for attention, memory, and action. [691] Posner notes that executive attention is associated with activity in the midline frontal areas in the anterior cingulated gyrus. [692] (See **2.5.5.**)

These views with respect to cognitive management of fear responses are consistent with recent findings of Hartley and Phelps.[693] They find, "Many different cognitive strategies can be used to regulate emotion, including

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[688] Vadim Zotev et al., "Self-Regulation of Amygdala Activation Using Real-Time fMRI Neurofeedback," *PLoS One* 6, 9 (2011).
[689] Mario Beauregard, et al., "Neural correlates of Conscious Self-Regulation of Emotion," The Journal of Neuroscience 21, (2001): 1-6.
[690] Posner and Rothbart, "Developing mechanisms of self regulation" 427-441.
[691] Pollak, "Early adversity and mechanisms of plasticity Integrating affective neuroscience with developmental approaches to psychopathology," 747.
[692] Posner and Rothbart, "Developing mechanisms of self regulation," 429.
[693] Catherine A. Hartley and Elizabeth A. Phelps, "Changing Fear: The Neurocircuitry of Emotion Regulation," *Neuropsychopharmacology* 35, 1 (2010): 136–146. Hartley and Phelps describe neural bases for four techniques of emotional regulation successful in management of fear: extinction, cognitive regulation, active coping, and reconsolidation. Reconsolidation notes the linkage between memory and fear, and refers to the capacity to reconsolidate and reconstruct memories more positively. Again these techniques can be taught. They note the role of the striatum in active coping strategies.

reappraisal,[694] selective attention, and suppression," noting that regulation strategies can be learned through cognitive therapy. Significantly with respect to this study, they note that, "once *habitual* (my emphasis), these strategies become easier to easier to enact over time." Cognitive regulation relies on DLPFC projections to the VMPFC inhibiting amygdalic acitivity. Ochsner discusses the various pathways involved in reappraisal mediated by DMPFC and VLPFC downregulation of the amygdala.

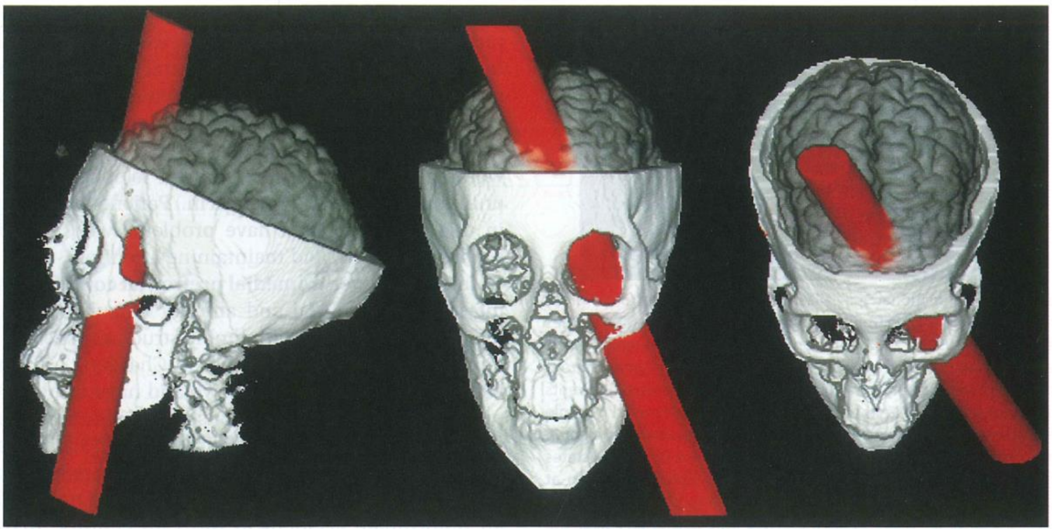

Figure 2.10 **Phineas Gage and the role of the medial PFC in emotion regulation.** A reconstruction of the injury suffered by Phineas Gage indicating extensive damage to the VLPFC. It appears the DLPFC was largely untouched.
Source: Damasio, H. et al. Science 264 (1994): 1102. Cited in Nolte, John. *The human brain. An introduction to its functional anatomy.* 6th ed. Philadelphia: Mosby, 2009. 136.

2.5.4 Plasticity in the mechanisms of emotional regulation.

The various mechanisms of plasticity underpin the patterns of emotional expression and regulation that develop in the individual.[695] Pollak says that "the

[694] Reappraisal involves "reinterpreting the meaning of a stimulus, including one's personal connection to it, to change one's emotional response." Kevin N. Ochsner, et al., "Functional imaging studies of emotion regulation:a synthetic review and evolving model of the cognitive control of emotion," *Annals Of The New York Academy Of Sciences* 1251, (2012): E1–E24. Ochsner et al. offer a current comprehensive review of emotion regulation.
[695] Davidson, "Affective style, psychopathology, and resilience: Brain mechanisms and plasticity," 1196-1214. Animal studies attest to the pronounced plasticity of emotional circuitry, showing that

heuristic of plasticity refers to how experience leads to changes in these affective neural networks, including the efficiency, activation thresholds, and time courses of those activations." [696] He argues, in alignment with Goldman-Rakic et al. (1997), that dopaminergic and serotonergic induced, experience-based, changes take place in the neural pathways involved in emotional regulation. [697]

He identifies the following features of plasticity in the affective pathways:

- The VMPFC and OFC are needed for associating incoming information with existing response contingencies, linking information to motivational importance, and for working memory... plasticity in these areas is necessary for object reward association memory, and contextual fear conditioning.
- In primate studies, the amygdala has been shown to project directly to medial thalamic nucleus and thence to VMPFC, facilitating involvement in processing social information requiring plasticity dependent learning and memory.
- He argues that although complex social behaviours are unlikely to be centred in one place, the amygdala seems to be critical in stimulus-reinforcement conditioning, whereby "neural cues acquire positive and negative incentive status and emotional meaning." [698]

He notes the contribution of DA induced plasticity in the emotional pathways, and highlights associations with attentional mechanisms: [699]

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early experience exercises extraordinary role in determining the final characteristics of the nervous system.

[696] Pollak, "Early adversity and mechanisms of plasticity Integrating affective neuroscience with developmental approaches to psychopathology,"735.

[697] Pollak, "Early adversity and mechanisms of plasticity Integrating affective neuroscience with developmental approaches to psychopathology,"747.

[698] Pollak, "Early adversity and mechanisms of plasticity Integrating affective neuroscience with developmental approaches to psychopathology,"742. Hence lesions to the amygdala impair performance on associative learning tasks involving emotional expressions. This is also relevant to the next section focusing on reward pathways.

[699] Pollak, "Early adversity and mechanisms of plasticity Integrating affective neuroscience with developmental approaches to psychopathology,"735. Pollak also draws conclusions the role that mechanisms of attention play.

- The mPFC, especially the ACC, has abundant links to the limbic system via the hippocampus, the shell region of the NAc and the amygdala. There is a likely contribution of this pathway to DA and 5-HT modulation of cortical socioemotional areas.
- He notes that release of DA, as we have seen a recognised mediator of plasticity, is triggered by corticolimbic afferents. He notes that repeated stressful experiences seem to alter the balance of both excitatory and inhibitory inputs from the limbic system and that the basolateral amygdala system may receive stress messaging from the VTA facilitating learning through DA neurons within the VTA, NAc and other areas.
- He notes the work of Passetti et al. suggesting that DA in the mPFC facilitates attention. And he suggests that the mPFC provides goal directed motor plans informed by context from the hippocampus.
- Following the work of Schultz in 1998 he argues that the DA system acts as a learning signal for behavioural reinforcement but also may well be involved in attention and motivation before all important events, both positive and negative. He notes also the work of Pruessner et al. (2004) on DA release in humans caused by psychological stress, and of Mayberg who insists that loops of brain activity need to be understood as part of the mechanism.

Systems for emotional management are summarised in **Table 2.8**.

2.5.5 Development of attentional mechanisms.

Attention facilitates cognitive regulation of emotion.[700]The psychology of attention goes back to William James at the end of the 19th century. He drew together the notions of attention and choice: “Volition is nothing but attention”

[700] Ironically training for mindfulness seeks to reduce habitual evaluative processing down the PFC midline, and direct attention to limbic in-the-moment sensory pathways. Norman A. S. Farb et al., “The Mindful Brain and Emotion Regulation in Mood Disorders” *Canadian Journal of Psychiatry* 57, 2 (2012): 70–77.

and that “effort of attention is the essential phenomenon of will”.[701] He defined attention as “the taking possession of the mind in clear and vivid form of one out of what seem several simultaneous objects or trains of thought.”[702] Attention may be seen on the one hand as a neural mechanism, albeit at the higher end of cognitive activity, for selection of stimuli or tasks. [703] It is also linked to consciousness and a facilitator of free choice.

Posner reviews the evidence that the development of attentional mechanisms constitutes the essential feature of affect regulation; “Within cognitive psychology, the mechanisms thought to be involved in self-control are collectively called attention.” [704] He notes particularly the work of Broadbent in the late 50s who first proposed that we have the ability to filter unwanted inputs so as to attend. He notes six forms of attentional plasticity are discussed, principally from the neurosystems level, dealing with mechanisms related to voluntary control of thought. [705]

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[701] Quoted in Schwartz and Begley, *The Mind and the Brain*, 317.

[702] Quoted in Schwartz and Begley, *The Mind and the Brain,* 325. William James argued that the essential achievement of the will was to fix the attention on a stimulus or thought and hold it fast before the mind, and that “Volition acts through attention – which magnifies, stabilizes, clarifies, one thought out of many. The essential achievement of the will is to hold one thought/attend to one object and hold it clear and strong before the mind, letting all others – its rivals for attention and all subsequent action – fade.”

[703] For overview of attentional mechanism see: John H. Reynolds, et al. “Attention” in Larry Squire, et al. *Fundamental Neuroscience*, 3rd ed. (Burlington, MA: Elsevier, 2008).

[704] Posner and Rothbart, “Developing mechanisms of self regulation,” 428. This view is based on the observation that parenting involves teaching children to pay attention to specific desirable behaviours and to be aware when personal behaviours become undesirable is looks on attentional networks, themselves affected by the social environment, as a key to developing regulation.

[705] Posner and Rothbart, “Developing mechanisms of self regulation,” 429. First, effortful control of attention means that we attend and amplify “the amount of neural activity within the area performing the calculation.” The second mechanism of plasticity is priming, whereby we are able to retune our attention in another direction because of a trigger event or word. Priming may occur independently of previous attention. Third, practice consolidates pathways to material which is already known. Fourth, new connections are established when new associations are being made. Fifth, are strategies of chunking, decoding, and sounding out. Finally changes in brain structures may develop over the early life of a person eg development of attentional structures in a young child over the course of several years... eg orienting and development of executive control.

Studies provide convergent evidence for a fronto-parietal attentional control system. [706] Structures in the parietal, frontal and cingulated cortices at the top of the visual system hierarchy, appear to generate signals guiding selective attention, providing feedback signals that influence sensory processing at the more physical level. Michael Merzenich regards the nucleus basalis, and the attention system in which it plays a critical part, as "the modulatory control system of plasticity". Learning in critical periods is effortless because the nucleus basalis is always on during these periods. Furthermore it has been shown that critical periods can be reopened by artificially turning on the nucleus basalis. ACh from the nucleus basalis appears to be responsible for the mediation of vivid memories. [707]

NE is important in the brain's attentional systems, with afferent distribution by two significant pathways to the frontal lobes. The first is via the cingulate gyrus and favours the right hemisphere, appearing to be associated with internal body states and sense of self. The second is from the amygdala to the OFC, favouring the left. It appears to be linked to close monitoring of behaviour.[708]

Certain forms of learning, and the plasticity associated with learning, are closely linked to the exercise of attention.[709] Intense concentration and full attention can provide a "necessary condition for plastic change".[710] Developmental plasticity

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[706] See for example: S. Kastner, et al., "Increased activity in human visual cortex during directed attention in the absence of visual stimulation," *Neuron* 22, (1999): 751-761.

[707] Observations of neuroscientist Michael Merzenich quoted in Doidge, *The brain that changes itself*, 84-88. See also: Koch, "Consciousness." Further studies reviewed and providing insight into attentional mechanisms: C. J. McAdams and J. H. Maunsell, "Effects of attention on the reliability of individual neurons in the monkey visual cortex," *Neuron* 23, 4 (1999):765-773. J. H. Reynolds and L. Chelazzi, "Attentional modulation of visual processing," *Annual Review of Neuroscience* 27, (2004): 611-647.

[708] Arden and Linford, *Brain-based therapy with children and adults*, 207. The EEG results are consistent with the view that attention facilitates emotional control.

[709] ADHD studies reveal the significance of linkages between the PFC and the striatum. Further studies reviewed and providing insight into reward mechanisms involving the PFC: R. A. Barkley, "Attention deficit hyperactivity disorder" in *Child psychopathology,* 2nd ed., eds. E. J. Mash and A. Barkley, A (NY: Guildford Press, 2006); F. X. Castellanos, et al., "Anatomic brain abnormalities in monozygotic twins discordant for attention deficit hyperactivity disorder," *American Journal of Psychiatry* 160 (2003): 1693-1696; J. N. Giedd, et al., "Anatomic brain imaging studies of normal and abnormal brain development in children and adolescence" in *Development psychopathology*, Vol 2, eds. D. Cicchett and D. Cohen (New Jersey: Wiley, 2006).

[710] N Doidge (2008) The Brain that changes itself. Melbourne: Scribe p249.

studies in the developing mechanisms of attention in children offer further insights. Children develop both reactive and self-regulatory mechanisms, balancing self-expression and conformity with basic social norms. There are various proposals why attention is necessary: to avoid bottlenecks, and avoid that several objects in a given spatial field activate the same neuron.

Executive attention is associated with activity in the midline frontal areas in the anterior cingulated gyrus. Nevertheless, even though hypnosis had been used to lessen anterior cingulate activity and the perception of pain without reducing the activity in the somatosensory cortex, when subjects were subjected to heat stimuli,[711] emotional regulation was not simply about learning not to pay attention. Genetic studies have shown *Attention Deficit Hyperactivity Disorder* (ADHD) genetic trait affecting the DA4 receptor expressed in Layer 4 of the cingulate. There is reciprocal interplay between affect and attention; studies show that anterior cingulate attention mechanisms automatically turn on as sadness heightens. [712]

Furthermore there are striking contrasts between universal trajectories of development and those of the individual child. Of particularly interest is the work of Kochanska et al. linking development of conscience to temperamental differences in effortful control. [713] Eigsti et al. note the ability to direct attention away from rewarding stimuli during a delay of gratification task in toddlers predicts cognitive control later in life.[714]

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[711] Posner and Rothbart, “Developing mechanisms of self regulation,” 427-441.
[712] Posner and Rothbart, “Developing mechanisms of self regulation,” 427-441.
[713] Posner and Rothbart, “Developing mechanisms of self regulation,” 427-441, for discussion of Kochanska’s work. They documented in 2000 that obedience at nine months predicts effortful control at 22 months. It seems that temperament and self regulation (including control of emotion) each follow a remarkably stable developmental trajectory in the first three years. Based on his studies of conflict resolution in children below 3 years using a modified Stroop test, Posner documents rapid gains in executive attention and executive control at about 30 months allowing the child to exercise inhibitory control over behaviour on his own. Yet in subsequent years, there are remarkable variations, typified perhaps most strikingly by Mischel’s marshmallow test of 1972 which successfully predicted adolescent self control on the basis of infant capacity for delayed gratification. Mischel, et al., "Cognitive and attentional mechanisms in delay of gratification".
[714] I. M Eigsti, et al., “Predicting cognitive control from preschool to late adolescence and young adulthood,” Psychological Science 17, (2006): 478–484.

In short, attentional mechanisms are amongst those neural pathways critical to effective affect regulation.

Attentional systems are summarised in **Table 2.9**.

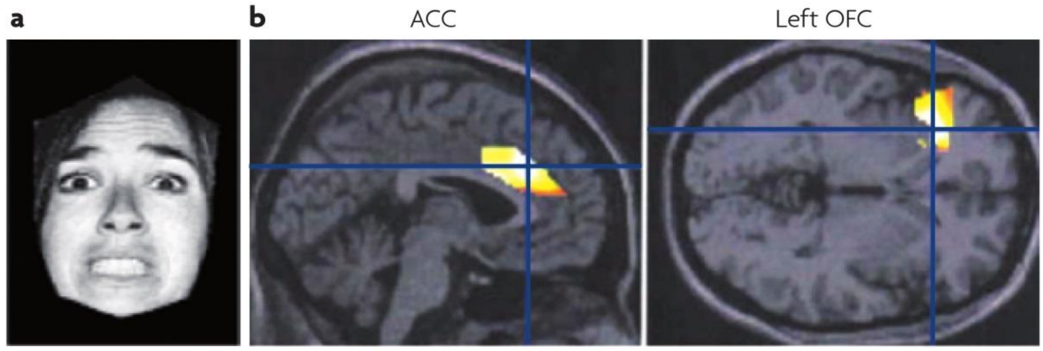

Figure 2.11 **Links between attention and emotion regulation.** An example of imaging that demonstrates the underdeveloped capacity of adolescents (in comparison with adults) to suppress fearful emotions in response to images of fearful faces (example in a), and also to attend to non emotional stimuli. Adolescents showed increased activation of the ACC and left OFC in comparison with adults. When attention was to the nose (not directly conveying emotion) only ACC showed increased activation. These results are consistent with the view that adolescents, in general, have underdeveloped capacities for attention and fear suppression, in comparison with adults. **Source**: Monk C.S. et al. Adolescent immaturity in attention related brain engagement to emotional facial expressions," *Neuroimage* 20 (2003) 420-428. Cited in Blakemore, Sarah-Jayne. "The social brain in adolescence." *Nature Reviews Neuroscience,* 9 (2008): 273.

2.6 Neural bases for goal directed behaviours and reward activation.

Having reviewed current research into the neural bases for habit formation and the role of emotions, we now turn to a closely related topic, the neural bases for goal directed behaviours and reward activation. There are various psychological theories accounting for motivation. The various approaches tend to reduce to two: behaviourists think in terms of drives whereas cognitive theorists consider goals. The anthropology of this study fits more comfortably with cognitive suppositions about human freedom. Within this view, human motivation is characterised by behaviours either to increase the probability of a desired result, or to reduce it. We can call the first <u>appetitive</u> motivation and the second <u>aversive</u> motivation. This view is broadly compatible with an Aristotelian-Thomistic understanding of human action: it sits most comfortably with the a recurrent theme in Aristotle's psychology: that we must raise children to seek pleasure in those things that are good for them, and to endure difficulties for a worthy goal.

Neuroscience has identified various reward pathways that facilitate both goal directed actions and reward based conditioning. DA modulation of activity in the BG is believed to be critically involved in mediating reward activation and associated goal directed activities. An appreciation of recent research in these areas is particularly important to this study if we consider that virtue is not simple habit but the acquisition of habits that during acquisition, or at least after acquisition (if those habits have been acquired as an infant), are the subject of appetitive motivation.

Converging research also identifies the close alignment of the neurobiology for pleasure and pain.[715] As neural bases of reward as well as for certain aversive events exhibit a "common currency" we gain insights into the processes of cortical regulation, "action selection between competing pleasant and aversive events".[716]

In this section I look at recent insights into forms of learning and motivation mediated by DA, and the interplay of the cortical regions with the reward and limbic emotional centres. I also draw some conclusions based on recent work on addiction.

In particular I note the involvement of cortical centres and the BG in the process whereby A-O goal oriented behaviours, with automatisation, change to S-O actions. I suggest that this provides a model for the development of virtuous behaviours which are resistant to reward devaluation, retain a certain intrinsic motivation, and for which we have developed an ease of action.

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[715] Leknes andTracey, "A common neurobiology for pain and pleasure," 314-320. The article reviews current literature in the field.
[716] Leknes and Tracey, "A common neurobiology for pain and pleasure," 318.

2.6.1 Reward pathways and motivation.

There are two chemical driven pleasure systems in the brain:

- The "exciting" pleasure system which is appetitive and involves tension. This is DA driven. Surges of DA consolidate reward associations in our brains particularly in the cortex and in the NAc.
- The "satisfying" pleasure system which is consumatory, calming, blissful and fulfilling. This is endorphin (opiate) driven.[717] Opiates are in four categories of neuropeptides: endorphins, enkephalins, endomorphins, and dynorphins.

These two systems are interactive. μ-opioid signalling is evident in pleasurable and antinociceptive (pain-killing) mechanisms, but also is mutually reinforcing of phasic DA release that is also associated with preparation or consummation of pleasurable reward.[718] Not only does DA facilitate goal election and emotional control, but as an initiator of plasticity, it holds a key to the consolidation of choices enabling future choices.

In addition the hormone oxytocin also seems to play a role upregulating mood, signalling affirmative social connection and facilitating bonding. (See **2.3.6.2.**)

There are two major dopamine systems in the brain:

- one projecting from the SNpc to the caudate and the putamen in the striatum and in a minor way to the NAc;
- another, the mesocorticolimbic DA system, sometimes known as the mesolimbic dopamine system, originating in the VTA and innervating the NAc, the amygdala and the various parts of the cortex, particularly the PFC. This second system is regarded as central to the brain's reward circuit.[719] It

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[717] N Doidge (2008) The Brain that changes itself. Melbourne: Scribe p108.
[718] Leknes and Tracey, "A common neurobiology for pain and pleasure," 318.
[719] Martin, *Neuroanatomy: Text and Atlas*, 3rd ed., 390.

is phasic DA signalling in this latter system that is is reciprocally reinforcing of μ-opioid release. [720]

The complex neuronal mechanisms of motivation have by no means been fully documented but there is a well founded view that DA release in the NAc, associated with specific outcomes either by anticipation or possession, is a powerful motivator.[721] This is of particular significance in this study as the NAc is a region of the BG and well connected with other regions.

LTP and LTD at the synapse seem implicated in positive reinforcement and habit learning. In the dorsal striatum, DA inputs especially in the medial and lateral areas that link to associative and sensorimotor cortical areas are received from the SNpc. The role of LTP and LTD in movement initiation and learning in this area have been well described. In the ventral striatum, although "mechanisms underlying the potential association between striatal neuroplasticity and reward-related behaviours and learning are still far from being elucidated"[722] hedonic reward has been long believed to be mediated by DA projections from the VTA of the basal forebrain. [723] Two classes of striatal neurons have been identified in signalling reward related events, in each case utilising DA.

DA as we have seen, along with ACh, Epi, Histamine, NE and 5-HT, constitutes the amines, neurotransmitters which are associated with the muscular interface, emotions, motivation and cognition. None seem to play a mediating role in the CNS, rather all have specific modulatory roles. Animal research supports the view that variation in a single amine can profoundly affect behaviour, and the

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720 Leknes and Tracey, "A common neurobiology for pain and pleasure," 318.
721 Bear, *Neuroscience. Exploring the Brain,* 526.
722 Di Filippo et al., "Short term and long-term plasticity at corticostriatal synapses: implications for learning and memory,"115.
723 Di Filippo et al., "Short term and long-term plasticity at corticostriatal synapses: implications for learning and memory,"116.

functioning of neural networks. This is confirmed, for example, in studies showing that variation in 5-HT is powerful predictor of human behavioural variation. [724]

2.6.2 Classical conditioning and DA reinforcement.

As we are focused on the development of virtue as a learned behaviour, it is appropriate for us to look at varieties of learned behaviours. We have seen that learning can be non associative (habituation and sensitisation) or associative (classical or operant conditioning, where reinforcement or punishment changes the probabilities of a given behaviour in the future).

Classical conditioning was discovered by Pavlov in 1927. As we have seen, the hippocampus is shown to be implicated in initial stages, and the cerebellum critical, at least for intermediate retention of the learned response.[725] Instrumental conditioning, a variety of operant conditioning, was first identified by Skinner in 1938 who showed that the provision of pleasurable consequences made it more likely that behaviours be reinforced or repeated. This reinforcement may be positive (involving rewards) or negative (withdrawal of a reward). It is noted that punishment is not as effective for learning as negative reinforcement.

Olds and Milner noted in 1954 that rats will self stimulate (by pressing a lever causing an electrical stimulus to the limbic system) in a highly repetitive way (2000 presses per hour). Monkeys have been noted at 8000 presses per hour. Humans wired for the same form of test found the stimulation pleasurable in a non specific way.

The median forebrain bundle has been shown to provide for reliable stimulation in humans through enhanced DA release. "The median forebrain bundle reinforces

[724] Depue andCollins, "Neurobiology of the structure of personality: Dopamine, facilitation of incentive motivation, and extraversion," 514.

[725] Casebeer, "Moral cognition and its neural constituents," 844. Note that the hippocampus appears implicated in explicit recall of memories that affect current goal setting. Roles of the hippocampus and cerebellum were initially identified by Thompson, et al.

the connection between the system that detects the pleasurable stimulus (eg seeing some food) and the motor system that carries out the desired behaviour (eg eating). In other words, this region of the brain carries the mechanism of reinforcement." [726]

This is of relevance on two counts. First, when a baby or an animal is trained in a good habit, there is a degree of conditioning involved. An incentive is provided. Forms of incentive learning can be central to the way in which we train children, and learn ourselves. We will see that this concept is of relevance to the development of fortitude and justice. Second, we will see that incentive conditioning can lay foundations in the striatum for habit, a critical component for both virtues and vices; behaviours which are resilient to removal of the incentive.

The relationship between DA and impusivity is an area of active current study.[727] Pine et al., for example discuss the role of disordered DA neurotransmission in mediation of impulsiveness in behaviours that include addiction, gambling compulsively, ADHD and dopamine dysregulation syndrome. They found that increased sensory quality of rewards increases DA uptake leading to increased impulsivity during decision making.

2.6.3 Goal directed plasticity in the amygdala.

It is apparent that the amygdala is involved in complex positive reward circuitry.[728] The research of Tye and colleagues (2008) finds evidence linking cue-reward learning and synaptic plasticity in the *lateral amygdala* (LA), and suggests that this is a decisive mechanism underpinning goal directed behaviour.

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[726] Wagner and Silber, *Physiological Psychology*, 213.
[727] Alex Pine, et al., *"Dopamine, Time, and Impulsivity in Humans," Journal of Neuroscience* 30,6 (2010): 8888–8896.
[728] S. B. Hamann, et al., " Ecstasy and agony: activation of the human amygdala in positive and negative emotion," *Psychological Science 13,* (2002): 135–141

The LA is recognised to associate emotional and motivational values to specific environmental cues including those associated with rewards. The authors were able to show in studies performed on adult male Sprague-Dawley rats (250-350gm) trained to self administer sucrose as a reward, that, within the space of one training session, reward learning was proportional to cue induced firing of amygdala neurons, and that this cue-reward learning highly correlated with induced strengthening of AMPA thalamic synapses. They demonstrated that NMDA receptor (NMDAR) blockade within the LA impaired these processes, consistent with established knowledge that the activation of NMDARs leads to increased AMPAR currents.[729] (For discussion of NMDA mediated plasticities see **2.2.5.1 a**)

2.6.4 Reinforcement in basal ganglia learning.

The BG are shown to be decisive in reward learning. Konorski notes that while lesions of sensorimotor cortex impede skilled movement, and lesions of premotor cortex "impaired the chaining of action repertoires", lesions of the BG affected the instrumentality of actions so that tested animals could no longer act for reward to avert adverse outcome. [730]

The two main forms of instrumental behaviour are associated with goal directed actions (A-O behaviours), with an intended consequence, and stimulus driven habits (S-R behaviours) essentially triggered by antecedent stimuli.[731] In this section we look more deeply at these types of instrumental behaviours, and the evidence for each of these in the BG. Each has different neural substrates within the BG.[732]

These insights are of significance in the present study for several reasons:

[729] Kay M. Tye, et al., "Rapid strengthening of thalamo-amygdala synapses mediates cue-reward learning," *Nature* 453, (2008): 1253-7.
[730] Yin and Knowlton, "The role of the basal ganglia in habit formation," 465.
[731] Yin and Knowlton, "The role of the basal ganglia in habit formation."
[732] Graybiel, "Habits, Rituals, and the Evaluative Brain," 364. Evidence suggests that learning in the BG is a dynamic process, facilitated by highly redundant parallel pathways.

i) They help to explain the facility with which actions can be carried out. A-O behaviours transform to S-R behaviours. [733] The interconnected loci of A-O and S-R circuitry in the BG is now reasonably well mapped both in human studies and in animal studies. "Human imaging studies of habit learning have found that overtraining of a behaviour shifts the cortical substrate."[734] The neural footprint during this process migrates from ventral to dorsal regions of the striatum. Ventrally based limbic reward becomes less significant; the dorsal striatum characterised by habit formation and addictions becomes associated with management pathways of actions. [735]

Studies by Dickinson et al. of habit formation in animals demonstrate that goal directed, A-O behaviours give way to S-R behaviours, with motivation of a current or future goal replaced by relation to a previous goal, under what is known as the reward devaluation paradigm.

A similar process happens in human beings. Learning of new motor responses, for example, activates the caudate and DLPFC, whereas with well learned sequences, the site of activation shifts to the putamen and motor cortices. When well trained participants were asked to pay attention to their actions, the caudate and the more ventral PFC again were activated."[736] The reward that is "devalued" is the external reward. This process of automatisation begins with greater cortical attention and activity, and as the S-R behaviours take over, is associated with a reduction in cortical activity. The S-R behaviours are carried out more by habit than by focussed attention. This explains the ease with which we perform habits that have

[733] Graybiel, "Habits, Rituals, and the Evaluative Brain,"364. Clinical studies show that frontal cortical inhibitory zones suppress lower order behaviours. So, for example, when prefrontal limbic afferent ties are inactivated goal directed behaviour in rats is reinstated.
[734] Yin and Knowlton, "The role of the basal ganglia in habit formation," 472.
[735] Graybiel, "Habits, Rituals, and the Evaluative Brain," 364.
[736] Yin and Knowlton, "The role of the basal ganglia in habit formation," 472.

previously taken considerable effort to acquire, and also how we can catch ourselves doing things by routine.

ii) This process offers insights into how emotion can be better regulated, a further process at the heart of virtuous activity. That ventrally based limbic reward becomes less significant as habits are learned fits most aptly with the nature of virtue that is resilient against reward devaluation as it is consolidated. External rewards are supplanted by intrinsic rewards.

iii) They offer an understanding of how repetitive, automatized actions can still be voluntary and chosen. It is a mistake to think that S-R behaviours are necessarily less free than A-O behaviours; established S-R behaviours are compatible with the free choice that underpins virtuous action. It is well understood that parents use forms of instrumental conditioning to train children in good habits (that are incomplete from the perspective of virtue because they lack free choice by the subject) but teens and adults themselves are able, of their *own* volition, to commit themselves to a regime of instrumental conditioning to build up a disposition in their own nature for behaviour in certain ways. So, for example, a high school student may decide that she will reward herself for the completion of three hours of study by permitting herself time on Facebook. This reward in turn becomes an incentive for the desired behaviour and a means to achieve the more remote positive outcome of maximising exam performance, etc. In other words we have the capacity to choose to condition ourselves for an intended positive outcome.

Yin and Knowlton raise significant questions about methodology in many studies of motivation. They argue there has been confusion as to the meaning of instrumental learning: ignoring for the most part, purposeful behaviour, that behaviour may be directed to a goal, the A-

O contingency.[737] In summary they claim, “The pervasive influence” of this thinking on neuroscience cannot be underestimated. “It remains powerful in many of the implicit assumptions made by researchers who interpret all neural activity solely as a function of antecedent stimuli presented before the motor response.”[738]

In a model of the human brain where functions are highly integrated in a web of interconnection, the idea that S-R conditioning can still be voluntary presents no obstacle: the cortex (associated with conscious behaviour) will be involved in every action in any case. If furthermore, this model of the human brain is married to an Aristotelian-Thomistic anthropology in which the person, not the brain nor a part of the brain, acts, then all difficulties in this regard should disappear.

Further to the discussion of above (**2.4.4**) Yin and Knowlton have proposed a framework whereby the loops which project to striatum are associated with specific types of learning. Anticipation of reward is a key factor in striatal activity. This accords with the fact that S-R cannot explain speed of learning; furthermore the motivational compulsion of addiction is poorly explained by S-R alone.[739] (See **2.6.6** for more detail.)

Table 2.10 synthesises and summarises the role of the BG in instrumental learning.

2.6.4.1 DA modulation in striatum for goal directed action

We are considering forms of reinforcement learning, a form of operant conditioning, which describes the way in which initially goal directed, reward

[737] They point out that Hull and followers focused almost exclusively on reinforcement of S-R bonds; and that Thorndike dismissed as “unscientific” intention, expectancy and internal representation.
[738] Yin and Knowlton, “The role of the basal ganglia in habit formation,” 465.
[739] Yin and Knowlton, “The role of the basal ganglia in habit formation,” 473.

seeking behaviours, are conditioned to a habitual preferential response; for example, a rat learns to prefer a particular pathway in a maze because it has found food in that pathway on previous occasions. This reward reinforcement is believed to be DA dependent. The NAc-cortical reward pathway has been well documented. DA is released into the striatum leading to limbic modification of neural transmission. DA modulation in the BG in turn effects a decisive modulatory effect back on the cortex via the cortical-BG-cortical pathways. The BG modify glutamatergic cortical outputs. Hence, DA, a principal mediator of plasticity, is decisive in development of habits of goal directed action.

Wickens writes: "There is growing evidence for the hypothesis that activity and DA dependent plasticity at (synapses in the cortico striatal pathway) is important for learning on the basis of reinforcement."[740] He identified the DA neurons of the midbrain VTA and the SN as the key component, and the striatum itself as the locus for the "cellular mechanisms of reward-related learning."[741] [742]

Horvitz has documented the role that DA plays in this conditioning. He refers to the need for a conjunction of "specific movement and reward expectation conditions" and that, "The acquisition and performance of learned movement sequences is severely disrupted by lesions or temporary inactivation of the *deep limbic system* (DLS), and by striatal DA depletion, consistent with the notion that establishment of striatal sequence coding requires DA-mediated strengthening of input-output connections corresponding to consecutive segments of a behavioural sequence." [743]

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[740] Wickens, "Synaptic plasticity in the basal ganglia," 125.
[741] Wickens, "Synaptic plasticity in the basal ganglia," 120.
[742] Other authorities concur. Di Filippo et al., "Short term and long-term plasticity at corticostriatal synapses: implications for learning and memory,"110 Di Filippo et al. writes, "Many parts of the striatum are involved in reward processing, and in various forms of learning and memory, such as habit learning, goal-directed-instrumental and reward-association learning and procedural and emotional learning."
[743] Horvitz, "Stimulus-response and response outcome learning mechanisms in the striatum," 131, 135. Horvitz further notes that motor behaviours in the striatum may be reinforced either by low-level codes to activate specific muscle groups associated with a movement segment, or higher order codes to move a limb to a target position. This is significant as we are not discussing motor

Horvitz further presents a view that DA mediated plasticity in the striatum is instrumental in directing activity of cortical cells. [744] He notes that DA mediated plasticity is involved in both S-R and A-O learning and that synapses in the DLS regions are strengthened through the mediation of DA in accord with "previously emitted movement", contributing thus to the selection of further movement in a behavioural sequence. DA striatal cells receive convergent inputs of reward expectation and movement direction, and establish activity of cortical cells coding movement direction occurs until the trigger stimulus initiates movement at which point persistent reverbatory activity may be established.[745]

The complexities of this finely balanced process are only starting to be documented. There is also evidence of retrograde signalling pathways, thalamo-striatal circuits, which hold striatal neurons just below action potential thresholds. Horvitz suggests there may be a similar mechanism acting on the cortical cells of the pathway. [746]

Da Cunha et al. (2009) suggested that DA release, triggered by the novelty of reward stimuli, is central to the creation and reinforcement of associations and is the condition for synaptic plasticity in the BG synapses between corticostriatal neurons and MSNs, possibly involving reverberation in the cortico-striatal loop.[747] The role of the BG in action selection and storage of non declarative memories is mediated by convergent projections, synchronised by the timing of ACh release by giant cholinergic aspiny neurons, which are *tonically active neurons* (TANs). Projections from various locations in the striatum signal via the GPi to the SNr and

skills at an elementary or gross level, but of motor skills offering the possibility of considerable complexity and refinement.

[744] Horvitz, "Stimulus-response and response outcome learning mechanisms in the striatum," 135-6.

[745] Horvitz, "Stimulus-response and response outcome learning mechanisms in the striatum," 135-6.

[746] Horvitz, "Stimulus-response and response outcome learning mechanisms in the striatum," 135-6.

[747] Da Cunha, "Learning processing in the basal ganglia: a mosaic of broken mirrors," 166.

thence into the thalamo-cortical pathway.[748] They propose that the high concentrations of DA, which are slower to clear from the NAc than the dorsal striatum, explain the fact that learning in the NAc is driven by reward.[749]

Recent trait acquisition studies have highlighted a key role for motivational neuromodulation by DA in the SN. [750] [751] Other studies have shown that the NAc is a major terminal area for representation of rewards modulated by VTA DA. [752]

Other studies have focused on the role of the OFC (particularly area MOC13 containing abundant reciprocal connections to areas of the amygdala) in

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[748] Da Cunha, "Learning processing in the basal ganglia: a mosaic of broken mirrors," 159 and 166. Da Cunha et al. propose a model for cortico-basal processing of procedural memories. Information about the body and environment is distributed repeatedly in the BG and processed by associations between functional units. The hypothesis of fragmented repeated representations is an extension of the work of Flaherty and Graybiel on "matrisomes", multiple areas of the striatum where motor and sensory inputs from the same parts of the body merge, a finding in opposition to the idea that the striatum consists of segregated parallel circuits.

[749] Da Cunha, "Learning processing in the basal ganglia: a mosaic of broken mirrors," 166.

[750] Traits are about as close as contemporary psychology gets to virtues and vices. A trait is "an enduring personal quality or attribute that influences behaviour across situations". (Gerrig et al., *Psychology and life*, 645.) Note that traits are not limited to good ends, and hence, are remotely connected to virtue. By another definition: "Traits are emotional, cognitive, and behavioural tendencies that constitute underlying personality dimensions on which individuals vary."(Burton et al., *Psychology*, 436.) From the contemporary study of traits and how they are acquired we can gain insights into virtue development and expression. In contrast with virtue, trait aggregates qualities of personality that are genetic, temperamental or acquired by dint either of training or personal attention; trait theories allow effective description of persons, but seem very limited in helping us understand people. D. A. Bernstein, et al., *Psychology*, 9th ed. (Belmont CA: Wadsworth, 2012), 573.

[751] Depue andCollins, "Neurobiology of the structure of personality: Dopamine, facilitation of incentive motivation, and extraversion," 499. Depue and Collins built on Gray (1973) who had proposed a model of personality traits based on sensitivity to stimuli associated with positive or negative reinforcement. They developed a psychobiological threshold model for extraversion, a personality based on positive incentive motivation, and saw this personality as a form of impulsivity, and therefore more sensitive to reward than punishment. They sought to explain how goal directed behaviours can be elicited. Central to this model was the concept of motivation and a network of brain structures that integrates motivation.

The authors sought to define the neurobiology of behavioural facilitation. They proposed a behavioural facilitation that is associated with the functional properties of the VTA DA projection system, with the DA ascending projections originating in the SN as "a higher order modulator of a neurobiological network that integrates behavioural functions associated with extraversion."[751] This projection system innervates some 20-30 structures and regions in the brain.

[752] Depue andCollins, "Neurobiology of the structure of personality: Dopamine, facilitation of incentive motivation, and extraversion," 500. Studies of rats and monkeys have shown that the NAc is a major terminal area of VTA DA projections. The authors attributed a critical role to the VTA-NAc DA pathway in facilitation of incentive motivation. The BLA, long seen as critical in classical stimulus-reinforcement conditioning, is topographically linked to the NAc. Simultaneous stimulation of NAc and the basolateral amygdala readily initiates forward locomotion.

integrating “the most complex level of associations of reinforcement with both stimuli and responses…. MOC13 forms higher-level conditional representations of sensory events by associating them with existing or newly developing response-reinforcement contingencies; more simply, MOC 13 may abstract an integrated structure of appetitive and aversive behavioural contingencies from the environment." [753]

2.6.5 Frontal cortex and reward systems.

Theories of cognition almost all agree that the capacity to set specific goals and to direct one’s actions to those goals is central to cognition. The PFC, which has been called “the great integrator, a brain region that synthesises information about the external and internal world for the purposes of producing goal directed behaviour”[754], seems to play a central role in this process of taking control of one’s actions. The PFC takes in converging information from many brain systems processing information from within and without the body, and targets motor system structures that will be involved in voluntary action. The association of the PFC with intentional action is clear. Virtue is described as “a habit of choosing”[755], and hence is closely associated with intentional behaviours.

With projections to and from the forebrain systems associated with sensory data, voluntary motor movement, long term memory, and systems processing affect and motivational state, the PFC is well placed to contribute to cognitive control. It is interconnected to brain areas processing sensorimotor information as well as to centres associated with affect, memory and reward.

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[753] Depue andCollins, “Neurobiology of the structure of personality: Dopamine, facilitation of incentive motivation, and extraversion,” 501; N. D. Daw and D. Shohamy, “The cognitive neuroscience of motivation and learning,” *Social Cognition* 26,5 (2008): 593-620, look explicitly at the critical role of DA in motivated, goal-directed behaviour.
[754] Miller and Wallis, “The prefrontal cortex and executive brain functions,” 1201. The source of material in this section unless otherwise cited.
[755] See **3.2.**

Cognitive control requires ready selection of sensory, memory or motor processes to be activated at any one time.[756] This single mindedness has advantages and suppression of goal irrelevant issues is a part. The capacity to focus attention is closely associated with this command capacity. Also the capacity to deal with time delay before the achievement of the goal is necessary: some form of working memory. Voluntary and goal directed behaviours require the capacity to interact with experience for rapid learning and adaptability. Cognitive control systems must be plastic and flexible, in contrast with automatic behaviours that are typically rigid.

PFC neurons encode rewards linking behaviours to goal directed consequences. Miller and Wallace state, “Feedback about consequences of actions is a key to acquiring new goal-directed behaviours. A large proportion of PFC neurons encode information about rewards.”[757] [758] PFC neurons appear to have the capacity to keep a spatial or object cue “on line” during memory delay. This short term memory function appears to depend on dopaminergic receptors which provide a gating signal to the PFC; precise timing permits the strengthening of current PFC representations. PFC neurons also demonstrate flexibility: the capacity of PFC neurons to modify their properties seems linked the primates’ ability to learn behaviours.

Neural loops between PFC and BG play a role in motor control and support decision making. They are also significant in recursive thought. Fast plasticity in the striatum favours learning the “snapshots” of action that capture immediate circumstances, favoured alternatives, and how to get there; slow plasticity of the PFC favours links to other centres and creation of entire models, future scenarios, of action.

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[756] Concurrent automatic somatic function does not experience the same restriction.
[757] Miller and Wallis, “The prefrontal cortex and executive brain functions,” 1217.
[758] Further studies reviewed and providing insight into reward mechanisms involving the PFC: S. P. Wise, et al., “The frontal-basal ganglia system in primates,” *Critical Reviews in Neurobiology* 10 (1996): 317-356. E. K. Miller, and Cohen, J. D. “An integrative theory of prefrontal function” *Annual Review of Neuroscience* 24 (2001): 167-202.

2.6.5.1 The role of the OFC.[759]

The OFC has been termed the "gatekeeper" to the PFC.[760] We have seen above (**2.3.6.1**) Schore described the OFC as the "hierarchical apex of the limbic system".[761] It is not surprising to find that it is implicated in the brain's reward systems, [762] and in fact is one of the main reward centres of the brain, along with the dorsal and ventral striatum, the amygdala, and the DA neurons. [763] Leknes and Tracey summarise the accumulated evidence that the regions of appetitive and aversive processing include the NAc, the pallidum and the amygdala in the deep cortical regions, as well as in the OFC to which they are interconnected. [764] They point out that DA and opioid systems are "neuroanatomically related", and that "they are prime candidates for systems that transmit signals relating to motivational and hedonic aspcts of both pain and pleasure."[765] The effects of these systems are felt by direct DA release in the OFC and other PFC regions, as well as by cortical modulation resulting from subcortical release.

It is well documented that the OFC codes for the reward value of stimuli, responding to anticipation of future events and so are shown to have access to

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[759] Animal studies are also enlightening as to the breadth of the role carried out by the OFC. "Evidence is accruing consistent with an involvement of the primate OFC in integrating information about rewards and punishments and their predictors and using this information to select goals for action." Roesch and Schoenbaum, "OFC as gateway," 201. In both the rat and the monkey, sensory information passes through the OFC and thalamus and via reciprocal pathways on to the amygdala and the striatum, which themselves are reciprocally linked permitting more complex loops. Affective and attentional processing of the goal may take place within the OFC. Data from Robert's and Parkinson's study of human subjects presented with menus varying in incentive value were consistent with the view that the mOFC "represents an area of convergence of sensory, value and other mnemonic information relating to prospective outcomes to allow for goal selection." Angela C. Roberts and John Parkinson, "Functions of primate orbitalfrontal cortex" in *The Orbitofrontal Cortex*, ed. David H. Zald and Scott L. Rauch (Oxford: OUP, 2006), Fig 8.1, 250, 258.

[760] Roesch and Schoenbaum, "OFC as gateway," 229.

[761] Schore, "Effects of a secure attachment relationship on right brain development, affect regulation and infant mental health," 7-66.

[762] Wagner and Silber, *Physiological Psychology*, 193.

[763] Wolfram Schultz and Leon Tremblay, "Involvement of primate orbitofrontal neurons in reward, uncertainty and learning" in *The Orbitofrontal Cortex,* ed. David H. Zald and Scott L. Rauch (Oxford: OUP, 2006), 194

[764] Leknes and Tracey, "A common neurobiology for pain and pleasure," 317-8. They point to the rostracaudal "hedonic gradient", spatial differentiation of function within the ventral striatum, NAc and OFC.

[765] Leknes and Tracey, "A common neurobiology for pain and pleasure," 316.

representations of the external world. [766] Reward representations are observed in the OFC and PFC, as well as amygdala.[767] The OFC responds to rewards in each of the sensory modalities but also with respect to abstract rewards such as money or praise. Possibly the medial OFC is implicated in reward and the lateral OFC in punishment. [768]

Left and right OFC appear to differ in function: left is associated with empathy, right with TOM. The role of the OFC in affective feelings has been discussed. [769] [770] (**2.3.6.1**)

The OFC links to cortical areas implicated in memory.

> "Connectivity often offers important clues to the critical function of a brain region. Just as the ventral striatum is critically positioned to serve as an interface between limbic and motor systems (Mogenson et al. 1980), the OFC is uniquely located to serve as the gateway between these limbic areas, which are concerned with passively encoding associations between cues and likely outcomes or consequences, and the active, representational memory systems of the prefrontal cortex."[771]

The OFC is reciprocally linked to other areas of the PFC "which are involved in the regulation of behaviour through representational memory and it sends output to the ventral striatum." [772] Representations of memory play a key role in all cortically mediated conscious action, and therefore also in the development of conscious habitual action.

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[766] John P. O'Doherty and Raymond J. Dolan,"The role of the human orbitofrontal cortex" in *The Orbitofrontal Cortex*, ed. David H. Zald and Scott L. Rauch (Oxford: OUP, 2006), 266.
[767] Horvitz, "Stimulus-response and response outcome learning mechanisms in the striatum," 133.
[768] O'Doherty and Dolan "The role of the human orbitofrontal cortex," 269.
[769] Arden and Linford, *Brain-based therapy with children and adults*, 103.
[770] Nitschke et al., "Orbitofrontal cortex tracks positive mood in mothers' viewing pictures of their newborn infants," 583-592.
[771] Roesch and Schoenbaum, "OFC as gateway,"202.
[772] Roesch and Schoenbaum, "OFC as gateway,"203.

It was suggested in the 1990s that the OFC stores associations between cues and outcomes on behalf of the amygdala and other brain areas but the contribution is apparently more complex than this with the OFC processing expectations for likely outcomes and allowing associative information from the amygdala to be processed in representational memory of the PFC. [773] It would seem that the OFC is not critical in simple cases of instrumental learning or Pavlovian conditioning, but only when information regarding outcomes requires further processing and integration for the generation of an appropriate response. [774] The end result of the gateway role that the OFC appears to play allowing association information to access representational memory is the promotion of "voluntary, cognitive, and goal directed (not stimulus driven) behaviour and facilitating new learning." [775]

The representation of the value of anticipated events and actions is a form of memory mediated by the OFC. Also, we have already noted the central role that attentional mechanisms play in self regulation. (**2.5.5 Development of attentional mechanisms)** The OFC is well placed to coordinate peripheral and central arousal mechanisms.[776]

2.6.5.2 Close alignment between OFC and striatum.

Current research notes the close alignment between the OFC and striatum. The architecture of the brain facilitates the close cooperation of NAc and OFC.[777] These two structures are adjacent, with the NAc sitting immediately on the inside of the OFC. The NAc, as we have seen, the area of the striatum most closely associated with reward, receives inputs directly from the adjacent mOFC. Via the

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[773] Roesch and Schoenbaum, "OFC as gateway," 219.
[774] Roesch and Schoenbaum, "OFC as gateway," 219.
[775] Roesch and Schoenbaum, "OFC as gateway," 229.
[776] Roberts and Parkinson, "Functions of primate orbitalfrontal cortex," Fig 8.1 p254.
[777] Anatomically, the NAc is ideally positioned to regulate the management that limbic and cortical regions exert over behaviour. The NAc has been seen as a "limbic-motor interface" determining response priorities of an organism. An alternate view is that the NAc transforms cognitive processes "into meaningful patterns of behaviour without being involved in cognition." cf Stan B. Floresco, "Dopaminergic regulation of limbic-striatal interplay," *Journal of Psychiatric Neuroscience* 32, 6 (2007): 400–411.

limbic loop this region connects back to the cortex via VP and the medial dorsal nucleus of the thalamus to the anterior cingulate gyrus and the orbitofrontal gyrus itself. Information in this loop is integrated in the VP with inputs from the hippocampus and the amygdala. The OFC transfers information via the lateral prefrontal cortices to the premotor areas for decision and action.[778] Further motor output is via the VP.[779]

The lateral OFC, the OFC, and mPFC are interconnected and play a critical role in cognitive and emotional processing and in the formation of motivation for the selection of behaviours.[780] The OFC and the mPFC are distinct but interrelated systems, with different but related functional roles. The OFC has reciprocal connections to the limbic system and to the striatum (including via the cortico-basal-thalamic loop) similar to a loop assocated with the mPFC. [781]

Like the OFC the striatum is activated in association with movement for an expected reward. [782] "Just like the OFC and the amygdala, the NAc is the site of convergence for numerous sources of motivational information, including the BLA, the OFC, the mPFC, and the dopaminergic VTA neurons." [783] Note that conclusions of interactions between the PFC, the amygdala, the striatum and the DA modulated VTA neurons are based on rat studies.

Horvitz draws attention to the sustained activity in cells of the striatum in anticipation of reward as a mirror of reward coding in the OFC.[784] He further argues for a close association between the striatum and the OFC by observation of

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[778] Barbas and Zikopoulos, "Sequential and parallel circuits for emotional processing in primate orbitofrontal cortex," 75.
[779] Roesch and Schoenbaum, "OFC as gateway," 201.
[780] Barbas and Zikopoulos, "Sequential and parallel circuits for emotional processing in primate orbitofrontal cortex," 57.
[781] Joseph L. Price, "Connections of the orbitofrontal cortex" in *The Orbitofrontal Cortex* ed. David H. Zald and Scott L. Rauch (Oxford: OUP, 2006), 39 and 52.
[782] Barbas and Zikopoulos, "Sequential and parallel circuits for emotional processing in primate orbitofrontal cortex," 64.
[783] Barbas and Zikopoulos, "Sequential and parallel circuits for emotional processing in primate orbitofrontal cortex,".
[784] Horvitz, "Stimulus-response and response outcome learning mechanisms in the striatum," 133.

differences between the sustained activity in striatal cells in comparison with the hundreds of millisecond activations of DA cells of the midbrain. [785]

The role of the OFC is quite specialised in these tasks. Some comparison to the roles of the striatum with which it is closely connected is enlightening. OFC neurons do not seem to have any direct involvement in initiation, planning or execution of motor processes whereas the striatum is implicated in these roles and thus facilitates OFC involvement in behavioural output mechanisms. "The neural activities in the striatum are examples on how motivational and motor processes can converge to produce mechanisms related to the acquisition of rewarding goals." [786]

Reward representations in the OFC are associated with goal-directed conscious choices of action; "In order to choose between different actions it is necessary to maintain a representation of the likely predicted future reward associated with each action. Such predictions need to be compared and evaluated to select the action with the highest overall predicted reward value." [787] Lesion studies by Bechara et al. (1994), Rolls et al. (1995) and Hornak et al. (2004) suggest that the OFC plays a role in action selection for reward either by maintaining representations of the predicted rewards or by participating in the actual process of decision making. Grace wrote that the "mPFC provides goal directed motor plans selected within the NAc on the basis of contextual and emotional associations from both the hippocampus and the amygdala".[788]

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[785] Horvitz, "Stimulus-response and response outcome learning mechanisms in the striatum," 133.
[786] Schultz and Tremblay, "Involvement of primate orbitofrontal neurons in reward, uncertainty and learning," 195.
[787] O'Doherty and Dolan "The role of the human orbitofrontal cortex," 276.
[788] Citation and quotation in Pollak, "Early adversity and mechanisms of plasticity Integrating affective neuroscience with developmental approaches to psychopathology,"738.

This relationship between the PFC and the BG appears special not only because of the projections into the striatum, in common with much of the rest of the cortex, but because PFC inputs to the thalamus are modulated by signals from the GPi.[789]

The findings of this study, with respect to reward processing and cognitive control of reward systems, are consistent with recent findings of Buitelaar who, in a 2012 review, summarises biological mechanisms at work in risk taking, and risk avoidance in teenagers, He finds teenage choices are assisted by the "dynamic interaction of the cognitive control system (medial/ventral prefrontal cortex), the reward system (nucleus accumbens), and the harm-avoidant system (amygdala)" He says, "Increased risk taking might then be the consequence of either a weak control system, or an easily activated and pushing reward system, or a weak harm-avoidant system, or combinations of these." He offers no information directly about any biological basis for habits that could dispose for improved rationality.[790]

Buitelaar notes that reward processing in striatal brain regions, if unmoderated by cognitive control, lead to greater risk taking. He suggests the balance of evidence is that the reward system is hyper-responsive in adolescence. He notes that adolescents show the ability to modify risky decisions when they put themselves, a capacity that improves on average in later adolescence. [791]

Recent studies continue to demonstrate the close relationship existing between the OFC and the striatum.

- Hetherington and Wagner conclude in a recent study, "Cognitive neuroscience research suggests that successful self-regulation is dependent on top-down control from the prefrontal cortex over subcortical regions involved in reward and emotion." They develop an

[789] Barbas and Zikopoulos, "Sequential and parallel circuits for emotional processing in primate orbitofrontal cortex," 73.
[790] Jan K. Buitelaar, "Adolescence as a turning point: for better and worse," *European Child and Adolescent Psychiatry* 21, 7 (2012): 357.
[791] Buitelaar, "Adolescence as a turning point: for better and worse," 358.

analysis of effective regulatory responses to the most common causes of self-regulation failure: negative emotions, escalation of indulgence, cue exposure, and impaired control.[792] They review inhibition studies and show that there is a pattern whereby intentional behaviour in addicts increases lateral PFC activity and reduces striatal and OFC activity.

- Somerville and Casey also find that cortico-striatal pathways are crucial for successful cognitive control. However, they harness mounting evidence for the counter intuitive position that striatal reward areas are capable of upregulation of cognitive control to win reward. [793]

2.6.6 Addiction studies offer insights into the reward systems.

Neuronal addictive processes are of relevance offering insights into how pathways of permanently heightened motivation for action can exist. Is it possible that the profound and life moulding changes at the striatal and cortical synapses that underpin addiction have common features with virtue learning?

I have used the work of Robinson and Berridge in reviewing current explanations for addiction: the hedonic view emphasizing the search for pleasure and avoidance of the unpleasant;[794] the view that addiction is brought about by aberrant learning;[795] Robinson's and Berridge's own incentive-sensitization view,

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[792] Heatherton and Wagner, "Cognitive Neuroscience of Self-Regulation Failure," 132-139.
[793] Leah H. Somerville and B. J. Casey, "Developmental neurobiology of cognitive control and motivational systems," *Current Opinion in Neurobiology* 20, 2 (2010): 236–241.
[794] The hedonic view suggests that drug use leads to DA release (required for rewards and motivational control of behaviour) from projections from the VTA and SN into the NAc and amygdala to be downregulated as tolerance grows. When drug use stops, withdrawal occurs, leading to further acute drop in DA and serotonin levels. There are grounds to think that persistent drug use engages the stress system on the hypothalamicpituitary axis. In response to stress *corticotrophin releasing factor* (CRF) is released by the hypothalamus; only small priming injections of the drug are sufficient to set off the whole addiction cycle even after the original neural responses are extinct.
[795] The aberrant learning view provides valuable insights into habit formation in the striatum. This is the "most prominent implicit learning view of addiction". It suggests that the automatic S-R habit hypothesis provides a more plausible account for addiction than A-O or goal directed processes. In this view, addiction involves a transition from explicit and cognitively guided behaviour, such as the memory of a pleasurable drug-induced experience, to comparatively automatic behaviour that is essentially a S-R habit, a behaviour that takes little or no account of expected outcomes and which can play out automatically, and for which the neural substrate is

focusing on neural sensitization as the cause for compulsion;[796] the explanation for addiction centring on a dysfunctional PFC acting in concert with impulsivity and poor judgement.[797]

Several insights become apparent.

- Addiction studies help us to understand the contribution of the BG and BG pathways to complex habitual behaviours in which the subject remains fully aware of what he is doing. These studies emphasise that drug seeking may involve the pursuit of complex *purposeful* (my emphasis) behaviour patterns: habit formation in the BG is not reducible to simple motor sequences. [798]
- Addiction studies are consistent with the view that DA reward pathways, striatal or cortical, may have a role in triggering or initial reinforcement of virtuous behaviours.[799]

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found in the corticostriatal loops operating through the dorsal striatum. It is argued that with sufficient practice any task can be automatised and that over-learned habits of drug use become so automatic that they become compulsive. Terry E. Robinson and Kent C. Berridge, "Addiction,"*Annual Review of Psychology* 54, (2003):25–53

[796] The authors write, "Habits are not intrinsically compulsive in any motivational sense, no matter how automatic they are…. there is no reason to believe that automatic S-R associations *per se* can confer compulsive qualities." Further, they maintain that S-R cannot explain the flexible, ingenious, frantic behaviours involved in pursuit of drugs by addicts. Therefore they seek additional motivational explanation in *stimulus-stimulus* (S-S) processes: pairing which is a type of paired associate learning that uses simultaneous presentation of two or more stimuli without explicit reinforcement or responding. Robinson and Berridge, "Addiction," 25–53.

[797] Robinson and Berridge, "Addiction,"25–53. Additional insights have been gained from the following other studies: N. Hiroi and S. Agatsuma, "Genetic susceptibility to substance dependence," *Molecular Psychiatry* 10, 4 (2005): 336-344; J. D. Jentsch and J. R. Taylor, "Impulsivity resulting from frontostriatal dysfunction in drug abuse: implications for the control of behaviour by reward-related stimuli," *Psychopharmacology* 146, (1999): 373–90; X. Liu, et al., "Smaller volume of prefrontal lobe in polysubstance abusers: a magnetic resonance imaging study," *Neuropsychopharmacology* 18, (1998): 243–52; R. Goldstein et al., "The orbitofrontal cortex in drug addiction" in *The Orbitofrontal Cortex* in ed. David H. Zald and Scott L. Rauch (Oxford: OUP, 2006), 276; Beretta et al., "Synaptic plasticity in the basal ganglia: A similar code for physiological and pathological conditions," 345-346.

[798] Beretta et al., "Synaptic plasticity in the basal ganglia: A similar code for physiological and pathological conditions," 345-346.

[799] Beretta's view is that addiction reaches the point that DA, having initially triggered plasticity, may no longer be required for behaviour, once response learning takes over, is consistent with the virtue oriented view that actions can be performed despite devaluation of the goal. Beretta et al., "Synaptic plasticity in the basal ganglia: A similar code for physiological and pathological conditions," 345-346.

- An integral role for the BG in virtue formation is not contradicted by addiction studies. Striatal plasticity essential to the processes of addiction and also normal reward processing.[800] Dysfunctional plastic change in the BG leads to compulsive behaviours, impacting on cognitive capacity to regulate emotion and reward craving.
- The close relationship between reward expectation and emotional control is emphasised. Addiction essentially involves dysfunction in the basal-cognitive circuitry that would normally facilitate emotional control. Addiction studies have uncovered substantial evidence for cognitive-basal dysfunction when addiction is present, with abundant evidence for "persistent drug-induced neuroadaptations" in the NAc at molecular, cellular, and neural system levels, in other words, plasticity."[801]

Table 2.11 summarises the reward and motivational systems operating and their relevance to the development and exercise of virtue.

2.7 Cognition and executive function.

2.7.1 The PFC coordinates executive function.

As we have seen, the PFC plays a central role in complex cognitive and executive function, involving many aspects of personality, and planning, insight and foresight.[802] [803] The PFC is one of the four functional areas of the frontal lobe: the primary motor cortex, the premotor and supplementary motor areas, Broca's area, and the PFC. The PFC is extensively and directly interconnected with the parietal, temporal, and occipital cortex via fibres in the subcortical white matter.

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[800] Di Filippo et al., "Short term and long-term plasticity at corticostriatal synapses: implications for learning and memory,"117.
[801] Robinson and Berridge, "Addiction," 26. The authors cite studies by Nestler et al. (1993); Robinson & Berridge (1993), (2000); Vanderschuren & Kalivas (2000); Hyman & Malenka (2001); Everitt & Wolf (2002); De Vries & Shippenberg (2002).
[802] A. R. Crossman and D. Neary, *Neuroanatomy. An illustrated colour text,* 3rd ed. (Edinburgh: Elsevier, 2005), 140.
[803] Nolte, *The human brain. An introduction to its functional anatomy*, 6th ed., 61.

The PFC, particularly the lateral PFC, is oriented towards action.[804] For example, at the cortical level, the premotor cortical regions, the association cortices, the PFC itself, the posterior parietal cortex and the limbic cortex all play a role in movement planning.[805] The activity of numerous cortical regions is orchestrated and coordinated by the PFC.

The PFC interacts with other brain areas, especially posterior and subcortical regions, in cognitive and emotional management. PFC and ACC seem to be the key neural substrates for response regulation. "The ACC works with the frontal cortex through the reciprocal cortico-cortical connections of the anterior cingulate cortex and the lateral PFC to monitor human volitional mental activity."[806] [807]

In this section we overview significant lines of current research into cognition and executive function which appear relevant to this study.

2.7.2 Functional studies of the PFC.

(Refer also: **2.5.3.1 Involvement of cortical areas in emotional response**.)

The PFC is clearly involved in behavioural regulation via inhibition of responses. Tatia et al. review various recent studies of response inhibition and find that response inhibition seems to involve DLPFC, VLPFC and parietal cortex, that the right hemisphere predominates in response inhibition along with the lateral and medial OFC, superior temporal gyrus and ACC. It appears inhibition of impulsive

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[804] Barbas and Zikopoulos, "Sequential and parallel circuits for emotional processing in primate orbitofrontal cortex," 73.

[805] Martin, *Neuroanatomy: Text and Atlas*, 3rd ed., 239.

[806] Lee, et al., "Regulation of human behaviours," 189-199.

[807] Nolte, *The human brain. An introduction to its functional anatomy*, 6th ed., 567. Nolte cites a 2006 review by S. J. Gilbert et al. of 104 PFC imaging studies published over the course of the previous decade identified the areas where increased blood flow indicated localised involvement in memory, in multiple tasking and in mentalizing about the mental or emotional states. It found that multiple tasking was closest to the frontal pole, with mentalizing deeper below the surface and memory on either side.

behaviour may be localised to the right OFC. The authors note that response regulation involves both response inhibition and the election of goal appropriate, though as yet non-habitual, responses.

Functionally the PFC divides into DLPFC, at the top and sides of the forward lobes and the VMPFC. The lateral and medial areas are densely interconnected.[808]

Tasks of executive function and working memory are mediated by DLPFC function. The DLPFC is the "key neural substrate in the regulation of cognitive processes".[809] The DLPFC is greatly interconnected to the parietal multimodal cortex as well as to the somatosensory, visual and parietal association areas, and has involvement in cognitive strategies and planning.

The DLPFC, which is one of the last brain regions to develop, plays a key role in manipulating various sources of information for decision making. It appears to draw together experiences, memories, anticipations, self evaluation, long and short term planning and measurement of personal conduct against norms; a damaged DLPFC impairs choice of behaviour, leading to disregard of context and opting for pursuit of familiar courses of action.

The VLPFC and OFC are closely linked.The VLPFC "can exert a bidirectional top-down modulation of activity for the regulation of cognitive processes".[810]

Tasks of emotional processing and social decision are mediated by VMPFC. The VMPFC extends into the anterior cingulate and orbitofrontal areas and is closely connected to the limbic areas. Damage to the VMPFC leads to impulsive behaviours as well as to socially inappropriate behaviours and inappropriate

[808] Source for information in this section on the frontal cortex is, unless otherwise specified: Lee, et al., "Regulation of human behaviours," 190.
[809] Source for information in this section on the frontal cortex is, unless otherwise specified: Lee, et al., "Regulation of human behaviours," 190.
[810] Source for information in this section on the frontal cortex is, unless otherwise specified: Lee, et al., "Regulation of human behaviours," 190.

emotional responses.[811] It was the VMPFC of Phineas Gage that was substantially damaged.

The *dorsalmedial PFC* (DMPFC) links with inferior parietal cortex, the DLPFC and the posterior cingulate. It receives limbic inputs and, with its linkages to other PFC areas, integrates the emotional reaction and experience with cognitive processing which is "critical in the emotional regulation and adjustment of behaviour on the basis of emotional cues". DMPFC also seems active in perspective taking and "theory of mind", when learning rules associated with goal-directed actions, problem solving and planning. These will be stored in the lateral PFC areas.

In addition there is the <u>OFC</u> (see above **2.6.5.1)** situated behind the eyes. It was first believed to be involved in olfactory processing. In recent years there has been intensified interest on this area which now seems essential in risk taking and decision making. The OFC links the PFC to striatal and limbic areas in regulation of motivated responses.[812]

Spindle cells link the OFC and the ACC. These cells have been associated with the capacity to make quick decisions. Spindle cells display rich interconnections, high velocity of transmission characteristics, and are well endowed with receptors for DA, 5-HT and vasopressin. Watson and Allman (2007) note, "At the cellular level, humans and apes are the only primates that have a type of neuron, the spindle cell, in the anterior cingulated, and frontoinsular cortex." The number of spindle cell in the human cortex is one thousand fold in excess of its presence in apes and implication of the cell in mechanisms of attention and self control are suspected.[813]

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[811] Nolte, *The human brain. An introduction to its functional anatomy*, 6th ed., 567.
[812] A principle throughout this study is that connections in the brain do not exist by chance. As pathways develop precisely through usage, connections demonstrate active communication.
[813] See discussion of the work of Tatia et al., and of Watson and Allman, in Arden and Linford, *Brain-based therapy with children and adults*, 104-105.

The OFC also links with the insula, the third site where spindle cells are found. This frontal cortical area within the lateral sulcus is adjacent to both the temporal lobe and the parietal. It appears to integrating various sensations: viscerosensations, taste, pain, and feelings of disgust.[814] The linkage is believed to facilitate rational processing of raw emotion.

There are significant linkages between the BG and the PFC through the OFC. It is now apparent that pathways for cognition and executive function do not reside solely in the outer cortical layers. "Recent evidence suggests that circuits through the BG have a role beyond motor control, including cognition, reward evaluation, motivated behaviour, learning, and memory which may be traced to pathways through the PFC."[815] As we have seen, interconnections with the BG via thalamus on the return pathway, and with the limbic system itself are now recognised as playing significant contributions. The PFC has extensive interconnections to the dorsomedial nucleus of the thalamus, lesions in which can have the same effect on executive function as lesions to the PFC itself. [816]

The PFC, along with the other cortical areas, requires continuous electrical stimulation from the lower brain areas for conscious activity to take place.[817] Excitatory signalling (utilising ACh), and reverbatory excitatory signalling, via the thalamus, to almost all cortical areas, are critical in this process. [818] In addition there are excitatory and inhibitory mechanisms of control.[819] (See also **2.5.3** for other neurotransmitter and neuromodulatory agents affecting the PFC.)

Table 2.12 summarises the domains of executive function.

2.7.3 Prefrontal plasticity.

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[814] Siegal and Sapru, *Essential neuroscience*, 6.
[815] Barbas and Zikopoulos, "Sequential and parallel circuits for emotional processing in primate orbitofrontal cortex," 73.
[816] Nolte, *The human brain. An introduction to its functional anatomy*, 6th ed., 567.
[817] Guyton and Hall, *Textbook of Medical Physiology*, 11th ed., 728.
[818] Guyton and Hall, *Textbook of Medical Physiology*, 11th ed., 729.
[819] Bear, *Neuroscience. Exploring the Brain,* 581.

Only recently has the potential for plasticity in the PFC been recognised.[820] Recent studies have confirmed however that association learning leads to plastic changes in the OFC, as well as medial and lateral PFC, and implicate both the medial and lateral areas in executive functions such as tuning of attention, and decision making.[821]

Insights are accruing into the functional differences between the lateral PFC and the medial PFC areas. Anderson et al. (2000) described the long term sequelae for two young adults, F.D. (female), whose head, when she was 15 months of age, had been run over by a car tyre, and M.L. (male), who, at 3 months suffered a resection of right frontal malignancy. Despite relatively unimpaired cognitive function, both had exhibited intractable chronic social maladjustment from early childhood, suggesting damage to the ventromedial area. F.D. showed little remorse for dishonesty and theft, precocious sexual activity, insensitivity to her infant's needs and inappropriate emotion; M.L. exhibited poor attention, impulsivity, difficulties interacting with others, inability to manage money, work or independence, obesity, substance abuse, sexual irresponsibility and little remorse for actions. The authors concluded that there may be limited plasticity in the sectors of the PFC that link emotion and decision making. The findings are consistent with the view that infantile damage to PFC can lead to "severe disruption of adaptive behaviour" without noticeable effect on standard educational and psychological testing and support the suggestion of Schwartz and Goldman-Rakic (1990) that several aspects of PFC neuronal organisation seem well specified in early development and not dependent on environmental

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[820] B. Moghaddam and H. Homayoun H, "Divergent Plasticity of Prefrontal Cortex Networks," in *Neuropsychopharmacology Review* 33, (2008): 43. "The idea that plasticity, or experience-induced lasting changes in synaptic strength or structural features, is a component of PFC function has historically received little attention because a lasting effect is somewhat inconsistent with the dynamic and flexible function of the PFC. Experience induced synaptic and structural plasticity have been generally localised to the hippocampus and the basal ganglia regions, such as the striatum."
[821] Moghaddam and Homayoun, "Divergent Plasticity of Prefrontal Cortex Networks," 42-55.

stimulation for determination.[822] Recent work also focusses on developmental plasticity of the PFC. [823]

Of great importance to this study, it is now accepted that cortical areas are vastly more interdependent and interconnected than had been previously thought. Moghaddam and Homayoun suggested that even apparently modular structure is actually a manifestation of the parallel networks that underpin brain activity. Their hypothesis was that the DLPFC, regarded as the executive regions of the PFC, respond in parallel to the limbic and limbically connected regions such as the OFC, and thus direct behaviour that is consistent with context and expected outcome.[824]

Table 2.13 summarises systems for cognition, consideration of consequences, planning, goal election and executive direction.

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[822] S. W. Anderson et al.,"Long-term sequelae of prefrontal cortex damage acquired in early childhood," *Developmental Neuropsychology* 18, 3 (2000): 281-296.

[823] R. Jacobs, et al., "Executive function following focal frontal lobe lesions: Impact of timing of lesion on outcome," *Cortex* 43, 6 (2007): 793. A 2007 Melbourne study by Jacobs and colleagues, investigating executive function in 38 children with focal (eg tumor or stroke) lesions involving the PFC, reinforced the view that there are critical periods of development when the PFC is especially vulnerable. Children with lesions present from before birth showed the greatest risk of major deficits while those lesions which arose during childhood were at less risk of severe executive impairment, on the basis of a battery of tests administered to the two groups. The authors suggested that this appeared to be the case because, at this stage of cognitive development, the brain relies on experience to strengthen connections, in other words that forms plasticity, "neuronal reorganisation … changes in dendritic and synaptic structure and connectivity", occurring in this developmental stage work to minimise the long term effects of the lesion. The study also found that residual deficits of focal lesions in early childhood were lower than those where diffuse pathology, for example traumatic brain injury and cerebral infection, were involved.

[824] Moghaddam and Homayoun, "Divergent Plasticity of Prefrontal Cortex Networks," 42-55. Moghaddam and Homayoun in 2008 sought to reconcile conflicting theories of cognitive processing. They argued that historical understandings of the cerebral cortex as being divided into elementary units, a modular theory of localisation of operations, can be reconciled with the contrasting view that there are parallel distributed neural networks operating. Some have seen the OFC and DLPFC regions as having different functions; under psychostimulants, these two regions display opposing patterns of plasticity. Others have sought evidence that these regions operate in parallel, monitoring similar events and that the dynamic conversation beween these areas during decision making is crucial for sound behaviour. For example, single neuron studies of rats presented with stimulus response tasks show simultaneous activity in the two regions, the OFC and the mPFC (the rodent equivalent to DLPFC in humans). Importantly, they demonstrate functional coupling during a working memory task. The two regions responded to stimuli with opposing patterns of activation. These patterns reflect differential patterns of plasticity.

2.7.3.1 Plasticity studies in the motor cortices.

Not within the PFC, but within the frontal lobe, the motor cortices are increasingly seen as an important site of plasticity.[825] There have been numerous studies demonstrating plasticity in the motor cortical areas. For example Michael Merzenich has pioneered this field with many studies into somatosensory cortical map plasticity. Further insights are now at hand from studies of subjects with prostheses. Hochberg et al. (2006) demonstrated that a human subject (M.N.) with tetraplegia, three years after spinal cord injury, was capable of cortical movement signals, and was able to effect control of *neuromotor prostheses* (NMPs) via intention driven neuronal activity converted via decoders linked to a 100 electrode sensor implanted in an area of the M1, the right precentral gyrus, into a control signal. By imagining certain hand movements M.N. was able to successfully activate control signals allowing him to open simulated email, operate television, and work a prosthetic hand.[826]

This study followed a ground breaking study, documented by Ramachandran and Rogers-Ramachandran (1996) of three subjects who had suffered amputation and were suffering from phantom limb pain. Subjects were exposed to virtual limb movement. Results suggested that this exposure brought about plastic changes in the motor cortex area pertaining to the impaired limb and that these changes had an ameliorating effect on phantom pain. Phantom limb movements, experienced as real by the subjects, led to significant M1 changes.

Table 2.14 reviews the brain areas, mechanisms and pathways implicated in the execution of motor commands and the relevance of these systems to the development and exercise of virtue.

2.8 Conclusion.

[825] P. Giraux and A. Sirigu, “Illusory movements of the paralysed limb restore motor cortex activity,” *Neuroimage* 20, (2003): 107.
[826] Leigh R. Hochberg et al., “Neuronal ensemble control of prosthetic devices by a human with tetraplegia,” *Nature* 442, (2006): 164-171.

This review of recent studies demonstrates that it is possible to identify mechanisms which modify the specific regions and pathways in the brain on the basis of conscious experience. I argue that these mechanisms, areas and pathways are essential to the acquisition and exercise of virtue.

This chapter has developed as follows:

After an initial overview of current lines of investigation into neural plasticity, the foundational mechanism which underpins all learning in the brain, I have overviewed contemporary lines of research in learning and memory. I have reviewed understanding of the BG, a subcortical structure integral to reward processing and habit formation, and implicated also in emotion processing and motor management. I then reviewed systems for regulation of emotion, reward processing and executive function in the brain.

Some initial observations about the aptness of task of this study can be offered.

- <u>The development of virtue will reflect processes of experiential learning:</u> experience-based learning follows Hebbian principles of synaptic strengthening and reinforcement of connections through use, or anti-Hebbian principles of refinement of pathways. The development of qualities of character, virtues, are a form of experience based learning acquired by repetition.
- Structural plasticity offers an attractive explanation for the Aristotelian principle that virtues in some way "make us who we are". It is reasonable, given the relative stability of the personality changes implied in virtue acquisition, that the plastic changes involved are structural not only functional. There are various <u>mechanisms of structural change in the brain</u>, but these appear to involve gene expression mediated by second messenger processes from the synapse. (**Table 2.15** summarises the various mechanisms for plasticity that have been throughout this chapter.

This table completes the discussion of **2.2** and **Table 2.3** in the light of the later sections in this chapter.)

- The development of myelination in the frontal cortex and motor pathways, offers a further mechanism of plasticity; in the first case to assist in understanding the development of self control, and in the second to better account for efficient action.
- Virtue is understood as the capacity for self-management. Cortical pathways for management of emotion are necessarily implicated in the neural correlates of virtue. We find that these pathways in the BG-thalamo-cortical loop already associated with habit formation and in the limbic loop entering the cortical domain via the OFC and the ACC.
- The architecture of the brain presents as a highly evolved and efficient network of complementing functionalities manifesting the Hebbian corollary that, where neural pathways exist, then neural communication has been present. The adjacent location of the NAc and the OFC, and rich connection between them consolidates a *prima facie* explanation of emotional management. Not only do the BG have the capacity, on the basis of reward representations, to modify cortical activity and motor commands, but by reciprocal cortical loops, they are themselves modified in their goal proposals. This offers a compelling mechanism for cortical management of emotion. The more pathways of emotional regulation are revisited, the more they are reinforced.
- Reward processing and habit formation are interlinked systems associated with the basal cortical pathways. This offers an explanation for the development of habitual behaviours that are consciously elected, with the flexibility to account for reward incentives in childhood. We have seen that conscious and reflective behaviours may be mediated by the basal-cortical pathways.
- DA signalling facilitates goal election and emotion regulation, and, as an initiator of plasticity, is critical in consolidation of regulation pathways through structural changes.

- Mechanisms of habit and procedural learning appear to offer some understanding for the phenomenon of established behaviours that remain robust in the absence of immediate rewards. The BG-thalamo-cortical loops with their widespread cognitive-emotional interaction offer insights into processes of planning, goal selection, self regulation, attention and motivation. The growth of intrinsic motivation over external reward as virtue is carried out for its own sake**,** resilience against reward devaluation, is consistent with the development of automaticity. That ventrally based limbic reward becomes less significant as habits are learned aptly fits with the nature of virtue.
- The ease with which virtuous action is completed argues for the forms of automatisation evidenced in habit. The ease of practice that is associated with virtue aligns readily with the greater speed, accuracy and efficiency associated with pathways reinforced by mechanisms of neuroplasticity. The neural motor underpinnings of automatisation are reasonably well described.
- The function and efficient interconnection of the limbic, cortical and basal-thalamic regions satisfy three pre-conditions for the presence of virtue, that the neural bases for emotional regulation, automatisation of action, and motivation and goal election, all integral to the expression of virtue, be present.
- An understanding of the attentional systems of the brain offers powerful insights into mechanisms in neural support of affect management and will power. Focussed attention permits directed plasticity in the brain: it is “the modulatory control system of plasticity”.[827]
- Studies of addiction reinforce the view that basal procedural function can be conscious and volitional. In a state of wellbeing the frontal cortex and the BG cooperate in conscious, volitional action. In an addicted state, plastic changes in the BG and the basal-cortical pathways lead to cortical dysfunction.

[827] Observations of neuroscientist Michael Merzenich quoted in Doidge, *The brain that changes itself*, 84-88.

- New insights into brain function, including new appreciation of the functions of the BG and the OFC, offer insights into how the discrete components of virtuous action (motivation, automatisation of action, and executive goal direction) may be integrated into a neural network. It is now understood that the role of the BG is far more complex than as a relay station for motor commands. It is now understood to play a key role, in modulating conscious motor activity, integrating planning with reward and motivational factors. The OFC is now understood to involved with limbic modulation.
- The capacity to set specific goals, to direct one's actions to those goals, to reason about consequences and means, appears central not only to cognition but to rational acts disposed by the virtue of prudence.
- The links between cognition, rationality and virtue are direct. Cognition implies a capacity for goal setting, reasoning, deliberation as to consequences and means, and final election. That one chooses goals fitting for one's nature is a mark of rationality. And virtue is essentially the habituation of this capacity. Hence the exercise of virtue requires rightness and perfection of reason, the operations of which are perfected by the virtues of prudence and justice**.**
- Specialist neurons such as spindle cells that are implicated in mechanisms of self control and cortical areas associated with appreciation of consequences, and mirror neurons that have been associated with imitation and empathy, appear to offer fruitful linkages to virtue theory. Aristotle wrote of the role of example in the acquisition of virtue; there is evidence at the neural level of mirror systems that facilitate adoption of example. Plasticity in the systems for empathetic response appears integral to the development of sensitivity for the rights and needs of others, and an understanding of the consequences of one's actions, which appear to be are at the core of the virtue of justice**.**
- To find pleasure in appropriate activities is the mark of virtue; appetitive responses to pleasure, aversive responses to fear and pain, reward

expectations, emotional responses, and conscious goal election, are all finely tuned in the state and exercise of virtue. A habit of appropriate reward expectation is directly linked to the development of the virtue of temperance**.**

- Amygdalic-cortical pathways of fear management, associated with sound goal election, appear to support the virtue of courage.
- Aristotle insisted on the ease with which children acquire virtue. This seems to be a reference to aspects of what we now understand to be sensitive periods for the development of qualities. Of particular interest in the field of virtue education are sensitive periods evident in responsiveness to affection, in the development of an affinity for the content of early experience, in ease of imitation, and in the adoption of new behaviours during early years. First impressions are lasting impressions; experiences during upbringing, particularly when the stimuli are associated with emotional significance, can be virtually indelible.
- In the exercise of virtue, memory of past behaviours, of reward, of contextual and emotional resonances, and of principles of right and wrong, are all required. Memory systems are functionally implicit to learning, to response to reward and emotion, to habit formation, to goal election, and all cognitive function. Mechanisms of non-declarative memory appear to facilitate the ease of practice and the inherent motivational rewards in virtue, while during the more arduous process of acquisition of virtue, declarative memory plays a significant role. A degree of explicit emotional/aesthetic/social/moral education, sometimes in the form of guided behaviour and sometimes through conceptual communication with relevant concrete illustration, is required for the development of virtue.
- Virtues empower action in ways tailored to the flourishing of our being. This includes disposing us to execute movement towards worthy objectives. Therefore the neural bases for virtue require effective connections with motor control, even though not all virtuous activity requires expression in motor activity.

- Habit, in providing a mechanism for the organism to act more efficiently at the neuronal level, dedicating attention elsewhere, and absorbing fewer cerebral resources, seems to satisfy Aristotle's litmus test for virtue, that it is attuned to the flourishing of the person.
- There is a strong inductive case to be made that wellbeing of the organism requires effective integration of systems of the brain. It is most reasonable to argue that the life of virtue, manifested as the integration of the cortical with the limbic, is an indicator of flourishing.

These correspondences between characteristics of virtue itself, and the neural structures and processes of the brain, will be developed in greater detail in **Chapter 5**. I suggest that these features present a strong inductive, empirical case in favour of specific neural bases implicated in the development and exercise of virtue. The weight of evidence argues that an alternative view appears incompatible with the neuroscience.

Given the myriad manifestations of virtue across the categories of the cardinal virtues (habits of sound judgement, of respect and responsibility, of self control, and of resilience and fortitude in the face of difficulties) the neural expression of virtue is likely to involve many different regions of the brain. The approach of this study, first by considering the nature of virtue, and then by study of the likely core neural processes at work, appears more appropriate than a methodology based on isolated imaging experiments. It is hoped however that the generalised findings of this study will be borne out by specific empirical investigation in due course.

Chapter 3

Investigating the characteristics of virtue.

"To be a great and virtuous man appeared the highest honour that can befall a sensitive being; to be base and vicious, as many on record have been, appeared the lowest degradation, a condition more abject than that of the blind mole or harmless worm."
Frankenstein; or, The Modern Prometheus
Mary Shelley

Introduction

What did Aristotle mean by describing someone as virtuous?

To be virtuous is more than to perform, like a sports car, at one's full design specifications. Human beings are more than performance; they are more than what they can *do*. The perfection of virtue is an intrinsic good suiting our very nature; we are perfected in our nature as composite beings of body and soul. To be in this state of virtue is to flourish according to our nature.
Aristotle held that to be virtuous is to be in a state of natural perfection: virtue is that which "makes its possessor good and his work good likewise".[828] It is an *arête,* an excellence of character. This state is characterized by intellect, will and sensitive appetites - the active powers of the human person - perfected in their biological development, and thus able to perfect intrinsically our operation as rational beings. Perfection of rationality disposes us to, but is not subordinated to, perfection in action.

Some elaboration is helpful here at the commencement of a chapter which focusses on the characteristics of virtue. As the starting point of his *Nicomachean Ethics,* Aristotle explained that all human actions seek goods that we deem will fulfil or perfect us. Therefore the very task of ethics is to distinguish in these goods what is really a good for us from the apparent. He proposed that fundamental

[828] *NE*, 1106a15.

desires of seeking pleasure and avoiding pain are the primary motivations in our lives and he insisted that these basic appetites must either allow themselves to be guided by our rational understanding of what is truly good for us, or they can and will exert an undue influence on our choices. Habits of self indulgence come at a price, and timidity in the pursuit of worthy goals will also leave us unfulfilled - rogue desires can deprive us of freedom and happiness.

Aquinas built on foundations laid out primarily by Aristotle. He too understood virtue as a state arising from the possession of habits perfecting the active powers of the sensitive appetites (the concupiscible appetite attuned to pleasure and the irascible to pursuit of arduous goals), of the intellect, and of the will. These perfecting habits enable us to act rationally despite appetites that draw us in contrary directions and despite external pressures seeking to turn us from our elected goals.[829] He taught that the most fundamental moral virtues are prudence (perfecting our practical judgements about how to act) justice (the habitual disposition of making choices that accommodate the needs and welfare of others), fortitude (the habit in the irascible appetite) and temperance (in the concupiscible appetite).

Aristotle argued that the highest end of a human agent lies in performing rational activity "well", activity that "aims at what is truly perfective of the human agent".[830] In other words not only the external end result is good, but the human agent is himself perfected. (**1.4.2** and **1.6.3**.) I argue in this study that this perfection includes our very neuronal activity, pathways and processes, and that this state of maturity is a natural and fitting state for human beings - when our neuronal development falls short of a consolidation of virtues, our personal fulfilment is compromised.

<u>Organisation of this chapter</u>

[829] Virtues are "habits by which a person acts well." *ST*, Ia-IIae, Q.55, Art.3.

[830] Aquinas, *Disputed Questions on Virtue: Quaestio disputata de virtutibus in communi and Quaestio disputata de virtutibus cardinalibus*, ed. Ralph McInerny (South Bend Indiana: St Augustine's Press, 1999), xii.

Chapter 3 should be read in the light of earlier discussions of Aristotle's notion of the hylomorphic nature of reality, the introduction to the Aristotelian-Thomistic account of virtue with a particular focus on the contribution of virtue to human flourishing, and the arguments for the unity of the person. In **Chapter 1** I noted the need to develop a methodology by which I can identify the core characteristics of the Aristotelian-Thomistic view of moral virtue. This methodology and this identification are the tasks of **Chapters 3** and **4**.

I commence with a case study from real life, a study of an exemplary figure from Japan living in the first half of the twentieth century, Takashi Nagai.

Recalling Elizabeth Anscombe's advice that, before we lose ourselves in ethical theory, we must account for the richness and complexity of real people who manifest the tension between rationality and emotion, free and impulsive behaviours, intrinsic and extrinsic motivation, and fulfilled and unfulfilled lives,[831] it is fitting to begin our discussion in the world of real people and actual behaviours. Real life scenarios are drawn from the life and autobiographical writings of Nagai, medical doctor and nuclear physicist who, in the years after WWII through his writings under the most difficult circumstances, was a great force for spiritual healing in a country gutted by the horrors of war. [832]

In **3.1.4** in the light of an understanding the human act and how it is perfected by virtue, I note features of virtuous action that are in evidence in the case studies presented. These observations ground subsequent discussion in **3.2** and **3.3** in the real world. In **3.2** and **3.3** I identify key characteristics of virtue, according to the Aristotelian-Thomistic account. In these two sections the Aristotelian-Thomistic account of virtue is dissected utilising primary texts and commentary, with some

[831] Anscombe, "Modern Moral Philosophy," 26-44.
[832] Introductory texts for an understanding of Takashi Nagai's life: Takashi Nagai, *The Bells of Nagasaki,* trans. William Johnson (Tokyo: Kodansha International, 1984); original title: *Nagasaki no kane* (1949). Paul Glynn, *A Song for Nagasaki* (Hunters Hill, Sydney: Catholic Book Club, 1988).

illustration from the glimpses in **3.1** into Nagai's life and mind, and from his approaches to fostering virtue in the lives of others including his own children.[833]

The goal of **3.2** will be a review of the nature of virtue and its ordination to human flourishing. In **3.3** I review the development of virtue. My aim here will not be to enter into nuances of interpretation nor controversies, but rather to provide an efficient review of the principal characteristics of virtue in the Aristotelian-Thomistic account. In the process I hope to capture something of the brilliance of the insights that Aristotle and Thomas have placed before us noting their applicability to real life scenarios in the life of a most admirable man.

Hence my methodology to identify the characteristics of virtue involves an analysis of Aristotelian and Thomistic texts, in the light of the actual behaviour of a virtuous man, and of an understanding of the human act. In **Chapter 4** the initial list of qualities identified in **Chapter 3** will be further refined in the light of the distinct roles of the cardinal virtues.

<u>What are we looking for?</u>

> 'Cheshire Cat,' she began, rather timidly...' would you tell me, please, which way I ought to go from here?'
> 'That depends a good deal on where you want to get to,' said the cat.
> 'I don't much care where...' said Alice.
> 'Then it doesn't matter which way you go,' said the Cat.
>
> **Lewis Carroll**
> ***Alice in Wonderland***

We need to know where we are going, what we are looking for. I have suggested that a great challenge facing the Templeton award winners is the imperative for them first to clarify the meaning and features of virtue. Without a well articulated, authoritative notion of virtue successfully reconciling the respective roles of the rational and non-rational in the development and practice of virtue, those studies must be at serious risk of failing in their endeavours. The task of this chapter is to

[833] A source for information about Nagai's life with his children will be Takashi Nagai, *Leaving my beloved children behind*, trans. M. M. Tatsuoka and T. Takai (Strathfield, NSW: St Paul's Press, 2010); original title: *Kono Ko o Nokoshite,*94.

identify characteristics of moral virtue able to be mapped against neurobiological knowledge of the human brain. A philosophically rigorous, defensible, understanding of virtue ordered to human flourishing, according to the Aristotelian-Thomistic account will be described and presented as an essential prerequisite to an identification of neural part-constituents. In the process I hope to convey something of the magnificence of virtue theory as a superlative account of rational behaviour and human fulfilment.

3.1 Dr Takashi Nagai (1908-1951).[834]

This first section presents glimpses into the inspiring and extraordinary life of Dr Takashi Nagai in order to demonstrate the remarkable relevance of virtue theory in its ability to account for human behaviour. In so doing, I will seek initial insights into the characteristics of virtue.

We will see, from his life and writings, that the nobility of Nagai's mature, considered actions and the richness of his emotional life typify what most would agree to be a state of virtue. It will be argued that virtue ethics provides a far more convincing model for the subject's actual behaviour than is provided by either deontological or consequentialist explanations. Whether or not the actions of others could be better described by observance of rules or duty, or by a preoccupation to achieve certain outcomes, it will be shown that in Nagai's case virtue theory stands out as a powerful explanation for his rational behaviour, for his ability to live with peace of heart in the midst of great difficulty, and for the richness and balance of his emotional life.

As virtue is known through its acts,[835] it is also highly appropriate that we commence with human acts demonstrating virtue. Actual scenarios of noble action are described and analysed. This serves to anchor our discussion of virtue,

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[834] My sources for this section are Nagai, *Leaving my beloved children behind;* Nagai, *The Bells of Nagasaki*; Glynn, *A Song for Nagasaki*; and Masao Shiotsuki, *Doctor at Nagasaki* (Tokyo: Kosei, 1987), original title: *Hasushigoto wa Anrakusatsu data*.
[835] *ST*, Ia-IIae, Q.56, Art.2.: "Habits are known through their acts."

from the very start, in the real world of sensation, passion, apprehension, deliberation, choice and action. In so doing, I hope to reinforce the conviction in the reader that virtues are not theoretical constructs for understanding behaviour, but manifest, objective, attributes of the person that facilitate behaviours which are good for us as human beings.

These scenarios drawn from the life of Dr Takashi Nagai will be revisited in the course of the current chapter in order to illustrate characteristics of virtue in a systematic overview. In the process I distinguish between the human act itself and that which pertains to particular virtues within the act. This will be of particular assistance, towards the end of **Chapter 5**, where one scenario will be used to illustrate the contribution of neural part-constituents to human behaviour.

Nagai's response to the cataclysmic event of August 9, 1945 led to his subsequent fame. His personal account of the immediate aftermath of the blast in Nagasaki became a best seller in Japan, and the subject of movie and popular song. He wrote some twenty books in the six years after the war.

Importantly for our purposes, Nagai demonstrated that he was a man of deep convictions and intelligence, concern for his fellow man, austerity of life, and courage. Greatly influenced by Pascal's *Pensées*, by his wife and perhaps also by his experiences as a doctor with the Imperial Army during its invasion of China, Nagai had become a Christian before the war. He was a devoted father and compassionate doctor; zealous for the advancement of medicine, he carefully documented the effects and effective treatments of radiation illness. Through all his suffering he manifested no bitterness towards the Americans for the bombing that destroyed half the urban areas of Japan and millions of lives. In post war Japan during the six years he lay dying of leukemia Nagai rose to prominence as a national spiritual leader as much for his extraordinary writings encouraging reconciliation and peace, as for his remarkable humility, inner peace, and absence of bitterness. "In the postwar years Nagai became a symbol of strength and optimism, a central figure in the spiritual and moral reconstruction of Japan. … His influence on the collective unconscious of Japan was very great." He was praised in the contemporary press as the "Gandhi of Japan".[836] He was in the common sense of the word, and in the sense understood by Aristotle and Aquinas, a man of virtue.

Figure 3.1 Dr Takaski Nagai **Figure 3.2 Nagai with his two children**.

3.1.1 Context: August 9, 1945.

On the morning the bomb fell, Nagai was at work in his laboratory in the hospital of Nagasaki choosing X-ray films to teach students the art of diagnosis. Without warning, at 11.02am, there was a flash of blinding light. Nagai's scientific training gave us this description.

> Tremendous energy was released. And this energy, a tempestuous blast of air travelling at a rate of two thousand meters per second, smashed, pulverised, and blew apart anything in its path. The void created at the centre of the explosion sucked up everything on the ground, carrying it high in the sky, and hurled it back violently against the earth. The heat of 9000^{o} Fahrenheit burned the surrounding area. Fragments of incandescent metal rained down in balls of fire

[836] William Johnson in preface. Nagai, *The Bells of Nagasaki*, *xx* and *xxii.*

> immediately setting everything alight. It is estimated that 30,000 people lost their lives.[837]

Nagai survived because, although only 500m from the epicentre, he worked in one of the few concrete buildings in that area.[838]

Everywhere there were dead and dying, convulsing, strangely swollen, skin peeling. Soon fires were raging. Weakened by previously contracted leukemia, and despite his own grave injuries, Nagai worked to utter exhaustion caring for the dying and injured through the day of the blast and the days that followed. As the hospital was gone he had to improvise everything. Only after three days did he return to his family home finding the charred bones and melted rosary of his beloved wife, Midori.

Nagai's scientific training and a sensitivity to psychological experience enhanced by his medical training are present throughout in his writing including in the extracts which follow. His capacity to describe with precision internal states and

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[837] Nagai, *The Bells of Nagasaki*, 28. This is typical of numerous passages in his account where he dispassionately and accurately analyses the event. Nagai's writing is in the spirit urged by another first-hand witness, Masao Shiotsuki: *"The atomic bomb must not be elegised or sentimentalised. It is not romantic fiction. It is not poetry. Its terrible workings and devastation it wrought must be approached and described as scientifically as possible and viewed as a pressing concern for all mankind."* Shiotsuki, *Doctor at Nagasaki*, 82. This effort to be truthful and objective will be commented upon later. The final toll was of course much higher than 30,000. The memorial in the Peace Park records 73,884 dead and 74,909 injured.

[838] Nagai, *The Bells of Nagasaki*, 11. Nagai recalled his own experiences:

> I immediately tried to throw myself to the ground, but before I could do so, the glass of the windows smashed in and a frightening blast of wind swept me off my feet into the air – my eyes wide open. Pieces of broken glass came in like leaves blown off a tree in a whirlwind. I felt that the end had come. … It was as though a huge invisible fist had gone wild and smashed everything in the room. The bed, the chairs, the bookcases, my steel helmet, my shoes, my clothes were thrown into the air, hurled around the room with a wild clattering noise, and all piled on top of me as I lay helpless on the floor. Then the blast of dusty dirty wind rushed in and filled my nostrils so I could scarcely breathe. I kept my eyes open, looking always at the window. And as I looked everything outside grew dark. There as a noise like a stormy sea, and the air everywhere swirled round and round. My clothes, the zinc roof, pieces of wood, and all kinds of other objects were performing a macabre dance in that dark sky. Then it gradually became cold, as at the end of autumn, and a strange and silent emptiness ensued. Clearly this was no ordinary event.

subjective responses, as well as external events, make his writing ideal for the purposes of this study.

3.1.2 Acts of virtue.

In the four scenarios which follow I focus on incidents drawn from Nagai's first hand accounts, and from biographical writings based on his own accounts.

Each scenario describes his own actions which specifically, in some way or other, could universally be acknowledged as noble and good. Each provides some psychological insight also. Commentaries below each offer a preliminary analysis.

In the first he describes carrying out a difficult task and a subsequent moment of insight. This experience occurred during his years as an army doctor in China. The second and the third are of intense experiences in the immediate aftermath of the bomb. In each of these, searing memories etch truthful vivid descriptions. The fourth scenario deals with Nagai's maturing attitudes in the last years of his life, and in particular with the composition of a short poem.

These examples also flag the danger of underestimating the complexity of virtuous actions. Bear in mind that any short real life description must necessarily be a gross simplification of actual events. In these four scenarios convey the great complexities possible in a moral act facilitated by virtue, as well as the difficulty in separating what is essential to virtue from what is additional in the act.

a) Scenario 1. Treating a prisoner.

A biographer describes a moment of enlightenment during his years in China.

> Nagai remembered his inner turmoil during the 1933-34 fighting in Manchuria. Yet now, though the fighting was far worse he enjoyed peace and freedom in his heart. He certainly

> had changed! One night he jotted an entry in his notebook about the exhilaration that flooded him that day when he was washing the gangrenous foot of a Chinese soldier-prisoner before an operation. He suddenly realised he felt the same compassion for a wounded Chinese as for a wounded Japanese, and wrote: "I now know I have come to China not to defeat anybody, not to win a war. I have come to help the wounded, Chinese as much as Japanese, civilians as much as combatants".[839]

Commentary

Nagai's "peace and freedom in his heart", his fulfilment as he dedicated himself compassionately to the care of the wounded, shines brightly on the pages of his journal. He reveals his consciousness of having grown greatly in interior peace, overcoming "inner turmoil" despite the increasing wartime danger. The moment described captures his flooding "exhilaration" at realising that he cares for soldiers of either side with equal respect and compassion. This moment of insight occurs precisely as he carries out the objectively repulsive task of washing a gangrenous foot, with all the associated stench and aversion to the task.

It will be shown that this growth towards inner fulfilment is an important facet of the virtuous life. Furthermore, the phenomenon of a flash of insight will be significant in later discussion about the virtue of justice.

b) Scenario 2. The Rising Sun.

Survivors worked frantically to assist survivors in the hours following the blast. Yet the task was too great. Nagai writes of his profound helplessness and discouragement. "I stood helplessly in the middle (of the wounded), doing nothing. … It was an utterly disheartening scene." [840] Most of his colleagues and

[839] Glynn, *A Song for Nagasaki*, 78.
[840] Nagai, *The Bells of Nagasaki*, 36.

students dead, survivors losing their nerve, ten years of academic work incinerated, Nagai collapsed, greatly weakened by loss of blood. “My knees trembled and I felt my strength ebbing away. ‘It’s the end,’ I murmured and collapsed.”

When he came to, despite his own dire situation, Nagai grasped the need to lift his followers, unite them in purpose, and rally them to the task of helping others. He called for a flag. Nothing was to be found, so he took a hospital sheet:

> Taking a handful of blood that was dripping from my chin, I traced a huge circular sun on the sheet, which now became a Japanese flag. Attaching this “Rising Sun” to the bamboo pole, we lifted it up and watched it flutter loudly as the hot wind blew around.
>
> With sleeves rolled up and a white band around his head, young Nagai[841] grasped the pole with both hands and raised the flag high in the air. And then he moved slowly forward carrying the bloody Rising Sun up that hill covered with black smoke. And we all followed in solemn and silent procession. It was five o’clock in the afternoon.[842]

One witness recalled long afterwards, “Suddenly we had our ‘headquarters’ to rally around, a centre that put order back into the picture.” Another wrote, “It was so simple an act and yet the psychological act was profound.”[843] By this action Nagai assembled the remnant of the medical staff to lead and carry survivors away from immediate danger to a hill overlooking the burning university.

<u>Commentary</u>

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[841] Another Nagai: a student who had survived the blast.
[842] Nagai, *The Bells of Nagasaki*, 42-3.
[843] Glynn, *A Song for Nagasaki*, 101-102.

Nagai overcomes his own weakness and discouragement in order to fortify his followers, and himself, with the improvised symbol of a Japanese flag.

Note how the qualities that Nagai shows are profoundly integrated in the action he carries out, a point carrying some significance in the discussion below in **3.4**. In this single action Nagai demonstrates prudence, fortitude, remarkable self control, and remarkable selflessness. He presents himself with a motive to overcome his lethargy, forms a practical plan, and launches into action. His fortitude is inseparable from his capacity to see the needs of others and from his own practical insight.

The insight of the witness is significant: "order" was restored by this inspirational action, a mark of rational direction. The mere sight of the flag has a remarkable restorative effect on all. The survivors' own self-directed and ordered actions follow their sight of the flag. The symbol sparked an effective response of loyalty and responsibility, in which it seems practically no words were necessary. The sight of the flag alone heartened them, somewhat restored peace of heart, and they were again able to move purposefully drawing on their long cultural and family traditions of self control and fortitude.

To further unpack the complexity of this moment: sense input, in this case the sight of a flag charged with emotional resonance, triggers a cascade of practical action, solidarity, self control and fortitude. Emotion laden input has imparted to the consciousness of each member of the group a truth on the basis of which each can act. Thus this scenario also demonstrates the complex relationship between emotion and considered action: at times emotion can *initiate* considered and virtuous action.

c) Scenario 3. The pamphlet.

This scenario presents a contrasting moment in which it was necessary to master emotion rather than capitalize upon it, for virtuous action.

On the day following the blast Nagai describes a moment when the truth dawns upon him that the destruction has been wrought by a nuclear device and consequently Japan must be defeated:

> The chief nurse came running up and handed me a sheet of paper. It was one of the leaflets dropped by enemy planes the previous night. As I glanced at it I shouted out spontaneously: “The atomic bomb!”
>
> In the depth of my being I felt a tremendous shock. The atom bomb has been perfected! Japan is defeated!
>
> … Conflicting emotions churned in my mind and heart as I surveyed the appalling atomic wasteland around me. … A bamboo spear lay on the ground. I kicked it fiercely and it made a dull, hollow sound. Grasping it in my hand, I raised it to the sky, as tears rolled down my cheeks. The bamboo spear against the atomic bomb! What a tragic comedy this war was! This was no longer a war. Would we Japanese be forced to stand on our shores and be annihilated without a word of protest? These are the words written on the leaflet:
>
>> *To the People of Japan*
>>
>> *Read carefully what is written in this leaflet. The United States has succeeded in inventing an explosive more powerful than anything that has existed until now. The atomic bomb now invented has a power equal to the bomb capacity of two thousand huge B-29s. You must reflect seriously on this terrible fact. We swear that what we say here is the solemn truth. … The President of the United States has already given you an outline of thirteen conditions for an honourable surrender. We advise you to accept these conditions and to being rebuilding a new and better peace-loving Japan. … If you do not do*

> *this, we are determined to use this bomb and other excellent weapons to bring this war to a swift, irresistible conclusion.*

> I read the leaflet once and was stunned. I read it a second time and felt they were making fools of us. I read it a third time and was enraged at their impudence. But when I read it a fourth time I changed my mind and began to think it was reasonable. After reading it a fifth time I knew that this was not a propaganda stunt but the sober truth.[844]

Commentary

The emotional significance of this moment is in the thunderclap insight that the war is inevitably lost. It is interwoven with a sense of burning shame, associated with defeat, inculcated through Nagai's culture since childhood. Nagai's description of how his passionate reaction subsides on successive readings of the leaflet gives us a remarkable insight into how deliberation can enable mastery of passion. What is initially less obvious is the interior battle that Nagai has to fight in order to respond rationally to the news. Had he torn up the leaflet after the first readings, he would not have come to the same conclusion. Unsaid is any reference to his education and upbringing that empowered him to exhibit the self control required to allow the news to sink in.

Acceptance of the truth about the existence of the bomb, is followed by very swift reasoning and insight that the Japanese defenders would be powerless on beaches against landings supported by atomic weapons. He then deliberates over whether he should accept the demand of the leaflet. Only in his fourth reading he "changes his mind" and finds the words "reasonable". Grasp of one truth leads to deliberation and reasoning that leads to the grasp of another truth. During the period of deliberation he keeps his emotions under control sufficiently to continue his deliberation.

[844] Nagai, *The Bells of Nagasaki*, 52-3.

Complexity is further added by the fact that, although it is not explicitly a factor in his deliberations, he has an audience. He has already demonstrated that he is finely attuned to his responsibilities to those he leads. It is reasonable to surmise that this sense of responsibility as well as his training in scientific objectivity assisted him in applying sufficient deliberation before committing himself to judgement.

d) Scenario 4. *Nyokodo*.

Nagai lived out his days in a humble hut that he christened *Nyokodo* meaning "Love-your-neighbour-as-yourself-house".[845] It was on the site of his former home, close to the epicentre. It was a mark of Nagai's fame that the Divine Emperor himself visited Nagai in that one room hut where he studied, wrote, meditated, and delighted in the roses he had growing, the stars above him and the mountains visible through his window.

Nagai advised his young visitors:

> Go to the mountains and meditate! If you stay in the hurly-burly of this world, you'll run around in circles without ever finding your way. You'll become the kind of person who just stamps and screams. But the blue mountains are immovable and the white clouds come and go. I look constantly at these mountains of Mitsuyama and continue my meditation.

A biographer remarks on the transformation of his life during these last six years:

> This professor who before 1945 had written nothing but scholarly reports with dry statistics now became a writer, a poet, an artist, a humanist, a mystic. Lying on his sickbed with his writing pad suspended over his head, he writes no less than twenty books before his death in 1951. He also writes poetry. Though Japanese poetry does not translate well into English let me refer to one.

[845] For discussion of the historical and cultural significance in Japanese tradition of the humble ascetic's hut as a place of purity of heart and solitude see Glynn, *A Song for Nagasaki*, 125.

The girls of the Junshin School died in the atomic blast chanting psalms under the leadership of one of their Japanese nuns, just as the twenty six martyrs of Nagasaki had died centuries before on crosses chanting psalms under the leadership of Paul Miki. About the schoolgirls Nagai wrote:

Virgins like lilies white
Disappeared burning red
In the flames of the holocaust
Chanting psalms
To the Lord

Nagai was also a master of calligraphy. As love for peace became an all consuming passion he would write for his visitors the characters *heiwa wo*, meaning "Grant us peace!"[846]

Figure 3.3 ***Nyokodo***. The hut in which Nagai lived during his last years.

[846] Nagai, *The Bells of Nagasaki*, *xvii-xviii.*

Commentary

The words of Nagai to his young visitors insist on the importance of meditation in order to put sense into the events of life. He presents reflection as an antidote to childish emotional tantrums, purposeless activity, and the distraction of life. It is clear from his own example that meditation however moves from contemplation to action. His remarkable output, during his years of illness, demonstrates this productivity.

The short poem, especially the use of the word "holocaust" and the comparison of the school girls with the 17th century martyrs of Nagasaki, manifests a conviction that there can be meaning behind tragedy, that there can be reasons that explain or help to explain difficulties, perhaps even that some pains are worth enduring. The simple beauty of the imagery, and the conclusion of the final line, suggest inner tension is resolved and that the poet, and also the girls themselves, are at peace.

In total, the scenario allows us to reflect on the phenomenon of growth in virtue. In his enlightened maturity, Nagai moves from preoccupation with the speculative to the exercise of contemplation which he channels through art and writing into powerful messages for his contemporary world. [847] Thereby too, he manifests his own peace of heart. [848]

3.1.3 Virtue and the human act.[849]

[847] Excellence in these activities is a demonstration of virtue according to the Aristotelian understanding. Aristotle describes art as the virtue of making, while effective writing and poetry require application of the practical intellect perfected by prudence. Cf *NE*, 1103a, 32-33.

[848] Glynn, *A Song for Nagasaki*, 130. In these years his calm and peaceful attitude was constantly in evidence. Above we see this in his calligraphy and his constant concern to send visitors away with this message of peace. Towards the end of his life he wrote for his small son and daughter, "Being pure in spirit and pure in heart might not win you a lot of money but will give you something even more precious, peace of heart." Biographers describe his affection for his children, typified by such beautiful letters full of encouragement, tenderness and tranquillity.

[849] Etienne Gilson, *The Christian Philosophy of St Thomas Aquinas*, (London: Victor Gollancz, 1961), 253.

Each of the scenarios above has focused on a rational act, what Aquinas calls a "human act".[850] Before I seek to discern what is common to virtue across the various scenarios, it will be helpful to review briefly a Thomistic understanding of the human act. (See also **3.1.4**).

Our goal here, in association with the subsections immediately following, is to identify more precisely the specific characteristics common to the state and practice of virtue, isolating from them the many other features present in any act of virtue which are not necessarily specific to virtue. I will comment also on the observed role of cardinal virtues at work in these scenarios.

Table 3.1 suggests that the human act itself divides into no less than twelve successive moments. At first this representation of the psychological steps I follow prior to acting may appear needlessly complex, yet, this structure is derived from

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As this study of a neural substrate contributing to virtue will need to account for the presence of biological aspects and representations, we must distinguish that which is material from that which is properly rational. For the sake of precision, the use of some terminology drawn from the rational psychology of Aquinas (**1.4.2**) is helpful here. In Thomistic psychology there is no psycho-physiological mechanism in the very act of knowing; the operation of the agent intellect renders the phantasm intelligible in the possible intellect. Note that although we use the term "agent intellect" there is only one agent, the person. "Agent intellect" refers to one function of the mind which can be identified in order to discuss the structure of thought. The proper object of the agent intellect is to dissociate the universal from the particular. Yet, a human act deals by necessity with both universals and with particulars. Hence, inextricably linked with this intellection and rendering it possible are very material processes. Furthermore, deliberation, in its duration, necessarily involves material cooperation at what we now understand as the neural level. Where the particular is present, the material must also be in evidence; "Human actions always have to do with the particular and the contingent." (Gilson, 253) Although we say that an act of the will is "indecomposable" (Gilson, 253) we do not deny that concrete imagery in the brain requires some material mediation. Hence we also say that the will involves "some kind of experience of the object to which it is attaching itself", "*quasi experientiam quondam sumens de re cui inhaeret*" (*ST*, Ia-IIae, Q.15, Art.1). These words are significant. They indicate that the will, through the sensitive appetite, is affected by the representations, phantasms, of the particular goods. As we have seen briefly in **Chapter 1**, a phantasm is an image of a particular thing: "*similitude rei particularis"* (*ST*, Ia, Q.84, Art.7.2). Phantasms are preserved in corporeal organs: "*similitudines individuorum existents in organis corporeis"* (*ST*, Ia, Q.85, Art.1.3). They are individual species residing in the imagination. Without question, phantasms associated with specific biological representations are integral to the human act, and therefore also to the operation of virtue.

[850] It is evident too, that while the action of rallying followers by an improvised flag is, in this light, a single act, it could also be regarded as a sequence of completed acts: an urgent request to a follower to find a proper flag, the improvisation of the sheet-flag, the communication of the action to followers, the formation of the column heading up the hill, etc.

observation of reality, accommodating the need for actions to be refined and finally elected on the basis first of initial attraction, initial information, and then of practical deliberation about alternatives and means to be employed. Furthermore this model accommodates the need for perfections of these steps if the act itself is to be well performed. These perfections are the virtues.

Table 3.1
The Human Act[851]

Mind	Will
Intention About ends	
1. Judgement that the end exists	2. Wish or want *velle, simplex voluntas*
3. Judgement that it can be achieved	4. Determination to achieve it *volition, volo, voluntas efficax*
About means	
5. Deliberation about ways and means *consilium*	6. Approval *consensus*
7. Discrimination and selection *proairesis*	8. Choice *electio*
Executio	
9. Practical and effective command *imperium*	10. Application to deed *usus activus*
11. Performance by appropriate power or powers *usus passivus*	
12. Fulfilment *quies*	

Table 3.1 illustrates that the human act is a complex reflexive process involving, as Gilson puts it, the intellect and the will, “acting and reacting upon each other”. [852] All the steps up to 11 are completed prior to executive action, prior often to anything apparent to the observer. Only the last steps involve manifest execution of the task and consequent fulfilment. [853] [854]

[851] Aquinas, *Summa Theologiae 1a2ae. 18-21*, ed. Thomas Gilby OP (Cambridge: Blackfriars/McGraw Hill, 1965), Volume 18, Appendix 5.
[852] Gilson, *The Christian Philosophy of St Thomas Aquinas*, 253.
[853] Aquinas, *Summa Theologiae 1a2ae. 18-21*, ed. Gilby, Appendix 5.
[854] These steps are not discrete events in a chronological succession. McInerny holds that Aquinas presents the three acts of the will in order of intention as volition, enjoyment, and intention; and in the order of execution, as above, consent, choice and use. (Ralph McInerny, “*Ethics”* in *Cambridge Companion to Aquinas*, ed. Norman Kretzman and Eleonore Stump (Cambridge:

Gilson explains that the process of the human act is initiated by "an indecomposable movement of our will"[855] (step 2 above) in the concrete apprehension of some goal (step 1 above). This indecomposable, and therefore non-material, enlightenment is an "intention" such as, for example, "I want to help this person with the gangrenous foot", "I want to communicate the importance of peace". 'In wishing the end, it necessarily wills the means, therefore the intention of the end and the willing of the means constitute but one single act....To will a remedy in view of health is one act of willing'.[856] These initial steps pass through refining stages (steps 4 and 5).

The intellect then provides preliminary deliberation defined as <u>counsel</u> (step 5). This "deliberation concludes with a judgement of the practical reason" [857] presenting several judgements with good under various aspects (step 7). For example Nagai could consider the various merits of calligraphy, poetry or prose to impart a message of peace.

The will is moved to what is good in each of the options (step 6). The will attaches itself to these choices offered by deliberation in the step we call <u>consent</u> (step 7). For example, in the scenarios above consent would be present just prior to the readiness to wash the foot, at the moment the plan is settled that will result in putting pen to paper, etc.

Finally the choice of one means to an end is made (steps 9-11). It depends "in part upon the intellect and in part upon the will"[858] which Aquinas concludes primarily

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Cambridge University Press, 1993), 205-208.) It is of course not reasonable to suggest that an action can actually be subdivided into watertight compartments. Nagai's creation of a poem would defy this discrete categorisation, and McInerny, to illustrate variations possible in the framework, points out that often in real life consent and choice are in the one step.

[855] Gilson, *The Christian Philosophy of St Thomas Aquinas*, 253.
[856] Gilson, *The Christian Philosophy of St Thomas Aquinas*, 253.
[857] Gilson, *The Christian Philosophy of St Thomas Aquinas*,) 253.
[858] "*appetitivus intellectus, vel appetitus intellectivus*". *NE*, II 5 2.

must be an act of the will,[859] because substantially this election is the movement of the soul towards the good which it chooses.

Note the complex interplay of the intellect and will in the lead up to the actions central to the scenarios above. Intellect, will, sensitive appetite, imagination and memory (for example in memory of the symbol of the flag) each play clear respective roles in the process of the human act. Let us now look specifically at the contributions of emotion and virtue.

Where do emotions fit into the human act? Sense appetite acts upon the will particularly at step 2 and to some extent at steps 4, 6 and 8. Undue sense appetition can negate effective use of the intellect as we see for example in Nagai's original struggles to overcome his passionate reaction to the flyer. In the exercise of a virtuous act, temperance and fortitude 'respond to the direction of reason'.[860] Appropriate sense appetition in the form of inspiring emotional symbolism, contributes to reason, motivating the followers of Nagai to retake rational control of their behaviours.[861]

Where do the virtues fit in to the human act? The active powers of intellect, will, and sensitive appetite are perfected by practical reason in the intellect, justice in the rational appetite, and the virtues of the sensitive appetite. These virtues, and in this study I focus on the cardinal virtues, are dispositions in some way facilitating the governance of reason. Gilson explains that when there is insufficient formation of these appetites they can distort the reasoning process.

> The person in whom concupiscence is the master judges his own desires to be good, even when such a judgement contradicts the

[859] *ST*, Ia, Q.83, Art.8 and Ia-IIae, Q.13, Art.1.
[860] Aquinas, *Disputed questions on virtue*, xiii.
[861] Understandings of the contribution of reason to rationality are a major area of interest in philosophical psychology.

> universal judgement of reason. It is to neutralise such sophistries of passion that man must be strengthened with moral habits.[862]

McInerny observes that prudence perfects the whole reasoning process: "This analysis of the complete human act into its components is another look at practical discourse as issuing in the command of prudence."[863] This overarching involvement of prudence at the various stages of the human act will have considerable significance in discussion in later sections of this chapter, as will justice which perfects the will with a disposition to act always taking one's duties to others into account.

Virtuous acts derive from an appetite inclined easily by reason perfected by prudence. In differing contexts they can be both cause and result of the "training of our emotions to respond to the direction of reason… a most difficult task".[864] McInerny clarifies that temperance and fortitude respond to the direction of reason, but are dispositions of the sensitive appetites: "The habit or disposition in the concupiscible appetite to respond to the direction of reason, and thus to pursue pleasures rationally, is called temperance. The habit or disposition to react rationally to threatened harm is called courage."[865]

3.1.4 Some observations about the characteristics of virtue.

In the light of this understanding of the human act and how it is perfected by virtue I am now in a position, by analysis of the scenarios above, to suggest a number of features of acts of virtue and of the relationship between the virtues. These initial observations based on common features evident in the various scenarios will be complemented by a systematic review of the central characteristics of virtue according to Aristotle and Aquinas in **3.2** and **3.3**.

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[862] I have drawn in this section from the masterful overview of the Thomistic analysis of the human act by Gilson, *The Christian Philosophy of St Thomas Aquinas*,
[863] McInerny, "*Ethics,*" 208.
[864] Aquinas, *Disputed questions on virtue*, xiii.
[865] Aquinas, *Disputed questions on virtue*, xiii.

i. Acts of virtue may be accompanied by a deep sense of peace, fittingness, and joy.

We see this in the exhilaration experienced by Nagai in China, by the calming effect of the focused orderly response to Nagai's example and to the symbol of the flag, in the calming of Nagai's passion as deliberation conquered raging emotion, and most of all, in Nagai's stable resolute peace in the face of his impending death.

ii. Effective action is evident in each scenario.

Each scenario presented above leads to a "successful" outcome because of Nagai's actions. The success of the outcome is certainly found in the effective cleaning of an enemy's foot, creation of an improvised flag, comprehension of the message of a leaflet, and completion of a work of art. The prudent election of means to perform planned actions is a constant element in these examples.[866]

iii. Due regard for the needs of others is evident in each scenario.

Preoccupation with the rights and needs of others appears to be an abiding motivation in virtuous action. The interpersonal dimension, arguably perfected by justice, is inseparable in each scenario: Nagai measures and devises his own actions by their impact on others. Hence, the cleaning of the foot is a demonstration of the conviction to serve without discrimination. The creation of the flag has the result of unifying and giving hope to the survivors.[867]

iv. Virtues appear to operate in an integrated way, in concert, with each other.

In the first scenario Nagai compassionately washes the enemy soldier's gangrenous limb, apparently moved by principles of duty and humanity. His action brings together prudence which is reflects the practical execution of the deed, justice which is the virtue by which he is disposed

[866] Of the examples, the fourth scenario provides the best demonstration of calmly considered actions tailored to the achievement of specific goals for a range of desired outcomes. Nevertheless, each demonstrates the directive role of reason in execution of the task.

[867] Further examples: the deliberation over the leaflet allows him to demonstrate to another the need for calm rationality in a crisis; and the composition and publication of the poem allows him to inform others with his refined insights.

to fulfil what he sees as his duty towards others, and self control and fortitude in suppression of his revulsion and his readiness to face difficulty.[868]

v. <u>It would appear that virtue can consist not only in rational management of emotion, but also in refined attention to one's emotional state.</u>

In the third scenario we see emotion and an overactive imagination clouding reason. We see too, Nagai's response of deliberation to manage that emotional inflammation so that he can act rationally and nobly. In contrast we observe in the episode with the flag that an emotion laden symbol can trigger virtuous actions.[869]

vi. <u>Prudence and justice may involve instantaneous insights.</u>

Although we have seen that, as in the third scenario, prudence may contribute to protracted deliberation and reasoning, at other times there is evidence of instantaneous flashes of conviction, of recognition of truth. For example Nagai himself describes the moment, while bathing a putrid foot, that the dignity of his calling to all without exception dawned upon him. Such instantaneous comprehensions of truth are consistent with the Aristotelian/Thomistic account of rational operations perfected by prudence and justice.[870]

vii. <u>Acts of virtue appear to arise from and lead to refined sentiments of self sacrifice, beauty and nobility.</u>

Note for example his generous self sacrifice as Nagai feels the conviction of serving the enemy wounded. Later in the conflict he would risk his very life and career, disobeying explicit orders, to save the lives of prisoners. We

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[868] Three further examples. In the second scenario, Nagai's sense of duty and concern for his colleagues lead to an act of great fortitude. His followers are in turn overcome their disorder and lack of self control by the symbolic reminder of needs greater than their own. Again we see all the virtues operating in an integrated manner. In the third, Nagai overcomes a response of great passion through great will power and determination to deliberate before passing judgement. It is evident that prudence and justice cooperate in the effective direction of emotion. Finally, in the fourth, Nagai's habitual self control and fortitude provide a platform for calm reflection. From that calm reflection comes an abundance of acts of service to his fellow man.

[869] Similarly in the fourth scenario Nagai's simple poem can evoke in us as we read it our own inner acts of compassion, essentially acts of love of fellow man, akin to justice.

[870] Similarly the mere glimpse of the flag, with its inherent truth of patriotism and solidarity, moved Nagai's companions.

also witness the refined love of country that underpins Nagai's inspirational action with the flag, and his love of humanity that drives him to insist tirelessly on peace after the war.[871]

viii. <u>The state of virtue appears to culminate in a higher, more refined capacity to act well.</u>

The last six years of Nagai's life are marked by prodigious industry under the most difficult circumstances, conducted in a spirit of deep humanity and cultural sensitivity, amidst personal austerity, and all the while maintaining mastery over wayward emotions of anger, revenge and bitterness, and manifesting a deep peace of heart to all despite personal and national tragedy. In total these portray a man who is a paragon of established, stable, personal qualities.

ix. <u>A life of virtue may find its culmination in a refined capacity to love others with deeds.</u>

It appears that Nagai, in his maturity, successfully channelled his energies into effective love of others.[872] Nagai's constant example through his illness, to his children, to visitors and to readers, was of loving concern. Such a disposition requires effective judgement, a highly refined capacity to measure one's actions against the needs of others, and the self control and tenacity necessary for the achievement of the goal. These final years of Nagai's biography suggest the capacity to love others with deeds to be the very crowning of the virtuous life.

3.1.5 The superiority of virtue ethics in accounting for noble human behaviour.

I have presented some detailed glimpses into the life of Takashi Nagai. His own account of actual behaviour appears to be reflective of the Aristotelian-Thomistic

[871] Furthermore, Nagai appears to draw strength from natural beauty: flowers, stars, and mountains. He is drawn to artistic expression to better communicate the refined sentiments that occupy his mind.

[872] It is reasonable to expect that such a selfless disposition has a prior history. Such selflessness is evident even the four scenarios: profound respect for others evident in his actions during the Chinese war; tireless attention to the victims of the bomb; and solicitude to provide effective leadership by example. These things demonstrate his dedication to others in years preceding his final illness.

understanding of virtue and the human act, from initial deliberation, through choice, to execution. It seems clear that the doctrine of virtue accounts effectively for the interplay of rationality with appetite and emotion, and thus offers an accurate understanding of human action.

In **1.6** it was noted that contemporary accounts of moral philosophy fall broadly into three groups: consequentialist ethical theories, deontological (duty based) theories, and virtue ethics. It is most interesting to compare these theories against Nagai's own moral decision making and his moral worldview.

If we study the four scenarios as test cases, examining them for whether Nagai acts out of an observance of rules or with an eye to bringing about a determined outcome, neither approach fits well with his behaviour without doing violence to the facts.

There was obviously no rule book for Nagai to follow to act well. For example, he explains that his treatment of the enemy soldier was prior to a realisation that he was observing any rule for his own behaviour. Similarly, the spontaneous action of improvising a flag could not be scripted; the unprompted conception of the action defies any explanation based on "duty" as an overriding motivation. Nor may Nagai's deliberation over the leaflet be interpreted as acting out of duty or observance of rules. It is clear that the various actions described arose from qualities in his character based on previously established behaviours, and from well formed convictions upon which he could draw.[873]

It is also clear that Nagai regarded his actions as intrinsically important, rather than as a simple means to an end. The creation of the flag was noble in itself, and integral to any positive outcome; it was not instrumentalised for some other consequence. His deliberation over the leaflet was prior to any goal setting. The

[873] There are of course literally infinite possibilities for individual moral acts: they may or may not be complex; they may be virtually instantaneous, or of considerable duration, and it is apparent that a virtue based ethical system allows flexibility in its response to moral dilemmas, to act well regardless of context.

prodigious output of Nagai's final years cannot be explained alone by a utilitarian framework; just as his literary and artistic endeavours and his advice for visitors transcend results. His very serenity is evidence that they are fulfilling in themselves. His dedication for the wounded without discrimination, his concern for those he was leading, and his love for his children and fellow countrymen, were all actions intrinsically important to Nagai, neither reducible to a sense of duty, nor to the expectation of a positive outcome. The love for others shown in these actions goes far beyond the strict reciprocity of some narrow conception of justice, highlighting the deficiencies of duty and consequence based measures in accounting for truly noble behaviour.

The concordance we have been seeing between these real scenarios and virtue theory demonstrate that an understanding of virtue is not an arbitrary or out-of-date framework which struggles to describe complex behaviours arising from either rational deliberation or emotional reaction. In fact, it would appear, *prima facie*, that it is virtuous character, not rule articulation nor outcome calculation, that is the well spring of spontaneous noble behaviours.

This ability for virtue ethics to account for noble behaviour and for the characteristics of noble personality in the real world is striking:

i. Nagai himself has adopted the view that moral behaviour is a consequence of character, the essence of a virtue ethics based approach. He advises the young men who come to see him that they should meditate, to change themselves, lest they become "the type of person" who stamps and screams. It is clear that moral behaviour, in Nagai's conception, is a consequence of character. Also, it is impressive to note that, even some 15 years before in China, his biographer noted his delight in realising the "change" in his personality, taking delight equally in treating allies and enemies. Nagai's own words reflect this discovery.
ii. Nagai's very qualities of character stand out as the most psychologically attuned explanation for Nagai's freely chosen behaviours, within a broader

understanding of human nature. This approach adequately accommodates rationality, free choice, motivation, and human fulfilment.

iii. Finally, Nagai's character based worldview of ethical behaviour was formulated not because of training in western classical philosophy but intuitively in a culture so different to that of the West. Nagai was a man of his times and nation, patriotic with what we might call a stoicism or even fatalism in handling difficulty typical of the nurture of a Japanese upbringing, and he still regarded moral decision making as an extension of character. This suggests that a virtue based view of human personality satisfies something deeply attuned to our nature; this is absent or less evident in a consequentialist or duty-observant paradigm for assessment of behaviour.

On any reasonable measure, Nagai is indisputably a noble and admirable human being: this study demonstrates that virtue ethics is well able to account for the moral growth, for the the decision-making and actions, for the stable qualities of character, and for personal fulfilment in maturity, of such a person. The study suggests that consequentialist and deontological approaches may be less effective in accounting for behaviour, character and fulfilment in such people.

In the balance of the current chapter the matter of these scenarios will also be used in illustration of characteristics of virtue. In **Chapter 5** I will return to one of these scenarios to illustrate the neural bases of virtue *in actu*, and in **Chapter 6** I will revisit the comparative evaluation of ethical paradigms.

3.2 The state of virtue.

In **3.2** and **3.3** I apply texts from Aristotle and Aquinas concerning the nature of virtue to these reflections about Takashi Nagai. First some contextual insights:

We know more about the man Alexander the Great than about his tutor Aristotle, but of course Aristotle's fame does not hinge on the achievements of a hyperactive pupil. As the *Britannica* puts it, Aristotle “perhaps more than any other thinker has characterised the orientation and content of all that is termed Western Civilisation”. His *Nicomachean Ethics* is one of the great texts of civilization. In it Aristotle gave us the first systematic vision of virtues as the basis for perfection of the human character, a view that has prevailed in all but the most recent decades of western civilisation, a view too that many have argued is universal to human experience.[874]

Some say the book was composed for Nicomachus, Aristotle’s son, others that the son was the editor; but how attractive it is to think that the great Philosopher may have written this beautiful account of human fulfilment for his own son. The argument of the work hinges on crucial linkages: between habit and virtue – “Moral virtue comes about as a result of habit”[875] - Aristotle goes to lengths to explain that virtues are deeply rooted habits of action, not just “values”, or nice sentiments; and between virtue and happiness – “Happiness is the reward of virtue”.[876] Aristotle realised too that fostering virtue requires personal effort, and if they are to be formed in a young person, parental expertise and example are important. He emphasised the importance of building these good habits in the early years of a child’s life. [877]

There are many beautiful passages in this work: close analyses of the various moral virtues, an insistence on intellectual virtues, a whole section dedicated to explaining the link between true friendship and happiness. And in culmination, the meaning of happiness, *eudaimonia*, itself is studied. The ten books of the work commenced with an inquiry into the meaning of happiness and they conclude by drawing the distinction between pleasure and happiness. Joseph Pieper saw this

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[874] See discussion in section immediately above with reference to Nagai. Martin Seligman and Christopher Peterson, *Character Strengths and Virtues* (Oxford: Oxford University Press, 2004); and C. S. Lewis, *The Abolition of Man* (1943);
http://www.columbia.edu/cu/augustine/arch/lewis/abolition1.htm#1 (accessed 6 November, 2012).
[875] *NE*, 1103a.
[876] *NE*, 1099b16.
[877] *NE*, 1103b.

discovery and articulation of virtues as a turning point in civilised consciousness.[878]

The *Nicomachean Ethics* is more than just another book on a dusty classics shelf! Surely we disregard such a heritage at our own peril.

In forming my views for the sections that follow, in addition to the primary texts of Aristotle and Thomas, I have drawn from a range of commentators, including Sherman, Irwin, Broadie, Hutchinson, Pieper, Porter and McInerny. My intention has been to steer clear of controversial matters providing a systematic, succinct review. I rely on key source passages in order to identify essential characteristics that will be a focus for the task of **Chapter 5**.

Essential characteristics for the state of virtue are identified below in **3.2**, and features associated with the development of virtue in **3.3**. Then, in the light of a discussion of the cardinal virtues in **Chapter 4**, my aim will be to distill from this list the characteristics of virtue that we may reasonably understand to have a biophysical basis.

3.2.1 Virtues dispose the appetites, the source of all human acts, to rationality.[879]

In **Scenario 3** we witnessed Nagai's emotional response to the leaflet calling for Japanese surrender. He described his repeated efforts to consider the American demand and he described his unwillingness to accept what he was reading. Finally only on the fourth and fifth readings did he accept the truth of what he was

[878] J. Pieper, *The Four Cardinal Virtues.* (Notre Dame, Indiana: University of Notre Dame Press, 1966). "This particular intellectual framework, the formula which is called the "doctrine of virtue," was one of the great discoveries in the history of man's self-understanding, and has continued to be part and parcel of the European mind. It has become a basic component of the European consciousness, and the result of centuries of persistent intellectual endeavour by all the creative elements of the emerging West, both the Greeks (Plato, Aristotle) and the Romans (Cicero, Seneca), both Judaism (Philo), and Christianity (Clement of Alexandria, Augustine)."
[879] Emotions are neither good nor bad in themselves but we must manage them. Aquinas wrote: "Passion, to Aristotle, is something to which we must choose to react." (ST, Ia-IIae, Q.59, Art.2)

reading. This effort to confront something deeply unpalatable bespeaks qualities of character, and a habitual restraint that withholds final judgement and continues deliberation without committing to an unbridled emotional response until a matter has been thoroughly considered. It illustrates well the capacity for trained passion to accept the guidance of reason, albeit with initial reluctance. In a similar way Nagai controlled his revulsion towards the gangrenous state of the enemy soldier's foot, and overcame his severe weakness to inspire his fellow workers by means of the improvised flag.

In these examples we are witnessing the habitual dispositions first of all in Nagai's sensitive appetites to respond to his direction, and also in his rational appetite, his capacity for make well deliberated choices responsive to the rights of others.

For clarification, let us return briefly to the model of the human act and to the notion of motivation. Whenever we act, we act for some purpose, we move toward something that we find appealing for some reason. Aristotle and Aquinas suggest that our appetites, both sensible and rational, themselves need to have been trained if a person is to possess such restraint and self control as we see in Nagai.

At the foundation of all good human activity is self management of the passions by temperance and fortitude. For this reason too, the will, or rational appetite, also "needs to be disposed to its operations by means of habits".[880] Aristotle had taught that it was by these habits, by the moral virtues, that "We are directed well or ill in reference to the passions."[881] Justice is a disposition of the rational appetite, the will, whereas fortitude and temperance are of the sensitive appetite. As we have seen in the overview of the human act, virtuous acts are commanded

[880] *ST*, Ia-IIae, Q.49, Art.4.1.
[881] *NE,* ii 4

by the rational appetite disposed by justice in concert with the intellect disposed by prudence.[882]

Habitual dispositions of these powers of the sensitive and rational appetites are the key to living well, to living according to reasoned choices.[883] "Knowing what is right does not make a wise man."[884] But, "Habits are necessary in order to act well."[885] Further Aquinas explains, "Human virtue is an operative habit, a good habit, productive of good works". [886] Aquinas explains that the particular type of habit that is virtue is "a principle of the movement of the appetite, being a kind of habit."[887] This differentiates it from a passion which is "a movement of the sensitive appetite". In other words, virtues in the sensitive appetites are dispositions in our passionate reactions.

In the two subsections which follow I examine the nature of the dispositions first of the sensitive appetites, and then of the rational appetite.

3.2.1.1 The virtues of the sensitive appetite refine our habitual dispositions to pain and pleasure.

In his final years, having suffered the loss of his wife, friends and colleagues, having seen the accomplishments of years of research vaporise before his eyes, as his life ebbs away through the inroads of leukemia, and in the midst of national humiliation and tragedy, Nagai demonstrates the most remarkable capacity to transcend his circumstances. We have read how, in the fourth scenario, he maintains his equanimity and a prodigious output of work in the service of his

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[882] Aristotle described virtue as the "habit of choosing the rational mean as a prudent man would discern it." *NE*, 1106b36.
[883] Nagai's self mastery includes not only articulated convictions of respect for fellow man, and his medical expertise, but also his mastery of his disgust at the unpleasantness of his task: actions in the sensitive as well as the intellectual domain.
[884] *NE*, 7.10.
[885] *ST*, Ia-IIae, Q.51, Art.1.3.
[886] *ST*, Ia-IIae, Q.55, Art.3.
[887] *ST*, Ia-IIae, Q.59, Art.1.

countrymen in a great work of national healing and reconciliation. He exemplifies the refined emotional life that Aristotle suggests is central to human wellbeing.

> Virtue consists in rejoicing and hating and loving aright, there is clearly nothing we are so much concerned to acquire and to cultivate as the power of forming right judgements, and of taking delight in good dispositions and noble actions.[888]

What exactly is this "hating and loving aright"? Aristotle insists that human motivation reduces to seeking pleasure and avoiding pain: "What affirmation and negation are in thinking, pursuit and avoidance are in desire."[889] He reflects on the danger of poor choices when "we choose the pleasant as a good, and avoid pain as an evil."[890]

That man has control over pleasure and pain differentiates him from the animals.[891] Aristotle argues that the capacity to control appetite is the mark of rationality. We see this in Nagai's self discipline, both in the face of a natural distaste for washing a putrid wound, and in maintaining equanimity in the face of his illness and separation from his children.

Pleasure and pain are universal in human experience… but it is how we react to them, and how we direct them that leads to peace or frustration. [892] [893]

> ...every passion and every action is accompanied by pleasure and pain....it is by reason of pleasures and pains that men

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888 Aristotle, *Politics*, 1340a18.
889 *NE*, 1139a18-26.
890 *NE*, 1113b1.
891 *NE*, 1111b13-16. "Choice is not common to irrational creatures, but appetite and anger are. The incontinent man acts with appetite but not with choice; while the continent man on the contrary acts with choice but not with appetite.... appetite relates to the pleasant and the painful, choice to neither the pleasant nor the painful."
892 *NE*, 1105a12. "The whole concern both of virtue and of political science is with pleasure and pains; for the man who uses these well will be good, he who uses them badly bad."
893 *NE*, 1104b11. "...moral excellence is concerned with pleasures and pains; it is on account of the pleasure that we do bad things, and on account of the pain that we abstain from noble ones."

> become bad by pursuing (the wrong pleasures) or avoiding (worthy pains)...[894]

It is in how we manage these experiences that virtue resides, “Virtues and vices are dispositions to find certain things pleasant and certain other things unpleasant. ... virtue is good taste in practical matters.” [895] And ultimately, therefore, this is the making of character, “Character is good or bad by pursuing and avoiding certain pleasures and pains”.[896]

3.2.1.2 Virtue is a habit of choosing.

Time and again, Aristotle insists that virtue is a habit of choosing, “a prohairetic state”.[897] He says, “The virtues are choices or they involve choice”[898] and, that “virtue is a habit of choosing the rational mean as a prudent man would discern it.”[899] It is choice in accordance with right reason, *orthos logos*.[900] [901]Aquinas echoes this: “The principal act of virtue is choice.” [902]

Choice is principally an act of the rational appetite, the will.

> Choice is substantially not an act of reason but of the will: for choice is accomplished in a certain movement of the soul toward the good which is chosen. Consequently it is evidently an act of the appetitive power.’[903]

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[894] *NE*, 1104b13.
[895] D. S. Hutchinson,*The Virtues of Aristotle* (London: Routledge and Kegan Paul, 1986), 5.
[896] Aristotle, *Eudemian Ethics*, 1221b32-34.
[897] See perceptive summary discussion of the prohairetic state in Sarah Broadie, *Ethics with Aristotle* (Oxford: OUP, 1991), 78-82.
[898] *NE*, 1106a3-4.
[899] *NE*, 1106b36.
[900] A further masterful summary of *orthos logos*, right reason, is to be found in Broadie, *Ethics with Aristotle*, 82-87.
[901] *NE*, 1107a. “Virtue is a state of character, concerned with choice, lying in a mean... determined by a rational principle, by that principle by which the man of practical wisdom would determine it.”
[902] Aquinas, *Disputed Questions on Virtue,* 4 ad 2.
[903] *ST*, Ia-IIae, Q.13, Art.1.

In short, virtuous action is characterised by well informed, right desires. The glimpses into Nagai's life illustrate some important clarifications about choice. Note, for example in the Chinese field hospital, the series of choices that make possible Nagai's powerful and articulated conviction that he is now a doctor for both friend and enemy. He chooses to carry out a repulsive task in the treatment of an enemy, he chooses to focus not on the disagreeable nature of what he is doing or a natural fear in treating an enemy, and instead he chooses to broaden this isolated incident into rule for his general behaviour; finally he chooses to write about the moment that night further reinforcing the conviction about what he has done and will do in future.

Sherman comments extensively on the complexity of the range of tasks and operations associated with choice. She holds that all have a role to play in virtuous action: correct perception, consideration of all issues, comparison of compelling ends, [904] sound deliberation about means[905], choice of actions "for their own sakes",[906] sensitivity to ethical salience.[907] She writes,

> Virtuous action will combine a judgement of circumstances, reactive emotions, and some level of decision about how to act. (Virtuous action may involve the following) emulated models... general precepts and rules of thumb. ... (Also required will be) cognitive skills, imagination, sensitivity...(Furthermore being) sensitive to the circumstances in which action is called for as well as flexible in one's conception of the requirements of a precept is all part of practising virtuous action.[908]

Ultimately, this habit of choosing requires rectitude in the sensitive appetites, in the rational appetite and in the intellect: "Since moral virtue is a state of character concerned with choice, and choice is deliberate desire, therefore both the

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[904] Sherman, *The Fabric of Character* (Oxford: Clarendon Press, 1989), 174.
[905] *NE*, 1113a14.
[906] Sherman, *The Fabric of Character*, 175.
[907] Sherman, *The Fabric of Character*, 28.
[908] Sherman, *The Fabric of Character*, 179.

reasoning must be good and the desire right, if the choice is to be good. Desire must pursue just what the reason asserts."[909]

3.2.2 Virtue lies in choice of the mean.

Virtue lies at the intermediate point, between excess and defect in relation to passions and actions.

> To feel (passions) at the right times, with reference to the right objects, towards the right people, with the right motive, and in the right way, is what is both intermediate and best, and this is characteristic of virtue. Therefore virtue is a kind of mean.[910]

We see this exemplified in the circumstances of Nagai's fabrication of the flag, an act of soundly considered fortitude. He accepts help from others and allows someone else to lead with the flag, but he sufficiently overcomes his own life threatening weakness to carry out the decisive actions required to restore hope to his shattered friends. Although, given his very great blood loss, the exertion is life threatening, the risk is warranted because the circumstances are dire. Nevertheless where he can step back and pass the responsibility to others he does so.

Aristotle argues that it is of particular importance to note that the mean is understood in relation to the particular person and his circumstances, and is dependent upon the correct deliberation and evaluation of the subject acting.

> Virtue then is a state of character concerned with choice, lying in a mean, that is *the mean relative to us* (my italics), this being determined by a rational principle, and by that principle by which the man of practical wisdom would determine it.[911]

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[909] *NE*, 1139a18-26.
[910] *NE*, 1106b21-23.
[911] *NE*, 1107a1-3.

In Nagai's situation, it was essential for him to assess his own physical state, judging the extent to which he needed to rely on others to sustain his own capacity to lead, yet provide the effective leadership required.

3.2.3 The motivation of virtue: "Virtuous actions are done for the sake of the noble."[912]

Motivation is the end to which we aim in an action. Gilson explains the need we have for fortitude and temperance perfecting the sensitive appetite, and of justice in our rational appetite, at the commencement of the human act:

> Ends are, in human acts, what principles are in the speculative sciences. To will the fitting end depends on a moral virtue. Once the end is willed, it is an intellectual virtue which will deliberate and choose the means suitable to the end. This virtue is prudence.[913]

In the scenario involving the flag, Nagai envisages his goal and the important impact it will have. He then he sets about fabricating a flag when an actual flag cannot be found. Prudence perfects the practical intellect in its deliberation and election of means.

Aristotle holds that virtuous actions are carried out "for their own sakes"[914], but this expression needs to be understood correctly. We must reconcile this with the understanding, time and again in Aristotle, that virtuous actions are carried out for noble reasons: "Virtuous actions are noble and done for the sake of the noble."[915]

[912] *NE*, 1120a23.
[913] Gilson, *The Christian Philosophy of St Thomas Aquinas*.
[914] *NE*, 1105a34. Also, in personal communication from Professor Julia Annas, July 2008.
[915] *NE*, 1120a23.

> A brave man will face death, "as the rule directs, for honour's sake… it is for a noble end that the brave man endures and acts as courage directs.[916] [917]

Aristotle makes clear that noble reasons are not extrinsic optional goods such as fame and wealth, but intrinsic goods such as one's own true welfare, and service to others. Virtuous actions are carried out "for their own sake", for intrinsically good reasons, whereby the very action of the virtue brings about the good outcome intrinsic to the action. Such intrinsic goods are manifestly present underpinning Nagais' actions: his very service to another in washing his foot, the very action manifesting remarkable dedication to duty and self control, is the end of his action. Intrinsic to this action also is the good respect for fellow man, perfected by justice. Therefore actions can be virtuous, "even if these actions do not ultimately achieve their planned goals."[918]

3.2.4 Virtues bring about states of character.[919]

Our character is the sum total of our behaviours arising from our habits. Virtue characterises who we are. An isolated action, perhaps an anomalous deed, does not define our character but habituations towards certain actions do. From their actions we know what things are. [920] [921]

Aristotle argues that virtues are a fundamental feature of soul:

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[916] *NE*, 1115b12, 23-34.

[917] *NE*, 1116a15. Whereas to face death for an ignoble end is not courage: "To die to escape from poverty or love, or anything painful, is not the mark of a brave man, but rather of a coward.... it is softness to fly from what is troublesome, and such a man endures death not because it is noble but to fly from evil."

[918] Sherman, *The Fabric of Character*, 176. We see this in Nagai's commitment to noble activity regardless of outcome. Noble actions enrich us regardless of the outcome. In this the human flourishing engendered by virtuous action is evident. Nagai has no control over whether or not message to his young visitors to go and meditate away from the pressures of daily existence will be put into effect, but by giving the message in all good will, he himself is perfected.

[919] In the expression "states of character" I offer a plural of "character". I am not suggesting two distinct concepts.

[920] *ST*, Ia-IIae, Q.18, Art.1. "*unaquaque res talem actionem producit, qualis est ipsa*."

[921] Hence we read in Aristotle: "The quality of a life is determined by its activities." *NE,* 1.10.

> Things that are found in the soul are of three kinds – passions, faculties, states of character, virtue must be one of these..... by states of character (I mean) the things in virtue of which we stand well or badly with reference to the passions eg with reference to anger we stand badly if we feel it violently or too weakly, and well if we feel it moderately; and similarly with reference to the other passions.[922]

Virtues are distinct from faculties: "We are not made good or bad by nature."[923] Nor are they passions. "We feel anger and fear without choice, but the virtues are modes of choice or involve choice."[924] Rather "a virtue is a state (*hexis*)"[925] being neither a faculty nor a passion.

A virtuous character may be understood as a person habitually with desires in accord with his good. Following discussion of just acts, courageous or cowardly acts, and temperate or self indulgent or irascible acts, Aristotle writes: "States of character arise out of like activities... this is why the activities we exhibit must be of a certain kind".[926] Consistency is required to build qualities of character. [927]

In a real sense our choices that make us who we are: "Choice is closely bound up with virtue and discriminates characters better than actions do."[928]

> Virtues are… means, states of character, tending by their own nature to the doing of acts by which they are produced, and they are in our power and voluntary, and act as right rule prescribes.[929]

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922 *NE*, 1105b20.
923 *NE*, 1106a9.
924 *NE*, 1106a2.
925 *NE*, 1106a10.
926 *NE*, 1103b15.
927 *NE*, 1139a31-35. "The origin of action – its efficient, not its final cause – is choice, and that of choice is desire and reasoning with a view to an end. This is why choice cannot exist either without reason and intellect or without a moral state; for good action and its opposite cannot exist without a combination of intellect and character."
928 *NE*, 1111b6.
929 *NE*, 1114b26-28.

Although in particular situations a man may act under the compulsion of unregulated passion, if he was responsible for the choices that led to this state, there is an argument that the subsequent state of compulsion is freely chosen: "By their slack lives (they are) responsible for becoming men of that kind, and men make themselves responsible for being unjust or self indulgent."[930]

Of relevance here is a comment from one of Nagai's biographers, Glynn, who points out that at a point in the early 1930s Nagai stopped drinking heavily. He accepted responsibility for character and therefore modified his actions to bring about a different habitual state with respect to temperance and, in his last years, a most remarkable self control. By this action he would win praise from Aristotle.

> Not to know that it is from the exercise of activities on particular objects that states of character are produced is the mark of a thoroughly senseless person.[931]

3.2.5 Virtues accord with the natural perfecting of the person.

We have seen that the capacity to act habitually in accord with right reason is the hallmark of goodness, hence, the virtuous man is good: "It is impossible to be practically wise without being good."[932] Aristotle understood a virtue as an excellence of character, making "its possessor good and his work good likewise".[933]

He argues that the development of virtue is a perfection according to nature, represented, for example, by Nagai in his maturity, who presents as the "true and finished man of character".[934]

[930] *NE*, 1114a3-8.
[931] *NE*, 1114a10-11.
[932] *NE*, 1144a37.
[933] *NE,* 1106a15. Good is understood as that which is in keeping with nature.
[934] Pius XI, *Divini Illius Magister* (1929). This is a document focussing on education of the person.

> Virtue implies directly a disposition whereby the subject is well disposed according to the mode of its nature: wherefore the Philosopher says (*Physics* vii, 17) that "virtue is a disposition of a perfect thing to that which is best: and by perfect I mean that which is disposed according to its nature".[935]

By inclining us to "that which accords with reason", [936] virtues order the organism to self management, and are therefore a *natural* perfection of the person.[937] Note that Aquinas quotes Aristotle's insistence that virtue involves not only good actions, but that the agent be perfect in itself, a rational being must not act below itself.

There is an increasing amount of literature linking ethical behaviour, self control, comprehension of consequences, empathy with others, and so on, to brain activity, and in a similar way, a growing literature linking anti social behaviours to other distinctive characteristics of brain activity. But this study goes two steps further than this.

- I argue that the development of a virtuous character itself has stable and predictable neuronal concomitants.
- Second, I argue that this rational creature is fulfilled by the perfected development of his rationality through changes in neurobiological activities, processes, and pathways and that this development of virtuous character is the natural and fitting trajectory for human development. Therefore persons who fail to develop in this way, have, in a real sense, failed to flourish.

3.2.5.1 Virtue is pleasant.[938]

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[935] *ST*, Ia-IIae, Q.71, Art.1.
[936] *ST*, Ia-IIae, Q.71, Art.2.1.
[937] *ST*, Ia-IIae, Q.71, Art.1.
[938] For an understanding of the meaning of pleasure in virtue, see Broadie, *Ethics with Aristotle*, 90-95.

In the following sections we review the Aristotelian notion that virtuous action brings pleasure and ease of action in the short term, and in the longer term a stable disposition towards rational action, deep peace, and natural fulfilment in the perfection of the body itself.

There is a pleasure that arises simply because we pursue what we love and this pleasure results for all choices, virtuous or otherwise. All choices are accompanied by a certain pleasure. We choose according to what is noble, advantageous, and pleasant… most of all, pleasant, "for pleasure accompanies all objects of choice; for even the noble and advantageous appear pleasant." [939] In contrast, Aristotle urges us to *appropriate* pleasure and pain, the characteristics of virtue. "It is the mark of virtue both to be pleased and to be pained at the right objects and in the right way."[940]

The pleasure of virtue must be understood correctly.[941] Irwin explains further that virtuous people "take pleasure in facing the dangers that brave people have to face, and in avoiding misguided pleasures that intemperate people avoid. This is an important difference between virtue and mere continence."[942] The virtuous person has effectively come to a reassessment of what is pleasurable.

Broadie holds that this pleasure is distinct from the pleasures of enjoyment of an activity. She says that the virtuous person acts "freely, unreluctantly, ungrudgingly... taking satisfaction" in the activity:

> The virtuous person takes pleasure in his virtuous acts because they do not go against the grain; and because they express his moral stature which is metaphysically anxious (so to speak) to be expressed in action.[943]

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[939] *NE*, 1104b33-35.
[940] *NE*, 1121a4.
[941] Terrence Irwin, *Classical Philosophy* (Oxford: OUP, 1999), 260.
[942] Irwin, *Classical Philosophy*, 291.
[943] Broadie, *Ethics with Aristotle*, 91.

This refined ability for pleasure and pain is more pleasurable, in the Aristotelian account, than the pleasures of non virtuous activities. The greater pleasure accompanying virtuous action is attributable to "increasingly fine powers of discernment".[944] Sherman writes,

> The pleasure which arises from virtuous activity[945] is the pleasure of realising a virtuous state without either internal impediments (ie insufficient or conflicting motivation) or external obstacles. In this way, the pleasure of virtue falls under the general account of the pleasure of excellent activity.[946]

She notes Aristotle's view that virtue leads to more complete actualisation in an activity with therefore greater pleasure forthcoming, although "even the learner gains pleasure from the exercise of his abilities".[947]

Ultimately, in a state of highest virtue, "that which is virtuous is pleasant or free from pain."[948] The hallmark of exquisitely virtuous action is that it is effortless and intrinsically rewarded.

> Lovers of what is noble find pleasant the things that are by nature pleasant; and virtuous actions are such, so that these are pleasant for such men as well as in their own nature. Their life has... pleasure in itself.[949]

This intrinsic reward is seen in the joy that Nagai exhibits in treating the enemy soldier and most of all in the calm he communicates despite his illness. We also see in evidence a pleasure derived from the effortlessness of the action, the absence of internal impediment. Hence the energy that Nagai applies to his fabrication of the Rising Sun belies, is virtually oblivious to, his precarious physical state.

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[944] Sherman, *The Fabric of Character*, 160.
[945] *NE*, 1104b3ff.
[946] Sherman, *The Fabric of Character*, 185.
[947] Sherman, *The Fabric of Character*, 187.
[948] *NE*, 1120a27.
[949] *NE*, 1099a13.

3.2.5.2 “Happiness is the reward of virtue”.[950]

Ultimately however, not even the heightened pleasure of virtuous activity necessarily brings happiness. “Aristotle agreed with Plato’s claim that pleasure is insufficient for happiness. ... The goodness of pleasures must be measured by standards other than pleasure and pain.”[951]

In this section I look at the subjective peace of soul that virtue bestows. In the following section, at the objective perfection of the organism. Both enjoy a relationship to rationality and self management.[952]

The happiness of virtue may be understood at a richer level beyond pleasure. In in **1.6.3**, we have seen that, according to the Aristotelian-Thomistic view, human flourishing requires the development of intrinsic qualities of self management. Virtues are seen as constitutive elements of human wellbeing. Virtues enable man to be self directing,[953] and to reach his full potential in this life:[954] “The happy life is the life according to virtue lived without impediment.”[955] Ultimately virtue is ordained to flourishing.[956]

Because a virtue is essentially the facility for carrying out with ease a chosen action, virtues free us to act: releasing us from external pressures and also from debilitating bad habits, or vices. Virtues enable us to be self directing in life… education in virtue gives us the freedom to chart our own course in life. Baring misfortune, virtue allows the fulfilment of potential, self directed activity

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[950] *NE*, 1099b16.
[951] Irwin, *Classical Philosophy*, 260.
[952] Irwin, *Classical Philosophy*, 278. Irwin insists that a correct account of happiness “must give virtue a prominent place”.
[953] Aquinas makes it clear that virtues facilitate *human* acts, actions proper to a human being. Hence the exercise of a virtue is dependent on free will.
[954] *ST*, Ia-IIae, Q.55, Art.3.
[955] Aristotle, *Politics*, 1295a36.
[956] Aristotle’s term *eudaimonia* denotes primarily objective fulfilment, but also subjective peace of soul.

governed by right reason, and the choice and attainment of real goods: "Happiness depends on ourselves."[957] Virtue brings a certain self sufficiency, desirable in itself and conducive to peace of soul.

On this broad canvas, virtue is a decisive factor in human flourishing. Aristotle wrote, "Happiness is an expression of the soul in considered actions."[958] The Aristotelian notion of happiness requires activity, not merely potential for action. Aristotle pointed out that happiness is not found in being in a particular state, but rather in activities that are made possible by being in that state. [959] "Happiness lies ... in virtuous activities."[960] This may be understood not simply as the pleasure intrinsic to a virtuous action, but as the sum happiness accruing in a life of virtue.

This is the long term view, transcending the simple pleasure of an isolated activity, but finding habitual fulfilment in the activities of virtue. Virtue empowers us to be happy in the long run:

> For one swallow does not make a summer, nor does one day;
> and so too one day, or a short time, does not make a man
> blessed and happy.[961]

Nevertheless, Aristotle argued that the life of virtue cannot guarantee external goods and so happiness is still unstable and subject to good fortune. [962]

In the *Rhetoric*, Aristotle listed constituent parts of happiness: good birth, numerous good friends, wealth, good children, plenty of children, a happy old age, bodily excellences such as health, beauty, strength and athletic powers, large stature, fame, honour, good luck, and virtue.[963] Apart from those that are natural endowments such as stature and health, these constituent parts, most particularly friendships, good children and honour, derive from character itself.

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[957] NE 1.9
[958] NE 1.8
[959] *NE*, 1176bff.
[960] *NE*, 1177a11.
[961] *NE*, 1098a18.
[962] Irwin, *Classical Philosophy*, 329.
[963] Aristotle, *Rhetoric,* 1360b.

However, Aristotle added the significant proviso that the virtuous person, as he will never act in a base or hateful way, cannot be unhappy.[964] He summed up: "We have practically defined happiness as a sort of good life and good action."[965]

This deep seated, subjective happiness, even despite external circumstances is exemplified in Nagai's habitual peace of soul in his last years. His capacity for self management, although ultimately taken from him by physical deterioration, appears largely unhindered by fears or by the pursuit of illusory pleasures. He shows, on the contrary, an astounding capacity for the energetic pursuit of demanding goals.[966]

3.2.5.3 Virtue brings about human fulfilment.

Nagai's mature years demonstrate the objective flourishing integral to the life of virtue. The Aristotelian and Thomistic view is not only that the development of virtue empowers us to act freely and therefore take control of our lives, but also that this development is fitting for the nature of the organism itself; the virtuous life is a state of maturity, at both organic and personal levels.

We witness that Nagai, his character perfected by the dispositions of virtue, is empowered to act freely and knowingly in ways that further enrich him as a person. Jean Porter insists:

> The human person's capacity to act well will be a component, and not merely a disposable means, of her attainment of perfection as a human being. Thus virtue … enables the human

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[964] Irwin, *Classical Philosophy*, 329.

[965] Aristotle argued elsewhere that happiness is in some form of contemplation, made possible in turn by virtue. Cf *NE*, 1098b20.

[966] On the other hand Aquinas held that the ultimate task of the virtues, extends beyond self sufficiency to empowering man to reach his end in God. "The virtues are nothing but those perfections whereby reason is directed to God, and the inferior powers regulated according to the dictate of reason.... it is accidental to temperance and fortitude to subdue superabundant passion, in so far as they are in a subject which happens to have superabundant passions: and those virtues are *per se* competent to moderate the passions." (*ST*, Ia, Q.95, Art.3.)

> person to act well, that is to say, in accordance with her specific nature as a rational animal.[967]

It is suggested that the attainment of human goodness requires not only intellectual grasp of the human good, but this mastery must also reach into the passions and will in addition to intellect. Human goodness is both attainment of "an external standard of rationality or perfection and intrinsically consists in the perfection of the human capacities which are exercised in act".[968]

Nagai's state of virtue entails not only acts that are objectively good, but acts carried out with highly developed individual powers of action. Nagai's incisive and practical intellect and his will, which is finely attuned towards the rights and needs of his fellow man, operate within the context of an enriched and enriching emotional life. His life therefore accurately reflects the understanding that in virtuous activity it is insufficient that the right things be done, but they must also be done *well*, ie "out of well formed passions, a good will, and intelligent judgement".[969] Not only the external act must be good, but its execution will be a "manifestation of the perfection of the individual's powers of action." [970] There are, then, complementary outcomes accompanying a state of virtue: that the actions be good, and that virtuous activity make the agent good, formed as nature intended.

As the soul united to the body "perfects the soul",[971] it is reasonable to argue that virtue, in its biological and rational elements, perfects the person. Aquinas tells us that the development of virtue, in all its bodily implications, is for the perfection of the person:

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[967] Jean Porter, *Moral Action and Christian Ethics* (Cambridge: Cambridge University Press, 1995), 140.
[968] Porter, *Moral Action and Christian Ethics*, 141.
[969] Porter, *Moral Action and Christian Ethics*, 142.
[970] Porter, *Moral Action and Christian Ethics*, 142.
[971] Aquinas, *Questions on the Soul*, trans. James Robb (Milwaukee, WI: Marquette University Press, 1984), 59-62. Cited in Hayden Ramsay, *Beyond Virtue Integrity and Morality* (NY: St Martin's Press, 1997), 137.

> Virtue implies not only a perfection of power, the principle of action; but also the due disposition of its subject.[972]

"Due disposition" implies a disposition suited by nature, a flourishing of the organism at the biological level, hence the teaching of Aquinas is that virtue implies a material biological ordering of the matter that is in keeping with nature, in keeping with the way it is meant to develop. This suggests a further dimension to the notion of flourishing when applied to virtue. Virtue permits man to develop in the way that he is meant to.

We find insights into this term "due disposition" in Aquinas' speculation about the presence of virtue after the resurrection of the body. He holds the virtues of fortitude and temperance to be compatible with man's perfection, arguing that in the resurrected state,

> ...the irrational powers will be in the bodily organs, just as they are now. Hence it will be possible for fortitude to be in the irascible, and temperance in the concupiscible part, in so far as each power will be perfectly disposed to obey reason.[973]

Hence, in Thomas' vision of the perfected man, virtue has an integral role to play for it is none other than a rightly ordered management of the body. He writes,

> ...the function of virtue (is)... to make (the sensitive appetite) execute the commands of reason, by exercising their proper acts. Whereby just as virtue directs the bodily limbs to their due external acts, so does it direct the sensitive appetite to its proper regulated movement.[974] [975]

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[972] *ST*, Ia-IIae, Q.71, Art.1.
[973] *ST*, Ia-IIae, Q.67, Art.1.3.
[974] *ST*, Ia-IIae, Q.59, Art.5., Further, Aquinas holds that while the development of virtue is natural while the development of vices are somehow not natural for a human being.
[975] We have seen that this ordering by reason brings major consequences:

a. In the animated flesh of a human person reason disposes matter such that the habituated behaviours of the person bring ease of action, pleasure, autonomy, and a consequent happiness.

3.3 Acquisition of virtue.[976]

Aristotle refers with frequency to children and to the process whereby they acquire virtue. By nature, the child's deliberative capacities are "in an underdeveloped form",[977] and so the child lacks the reflective capacities for choice and action that characterise the adult. [978] As a consequence children pursue pleasures "not unqualifiedly good".[979] Therefore a child requires external reason to guide him or her.[980] The virtue of the child is "relative"[981] to the one in authority over him.

Of course it is not only children who are able to learn virtue. All of us can develop new behaviours and eliminate previous behaviours. Nevertheless the process of raising a child in virtue, involving as it does, not reformation of bad habits, but formation from a state of absence of habit, the state of childhood is naturally prior

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b. At the more immediate level, by rational actions the person is able to modify his organism in a way that the execution of future acts of the same type are facilitated. In this second sense, the person acting rationally, orders what Thomistic philosophers have called"secondary matter".
c. A third implicit consequence makes clearer the relationship of this ordination to human flourishing. Virtue orders passion. Just as the role of virtue is to bring about right order in bodily actions, fortitude and temperance, facilitated by acts of prudence and justice, give rise to passionate acts of the corresponding virtue. This right ordering includes "ordinate passion" (*ST*, Ia-IIae, Q.59, Art.5.1.)[975] and, in justice, joy. Just as the role of virtue is to bring about right order in bodily actions, fortitude and temperance give rise to passionate acts of the corresponding virtue. The virtue of justice can give rise to joy. Hence: "Those moral virtues, however, which are not about the passions, but about operations, can be without passions. Such a virtue is justice; because it applies the will to its proper act, which is not a passion. Nevertheless joy results from the act of justice; at least in the will, in which case it is not a passion. And if this joy be increased through the perfection of justice, it will overflow into the sensitive appetite; in so far as the lower powers follow the movement of the higher, as stated above (Q.17, Art.7, Q.24, Art.3). Wherefore by reason of this kind of overflow, the more perfect the virtue is, the more does it cause passion." (*ST*, Ia-IIae, Q.59, Art.5.)[975]

[976] The work of Nancy Sherman on moral education in Aristotle is a most useful source here. See for example, Nancy Sherman, *The Fabric of Character*, (Oxford: Clarendon Press, 1989); and Nancy Sherman, *Making a Necessity of Virtue: Aristotle and Kant on Virtue* (Cambridge: Cambridge University Press, 1997)..

[977] Aristotle, *Politics*, 1260a13-14.

[978] *NE*, 1111a25-26, 1111b6-8, 1144b8.

[979] *NE*, 1152b19-20, 1153a28-31, 1176b28-30.

[980] Aristotle, *Politics*, 1260a34, 1260b3-8.

[981] Aristotle, *Politics*, 1260a32-3.

to that of an adult. Fittingly the formation of children in virtue receives much attention from Aristotle.

The points which follow are not intrinsic to virtue, but contextual factors, in most cases, necessary contextual factors for the development of virtue. They are inherently associated with the development of virtue and represent, in most cases, the normal trajectory for its development. As such they reveal to us characteristics of virtue itself.

In many cases illustrations from the life of Nagai for a point in question immediately spring to mind. A source in this section is Nagai's most beautiful writing left for his children, published posthumously under the title *Leaving my beloved children*.[982] Aristotle's and Aquinas's understanding of the process of the acquisition of virtue are reflected in Nagai's life and writing; these parallels further strengthen the case for the doctrine of virtue as a model of human development.

3.3.1 Both "training" and "education" are needed to build virtue.

Aristotle explains that virtues develop as a result of training, understood as habituation, and education, moral tuition.[983] This is true in adults and children alike although a time of training is particularly appropriate in laying foundations for virtues. Habituation and teaching are presented as both necessary and complementary. A correct understanding of the distinction between habituation and teaching is important.

> Intellectual virtue in the main owes its birth and its growth to teaching (for which reason it requires experience and time), while moral virtue comes about as a result of habit.[984]

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[982] Nagai, *Leaving my beloved children behind.*
[983] Aristotle writes, "Some think we are made good by nature, others by habituation, others by teaching." (*NE*, 1179b20.) While he proposes a certain natural virtue in some (*NE*, 1144b3) an endowment received by virtue of particular temperament, his main focus is on habituation and teaching.
[984] *NE*, 1103a15-15.

In total, Aristotle's vision of moral education is of an education which "involves the rational understanding and appropriate training of one's emotions."[985]

Habituation is primarily associated with the moral virtues; teaching, with the development of prudence, and to some extent justice. Aristotle relates these tasks respectively to training and education. Within training he includes the role of parents and tutors in habituating certain behaviours, he includes compliance with demands placed by laws and family culture and affection, and he includes the virtually subconscious role of imitation and example.

Education is the process of developing the mind of one's charge, of nurturing fine and noble ways of seeing and responding to the world, of giving criteria. Broadie holds that this education does not lie in a teaching "which is a business of words, reason and explanations, but by a process called *ethismos*, the inculcation of *ĕthe* understood as habits or customs."[986] In turn *ĕthe* is the building material of *ēthe*, moral qualities. Hence education also employs strategies of habituation.

These features are found in the approach Nagai takes with his own children. He forms his children (his fellow survivors, visitors to his hut, and readers of his works, as well) in refined emotional responses: to difficulties, to self indulgence, and to the needs of others. He insists that they think their way through difficulties. He strives to provide example, teachings, affection, inspiring goals and experiences that will reinforce the formation he offers.

3.3.2 An emphasis on the early years assists in fostering virtue.

Nagai is dedicated to the training and education of his own children even in their youngest years.[987] This approach is certainly in keeping with Aristotle's insistence

[985] Irwin, *Classical Philosophy*, 290.
[986] Broadie, *Ethics with Aristotle*, 103.
[987] The dedication of Nagai is evident throughout his writings for his children. Nagai, *Leaving my beloved children behind.*

that the habits underlying virtue are more easily learned in younger years and that the opportunity must not be missed.

> It makes no small difference, then whether we form habits of one kind or of another from our very youth; it makes a very great difference, or rather all the difference.[988]

Aristotle argues that children are particularly suited for education in virtue. There are a number of reasons for this: the affection and attentive care of parents assists in the process; children are disposed to imitate; and the practice of obedience is training for obedience to one's reason. Furthermore the very fear of dishonour, which he calls shame, is more prevalent in youth (at least in those of ancient Athens) curbing excesses.

> Young people ... live by feeling and therefore commit many errors, but are restrained by shame; and we praise young people who are prone to this feeling.[989]

Early training then has the aim of fostering self regulation and independence of thought. It should be carried out with an eye on the future: "with a view towards the next stages",[990] looking forward to the day when this person possesses the intrinsic and extrinsic goods necessary for happiness.[991] Texts also suggest that early impressions are virtually indelible and that these first impressions must be well managed.[992]

The earliest years are years where training must take place if the process is to be most successful. Aristotle draws a distinction between virtues of intellect which require time and experience, and virtues of character, for which "no time should

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[988] *NE*, 1103b.
[989] *NE*, 1128b15-18.
[990] Aristotle, *Politics*, 1336b37 and 1340b35-9.
[991] *NE*, 1100a1-4.
[992] Aristotle, *Rhetoric,* 1371b4-10. Texts from Plato concur: "Anything received into the mind at that age is likely to become indelible and unalterable; and therefore it is most important that the tales which the young hear first should be models of virtuous thought." (Plato, *Republic*, Bk 1).

be lost before inculcation begins”. [993] Sherman is also quick to point out that the pre-rational years of childhood are also a rich period for moral attitudes, the development of refined attitudes towards others which will play such a part in later prudential assessment of situations.

3.3.3. Imitation can assist the formation of virtue.[994]

Nagai’s consciousness of the importance of imitation shows in his example to his followers in the tragic days following the bomb. He is careful to model bravery, calm deliberation, self control, and loyalty and patriotism. With his own children we see that he reinforced explanations with his own abiding serenity.

That children are impressionable and superb imitators was lost neither on Nagai nor on Aristotle. Aristotle noted how life experiences play such a great part in the training for virtue that is required in the young. He wrote of how natural it is for us all to derive joy from the perception and discrimination of sight.

> Imitating is natural to humankind from childhood up and human beings differ from animals in this, that they are the most imitative of creatures and learn first through imitation.... learning is the greatest of pleasures... we delight in seeing representations... [995]

We see an echo of this in Nagai’s encouragement to young visitors to find peace in natural beauty. Aristotle linked the joy in natural discovery found in children to their propensity for imitation, “this discriminatory activity will often take the form of mimesis.”[996] He noted that first impressions are often the strongest. He noted that experiences can also dispose to vice.

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[993] Broadie, *Ethics with Aristotle*, 71.
[994] See Broadie, *Ethics with Aristotle*, 116 for useful insights into the role of example in parental action.
[995] Aristotle, *Poetics,* 1448b4-17. See also *Rhetoric*, 1371b4-10.
[996] Sherman, *The Fabric of Character*, 167.

> We always like best whatever comes first… and therefore youth should be kept strangers to all that is bad, and especially to things which suggest vice or hate.[997]

Note Nagai's warning to his young visitors that unless they take deliberate action to manage their emotion, there will come a point where their emotions will manage them, they will become the *type* of persons who just "stamp and scream".[998]

Aristotle insisted on the corrupting effect of bad example.

> Banish indecent speech, and indecent pictures and speech from the stage, from the sight and hearing of the young. The Legislator should not allow youth to be spectators of iambi or of comedy until old enough to sit at the public tables and drink strong wine; by that time education will have armed them against the evil influences of such representations. [999]

This impressionability requires great responsibility on the part of those responsible for the child, whether they be family or in civil roles. He stressed the role that example can play in teaching adult responsibilities.

> The Directors of Education, as they are termed, should be careful what tales or stories the children hear, for all such things should be designed to prepare the way for the business of later life, and should be for the most part imitations of the occupations they will pursue in earnest.[1000]

We see Nagai's preoccupation to publish, to influence national culture in the crucial years after the war. He realised that if calm reconciliation did not prevail, anger and bitterness would exact a further terrible toll on his people.

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[997] Aristotle, *Politics*, 1336b35.
[998] Scenario 4 above.
[999] Aristotle, *Politics*, 1336a 27ff.
[1000] Aristotle, *Politics*, 1336a 27ff.

3.3.4 Virtues are acquired by repeated acts.[1001]

In Nagai's life there is abundant evidence that steady application to particular tasks is required to consolidate behaviours. He shows, from his reading and rereading the leaflet, that he had developed a facility for staying with a task until mastered. We know too from his biographers that he that treated wounded enemy soldiers consistently in an even handed, compassionate manner. We know too that he asked of his children what he demanded of himself: he encouraged his children to be persistent. [1002]

These are examples of the process of habituation described by Aristotle. We have seen that moral education consists of habituation and education. Habituation is possible because behaviour builds a greater facility for subsequent behaviours of the same type. "We get the virtues by first exercising them."[1003]

> We become just by performing just actions, temperate by performing temperate actions, brave by performing brave actions.[1004]

Children, most of all, learn by doing.[1005] Children, although not understanding all the reasons can still perform correct behaviours... to share, to wait patiently, to be satisfied with what one has eaten. [1006] All these behaviours are the stuff of habit, which in turn is the stuff of virtue. Children do not have the maturity to analyse what a situation requires, desire right action and enjoy its accomplishment. Instead we train them to behave correctly according to situations.[1007]

1001 *ST*, Ia-IIae, Q.65, Art.4.
1002 Nagai, *Leaving my beloved children behind,* 94.
1003 *NE*, 1103a32.
1004 *NE*, 1103b1.
1005 An insight also utilised by Jean Piaget, John Dewey and others.
1006 D. Goleman, "What makes a good leader," *Harvard Business Review*, (Nov-Dec 1998).
1007 D Goleman, "What makes a good leader".

This habituation in the concupiscible and irascible appetites is central to the acquisition of moral virtue, and, in a sense, to the development of virtuous character, being in the state of virtue.

> Character, being as its name indicates, is something that grows by habit. That which is under guidance other than innate is trained to a habit by frequent movement of a particular kind... in things inanimate we do not see this..... Consider, then, character to be this: a quality in accordance with governing reason belonging to the irrational part of the soul which is yet able to obey the reason.[1008]

A further dimension of ethical habituation is discussed by Broadie, that of the child's growing awareness of the need to manage impulses. Broadie explains that getting a small child to act in a certain way out of obedience teaches a vital lesson.

> (The child) becomes aware that his own not anyway wanting to do it is not a consideration for the parent.... we learn that things are good in a way which belongs to a world beyond the world of impulse.[1009]

Critical practice is required.[1010] So for example, we are told it is not just a question of playing the lyre but of measuring our performance against real expertise, and in the same way moral excellence is attained. This guided experience is crucial. Life experience of particular cases is for the development of practical wisdom.[1011] There is no short cut to virtue.

3.3.5 Obedience to others empowers for obedience to one's own reason.

[1008] Aristotle, *Eudemian Ethics*, 1220b6-8.
[1009] Broadie, *Ethics with Aristotle*, 103.
[1010] As practical reason needs to operate in conjunction with the sensitive appetites, Aristotle presents the view that experience also trains practical reason through trial and error in our behaviours, and that this inquiry based approach is at the heart of sound ethical training. Sherman calls this form of experience critical experience... guided and appropriate training, taking place at the right time. cf Sherman, *The Fabric of Character*, 160.
[1011] *NE*, 1142a13-16.

As we have seen, children are directed by the reason of their parents and minders. Through obedience in childhood, Aristotle's argument is that they develop the facility to obey their own reason later on.

He writes on the necessity of the habit of obedience.

> The rich find it hard to follow the rational principle, being neither willing nor able to submit to authority. The evil begins at home; for when they are boys by reason of the luxury in which they are brought up they never learn, even at school the habit of obedience.[1012]

Training for the rationality of desire is a "kind of obedience"[1013] to a separate and higher power "as a child listens to his father".[1014] The father's bonds of affection with a child assist his son in obeying.

> As in cities, laws and prevailing types of character have force, so in households do the injunctions and the habits of the father, and these have even more because of the tie of blood and benefits he confers; for the children start with a natural affection and disposition to obey.[1015]

The rule of a father over his children is 'royal', for he rules by virtue both of love and of the respect due to age, exercising a kind of royal power. His authority is moral as well as social. But he is called to moral virtue in perfection. Aristotle tells us,

> Homer has appropriately called Zeus "Father of Gods and men". If the ruler is intemperate and unjust, how can he rule well?[1016]

[1012] Aristotle, *Politics*, 1295b16-25.
[1013] *NE*, 1102b12 – 1103a4.
[1014] *NE*, 1102b31-1103a3.
[1015] *NE*, 1180b.
[1016] Aristotle, *Politics*, 1259a.

Habituated obedience would appear to have a clear biological dimension that is analogous to that of a dog trained to obey its master.

A dog develops by training the capacity for obeying the command of another to sit at the kerb, etc. Children are like dogs, in that they too are trained to obey the reason of others, of their parents; the difference is that they will, unlike Fido, develop as they grow the capacity to rule from within. Before reason is developed, in either the dog or the child, only the biological is present, albeit in a state of developing also. The dog and the child are only capable of exercising, of the cardinal virtues, temperance and fortitude. With developing reason, the child will develop the capacity for justice and prudence, to take others into account and to rationally self manage.

The suggestion that obedience habituated in a pre-rational child lays foundations for the rule of reason over desire for pleasure and aversion to pain is of great interest to us in this study and we will return to this.

3.3.6 Affection assists in fomenting virtue.

We gain a glimpse of Nagai's affection for his children in the short extract above in commentary on **Scenario 4**, but some of his writings are motivated almost exclusively by his love for them. In *Leaving my beloved children behind* Nagai wrote a personal message to his children in the face of his approaching death. He seeks to pass on to his son and daughter his main discoveries about life. He describes, in a typical understated manner, the encompassing love he feels for his children. These words of Nagai exemplify the powerful educative effect Aristotle has observed in the affection children feel for their fathers: [1017]

> It is an affection born of flesh and blood, which for some strange reason seems akin to the steam that bursts forth from the hibachi at the head of my bed. … As I continued pretending

[1017] Cf *NE*, 1180b.

> to be asleep that day, Kayano became bolder and held her cheek against mine. Her cheek gradually became warmer. As though she were secretly enjoying a little treasure that she was hiding from others, Kayano softly whispered, "Daddy." She wasn't really calling me. It was rather that the thoughts that were stuffed into her little breast had leaked out just a little. [1018]

Aristotle insisted on the importance of a loving home atmosphere as the preferred place of early moral education.[1019] Moral education requires great rectitude from the parent, and respect for the person of the child. This rectitude is fostered in the home where each family member is valued for who they are, rather than what they can do. The parent must be careful not to manipulate the child's beliefs and emotions to conform with whim and opinion, but to guide the child to form true judgements. The child "borrows the eyes of wisdom",[1020] "listens to the words of elders and the more experienced",[1021] and to their reasoned admonition and exhortation.[1022] In turn the child discovers, as Sherman says, "the intrinsic pleasure of approximating virtue through action and emotion."[1023] Note the imitative aspect is linked to the parent child relationship.

3.3.7 Development of virtue requires formation in what is appropriate in respect to pleasure and pain… emotional education.[1024]

Nagai entitles one chapter "Words of wisdom I gave my children".[1025] He encourages them, "Don't scream out just because the light went off in a power blackout."[1026] Elsewhere he writes for them, "Physical pain is relatively trivial. It can be borne, and it's gone when you die. Spiritual pain is more serious. You can't

[1018] Nagai, *Leaving my beloved children behind.* 24.
[1019] Sherman, *The Fabric of Character*, 152.
[1020] *NE*, 1144b10-12.
[1021] *NE*, 1143b11-13.
[1022] *NE*, 1102b33-1103a1.
[1023] Sherman, *The Fabric of Character*, 152.
[1024] Nancy Sherman is a particularly good source for this subsection.
[1025] Nagai, *Leaving my beloved children behind.* 94.
[1026] Nagai, *Leaving my beloved children behind.* 94.

cure it on your own. Furthermore it's still there after you die." [1027] His parenting intuition is that he must form his children in these matters. Note that it is not simply a question of stoically gritting one's teeth. Rather intellect is engaged. It is a question of analysing the type of pain and making a judgement. He explains the lesson to his child, and reinforces it with his own example.

This view is very much in step with Aristotle and Plato on the necessity for formation of children in appropriate emotion, and the suggestion that the virtues should also be considered as dispositions to *feel* appropriately. Broadie argues that Aristotle is interested in *feeling* because feeling will often lead to action; also he is concerned with appropriate and inappropriate feeling on its own account.[1028]

> We must take as a sign of states of character the pleasures or pain that ensue on acts; for the man who abstains from bodily pleasures and delights in this very fact is temperate.... Hence we ought to have been brought up in a particular way from our very youth, as Plato says, so as both to delight in and to be pained by the things that we ought; for this is right education.[1029]

In its simplest form this appropriate emotion is the expression of what is appropriate in respect to pleasure and pain. He writes, "All moral virtue has to do with pleasures and pains."[1030] Virtue is not simply about maximising pleasure and minimising pain, "but within the limits of 'as one ought to', and 'when one ought and ought not'".[1031] Here he is referring to action according to the right rule.[1032]

He argues that parental training involves a range of guided experiences.

> In educating the young, we steer them by the rudders of pleasure and pain; it is thought too that to enjoy the things we

[1027] Nagai, *Leaving my beloved children behind.* 95.
[1028] Broadie, *Ethics with Aristotle*, 75.
[1029] *NE*, 1104b5-13. The reference to Plato: Plato, *Laws*, 653Aff; *Republic*, 401E-402A.
[1030] Aristotle, *Eudemian Ethics*,1121b38.
[1031] *NE*, 1104b26.
[1032] *NE*, 1103b32.

ought and to hate the things we ought has the greatest bearing on virtue of character.[1033]

Finding appropriate pleasure and pain consists in an emotional education with a focus on such emotions as compassion, solidarity, right admiration and appreciation, appropriate shame, appropriate contrition, pleasure in obedience, pleasure in self control, and pleasure in generosity and sincerity in the right occasions. Appropriate intellectual delight at discovery, also constitutes appropriate emotion and an introduction to "non procedural" reasoning and inference.[1034]

3.3.8 Laws, culture and expectations assist in fostering virtue.

We have seen a little of Nagai's persistent efforts to build a culture of peace and reconciliation amongst his countrymen. He understood that to foster such personal attitudes on a widespread basis would take enormous work and energy. He threw himself into the task despite his leukemia.

Aristotle's view too was that the culture prevailing in any environment has a profound effect on the development of virtue. Family and parental expectations on the one hand, and social mores and laws on the other, must assist in training in virtue.

> The man who is to be good must we well trained and habituated... (hence there is a need for laws) proceeding from practical wisdom and reason.[1035]

Good laws "providing for the education of individuals and of groups and good occupations are an important factor that should not be neglected. However,

[1033] *NE*, 11172a24.
[1034] Sherman, *The Fabric of Character*, 168.
[1035] *NE*, 1180a21-23.

Aristotle warns, if the state helps little it is still up to each man to help his children and friends to virtue. [1036]

Aristotle's concern was not solely with children but also with grown citizens prone and even hardened to ignoble behaviours.

> Laws not only necessary for the young: most people obey necessity rather than argument, and punishments rather than the sense of what is noble.[1037]

Sound laws and wise lawmakers are needed.

> Arguments alone are insufficient. They may have the power to encourage and stimulate the generous minded among our youth, and to make a character which is gently born, and a true lover of what is noble, ready to be possessed by virtue, ... but they are not able to encourage the many to nobility and goodness (who have not shame but fear of punishment, but live by passion and have no conception of what is noble and truly pleasant).[1038]

Right laws create a regime where certain behaviours of virtue can be inculcated. The focus is on laws promoting temperance and a healthy hardiness:

> To live temperately and hardily is not pleasant to most especially to the young... hence there is a need for training "under right laws" as this lifestyle will not be painful if customary.[1039]

Yet this training must not simply demand conformity but must be accompanied by internal formation as well, of the type we have seen above.

[1036] *NE*, 1180a27-30ff.
[1037] *NE*, 1180a1-5.
[1038] *NE*, 1179b5ff.
[1039] *NE*, 1180a1-5.

> The best laws, though sanctioned by every citizen in the state, will be of no avail unless the young are trained by habit and education in the spirit of the constitution.[1040]

The role of environment and early experience in the inculcation of virtue, in general, has already been noted. Aristotle would argue that home environment and family culture (even institutional culture at grandma's, at pre-school, and at boarding school) play a clear role in establishing an environment of security and affection, as well as clear expectations for children, both for formation of conscience (one aspect of prudence) and in order to establish effective regimes of practice for habituation.

We shall now see that the developmental trajectory of virtue, moving from a young child's habituated behaviours to fitting affectivity and judgements, was recognized by Aristotle.

3.3.9 The development of virtue takes place over time and respects the development of the body.

We have already seen that training, to the moral virtues, is as education, to the practical reason.[1041] Until a certain point is reached, a baby has no effective capacity for education in the Aristotelian sense, but only for training. Thereafter, progressively, the capacity for education develops. Aristotle is most conscious of the developmental trajectory established at the biological level.

> As the body is prior in the order of generation to the soul, so the irrational is prior to the rational. The proof is that anger and wishing and desire are implanted in children from their very

[1040] Aristotle, *Politics*, 1310a12-36.
[1041] *NE*, 1103a.

> birth, but reason and understanding are developed as they grow older.[1042]

In the development of virtue, nature, nurture and the rational principle,[1043] all play their part.

Nature involves a process of anatomical development that is a precondition for human flourishing at the biological level. Aquinas acknowledges what we understand today as the normal processes of neural development occurring as part-constituent of rational operations beginning to take place in the maturing human being. In his discussion about whether children in state of innocence would have had the perfect use of reason, Aquinas argues that in babies and young children there is a "special impediment" to the use of reason deriving from the immaturity (which he describes as "humidity") of the brain.

> Even other animals have not at birth such a perfect use of their natural powers as they have later on. ... birds teach their young to fly. Moreover a special impediment exists (for man to exercise his natural powers of reason) in man from the humidity (immaturity) of the brain, as we have said above.[1044]

This concept of "special impediment" is in keeping with the view that biological development is a condition for the development not only of intellect, but of virtue. Man's trajectory of development is not purely genetically programmed, but it reflects man's free interplay with nature.[1045] States of virtue and vice may be understood as the natural endpoint of a man's experiences. The self-actualisation of this biological "history" brings with it the potential for human flourishing or frustration.

[1042] Aristotle, *Politics*, 1334b.
[1043] Aristotle, *Politics*, 1332a39.
[1044] *ST*, Ia, Q.101, Art.2.2. Reference to 99.1.
[1045] Gilson, *The Christian Philosophy of St Thomas Aquinas*, 256. Gilson puts this beautifully: "Man's efforts to attain his end leave their mark upon him. Man's soul as well as his body has a history. It conserves its past in order to enjoy and utilise it in a perpetual present. The most general form of this fixing of past experience is called habit."

Sherman observes that Aristotle adopts “a developmental conception of the cognitive and affective capacities, as well as a conception of habituation in varying degrees reflective and critical.”[1046] Initially a child develops, in an incremental way, perceptual and discriminatory capacities. As he grows the cultivation of these cognitive capacities becomes an essential task in his affective development. Nevertheless, “he will not yet, in a substantive way, cultivate the more deliberative skills that enter into complex choice making.” [1047]

The time arrives when there is a change of ruler. Adopting an Aristotelian idea, Plutarch writes:

> For intelligent people the passage from childhood to adulthood
> is not an abandonment of rules, but a change of ruler.[1048]

The young person’s own reason takes over from the guidance of her carers. Personal and biological maturity permits responsible, autonomous action. Nevertheless, adolescence is a time when children “have strong passions and tend to gratify them indiscriminately.”[1049] Youth are, “owing to the growth that is going on, in a situation like that of drunken men.”[1050] It is a time of uneasy tension.

In the next chapter we will seek explanations at the biological level that assist in understanding this development.[1051]

3.3.10 Practice of virtue requires effortful attention.[1052]

Amongst Nagai’s advice to his children he writes,

1046 Sherman, *The Fabric of Character*, 160.
1047 Sherman, *The Fabric of Character*, 159.
1048 Plutarch, *On Listening*.
1049 Aristotle, *Rhetoric*, 1389a.
1050 *NE*, 1154b10.
1051 Neuroscience has described the link between the slow maturation of the frontal lobe that assists in regulation of emotion and assessment of consequences for behaviour.
1052 Aristotle says three things are required for virtue: to know, to will, and to work steadfastly. “First of all, that a man be aware; secondly, that should he choose, it should be in view of a particular end; thirdly, that he should hold to his choice with firmness and steadfastness, and carry it out.” (*NE*, 1105a31.)

> Don't start anything that you can't make into a first-rate job.
> Don't quit anything you've started until you've made it into a
> first rate job. [1053]

Virtues are acquired by means of effort. At the heart of effort is sustained attention. "It is easy to perform a good action but not easy to acquire a settled habit of performing such actions."[1054]

Recall the view of William James - our will is manifested in the attention we pay. When the will is underdeveloped, or biological maturity inadequately supports rationality, we may struggle to give attention where our reason tells us we should (as opposed to where our sensitive appetite takes us).

This steadfastness requires the application of patience and constancy. Repetition can be hard work. The acquisition of virtue is arduous. [1055]

> Virtue requires some process of learning or training ... all who are not maimed as regards their potentiality for virtue may win it by a certain kind of study and care.[1056]

It is difficult enough for young men to develop virtue in depth, owing to the relationship between wisdom and experience.

> It is thought that a young man of practical wisdom cannot be found... The cause is that such wisdom is concerned not only with universals but with particulars, which become familiar from experience, but a young man has no experience, for it is length of time that gives experience[1057]

[1053] Nagai, *Leaving my beloved children behind.* 94.
[1054] *NE*, 5.9.
[1055] *NE*, 1105a31.
[1056] *NE*, 1099b16,20.
[1057] *NE*, 1142a13-16.

Yet, if the foundations of patience, constancy and determination, have not been laid in childhood, it can be difficult for older children and teenagers, in the adolescent tempest of emotion, to make moral headway at all.

3.3.11 Virtue requires intrinsic motivation.[1058]

We have observed in Nagai's actions that he acts for intrinsically rewarding reasons. This does not mean that there may not be a desirable positive outcome, but that the performance of the action is rewarding independent of the outcome. Would Nagai have sought to rally his workers around the Rising Sun even should their efforts have been pointless in saving lives? Given the patriotism shown in his initial rejection of the message on the leaflet there seems every indication that he regarded this action as worthy for its own sake. Would he still have treated the enemy compassionately even if the wounds were mortal? No doubt he would have. Would he urge peace even if the message fell on deaf ears? Again without question this would have been the case.

Virtue fosters intrinsic rewards.[1059] As we have seen, Aristotle proposed that virtue is its own reward, and that the fulfilment ensuing on virtue, the acquisition of genuine goods, is intrinsic to the practice of virtue. Virtue is "a prerequisite to happiness and at the same time, happiness itself." [1060] Virtue is not a means to an end. Rather the end results of virtuous action are implicit in the very activities of virtue.

[1058] Samuel S Franklin, *The Psychology of Happiness. A good human life*. (NY: Cambridge University Press, 2010). Franklin's discussion of the influence of Aristotelian ideas on the contemporary concept of intrinsic motivation gave rise to this section.

[1059] We have encountered in Chapter 2 the concept of reward devaluation and the observation that the development of habits fortifies against this. A fascinating study by Deci, Koestner, and Ryan who reviewed over 100 experiments on the demotivating effects of extrinsic rewards, found clear evidence of the way in which tangible rewards like money, candy, and prizes reduce interest in a task at hand. These results are consistent with the view that the intrinsic motivation of virtuous behaviour promotes wellbeing both subjectively and objectively. E. L. Deci et al., "A meta-analytic review of experiments examining the effects of extrinsic rewards on intrinsic motivation," *Psychological Bulletin* 25, (1999): 627-668. Cited in Franklin, *The Psychology of Happiness. A good human life*, 58.

[1060] Franklin, *The Psychology of Happiness. A good human life*, 17; cf 84.

3.3.12 Education specifically in wisdom and beauty is necessary in the formation of virtue.[1061]

Nagai advises his visitors to find pleasure in natural beauty as an antidote to a frenetic and aimless lifestyle that takes away peace. This advice is in close accord with Aristotle's view, noted immediately above, that moral education includes learning to feel appropriately. This sophisticated moral education extends to an appreciation, first lived and only then understood, of what worthy and noble. The soul must be cultivated by habits of loving and hating finely.[1062]

Aristotle's argument is that perceptual, affective and deliberative capacities will all be most effectively fostered within such a refined education. "Full virtue is not simply the excellence of the non rational part but itself combines the excellence of character and of practical reason".[1063]

It cannot be argued that "rationality emerges in an instant"; Sherman notes that Aristotle refers to clear stages of child development, from an early period of affective development and then the "more active development of the rational (and deliberative) capacities, and then eventually the emergence of full rationality."[1064]

Aristotle urges an education which elevates the spirit. "There is a sort of education in which parents should train their sons, not as being useful and necessary, but because it is liberal and noble."[1065]

He writes of the need not to vulgarise children in their upbringing.

> Hence we may infer that what is noble, not what is brutal, should have the first place. And parents who devote their

[1061] "For the sake of the noble." Broadie, *Ethics with Aristotle*, 90-95.
[1062] Cf *NE*, 1179b24-31.
[1063] Sherman, *The Fabric of Character*, 158.
[1064] Sherman, *The Fabric of Character*, 159.
[1065] Aristotle, *Politics*, 1337b30ff.

> children to gymnastics while they neglect their necessary education, in reality vulgarize them. For they make them useful to the art of statesmanship in one quality only.[1066]

Rather than passing on a set of pragmatic skills, we must raise children to aspire to what is good, true and beautiful. Wisdom implies this deep respect for the truth. Not surprisingly Nagai echoes this sentiment in his advice for his children: "Science means falling in love with the truth." [1067]

In the Aristotelian vision music had an important role in moral education. The emulative and empathetic mimetic enactment combined with positive reinforcement from the music itself leads to a certain habituation.[1068]. This is a reminder for our own times, that literature is a powerful medium for refined education, and a warning that Lady Gaga's words and actions do more damage to young minds than we might be prepared to admit. "To judge rightly and to delight in good characters and fine actions" is the very stuff of moral education. [1069]

3.3.13 Overcoming incontinence and unlearning vice.

Nagai is of the view that persons in maturity can change their behaviours and attitudes. He devotes much time in his final years to urging his fellow countrymen to paths of peace and reconciliation. It is also apparent that he regarded the effort to build peace as a difficult task that had to be attempted. It would be all too easy to surrender oneself to the bitterness and hatred for the occupying forces. He saw that such an unleashing of negative emotion would ultimately be counter productive as explicitly he argued that man has a calling to love,[1070] and that love, and a character disposed to love, fulfil our human nature. Again Nagai's intuitions are in step substantially with the accounts of Aristotle and Aquinas.

[1066] Aristotle, *Politics*, 1338b40-1339a5.
[1067] Nagai, *Leaving my beloved children behind.* 95.
[1068] Sherman, *The Fabric of Character*, 182.
[1069] Sherman, *The Fabric of Character*, 183.
[1070] Nagai, *Leaving my beloved children behind.* 164. Nagai's Christianity becomes more explicit in his later writing, and he argues that love of God is man's ultimate fulfilment.

The nature of vice is instructive of the nature of virtue.[1071] Vice is the state of no longer having within oneself noble desires and a noble end for one's actions. The vicious man deliberates and chooses a course of action for a good that will harm him or others, taking pleasure in this. While virtue and vice are both habits, vice is contrary to nature.[1072]

Hence, while virtue is freedom from those passions "that are not as they should be as to manner and time"[1073], vice is the disposition to give free rein to some passion. Applying to this context the insight that reason is the form of virtue,[1074] that rationality provides for the ordering of material constituents to establish the virtue, it would seem that vice can be seen as a lack or absence of right ordering of the material constituents indirectly by our rationality and directly by the person through the use of reason.

Essentially vice represents a complacent failure to have developed capacities for self management; capacities which could reasonably have been expected to have been developed are absent. This insight will have implications when we consider the neural substrate of virtue.

3.4 Conclusion.

In this chapter I have reviewed the principal features of the Aristotelian and Thomistic conceptions of virtue. On the basis of the scenarios from Nagai's life

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[1071] Aristotle also develops the notion of incontinence, of less direct relevance here. "The incontinent man, knowing that what he does is bad, does it as a result of passion; the continent man, knowing that his appetites are bad, refuses on account of his rational principle to follow them"(*NE*, 114510-11) "Incontinent people are not criminal, but they will do criminal acts." (*NE*, 1151a10) The incontinent man knows he is doing what is not good for him but is too weak to avoid it, whereas the vicious man is complacent in his choice.

[1072] *ST*, Ia-IIae, Q.71, Art.2.

[1073] *NE,* ii 3.

[1074] It will be seen below that Aquinas specifies reason as the "form" of virtue (**4.1.1.2**). I would suggest that "to give free reign" could take place two ways: the deliberate choice to follow inappropriate passion, either for the recognised benefits of immediate gratification, or from motives of self love despite awareness of duties to others; the complacent refusal to exercise the reflection and judgement required to moderate the passion.

presented in **3.1.2** I identified prominent characteristics of virtue evident in real life in **3.1.4**. Then, in **3.2** and **3.3**, I identified broad characteristics of virtue distilled from texts from Aristotle and Aquinas. The 23 qualities identified will, at the conclusion of **Chapter 4** and in the light of the content of that chapter, be distilled into **Table 4.1**, in which they are cross referenced to the observations from Nagai's life, providing a simple demonstration of the effectiveness of the Aristotelian/Thomistic template in describing superior personal qualities encountered in real life.

Chapter 4

Understanding the cardinal virtues.

"...we are unfashioned creatures, but half made up, if one wiser,
better, dearer than ourselves - such a friend ought to be - do not lend
his aid to perfectionate our weak and faulty natures."
Frankenstein; or, The Modern Prometheus
Mary Shelley

The illustrations above, drawn from the life of Dr Takashi Nagai, demonstrate a complex interplay between the cardinal virtues in each of his deliberate actions. In **Chapter 4** I investigate the distinctive qualities of each of the cardinal virtues. In **4.1** I argue for a restricted reading of Aquinas' notion of "rational by participation"[1075] in reference to the dispositions of the sensitive appetites and examine the case for and against whether fortitude and temperance may be considered essentially biophysical qualities; in **4.2** I seek to clarify the specific tasks of the cardinal virtues; and, and argue that each has a distinguishing biological constitution. Finally, in the light of preceding discussion, in **4.3** I present the case for the unity of the virtues.

I conclude by identifying 17 characteristics of virtue that will, in **Chapter 5,** be aligned with neuroscientific data.

4.1 The cardinal virtues.

<u>The argument.</u>
In this following section, the differences between these virtues are analysed in the light of Aristotelian and Thomistic texts.

I argue that:

- Each cardinal virtue has a distinctive biophysical "signature".

[1075] *ST*, Ia-IIae, Q.50, Art.4.See also Q.59, Art.4, and Q.61, Art.2.

- Prudence and justice consist in habits perfecting the rational faculties: in the performance of a virtuous act, their role is consequent to the presentation of arduous goods and pleasurable goods to the intellect and will by the sensitive appetites. The habits of prudence and justice are corporeally manifested in perfections of certain biological structures that are necessarily associated with rationality in the embodied life.
- Fortitude and temperance are essentially perfections of biological structures of the body which facilitate the presentation of appropriate arduous goods and pleasurable goods for rational consideration.[1076]
- Consequently it may be concluded that in actions of perfect virtue all four cardinal virtues are present, not simply because Aquinas said it should be so, but rather because the four cardinal virtues each perform different roles, all of which are needed for the completion of a good action.
- These arguments form a compelling case for the notion of the unity of the virtues.

And these clarifications are essential if we are to identify that which is bodily in relation to each of the cardinal virtues, the task which is the role of this study. These views will inform **Table 4.1** and therefore the work of **Chapter 5** where pertinent biological structures will be discussed in detail, and the actual part-constituents of virtue will be sought – the specific regions, neural pathways and biophysical processes – that underpin virtue, in the sense already explained in **Chapter 1**. Hence a necessary task of this chapter is the delineation of the roles specific to each of the cardinal virtues.

<u>Overview</u>

[1076] The view that temperance and courage are essentially embodied has its advocates. Titus and Moncher write, "An Aristotelian-Thomist perspective, for its part, has argued that certain virtues reside in the embodied emotional dispositions (not just in reason and will)… (relying on) instinctual and acquired neural circuitry, and thus are properly considered bodily. The virtue tradition has distinguished two large areas of affective virtues that accord with two types of embodied affectivity: the emotions of desire (the attractive good) and those of difficulty (the difficult good)." Craig Steven Titus and Frank Moncher, "A Catholic Christian Positive Psychology: A Virtue Approach," *Edification* 3, 1 (2009): 57-63.

It is essential now to look closely at the individual cardinal virtues in order to better understand their individual characteristics.

I argue that fortitude and temperance are essentially biophysical qualities of the human body disposing the sensitive appetites to seek good that is in keeping with reason. They are caused by reason either in that they are developed through childhood training obedient to the reason of their parents, as simplistically speaking, a dog develops obedience; or they are developed as a consequence of one's own rational actions.

Aquinas states, following Aristotle, that the moral virtues are rational "by participation".[1077] This section argues for a restricted reading of this notion. It is argued that fortitude and temperance should be understood most properly as dispositions of the sensitive appetitive faculties, obedient to reason disposed by its own proper virtues – in other words, that fortitude and temperance do not pertain to rationality as their subject, and in themselves they do not moderate rationality properly speaking, which is the task of both prudence and justice. Rather, in their formation they require the ordering contribution of rationality. In disposing acts of temperance or fortitude, the virtues of temperance and fortitude are guided by reason disposed by knowledge of first principles, as well as the virtues of prudence and justice. Although the virtues of fortitude and temperance may be said to be caused by rationality and to dispose the body to rationality, they are not dispositions of rationality.

Prudence and justice are habits of the operative (rational) powers, distinct from fortitude and temperance (habits of the sensitive appetites). In the performance of acts of virtue, it is argued that rationality itself is perfected only by the specific virtues of the operative powers. It will be argued that the contribution of the virtues of the sensitive appetite is prior, properly speaking, to the dialogue between intellect and will as the human act unfolds.

[1077] *ST*, Ia-IIae, Q.50, Art.4. See also Q.59, Art.4 and Q.61, Art.2.

This preclusion of direct involvement of rationality in the intrinsic operation of the moral virtues of the sensitive appetites, and the integrated involvement of the four cardinal virtues in all virtuous acts, will be seen in **Chapter 5** to be most consistent with the neural structures associated with the operation of the virtues. It will be suggested in **Chapter 5** that an analysis of the biological part-constituents of virtue supports the views developed in this section and adds a dimension of experimental proof to the distinction between moral virtues.

There will be continued emphasis on the human act serving to emphasise the interdependence of the virtues and their integral operation in the completion of the human act. Further illustrations will be drawn from the life of Nagai, serving to test the discussion against reality, demonstrate the complex involvement of virtues within individual good human actions, and illustrate the integrated cooperation of various virtues in the exercise of such actions.

I now present the case for a restricted reading of Aquinas' notion of "participation" in reason by the moral virtues of the sensitive appetites. In **4.1.1** we will examine the principal arguments opposed to a restricted reading and these arguments are answered systematically in **4.1.2**. Specifically, the discussion is focused on arguments for and against the view that fortitude and temperance are more than ordered biophysical qualities of the human person. Clarity on this issue will enable us, in **4.2** to look in turn at each of the cardinal virtues identifying distinct features, and in **4.3** to reflect on the way in which the cardinal virtues work together in the completion of the human act.

4.1.1 Arguments opposing the view that fortitude and temperance are ordered biophysical qualities of the human person.

Note that arguments presented below in **4.1.1.1-10** are answered in turn in **4.1.2.1-10**.[1078]

4.1.1.1 Virtue is of the soul.[1079]

Virtue is properly of the soul. A good action is "activity of the soul in accordance with virtue." [1080] Human habits may only reside in the soul.

> They cannot reside in the sensitive powers as such. These powers, considered independently of reason, are determined to their act by a kind of natural bent.... Only in the intellect do we encounter that multiplicity of indeterminate powers capable of being combined and organised among themselves. ... (These habits) are super added determinations which establish definite relations between the intellect and its objects or possible operations.[1081]

Hence virtuous action is freely elected; not only is habit "that which one uses when one wills,"[1082] but virtue is the facilitation of the rule of reason. It would appear therefore that fortitude and temperance are necessarily more than ordered biophysical qualities of the person.

4.1.1.2 Reason is the "form" of the virtues.

Aquinas offers a most perceptive insight into the structure and nature of virtue in his discussion "Whether the moral virtues remain after this life?" In this topic he addresses the challenge of distinguishing that which in virtue is biophysical, and therefore prone to decomposition, from that which is formal. Aquinas argues "the

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[1078] An echo of the *Summa*'s methodology seems appropriate here.
[1079] *NE*, 1185.
[1080] *NE*, 1198a18.
[1081] Gilson, *The Christian Philosophy of St Thomas Aquinas*, 257.
[1082] *ST*, Ia-IIae, Q.50, Art.5.

formal element is precisely this order of reason",[1083] that the formal element of virtue is the ordering of the material organism to facilitate the management by reason of passion. This is a consequence of the notion that the soul, the intellectual principle, "is united to the body as to its form."[1084] "Form," insists Aquinas "causes matter to be."[1085]

As virtue represents an *ordering* its association with reason seems inescapable. Aquinas explains that the virtues consist in the ordering, according to reason, of the various powers of the soul, an ordering to each other and to external ends:

> Virtue ... is an ordered disposition of the soul, in so far as, to wit, the powers of the soul are in some way ordered to one another, and to that which is outside.[1086]

Elsewhere we read: "Moral virtue is properly a perfection of the appetitive part of the soul in regard to some determinate matter."[1087]

Rationality is the *form* of virtue, according to Aquinas. Rationality disposes matter to support virtue, to sustain the operations of the soul, including understanding, choosing, and more broadly, forming and exercising virtue. It seems therefore reasonable to suggest that fortitude and temperance may not be understood simply as ordered biophysical qualities of the human person.

4.1.1.3 Virtue is a "habit of choosing" and therefore all virtue would appear to be a disposition of the rational appetite.

Quoting Aquinas, Jean Porter seems to insist that moral virtue resides in the reason.

> Thomas distinguishes the intention of the end, which belongs to the moral virtues, from the specific choice, which belongs to

[1083] *ST*, Ia-IIae, Q.67, Art.1.
[1084] *ST*, Ia, Q.76, Art.1.
[1085] *ST*, Ia, Q.75, Art.5.3.
[1086] *ST*, Ia-IIae, Q.55, Art.2.1.
[1087] *ST*, Ia-IIae, Q.64, Art.1.

> prudence.[1088] "Finally, according to the *Ethics*, the principal act of moral virtue is choice."[1089] Choice, however, is not an act of the irascible and concupiscible powers, but of reason, as has been said above. Moral virtue, therefore, is not in the irascible and concupiscible powers, but in the reason.[1090]

In fact, as has been seen Aristotle presents each of the virtues as a "habit of choosing". This leads commentators to adopt the view that all virtues are essentially about the perfection of the will: "the moral virtues perfect the will."[1091] Thus, even the virtues of the sensitive appetites seem to play a direct role in perfecting the rational appetite.

Furthermore, at the most refined level, Aquinas specifies the connection between love and virtue. Virtue ensures that our loves are under the sway of rationality.

> When we say that virtue is the order or ordering of love, we refer to the end to which virtue is ordered: because in us love is set in order by virtue.[1092]

To love is an operation proper to the rational appetite, and therefore it would appear that all virtue is ordered to love, and that rationality is inseparable from the virtues.

4.1.1.4 Aquinas appears to suggest that the moral virtues are rational.

Texts of Aquinas appear to reinforce the notion that reason operates intrinsically within virtue. In Aquinas' vision of the perfected man, virtue has an integral role

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[1088] *ST*, Ia-IIae, Q.56, Art.4.4.
[1089] *NE*, 1163a22.
[1090] Jean Porter, "Contested categories: Reason, Nature, and the Natural Order in Medieval accounts of the Natural Law," *Journal of Religious Ethics* 24, (1996): 259.
[1091] John E. Naus, *The Nature of the Practical Intellect according to St Thomas Aquinas* (Roma: Libreria Editrice dell Universita Gregoriana, 1959), 75.
[1092] *ST*, Ia-IIae, Q.55, Art.1.4.

to play for it is none other than a rightly ordered management of the body. He writes,

> Whereby just as virtue directs the bodily limbs to their due external acts, so does it direct the sensitive appetite to its proper regulated movement.[1093]

This view, appearing to attribute the ordering of reason to the virtues of the sensitive appetite would seem difficult to reconcile with the view that fortitude and temperance are essentially biophysical.

4.1.1.5 The practical intellect appears to play an intrinsic role in the virtues.

Christine Swanton appears to ascribe an intrinsic role to the practical intellect:

> Aristotle (rightly) regards practical wisdom as the glue which not only integrates the components of the profiles of the individual virtues, but also unites those virtues one to another.[1094]

If by "integrates the components of the profiles of the individual virtues", Swanton means an agent that is intrinsic to virtue, and use of the word "glue" seems to suggest just this, then practical reason would seem to play some form of intrinsic role in each of the virtues.

4.1.1.6 The speculative intellect appears to play a role within each of the virtues.

It would appear that the speculative intellect is also necessary for virtue. We read for example:

> Moral virtue can stand without wisdom, science, or art, but not without the habit of first principles and prudence.[1095]

[1093] *ST*, Ia-IIae, Q.59, Art.5.
[1094] Swanton, *Virtue Ethics: A Pluralistic View*, 27.
[1095] Naus, *The Nature of the Practical Intellect according to St Thomas Aquinas,* 75. Cf *ST*, Ia-IIae, Q.58, Art.4.; *ST*, Ia-IIae, Q.65, Art.1.3.

Hence, it would appear that speculative intellect plays an intrinsic role in each of the virtues.

4.1.1.7 It would appear impossible to hold the view that acts of individual virtues are not rational.

Aquinas appears to suggest that each virtue is instrumental in the exercise of its own acts.

> The function of virtue (is)... to make (the sensitive appetites) execute the commands of reason, by exercising their proper acts. [1096]

If the moral virtues were not inherently rational it would seem difficult to argue that there could be, for example, acts of temperance or fortitude.

4.1.1.8 Virtue results from the ordering of corporeal processes by reason.

Although the virtues of the irascible and concupiscible reside in the sensitive part of the soul we also read that they are in the reason and will according to their "origin and beginning". Aquinas argues that the rational constituent of virtue consists in the ordering of the sensitive appetites by reason.

> ...habits of moral virtue are caused in the appetitive powers, according as they are moved by the reason....[1097]

So, it would appear that the co-constituents of virtue to be reason and biophysical processes. Hence it would seem that the notion of virtue must embrace reason.

4.1.1.9 As virtue is "perfection of a power to act", therefore it "belongs to that which is proper to the soul". [1098]

[1096] *ST*, Ia-IIae, Q.59, Art.5.
[1097] *ST*, Ia-IIae, Q.51, Art.2.
[1098] *ST*, Ia-IIae, Q.55, Art.2.

Aquinas argues that as virtue is a power to act, it would appear to be necessarily of the soul.

> Virtue implies some perfection of power... power in reference to being is on the part of matter... power in reference to act, is on the part of the form, which is the principle of action, since everything acts in so far as it is in act... the body holds the place of matter, the soul that of form. ... only those forces proper to the soul, namely the rational forces, belong to man alone. And therefore, human virtue... cannot belong to the body, but belongs only to that which is proper to the soul. Wherefore human virtue does not imply reference to being, but rather to act.[1099]

4.1.1.10 The habits of virtue all enjoy a certain durability.

It would appear that the habits of virtue all enjoy a certain durability:

> No bodily change seems capable of corrupting the intelligible species residing in the intellect; since the intellect independently of the body is the proper abode of the species; for which reason it is held that habits are not lost either through old age or death. ... For the same reason neither can habits of virtue be corrupted, since they are also in the rational soul, and as the Philosopher declares (*NE,* 1, 10) "virtue is more lasting than learning". [1100]

Ramsay suggests that, even after dissolution of the body, both the rational and sensitive appetites shed corporeal aspects but that the moral virtues, as rational dispositions, all are retained:

> After mortal life the absence of needs and disorder among the bodily passions means that the material aspects of the virtues

[1099] *ST*, Ia-IIae, Q.55, Art.2.
[1100] *ST*, Ia-IIae, Q.53, Art.1.3.

> will not endure, but since the Blessed will possess perfect rationality concerning every part of their existence and complete conformity of their appetites to this, virtue will still endure formally. Perfect virtue, the perfectly rational disposition, is not a habit in the passions or the will, but *a unifying experience of reason* which is extended to every intellectual operation and with which every appetitive operation conforms. The virtues, then, point towards Virtue as an experience of reason.[1101]

This view seems incompatible with a conception of fortitude and temperance as essentially corporeal.

4.1.2 Arguments supporting the view that fortitude and temperance are ordered biophysical qualities of the human person.

4.1.2.1 Virtues "in the soul" must be understood correctly.

Even our superficial glance at the life of Nagai demonstrates that Nagai *is* the man with these personal qualities. There is a grand inescapable reality about the virtuous man… that he is the sum of his habits, and the corollary: that he operates therefore through his habits. The person acts, in a moral sense, through his virtues. Virtues empower us to act well. Because members of the body are organs of the soul's power, moral virtue is said to be of the soul.[1102]

The fact that the moral virtues are all "rational" should not lead to an assertion that fortitude and temperance have no basis in the biophysical qualities of the human person. As there is an obediential relationship, in a state of virtue, of the sensitive powers towards reason, it is not necessary to assert some intrinsic role

[1101] Ramsay, *Beyond Virtue. Integrity and Morality*, 173.
[1102] *ST*, Ia-IIae, Q.17, Art.9. "... all movements of members that are moved by the sensitive powers are subject to the command of reason…. as the powers of the soul stand in respect of obedience to reason, so do the members of the body stand in respect thereof."

for reason within fortitude and temperance. [1103] Aristotle and Aquinas maintain a clear distinction between what is rational and what is sensitive.[1104] Aquinas demonstrates the distinction between virtues perfecting the rational as their subject and those of the irrational part of the soul, by speculating on the state of the human soul after death. [1105] Aquinas clarifies that the powers of the sensitive soul cannot exist without the body and therefore these virtues do not either. [1106]

All human acts require operation of the rational appetite informed by the intellect; it is therefore clear that the virtues of justice and prudence, associated with these rational operations, must be powers of the soul.[1107] This is so because, "Habit needs to be in that power which is the principle of the act", and hence for example, "the possible intellect is the subject of intellectual habits".[1108]

[1103] Naus, *The Nature of the Practical Intellect according to St Thomas Aquinas*, 69-70. "Some actions proceed from the soul through the body, and are, therefore, principally in the soul, secondarily in the body. The same is true of the habits which modify them: they dispose the body habitually to serve the operations of the soul. Accordingly there can be habits in the sensitive powers in so far as they act under the command of reason. … (These moral virtues nevertheless) perfect man as man. These are the intellectual and moral virtues of intellect and sense and intellectual appetites."

[1104] Aristotle and Aquinas hold that the virtues of the irascible and concupiscible reside in the sensitive, irrational, part of the soul.

[1105] *ST*, Ia, Q.77, Art.8. "Some powers belong to the soul alone as their subject; as the intelligence and the will. These powers must remain in the soul, after the destruction of the body. ... Now accidents cannot remain after the destruction of the subject ... such powers do not remain actually; but they remain virtually in the soul as in their principle or root."

[1106] Aquinas, *Disputed questions on the cardinal virtues*, Art 4 Ad 13. "It should be said that some teach that the irascible and concupiscible, the subjects of temperance and fortitude, are in the higher part, not in the sensitive part of the soul. But this conflicts with what the Philosopher says in *Ethics* 3, namely, that virtues are in the irrational parts. Others say that the powers of the sensitive part remain in the separated soul either according to potency alone or according to act. But this cannot be because the acts of the sensitive power cannot exist without the body; otherwise the sensitive soul of the brutes would be incorruptible, which is erroneous."

[1107] Strictly speaking, justice and prudence are not powers of the soul, but "in a power of the soul". Aquinas further states: "a power of the soul is the subject of virtue." (ST, Ia-IIae, Q.56, Art. 1).For the purposes of this thesis however, I do often refer to "person" as the subject of virtue. This is an acceptable convention: for example, Jean Porter writes of "the person of true virtue" and "it is proper to justice among the other virtues to direct the human person" (Jean Porter, *The Recovery of Virtue*. (Louisville: Westminster/John Knox Press, 1990), 114 and 124). Clearly, however, debate over the true subject of the virtues is an important part of scholarship concerning Aquinas's moral theory.

[1108] *ST*, Ia-IIae, Q.54, Art.1.

Ultimately that virtues are “in the soul” means that they can be utilised by the human person to facilitate his wellbeing, they are not a rule unto themselves. It does not imply that all virtues belong to the soul as their subject.

In summary, it is clear that moral virtues are properly “in the soul” as they are acquired and directed by the person. Yet, as these moral virtues of fortitude and temperance are habits of management of bodily emotion, they must corporeal. The argument of this study is that this substrate consists in anatomical parts, processes, and pathways which may reasonably identified within the organism.

Specifically, the virtue of fortitude will exhibit part-constituents with roles mediating apprehension and management of fear, pain and anxiety. The virtue of temperance will exhibit part-constituents mediating reward systems and apprehension of pleasure. In common they will consist in part-constituents which link emotional centres with cortical regions implicated in imagination, memory, deliberation, and goal election. Each also will feature part-constituents which account for habit formation, habituation of specific processes, etc. These characteristics will be explored in **Chapter 5**.

4.1.2.2 Reason as the “form” of virtue correctly understood.

That reason is the “form” of the virtues may, at first sight, seem to suggest that reason, as a matter/form co-constituent, is intrinsic to all virtue. But I suggest this is an erroneous reading of this key source passage:

> The material element in these virtues is a certain inclination of the appetitive part to the passions and operations according to a certain mode:- and since this mode is fixed by reason, the formal element is precisely this order of reason.[1109]

[1109] *ST*, Ia-IIae, Q.67, Art.1.

The material element absent after death, is “a certain inclination of the appetitive part to the passions and operations according to mode fixed by reason”.[1110] It is this “certain inclination” that is the very subject of this study. Aquinas’s words, “a certain inclination of the appetitive part”, are consistent with the view proposed by this study that the human organism is able to develop neural pathways that dispose for self directed higher cortical modification of emotional reactions.

The formal element is not reason itself but “the order of reason”[1111] which has fixed the material element in a certain way.

In the life of Nagai, we witness extraordinary qualities of character in his later years; his impressive peace and self-control have been noted above. It is eminently clear that these qualities have a material element for they include the ability to transcend fears of death, and separation from his deceased spouse for whom he held a passionate love.

The position of this study is that our free and conscious efforts form, or reform, our very biophysical constitution. By the effort we invest in good behaviours we actually build virtue, we order our material constitution into neural structures, better capable of supporting effective self management at the rational level. Fortitude and temperance are habits caused in the sensitive appetite by repetition of actions, actions which are repeated owing to the settled rational conviction that personal actions for human flourishing must demonstrate fortitude and temperance. It would appear that reason, perfected by prudence, the habitual disposition of the practical intellect for right counsel, judgement and command, plays a role in ordering the biophysical processes that are part-constituents of the other cardinal virtues. Reason, human thought, directs the very ordering of matter.

[1110] *ST*, Ia-IIae, Q.67, Art.1.

[1111] *ST*, Ia-IIae, Q.67, Art.1.

For reason to be the form of the virtues of temperance and fortitude poses a further challenge. These virtues are “of the soul” because they are at the free service of the person, but they are dispositions of the sensitive appetite, and these facts seem difficult to reconcile. A key to the solution lies in the fact that, as we have seen in the life of Nagai, the cardinal virtues operate together. Acts of the virtues of fortitude and temperance, dispositions of the sensitive appetites, will be directed by rational operations which are themselves disposed by justice and prudence. Without acts of prudence and justice there can be no rational direction of the sensitive appetites; without prudence and justice rationality is unable to inform the acts of these pathways of habituation. Therefore, as virtues are known through their acts, acts of temperance and fortitude will be informed by acts of prudence and justice. It would seem then that reason directing the individual acts through acts of prudence and justice, builds up and characterises as virtues, the virtues of fortitude and temperance.

The canine analogy can help. A dog has a trained disposition to obey the reason of his master. Yet the dog is wholly material. So too fortitude and temperance are acquired (and finely attuned) dispositions to obey our rational choices.

4.1.2.3 A correct understanding of “habit of choosing” is required.

It is true that virtue is presented by Aristotle and Aquinas as a “habit of choosing”, yet this notion also must be reconciled with the clear distinction between virtues of the sensitive appetites and those of the rational appetite and intellect.

The human act is a team effort: deliberation of the will informed by the intellect leading to choice, and all with the prior input from the lower appetites, appetites that to a greater or lesser extent have been already schooled in rational management, to the extent that they are already disposed by pre-existing habits.

> Choice resides formally in the will, but it does result from a concurrence of the intellectual and volitional powers through a

> mutual causality in the orders of specification and exercise respectively.[1112]

A key to clarification of the various roles of the virtues, the good moral habits, lies in a correct understanding of habit. Habits hold a very special place in the anthropology of Aquinas.

Habit is presented as a most broad category. Etienne Gilson observed:

> Habits are not only qualities and accidents, but they are qualities and accidents which lie closest to the nature of a thing, and which come closest to entering into its essence and integrating themselves into its definition.[1113]

Each power, rational and sensitive, is disposed by its distinctive and corresponding habit. It is apparent that *habit* is a most broad category, simply indicating the disposition appropriate to the power that it perfects.

Aquinas wrote:

> Every power which may be variously directed to act, needs a habit whereby it is well disposed to its act.[1114]

Within this broader category of habit Aristotle positioned virtue. Each faculty directly involved in moral action is disposed by its appropriate habit. The appropriate habits for the sensitive appetites are moral virtues of the concupiscible and irascible appetites. The rational appetite, too, has its own proper disposition, justice. The practical intellect is disposed by its own habit, prudence.

The good habit, or virtue, appropriate to the nature of each power (the speculative and practical intellect, and the rational and sensitive appetites) assists

[1112] Edward Cook, *The deficient cause of moral evil according to Thomas Aquinas* (Washington: Paedeia Publishers and The Council for Research in Values and Philosophy, 1996), p93. This text is a volume of *Series on the foundations of moral education and character development*.
[1113] Gilson, *The Christian Philosophy of St Thomas Aquinas*, 256.
[1114] *ST*, Ia-IIae, Q.50, Art.5.

in the operation and function of that power, in integrated concert with the action of the other habits, with the outcome that the whole organism flourishes.

It therefore stands to reason that wherever rational operations coincide with sensible powers the rational operations can only be disposed by their own proper virtues. Therefore, strictly speaking, it is incorrect to assert that all virtues pertain to rationality as their subject.

A certain imprecision of terminology abounds in this area. We read: concupiscence "judges its own desires to be good"[1115], yet it is clear that unmoderated sensual pleasure cannot judge. At best we can say that the intellect presents to the will the principle that pleasure is to be pursued, and so pleasure in the will is then pursued. But in this case it is clearly the rational appetite, not the vice of intemperance, that does the choosing.

The capacity for choice does not properly reside in temperance and fortitude as they are perfections of material appetites. For virtue to be a habit of choosing, it is necessary, as a minimum, that every virtuous action be guided by rationality. This is achieved by the contributions of prudence and justice in every action of perfect virtue.

4.1.2.4 The moral virtues of the sensitive appetite are rational "by participation".

Aquinas argues that: "According to the mind of Aristotle... it is manifest that the sensitive powers are rational, not by their essence, but only by participation (*Ethic* i 13)."[1116]

I propose that to say of virtues that they are rational "by participation" is to say that they are biologically grounded habits which reflect the right ordering of

[1115] *ST*, IIIa, Q.156, Art.3.
[1116] *ST*, Ia-IIae, Q.50, Art.4. See also Q.59, Art.4 and Q.61, Art.2.

reason as their cause, and which perfect their respective appetites to desire pleasures and avoid pains in keeping with right reason. Therefore I propose a restricted reading of rational "by participation"; this view contrasts with a certain accepted reading of Aquinas that suggests, wrongly in my opinion, an intrinsic role of reason in the virtues of the sensitive appetites.

Fortitude and temperance, as habits of the sensitive appetites, lack in isolation the necessary intrinsic rationality to be described properly as "rational". Aquinas says that "in so far as they *obey* reason the sensitive powers are said to be 'rational'."[1117] Elsewhere we read: "Appetite is the principle of human acts insofar as it partakes of reason."[1118]

They are not even dispositions of the intellect or will, properly speaking.

Yet, again Thomistic terminology can be frustratingly equivocal. For example, Aquinas makes cardinal virtues, instead of the agent, the subject of active verbs: for example, he writes that prudence brings about the good respecting the consideration of reason; that justice brings about what is due and upright in operations; that temperance "restrains desires for the pleasures of touch"[1119]; that fortitude brings about firmness of soul against any of the passions. This transfer of agency can somehow give the impression that the virtues are in command, or that somehow they are synomymous with reason. Yet only the person acts; and properly speaking, for example, it is only with the assistance of temperance that the person restrains desires. [1120]

The view that all four cardinal virtues contain in some way an intrinsic rational element appears to adopt this, unintended, transfer of agency. Such imprecise

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[1117] *ST*, Ia-IIae, Q.53, Art.1.
[1118] *ST*, Ia-IIae, Q.58, Art.2.
[1119] *ST*, Ia-IIae, Q.61, Art.3.
[1120] Naus, *The Nature of the Practical Intellect according to St Thomas Aquinas,* 72. Here we read for example, "Moral virtues perfect the appetitive part of the soul to desire good." The active verb "perfects" can be understood correctly, or if mistakenly, can perpetuate this mistaken view that the virtues have more authority than then do.

readings of Thomistic texts appear to reinforce mistaken assumptions about virtue.

What Aquinas means by “participation” may be further clarified by reference to the doctrine of “participation in being”, introduced in **Chapter 1**, as analogously relevant.[1121] Participation implies exercise and enjoyment of certain benefits that are not properly one’s own. It should be remembered that Aquinas taught that substances possess being only *by participation* - being is predicated of finite creatures by participation:[1122] “All other beings that are not their own being but have being by participation must proceed from that one thing.”[1123]

We can relate these reflections back to our discussion of Nagai. It has been noted a number of times that each of the actions of Nagai appear to reflect dispositions of various virtues, both at the material and the rational level. For example, the compassionate treatment of the enemy soldier reflects not only justice but also temperance (understood in a broad sense), fortitude, and prudence. Hence it may be argued from this example that habits of the sensitive appetite are able to be guided by habits of rationality, and in this sense we are able to say that these habits are rational “by participation”.

4.1.2.5 The practical intellect is perfected by its own proper habit, prudence.

In a tightly argued text, Aquinas provides insights into the operation of prudence, a “habit of the reason”. The text attributes to prudence an explicit ordination to human flourishing, a direct consequence of the rectitude, the perfection, of reason resulting from exercise of the virtue. He argues that prudence is needed to perfect reason and so provide effective guidance to the other virtues. He concludes, “An intellectual virtue is needed in the reason, to perfect the reason,

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[1121] Arguably, according to Aquinas, the participation of virtue in reason is not only analogical but ontological. Such a discussion would stretch the parameters of this current study.
[1122] Torchia, *Exploring Personhood*, 129.
[1123] Aquinas, *On the Power of God*, Q3 a5.

and make it suitably affected towards things ordained to the end; and this virtue is prudence."[1124]

Nagai's consistent mastery of his own actions demonstrates the presence of a perfecting habit of the practical intellect. It makes no sense to hold that this habit is intrinsic also to the perfecting habits of the sensitive appetites, which demand their own perfecting habits which *by necessity* must be distinct from habits perfecting rationality.

Reason exercises royal command. Reason governs the virtues of the sensitive appetite not directly, or "despotically" as Aquinas would say.[1125] Rather, he explains, the appetites may or may not obey. Aquinas holds that fortitude and temperance obey reason "royally". This principle may also be used to demonstrate what we could call the "exteriority" of reason to the sensitive appetites.[1126]

The bottom line is that rationality, which must be present in any human act, will have its own proper disposing virtues. When rationality is involved in acts of fortitude and temperance, it will be disposed to act well by its own proper virtues of justice and prudence. Fortitude and temperance are rational virtues, not

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[1124] *ST*, Ia-IIae, Q.57, Art.5. The full quotation is as follows: "Prudence is a virtue most necessary for human life. For a good life consists in good deeds. Now in order to do good deeds, it matters not only what a man does, but also how he does it; to wit, that he do it from right choice and not merely from impulse or passion. And since choice is about things in reference to the end, rectitude of choice requires two things; namely, the due end, and something suitably ordained to that due end. Now man is suitably directed to his due end by a virtue which perfects the soul in the appetitive part, the object of which is the good and the end. And to that which is suitably ordained to the due end man needs to be rightly disposed by a habit in his reason, because counsel and choice, which are about things ordained to the end, are acts of the reason. Consequently an intellectual virtue is needed in the reason, to perfect the reason, and make it suitably affected towards things ordained to the end; and this virtue is prudence. Consequently prudence is a virtue necessary to lead a good life."

[1125] *ST*, Ia, Q.80, Art.3.

[1126] We have seen that virtues facilitate the rule of reason. A number of times Aquinas contrasts the terms "despotic" and "royal". "Royal" supremacy, "whereby the free are governed", denotes for example the rule of reason over the appetites. He argues clearly that the moral virtues, of the rational and of the sensitive appetites, partake of reason but that there is no intrinsic role for, as opposed to obediential relationship to, intellect in acts of the virtues of the sensitive appetite. He applies this view also to justice, the habit disposing the rational appetite.

because rationality is intrinsic to them, but rather because they are dispositions of their respective appetites to obey reason.

There are intimations of this distinction in the scenarios presented about the life of Dr Nagai. The process whereby he brings his emotions under the rule of reason is demonstrated in his response to the Allied leaflet dropped from the plane. This contrasts with the apparently instantaneous insight to treat friend and foe with the same kindness.

4.1.2.6 If in addition to prudence, the speculative intellect plays a role in virtue, the speculative intellect will be perfected by its own proper habits.

Keenan clarifies the relationship between the speculative intellect, the practical intellect and moral virtue. Each is distinct. He writes of "an implicit hierarchy" in Aquinas: synderesis,[1127] prudence, and then the moral virtues.[1128] It is "Natural reason known as synderesis (that) appoints the end to moral virtues."[1129] Each is distinct: "Prudence relies on the moral virtues to dispose themselves to those ends that synderesis has appointed."[1130]

That the speculative intellect disposes moral virtue to its end, does not mean that the speculative intellect is somehow internal to moral virtue. In fact we read that the speculative intellect is perfected by its own appropriate habit: there are three habits of the speculative intellect: wisdom, science and understanding.[1131] Although we read that the virtue of understanding[1132] (habitual awareness of first

[1127] Porter, "Contested categories: Reason, Nature, and the Natural Order in Medieval accounts of the Natural Law," 218. Jean Porter notes that synderesis is not the natural law but "the habitual knowledge of the fundamental principles of the natural law"
[1128] James F. Keenan, "The virtue of prudence" in *The Ethics of Aquinas*, ed. Stephen J. Pope (Washington DC: Georgetown University Press, 2002), 260. See *ST*, IIa-IIae, Q.47, Art.6.
[1129] "The moral virtues tend to an end appointed by human reason."(*ST*, IIa-IIae, Q.47, Art.6.3.)
[1130] Keenan, "The virtue of prudence," 261.
[1131] *ST*, Ia-IIae, Q.57, Art.2.
[1132] "Sometimes, in the context of practical intellect (this is) called synderesis" Naus, *The Nature of the Practical Intellect according to St Thomas Aquinas,* 87. "The habits from which conscience is informed, although they be many, nevertheless all have efficacy from one first source, sc., from the habit of first principles which is called synderesis." *ST*, Ia, Q.79, Art.13.3.

principles) is necessary for the operation of virtue, we return to the fundamental principle that each power is perfected by its own specific virtue. In summary, the speculative intellect does play a prior role in the exercise of moral virtue but is, itself, perfected by its own distinct virtue, understanding.

Understanding and prudence do not operate like justice, nor justice like temperance or fortitude. The rational virtues operate in modalities quite different from those of the virtues of the sensitive appetites. A disposition of the sensitive appetites must itself have exclusively sensible characteristics. Again consider the analogy of the "self control" of a dog sitting on command, a self-control founded on biological processes and elements; on the other hand, a disposition of the reason, or of the rational appetite, may be expected to manifest less "materiality".

4.1.2.7 Rather than of "an act of an isolated virtue" it appears more appropriate to think in terms of "a moral operation perfected by the integral involvement of multiple virtues".

Although it is common usage, strictly speaking it is a misnomer to think or write in terms of "acts of individual virtues". Virtues do not act, rather they are dispositions that perfect moral action. Furthermore, it would appear that "moral acts disposed by individual virtues" itself is a rather theoretical construct. In practice, every moral act requires prudent judgement and deliberation, consideration of impact of the actions on others, and habitual self management disposed by the virtues of the sensitive appetites.

It is evident from the scenarios presented in the life of Dr Nagai, that each of the actions we examined in detail could be interpreted as an action in which dispositions of the four cardinal virtues were all in evidence. For example, his fabrication of the Japanese flag from his own blood demonstrates prudent action, a concern for those he leads, as well as remarkable fortitude and self control.

It is more accurate for us to utilize language such as, “a moral operation perfected by various virtues.” If we think in terms of “moral operations”, actions disposed by virtues in concert, rather than actions disposed by “moral virtues acting in isolation from each other” there is no longer any difficulty in ascribing rationality to the actions of temperance and fortitude.

In contrast to a view that each of the individual moral virtues requires its own internal “package” of rational and corporeal components, let us think rather in terms of moral operations. Aquinas seems to suggest as much when he writes,

> As much as the intellect considered in its purity differs from the composite of soul and body, so much does speculative operation differ from operation which takes place according to moral virtue.[1133]

Note that he applies the term “operation”, specifically reserved to the action of the intellect and will, to virtuous action in general which he suggests in the analogy has a corporeal as well as rational dimension, a dimension extending into the domain of the virtues of the sensitive appetites. If this reading is correct, he therefore suggests the integrated complicity of various virtues in the completion of one moral operation.

Furthermore, complexity of motivation suggests that virtues are present in concert. Considerations of motivation are a useful lens through which we can study whether or not “actions of individual virtues” may be said to occur. The appropriate motivation of any action is that the deed be worthy in itself and carried out for a noble end, that is, an end which is according to right reason and which takes into full account one’s duties towards others. Hence the simple act of a doctor carrying out a most unpleasant act is disposed by fortitude, and carried out therefore according to right reason (prudence) with perfect regard for their

[1133] Aquinas, *In X Ethicorum,* trans. C. I. Litzinger (Chicago: Henry Regnery, 1964), 1, 11.

impact on others (justice); yet while it may be disposed by fortitude, it is clearly an operation involving the contribution of all the virtues.

And is temperance involved in this action? Most definitely. One of the reasons Aquinas offers for separate virtues for the concupiscible and irascible appetites is that at times these appetites operate at cross purposes: the ardous and nauseating good of treating a putrid wound is undermined by one's desire for delectable sensation. Both virtues are required.

It is clear that in this arguably-single action, Nagai is motivated by a variety of intentions: to exercise his duty of leadership, to withstand pain sufficiently to accomplish the action, to lift his own spirits. These intentions suggest the involvement of various virtues, respectively justice, fortitude and perhaps some virtue associated with temperance. Hence in this action of Nagai all the virtues are arguably present.

4.1.2.8 As it is the cause of virtue, reason is necessarily external to moral virtue.

The moral virtues of the sensitive appetites may only exist properly speaking in ensouled matter; the human body enjoys its capacity virtue because human beings are rational. At the metaphysical level, the soul animates the body, rationality disposes matter for virtue; and at the biophysical level, virtue is "caused by human acts... (proceeding) from reason, by whose power and rule the aforesaid good is established."[1134] The very acquisition of virtue is natural to a human being. These insights offer far reaching implications for this study.

There is no question that reason, guided by the rationality of the agent, plays a decisive role in the formation of the virtues. We read: "Habits of moral virtue are caused in the appetitive powers, according as they are moved by the reason."[1135]

[1134] *ST*, Ia-IIae, Q.62, Art.2.
[1135] *ST*, Ia-IIae, Q.51, Art.2.

Yet another, short, fascinating passage assists us in interpreting this "according to mode fixed by reason"[1136]. Aquinas allows either for habits acquired by training as a young child, or acquired by deliberate personal choice of repetition of acts. He states that virtue is caused by human acts carried out at the direction of reason. He writes,

> Human virtue.... can be caused by human acts... (proceeding) from reason, by whose power and rule the aforesaid good is established.[1137]

This is born out also in a passage where Aquinas differentiates between the material presence of the virtue and the origin of the sensitive virtues whereby they are in reason and will, virtually, as a root. He uses the case of the separated soul to illustrate the limitations of the virtues of the sensitive appetites. [1138]

Of course, and here is the crux of the argument, if reason is decisive in giving virtue its form, in being "origin and beginning", then it is *extrinsic* to virtue. Reason in such a role, would need to be perfected itself by previously existing habits.

At times Nagai takes decisions that subsequently serve to build up his virtuous character. For example, the decision to treat enemy patients with compassion and the subsequent exercise of this decision, led to an habituation of these selfless actions and to the discovery of the joy intrinsic to the virtue. In this we see an example of how reason gives rise to virtue as its cause.

4.1.2.9 Analysis of the human act supports the view that various virtues are present in concert in a single human act.

[1136] *ST*, Ia-IIae, Q.67, Art.1.
[1137] *ST*, Ia-IIae, Q.62, Art.2.
[1138] Aquinas, *Disputed questions on virtue*, 4 ad13. "Powers (of the sensitive part of the soul) … do not remain in the separated soul, save virtually, as in a root, because the powers of the soul flow from its essence. But these virtues are in the irascible as far as their derivation goes, but according to origin and beginning they are in reason and will, because choice is the principle act of moral virtue and it is an act of rational appetite. But by a kind of application this choice terminates in the passions of the irascible and concupiscible because of temperance and fortitude."

Virtue empowers us to act, but it is incorrect to conclude that therefore all virtue pertains to the soul as its subject. It is argued here, in considering the elements of the human act, that all the virtues are required for a perfect human act, and that these virtues perform quite distinct contributions within the human act as it evolves. Again the moments we have studied from the life of Nagai appear to bear out the view that the various virtues are all present. Also, we see, for example in his consideration of the leaflet, that it was only after he mastered his anger and sensitivity to the enemy leaflet's wording, that he was able to rationally assess the message.

i. <u>Input from the sensitive appetite precedes the rational in the human act.</u>

Aquinas states clearly that in the completion of good human acts, both intellectual and moral virtues are needed.

> …for a man to do a good deed, it is requisite not only that his reason be well disposed by means of a habit of intellectual virtue; but also that his appetite be well disposed by means of a habit of moral virtue.[1139]

But what is the relationship between these virtues as the act "evolves" through the steps of *intention* and *execution* as outlined in **Table 3.1**?

Reflection on the "structure" of the human act suggests that input from the sensitive appetite takes place prior to the interplay of intellect and will that is present in every human act. Therefore it would be incorrect to confuse the virtues of the sensitive appetite and the various virtues disposing rationality.

At their origin, there are two basic kinds of appetitive potencies, one pertaining to sense knowledge, the other to intellectual knowledge.[1140]

[1139] *ST*, Ia-IIae, Q.58, Art.2.
[1140] H. D. Gardiel OP, *Introduction to the Philosophy of St Thomas Aquinas (III Psychology)*, (St Louis: Herder, 1956), 82.

> In man there are but two principles of human actions, namely, the intellect or reason, and the appetite: for these are the two principles of movement in man as stated in *De Anima* iii text 48. Consequently every human virtue needs be a perfection of one of these principles.[1141]

The appetitive potency relating to sense knowledge has its own proper disposition.

> Sensitive appetite tends only towards particular goods as such, but intellectual appetite, which is the will, always desires these goods under some universal aspect of good.[1142]

Thomas argues the sensitive appetites is composed of the concupiscible, attracted to easily attained goods, and the irascible, attracted to arduous goods. The concupiscible appetite is moved by the imagination and the common sense, the irascible by the cogitative and the memory. [1143] Gardiel reflects, "Since the faculties eliciting these acts are organic powers, the acts necessarily involve bodily changes," [1144] changes, according to Thomas, in the passions.[1145]

These organic powers present input to the rational appetite, by way of phantasm, in the first steps of the human act.

Because these steps precede the interactions of the intellect and will that have been outlined in **Table 4.1**. Because of this temporal precedence, *in actu* it is evident that rationality and the sensitive appetites are distinct.

[1141] *ST*, Ia-IIae, Q.58, Art.3.
[1142] Gardiel, *Introduction to the Philosophy of St Thomas Aquinas (III Psychology)*, 82.
[1143] Gardiel, *Introduction to the Philosophy of St Thomas Aquinas (III Psychology)*, 83.
[1144] Gardiel, *Introduction to the Philosophy of St Thomas Aquinas (III Psychology)*, 84.
[1145] Aquinas enumerates 11 passions: love or hatred, desire or aversion, hope or despair, courage or fear, anger, and joy or sorrow. See *ST*, Ia-IIae, Q.22-48.

ii. The contribution of emotion to rationality also argues for a "moral-operations view" rather than of a view of actions disposed by isolated virtues.

Analysis of the human act will not only account for rational action but for rational action enriched with emotional input. In illustration we see in the life of Nagai that the remarkable fabrication of the flag is propelled by patriotic emotion. An analysis of how this happens can assist us in defining the respective roles of the virtues.

There is necessarily a point in the deliberation preceding the completion of a human act where emotional readings of the situation and an appreciation of context of action come into play. I suggest that this can happen at two points.

First, positive emotion associated with an action can provide stimulus prior to the action. For example, a love of nature leads Nagai to write poetry with imagery drawn from nature. Note that this refined pleasure is prior to the actual choice to act. (Also prior to the action proper, negative emotions can be mastered, as we have seen in his reaction to the leaflet.)

Second, positive emotion can be generated at the level of relationships with others. Pertaining to the virtue of justice, and therefore in the rational appetite, this takes place within the steps outlined of the human act. This contribution takes place, it would appear, at the stage in the human act which some term the practico-practical judgement in Aquinas's psychology (Steps 6-8 in **Table 3.1**), in which the will adds its own particularising content to the input it receives from the intellect (correspondingly the speculative-practical judgement) prior to its act.[1146] This particularising content is arguably moderated by the virtue of justice.

[1146] For clarity of understanding about the role of the practico-practical judgement (not extending however to implications for the virtue of justice) I have drawn on an article of Alice Nelson, Centre for Thomistic Studies teaching materials: http://www.cts.org.au/articles (accessed 24/10/2012).

This is a further argument for the complex interplay of all the virtues in each act of virtue and a further compelling argument that no fully moral action can be performed without taking the impact of one's action on others into account.

iii. Furthermore, discrete ascription of a particular action to a single virtue is problematic. Actions in real life manifest the constellation of virtues.

Actions in the real world defy discrete classification into boxes of one virtue or another. For example, Jean Porter has drawn attention to the folly of considering acts of temperance as if these are pursuits distinct from concern for others. It is not possible to consider sexual temperance in isolation from justice understood as a consideration for how one's actions impact on others. Every sexual act impacts potentially, and often immediately, on others. Both notions, and therefore both virtues, are present.[1147]

It would seem too that acts of perfect virtue must be enriched by justice. Nancy Sherman draws attention to the need for virtuous acts to be moderated by justice: "Virtuous agents act taking into account the wellbeing of others, the common good."[1148] This is in accord with the intuition that it is necessary to take into account the impact of our actions on others for a given action to be just. In fact, acts of prudence will not be perfect unless they take into account "circumspection". I suggest that to do so, in those matters relating to the rights and good of others, the habit of justice is required in the will.

Jean Porter insists that it is recurring real life actions that provide the matter for virtues. "Justice is concerned with actions which involve others,

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Accessed 24/10/2012

[1147] This is of course in keeping with the Thomistic view (*ST*, Ia-IIae, Q.61, Art.4).

[1148] Sherman, *The Fabric of Character*, 4.

and not just the agent herself". We should consider that all actions require require rationality informed by justice for their perfection.[1149]

Note that Porter contrasts virtuous actions in real life with a rarefied theoretical perspective that would like unrealistically to see a neat delineation of virtues. Surprisingly she finds fault in Aquinas's view of acts of temperance, suggesting that such acts seem to exclude justice. Yet it is Aquinas himself who insists that in a perfect act of one virtue all virtues are present. (See also **4.3.1**.)

> However a perfect moral virtue is a habit directed to a good work, done well. And taking the moral virtues in this way, we ought to say that they are connected, as nearly everyone agrees.[1150]

4.1.2.10 The "durability" of the individual virtues differs in meaning according to the specific virtue.

The hypothetical discussions in Aquinas about the duration of the virtues in the disembodied state are most illuminating on this question of the differences between the virtues. He makes crucial distinctions between the virtues perfecting rational operations and those perfecting the sensitive appetites.

Aquinas argues that the habits of virtue all enjoy a "certain" durability but draws significant contrasts. In what does their durability variously consist?

Prudence retains a "quasi-formal element"[1151], the intelligible species that remain after corruption of the body. Aquinas naturally holds that, at the decomposition of the body, any corporeal substrate of prudence and of the moral virtues decomposes. Although Aquinas refers specifically to the phantasms the position of

[1149] Porter, *Moral Action and Christian Ethics*, 143.
[1150] *ST*, Ia-IIae, Q.65, Art.1.
[1151] *ST*, Ia-IIae, Q.67, Art.2.

this study would be that the bodily substrate should be considered more broadly to include the array of neural processes, pathways and mechanisms assisting virtue. Aquinas writes:

> …the phantasms, by turning to which man understands in this life by applying the intelligible species to them,[1152] cease as soon as the body is corrupted.[1153]

Similarly justice, although a disposition of the rational appetite, has a bodily element that must ultimately decompose. [1154]

Aquinas argues that, after the corruption of the body, in the state preceding resurrection of the body, justice nevertheless will have a presence. [1155]

Justice, then, enjoys an immateriality comparable to that of prudence, although the operations of acts of justice and prudence stand somewhat in contrast. Prudence is a habit of intellect. Justice is a habit caused in the will by reason, by the settled conviction that personal actions must respect the rights of others. Acts of justice will implicate specific part-constituents in memory, imagination and presentation of the phantasm, motivation, empathy to others, reward systems of the body, etc.

Justice will only operate in concert with prudence and the virtues disposing the sensitive appetites. Aquinas says that the will is always implicated in the exercise of moral virtues: "...since the will is a rational power, it may be variously directed to act."[1156] On the one hand, as the virtue properly of the rational appetite and through the involvement of reason, it would seem that biophysical pathways and

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[1152] cf *ST*, IIae, Q.84, Art.7 and IIae, Q.85, Art.1.5.

[1153] *ST*, Ia-IIae, Q.67, Art.2.

[1154] *ST*, Ia-IIae, Q.53, Art.2.3. "The intellectual part of the soul, considered in itself, is above time, but the sensitive part is subject to time, and therefore in the course of time it undergoes change as to the passions of the sensitive part, and also as to the powers of apprehension. Hence the Philosopher says (Phys iv text 117) that time makes us forget."

[1155] *ST*, Ia-IIae, Q.67, Art.1.3. "Justice however will remain because it is in the will. Hence of justice is it specifically said that it is perpetual and immortal; both by reason of its subject, since the will is incorruptible; and because its act will not change, as stated."

[1156] *ST*, Ia-IIae, Q.50, Art.5.

processes are concurrently implicated in the reasoning processes of rational judgment and command, presenting particulars at the service of rationality. On the other hand, justice is not present without the presence of the virtues of the sensitive appetite. In sum, a constellation of part-constitutional processes accompany the exercise of every virtue.

On the other hand, Aquinas draws a complete distinction between virtues of prudence and justice, and the virtues of the concupiscible and irascible powers.[1157] Aquinas writes, "In these (moral) virtues (in the afterlife) there is a formal element, which is the 'order of reason' (as we have seen above), and a quasi-material element."[1158] Note the contrast with prudence, which he explains retains a "quasi-formal" element.

The intellectual appetite is quite distinct from sensitive appetite "since what is apprehended by the intellect is different from what is apprehended by the senses."[1159] This is consistent with the view expressed elsewhere by Aquinas that justice endures when the body and soul are separated. He explains that "the intellectual appetite ... tends to individual things which exist outside the soul... as standing under the universal; as when it desires something because it is good."[1160] The virtues of the sensitive appetites do not continue to exist except for the "order of reason", which as we have seen exists externally to the virtue, and in the somewhat perplexing "quasi-material element"; yet after death, material goods themselves are absent, nor is there any biological substrate to present phantasms of that which is pleasurable and that which is painful.

In answer to Ramsay's suggestion that the moral virtues, as rational dispositions, continue to exist after dissolution of the body, it would seem important to clarify the meaning of "rational disposition". The only truly rational dispositions are prudence and justice, or understanding, which perfects the speculative intellect

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[1157] *ST*, Ia-IIae, Q.57, Art.4.
[1158] *ST*, Ia-IIae, Q.67, Art.1.
[1159] *ST*, Ia, Q.80, Art.2.
[1160] *ST*, Ia, Q.80, Art.2.2.

and establishes the end of the moral virtues. Aquinas makes it very clear that fortitude and temperance are in fact dispositions of the material appetites, albeit orderly dispositions caused by reason.

In summary, what is the role of reason with respect to the sensitive appetites? Reason appears to interact with the sensitive appetites in two principal ways, which we can refer to, for the sake of clarity, as the micro level, and the macro level. [1161]

i. At what we can consider as the micro level, Aristotle argues that in each human act motivated by the sense appetites one is moved by the desire for appropriate pleasures and to avoid specific pains regarded as inappropriate and disproportionate to a worthy outcome. Reason then, in bringing to completion the human act, responds to the initial appetitive stimulus, either by legitimising the choice, or rejecting it. [1162] Secondly, also at this micro level of individual acts, reason is able to harness the energy of the passions at the service of the person.
ii. At what we could call the macro level, a further outcome of this process is that reason "trains" the sensitive appetites over time in what is appropriate pleasure and pain.[1163]

4.2 Biological and functional distinctions between the virtues.

Now, having presented a systematic case for a restricted reading of "by participation", in the section which follows, I summarise Aquinas' understanding

[1161] Naus, *The Nature of the Practical Intellect according to St Thomas Aquinas*, 73. These two processes appear described (albeit in a rather muddy fashion) by one commentator in the following text: "Therefore reason, which moves the sense powers of appetite, and the appetites themselves need habits in order to operate well. So in the concupiscible appetite there is the virtue of temperance and in the irascible that of fortitude. These virtues keep their respective powers habitually in line with reason."

[1162] *ST*, Ia-IIae, Q.57, Art.4. "... it is a requisite for prudence....that man is well disposed with regard to the ends; and this depends on the rectitude of his appetite. Wherefore, for prudence there is need of a moral virtue, which rectifies the appetite."

[1163] This also corresponds to the process of "training" that Aristotle identified, along with "education" which is more to do with the rational appetite and intellect, as one of the two key methods of bringing about virtue.

of the distinctive characteristics and role of each of four cardinal virtues. Throughout I argue that Aquinas' understanding of the moral virtues of the sensitive appetites is indeed one in which reason plays a causal role in the formation of virtue, but that in themselves, the dispositions of the sensitive appetites are founded exclusively on the biological.

In order to better understand the relative roles of the cardinal virtues, and in particular, to develop a clearer understanding of areas where we will expect to find biophysical part-constituents for each, it is highly advantageous to utilise the lens of hylomorphism.

This section builds upon, and should be read in the light of **1.4** in which the hylomorphic underpinnings of this study and certain principles of rational psychology are discussed.

An hylomorphic analysis of virtue, following Aristotle and Aquinas, will assist us in discriminating between aspects of virtue associated with the operations of rationality, and aspects pertaining to sensitive activity. Such an analysis provides insights into the specific contribution of rationality to the formation and exercise of virtue, into the ordering or "disposition" of anatomical structures and dynamics which appear to facilitate virtue, and insights also into the distinction between the various virtues in regard to their "corporeality". Such an analysis is essential prerequisite for **Chapter 5**, in which neural locations, pathways and processes will be suggested, on the basis of current neuroscientific knowledge for the material substrate of virtue. As neuroscience can only shed light on the material aspects of virtue, a prerequisite for resolution of this task is to distinguish between the rational and material characteristics of virtue.

It is important to bear in mind that while the cardinal virtues are regarded as the principal umbrella categories of virtue, other virtues may or may not neatly categorise under one or other of the cardinal virtues. Nevertheless, for the purposes of clarity, this study focuses almost exclusively on the cardinal virtues.

4.2.1 The cardinal virtues have distinctive roles in the operation of virtue.

As an introduction to an examination of the exercise each of the cardinal virtues, let us turn to some elegantly condensed argument from Aquinas where he explains their distinctive roles:

> Things may be numbered either in respect of their formal principles, or according to the subjects in which they are: and either way, we find there are four cardinal virtues. For the formal principle of the virtue of which we speak now is good defined by reason; which good can be considered in two ways. First as existing in the very act of reason; and thus we have one principal virtue called Prudence. Secondly, according as the reason puts its order into something else; either into operations, and then we have Justice; or into passions, and then we need two virtues. For the need of putting order of reason into the passions is due to their thwarting reason, and thus the passions need a curb, which we call Temperance. Second, by the passions withdrawing us from following the dictate of reason, eg through fear of danger or toil: and then man needs to be strengthened for that which reason dictates, lest he turn back; and to this end there is Fortitude.
>
> In like manner, we find the same number if we consider the subjects of virtue. For there are four subjects of the virtue we speak of now; viz, the power which is rational in its essence, and this is perfected by Prudence; and that which is rational by participation, and is threefold, the will, subject of Justice, the concupiscible faculty, subject to Temperance, and the irascible faculty, subject to Fortitude.[1164]

[1164] *ST*, Ia-IIae, Q.61, Art.2.

In the sections below, in turn we will focus on the specific role of each of the cardinal virtues: prudence the virtue perfecting rationality, justice perfecting the will, fortitude the irascible appetite, and temperance the concupiscible.

a) The distinction between the virtues properly of the soul and those properly of the body.

In the examples from the life of Nagai we saw moments of instantaneous insight, convictions, and dispositions towards his fellow men, that are seemingly independent of time and place, and any process of clarification; other actions both of deliberation and of self control appear to take time with the subject acquiring progressively greater lucidity. An example of the first is the powerful conviction that he must treat all men equally; of the second, his ruminations on the import of the leaflet. These contrasting examples suggest fundamental differences between some virtues and others. Some appear to pertain to a truth that is grasped, another to a process of managing one's emotions.

First let us consider the broader contrast between the prudence and justice on the one hand, and fortitude and temperance on the other. The cardinal virtues appear to be part-constituted to differing extents by a material substrate. As we have seen, habit is a broad term, denoting simply some form of disposition. The various cardinal virtues are not habits in the same fashion. It is helpful to distinguish between those cardinal virtues more closely associated with rationality, namely prudence and justice, and those directly associated with the sensitive appetites.

b) Prudence and justice, as they are associated more directly with the rationality, are more removed from the biophysical substrate.

Aquinas argues,

> Some of the powers of the soul are in it according as it exceeds the entire capacity of the body, namely the intellect and will;

whence these powers are not said to be in any part of the body.[1165]

I suggest, on the basis of reasoning that "of the soul" can be understood broadly as "of the person", that it is within a reasonable understanding of this passage to affirm that prudence and justice are, in part, neurobiological modifications of pathways, processes and mechanisms, and that it is within the very nature of the ensouled body, animated matter, that these pathways, processes and mechanisms perfect rationality.

Aquinas goes on to suggest,

> Other powers are common to the soul and body; wherefore each of these powers need not be wherever the soul is, but only in that part of the body which is adapted to the operation of such a power.[1166]

In other words, powers common to the soul and body, and by this we can understand all the virtues, are quite localised. Of course this view is compatible with the view that the virtues, including fortitude and temperance, are also powers of the soul, just as any other material organ able to be directed by the rational appetite (for example the eye) operates as a power of the soul.

c) Fortitude and temperance have a dual dependency: on the soul and on the corporeal organs.

The soul is the principle of the act of virtue; the corporeal organs are material causes of rational operations. Aquinas explains:

> Every act of a power that uses a corporeal organ, depends not only on a power of the soul, but also on the disposition of that corporeal organ: thus the act of vision depends on the power of sight, and on the condition of the eye, which condition is a help

[1165] *ST*, Ia, Q.76, Art.8.4.
[1166] *ST*, Ia, Q.76, Art.8.4.

> or a hindrance to that act. Consequently the act of the sensitive appetite depends not only on the appetitive power, but also on the disposition of the body.[1167]

In other words fortitude and temperance, habits by which the irascible and concupiscible sensitive appetites are docile to reason, achieve their effect wholly by means of corporeal processes and pathways that have been ordered by reason.[1168]

d) Temperance and fortitude are at the heart of a rational response to pain and pleasure and therefore to appetition that is truly human.

Examples from the life of Nagai demonstrate just how fundamental to human existence are the dual challenges of curbing wayward passions and overcoming difficulties in the pursuit of difficult goals. We see this time and again: Nagai's repulsion to the putrid wounds is overcome in order for him to put into practice his noble goal of ministering to the wounded; he overcomes his exhaustion and concern for his safety in order to give positive leadership to his workers; he masters his humiliation and anger to consider the implications of the Allied leaflet; he masters his self pity and apathy in his illness to deliver a prodigious output of writing aimed at helping others. There is no question that direction and mastery of our sensitive appetites are the very matter of our daily lives.

On the one hand, the four cardinal virtues are concerned with management of the realms of human activity... intellect, will, and sensitive appetites. But we must remind ourselves that the intellect and will operate in this material world. To some extent it is true to say that prudence and justice exist so that temperance and fortitude are well guided. Aristotle's emphasis on pleasure and pain in his discussion of virtue helps us to see this clearly, and also this *constitutive view* of

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[1167] *ST*, Ia-IIae, Q.17, Art.7.

[1168] Ordered by reason in two senses: first informed by rationality and therefore matter that is "special", and second because reason has contributed to the very development. (cf notion of use-induced plasticity leading to the development of neural complexity).

virtue, with its emphasis on the role of rationality in managing the biological aspects, can add clarity.

Aristotle places fortitude and temperance, ordered to the cultivation of man's passions,[1169]at the very heart of human appetition: to seek pleasure and avoid pain. At this most elemental level temperance in response to hedonism, and fortitude in response to fear and pain, are dispositions to self mastery. These basic motivations are widely accepted by clinical psychiatry and supported also by neuroscience. For example, the dominance of fear in the unregulated person has been noted in contemporary psychopathology:

> Brain scans show that many violent adults are still driven, just like infants, by their ancient rage/fear and defence/attack responses deep in the mammalian and reptilian parts of the brain. The brain scans show all too little activity in the parts of the higher brain that naturally regulate and modify raging feelings. [1170]

Aristotle and the psychopathologists would agree on many things. In a similar way, children lack the wherewithal to manage their passions: The lives of children, as much as that of intemperate men are governed by their desires.[1171]

Aristotle explains that pain and pleasure enter into *both* temperance and fortitude.

> The self indulgent man craves for all pleasant things or those that are most pleasant, and is led by his appetite to choose these at the cost of everything else; hence he is pained when he fails to get them and when he is merely craving for them (for appetite involves pain).[1172]

[1169] Gilson, *The Christian Philosophy of St Thomas Aquinas*, 308.
[1170] M. Sunderland, *The Science of Parenting* (London: Dorling Kindersley, 2006), 25.
[1171] *NE,* 3.12.
[1172] *NE*, 1119a1-5.

Yet, the specific distinction between temperance and fortitude is clear. [1173]

> The good of curbing the passions is found chiefly in those passions which are most difficult to curb, viz, in the pleasures of touch. The good of being firm in holding to the good defined by reason, against the impulse of passion, is found chiefly in perils of death, which are most difficult to withstand.[1174]

Aquinas stressed that these emotional responses are positively good but only if they are managed by reason.

> Emotion leads away from moral behaviour in so far as it is uncontrolled by reason; but in so far as it is rationally directed, it is part of the virtuous life.[1175]

Now I review the specialized roles of the four cardinal virtues below with a view to gaining insights into the biophysical contribution of the body in the development, state and expression of virtue.

4.2.2 Prudence.[1176]

The contribution of prudence, perfecting each action, has already been noted in the four scenarios pertaining to Nagai above. Prudence on the one hand it is the habit of readily recognizing and acknowledging what is right and true, and on the more practical side, it is the habit of making sound judgements about what we will do. The first refers to recognizing reality; the starting point of prudence is

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[1173] Gilson, *The Christian Philosophy of St Thomas Aquinas*, 263. This text from Gilson serves as a further guide: "(Fortitude and temperance) bear upon the quality of acts, considered in relation to the one performing them. Thus, they deal with the interior dispositions of the agent at the moment of acting. They deal, in a word, with passions." Hence he explains, "If the agent is actually prevented from acting by fear of danger or of effort or the like, he needs fortitude to strengthen him in the resolutions his reason dictates." Analogously, temperance moderates the concupiscible appetite allowing one to act according to right reason.

[1174] *ST*, Ia-IIae, Q.61, Art.3.

[1175] *ST*, Ia-IIae, Q.24, Art.2.

[1176] Aristotle and Aquinas held that prudence, *auriga virtutum*, drives the chariot of the virtues. Aquinas writes, "Prudence not only helps us to be of good counsel, but also to judge and command well."

knowledge of reality.[1177] Second, prudence pertains to making decisions on right principles. It is an essential virtue for effective action: “practical wisdom is concerned with action.” [1178] What should also be evident are the common characteristics of deliberation, judgement and action.[1179]

The goal of the practical intellect is “truth in agreement with right desire”.[1180] And the intellectual habit of the practical intellect is prudence, having “something in common with the moral virtues; for it is right reason about things to be done.”[1181] The role of prudence is quite distinct from that of the moral virtues. [1182]

Most importantly, we have seen that prudence is ordained to human flourishing: “Prudence is a virtue of the rational part capable of procuring all that tends to happiness.”[1183] [1184]

4.2.3 Justice

a) A broad understanding of justice

[1177] “that which is prudent is in keeping with reality”: Pieper, *The Four Cardinal Virtues*, 9.
[1178] *NE,* 1141b21; Aristotle, *De Virtutibus et Vitiis*, 1250a30-37: “To prudence belongs right decision, right judgement as to what is good and bad, and all in life that is to be chosen and avoided, noble use of all the goods that belong to us, correctness in social intercourse, the grasping of the right moment, the sagacious use of word and deed, the possession of experience of all that is useful. Memory, experience, tact, good judgement, sagacity – each of these either arises from prudence or accompanies it.”
[1179] Pieper, *The Four Cardinal Virtues*, 72: “Prudence implies a transformation of the knowledge of truth into decisions corresponding to reality. This transformation is achieved in three steps: deliberation, judgement, decision.” Cf Gilson, *The Christian Philosophy of St Thomas Aquinas*, 288. Gilson writes of the facets of prudence: deliberation (*eubuilia*) and good judgement (*synesis, gnome*). It is not simply concerned with abstract truths. Aquinas says practical wisdom issues commands, distinct from understanding which judges the objects of practical wisdom. (*NE,* 1143a10)
[1180] *NE,* 11139a30
[1181] *ST*, Ia-IIae, Q.58, Art.3.1.
[1182] Aquinas writes, “It is not possible (for prudence to operate effectively) unless the impediment of the passions, destroying the judgement and command of prudence, be removed; and this is done by moral virtue.” *ST*, Ia-IIae, Q.58, Art.5.3.
[1183] Aristotle, *De Virtutibus et Vitiis,* 1250a30.
[1184] Gilson explains: “Prudence is a practical presence of mind.... well trained reason, capable of working out the particulars of a problem, of foreseeing the probable consequences of an act, of using powers of circumspection, of weighing the individual circumstances of a situation, of exercising caution lest good intentions ultimately do more harm than good. Reasoning, foresight, watchfulness, precaution are all essential elements of prudence, and there is no real prudence without them.” Gilson, *The Christian Philosophy of St Thomas Aquinas*, 288.

A broad notion of justice is exemplified in the scenes presented from the life of Nagai. His service to his enemies, his patriotic leadership, his faith, his concern for his countrymen, his diligent parenting… all of these are not strictly reciprocal, but they all reflect a deep abiding concern to respect others and to live up to one's duties towards them.

In this study I adopt the broad understanding of justice that is in best keeping with the spirit of the discussion in both Aristotle and Aquinas, and is also most consistent with the neuroscientific insights on offer.

In *The Recovery of Virtue* Jean Porter argues for a broad notion of the virtue of justice extending beyond strict reciprocity. Such an understanding, a justice by which we measure our actions by the love and respect we have for others, is able to demonstrate the deficiencies of duty and consequence based measures in accounting for truly noble behaviour. Such a view is very attractive to this current study which proposes for justice a contributory role in every perfect human act whereby the impact of one's actions on others is considered prior to the decision to act.

Justice on this broad understanding is the disposition to act at all times offering all others the respect due to them, with full acceptance of all our responsibilities in this world. A parenting author who structures much of his work around the development of virtue prefers to write of justice as just this: "respect and responsibility".[1185] Another has founded the Institute for the 4th and 5th Rs – denoting *respect* and *responsibility*.

Gilson describes justice in this broad manner.

> (Justice) regulates the content and nature of the operation of the will... assuring the moral value and rectitude of all

[1185] James B. Stenson, http://www.parentleadership.com (accessed 10 May 2011).

operations in which ideas of what is due and not due are implied.[1186]

This second of the cardinal virtues" ensures rectitude in the election of the will for means required in the pursuit of goals. Aquinas describes justice as the psychological and moral state of a man who "firmly and permanently chooses to render to each one his due."[1187] Aristotle teaches, "The best man is he who exercises his virtue towards another".[1188] He dubs justice "the complete virtue" because it orders one's acts with respect to others.

Justice is often thought to be the greatest of the virtues... proverbially "in justice is every virtue comprehended".

We must not define justice in terms of tangible transaction, nor narrow the scope of justice. Justice manifests externally but as a virtue it concerned with inner dispositions, with choices. [1189] Universally, the just denotes what is lawful; and particular case, what is fair and equal. It is a complete virtue because "it is the actual exercise of complete virtue... because he who possesses it can exercise it not only in himself but towards his neighbour also".

It would appear that Aquinas, by aligning justice to the good of reason, himself favoured a broad interpretation.[1190] [1191] Aquinas argues that justice is the state of character that makes people disposed to do what is just, and makes them act justly and wish for what is just.[1192]He explains the role of the virtue of justice.

Justice is "a habit whereby men will and do that which is just" (*Ethic* v 1). Therefore the will is the subject of habit. ...The will is inclined to the good of reason. But because this good is varied

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[1186] Gilson, *The Christian Philosophy of St Thomas Aquinas*, 263.
[1187] ST, IIa-IIae, Q.58, Art.1.
[1188] *NE,* 1129b25ff.
[1189] *NE,* 1134ff.
[1190] It is true that Aquinas explains a taxonomy of justice, corresponding to the three basic relationships: *reciprocal* justice (individuals to one another), *distributive* justice (community to the individual), and *general* justice (individual to the community).
[1191] Pieper *opcit* p.27 Pieper, a close follower of Aquinas was of this opinion. "'It is the function of justice to carry out the order of reason in all human affairs." "The other virtues – fortitude and moderation – serve the conservation of this good; it is their function to preserve man from declining from the good. … Fortitude protects this realization (of the good made compelling evident through prudence) and clears the road for it."
[1192] *NE,* 1129a7ff.

> in many ways, the will needs to be inclined, by means of a habit, to some fixed good of the reason, in order that action may follow more promptly.[1193]

In writing about the various forms of debt that give rise to justice, it is clear that he goes beyond strict reciprocity, including duties of religion and of filial gratitude.[1194]

Aquinas explains that the rational appetite, being naturally attracted to the good of the subject, requires no virtue to exercise this natural operation. The virtue which disposes the rational will to act for the good of another, in contrast to that of oneself, is justice. As we have seen, justice will always act in concert with prudence, and that the moral virtues are "rational by participation".[1195]

In summary, it is the position of this study that all moral acts require the deliberations of justice. Every moral act has a dimension impacting on others and so requires the exercise of justice if it is to be a good act. It is also apparent that prudence is not possible without deliberations of justice, nor temperance nor fortitude. It is perhaps for this reason Gilson suggests that justice incorporates the other virtues: "Justice is a kind of general virtue which includes all other virtues."[1196]

4.2.4 An understanding of the biophysical dimensions of prudence and justice.

(Read in conjunction with **4.2.1 a** and **b**.)

a) What is the matter?

[1193] *ST*, Ia-IIae, Q.50, Art.5.
[1194] *ST*, Ia-IIae, Q.60, Art.3. "Corresponding to these various kinds of debt there are various virtues…. Religion whereby we pay our debt to God, piety (respect) whereby we pay our debt to our parents or to our country; gratitude, to our benefactors, etc."
[1195] *ST*, Ia-IIae, Q.59, Art.4.
[1196] Gilson, *The Christian Philosophy of St Thomas Aquinas*, 292.

Acts of prudence and justice are acts of rationality with indirect material cooperation to extent that each inform our reasoning processes involving material assistance of memory, phantasm, imagination, etc. To the extent that these biologically based processes are necessary (but not sufficient) for these virtues to operate, they may be understood as part-constituents of virtue.

Various arguments support this view.

i. It is important to understand that the management of the concupiscible and irascible appetites is normally the product of a reasoning process. Reasoning implies a *process* of thought disposed by habit.[1197] In our exploration of this issue it is essential to distinguish reason from immaterial rationality.[1198]
ii. A reasoning process implies that there must be biophysical elements that enable the process of reasoning: "the irascible and concupiscible are said to obey reason rather than the intellect."[1199] Bodily elements imply duration in decision making. We have seen in the examples from the life of Nagai, for example in his consideration of the leaflet dropped from the Allied plane, that deliberation as a precursor to virtuous action can take just such duration.
iii. The significance of phantasms has already been noted. Aristotle reminds us that prudence involves assessment of particulars, necessitating

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[1197] "Excellence in deliberation is clearly a kind of correctness."(*NE*, 1142b9) It involves reasoning. It is "correctness in thinking"(*NE*, 1142b12). But it is not simply following formal rules of logic which could lead a bad man to evil deeds. Excellence in deliberation is that which pertains to a worthy end.
[1198] *DA*, 427b27-28. In *De Anima* Aristotle addresses the interaction of intellect with the internal senses of memory and imagination. He is of the view that the activity of "thinking" is partly in the imagination and partly in the judgement of the intellect itself. "Thinking is different from perceiving and is held to be in part imagination, in part judgement."
[1199] *ST*, Ia, Q.81, Art.3.
The full quotation: "The irascible and concupiscible powers obey reason... universal reason directs the sensitive appetite, which is divided into irascible and concupiscible... but to draw particular conclusions from universal principles is not work of the intellect , as such, but of reason: hence it is that the irascible and concupiscible are said to obey reason rather than the intellect.... Man is not moved at once according to the irascible and concupiscible appetites: but he awaits the command of the will."

complicity of the material. [1200] The same may be said of justice. Aquinas quotes Augustine's view that while the intelligible species can be held in an intellectual memory, intelligence itself "that by which we understand when actually thinking",[1201] only exists *in actu*.[1202] This supports the view that the act of understanding is concurrent with and immediately dependent upon the presentation of the phantasm. This appears to constitute a further argument that there is no independent intellectual operation, of the body and soul united, without biophysical complicity. [1203]

iv. The role of the intellect and rational appetite in voluntarily calling up memories is contrasted with the formation of opinions (which Aristotle holds is not voluntary as it is a reflection of perception of truth in the intellect.) [1204] This interaction between imagination and reason, between the concrete representation and the universal, is present in every human act. Hence, every human act is carried out with the part-constituent of neural complicity. Aristotle insists on this. [1205]

v. All this sits perfectly with the earlier discussion about the role of reason in pursuit of the pleasurable and avoidance of pain. [1206]

vi. Furthermore, Aquinas tells us that "Words signify the conceptions of the intellect".[1207] It would appear that language facilitates reason. Without

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[1200] *NE,* 1141b15-25. "Practical reason is not concerned with universals only – it must be concerned with the particulars: for it is practical and practice is concerned with particulars."

[1201] *ST*, Ia, Q.79, Art.7.2.

[1202] Cf Augustine, *De Trinitate,* XIV.

[1203] *ST*, Ia, Q.79, Art.8. Aquinas sheds further light on material complicity in the virtue of prudence. He writes, "Reason and intellect in man cannot be distinct powers. We shall understand this clearly if we consider their respective actions. For to understand is simply to apprehend intelligible truth: and to reason is to advance from one thing understood to another, so as to know an intelligible truth." Hence, Aquinas defines reason as the progression from one thing understood to another; such a process of advancing from an understanding of "one thing" to another "thing" necessarily would require constant reference to the phantasm, and interdependence on the material. This opens the door to material processes that enable the process of reasoning, not of course the understanding itself that is the product of reasoning.

[1204] *DA,* 427b20.

[1205] *DA,* 431a17. "To the thinking soul images serve as if they were contents of perception (and when it asserts or denies them to be good or bad it avoids or pursues them). That is why the soul never thinks without an image..."

[1206] *DA,* 431b4-5. "The faculty of thinking then thinks the forms in the images, and as in the former case what is to be pursued or avoided is marked out for it, so where there is no sensation and it is engaged upon the images it is moved to pursuit or avoidance."

[1207] *ST*, Ia, Q.85, Art.5.

language, utilising, as we have seen in **Chapter 2**, specialised locations in the brain and specific biophysical processes for memory, our capacity for intellectual thought could be largely curtailed.

b) Biological perfections.

In summary, prudence and justice utilise biophysical processes and pathways (associated with reasoning, memory, imagination, etc) that themselves are identified with localised regions and processes in the brain.

Human action is rational action. Prudence and justice dispose our rational responses. They dispose the intellect to act with habitual sound judgment and the rational will to act with habitual respect for the rights of others. The rational operations of truth and love require the assistance of biological part-constituents in two senses:

i. The very operation of reason requires the assistance of imagination, memory, and other cortical systems and sensitive faculties.
ii. Because, as it is proposed, the virtues all operate in harmonious integration in support of rationality, it would appear that the part-constituents of the virtues disposing the sensitive appetites may also be understood, to the extent that they offer necessary assistance, as part-constituents of the rational operations.

In conclusion, it is proposed at the neurobiological level, prudence and justice are perfections of specific biological structures that are necessarily associated with rationality in the embodied life. These perfections of bodily structures are essentially neuronal facilitations of counsel, deliberation, judgement, command, and disposition to accommodate the good of others, as required by the virtues of prudence and justice.[1208]

[1208] Counsel may be understood as a having a sound grasp of reality and duty in both physical and ethical dimensions. Judgement implies the capacity to evaluate the intrinsic and extrinsic benefits

4.2.5 Fortitude

As we have seen, the moral virtues of justice, fortitude and temperance reside in the appetites.

Courage, as we have seen, is not about having the loudest war cry, but rather about having a particular quality of self management. This latter notion of courage is shown in the life of Nagai: risking his life to treat enemy soldiers with care and dignity, overcoming his pain, discouragement and disorientation to push himself to the limit in helping the victims of the bomb. Courage denotes a reflective bravery… not simply the bold actions of an impulsive person under pressure. Virtues are inner states. Aquinas says simply: "Endurance is more the essence of fortitude than attack."[1209]

An Aristotelian understanding of courage presents the virtue as:

> The habitual choice of the golden mean that resides between cowardice and recklessness in situations of danger that really merit some fear.[1210]

The right management of one's fear and its concomitant sorrow is at the heart of the virtue. The essence of the virtue of courage is mastery of one's emotions of fear, to puts one's life knowingly and calmly on the line. Joseph Pieper writes that "the man of fortitude relinquishes, in self forgetfulness, his own possessions and his life."[1211] Pieper, following Aristotle, argues that courage always contains an element of a preparedness to risk one's neck for a good cause[1212].

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of an action taking into account the good of others. Command implies the executive capacity to carry decisions into action.

[1209] ST, IIa-IIae, Q.123, Art.6.

[1210] *NE*, III, focusses on courage and temperance and their corresponding vices.

[1211] Josef Pieper, *Fortitude and Temperance* (London: Faber and Faber, 1955), 54.

[1212] "… all fortitude has reference to death… readiness to fall, to die, in battle. … Fortitude that does not reach down into the depths of the willingness to die is spoiled at its root and devoid of effective power. Readiness proves itself in taking a risk, and the culiminating point of fortitude is the witness of blood. … Without this readiness there is no Christian fortitude." Pieper argues "the cornerstone of the Christian ethical teaching is the concept of the bonum arduum." Pieper, *Fortitude and Temperance*, 14-16.

Acts of fortitude are exercised in concert with acts of prudence and the other virtues. Hence courage is exercised in making habitual choices, good choices put forward by the virtue of sound judgement. Aquinas explains, in overcoming danger, fortitude seeks not danger itself, but the realization of a "rational good"[1213], a rational good proposed by prudence. Without sound judgement there can be no effective fortitude. St Ambrose, a man of both action and learning, said simply, that fortitude must not trust itself. [1214]

Aquinas held that reason ought to be the ruler of the passions. He held that since the passions can be controlled by reason they should be controlled by reason[1215]. This is not semantics… he held that all those activities of man that can be guided by reason must be guided by reason, or else man acts below himself; he acts in a sub-human way. Hence, "fortitude without prudence is not fortitude".[1216] Rash action not guided by prudence, even if wearing a Victoria Cross, would not qualify. The Athenian admiral Thucydides has Pericles proclaim this very doctrine:

> For this too is our way: to dare most liberally where we have
> reflected best. With others, only ignorance begets fortitude;
> and reflection but begets hesitation.[1217]

Once the necessary link between true fortitude and reason is accepted, the link between fortitude and freedom follows; it is man's spiritual powers, the will making rational choices, that allow him freedom. In his saying, "Those who are brave are free," Seneca reminds us not only of the link between fortitude and reason, but also that it is in the exercise of virtues, (viz. sound, habitual, rationally guided choices) that man finds his freedom.

4.2.6 Temperance

1213 Aquinas, *Virt Card*, 4 ad 5.
1214 Ambrose, *De Officiis*, (http://www.documentacatholicaomnia.eu/03d/0339-0397,_Ambrosius,_De_Officiis_Ministrorum_Libri_Tres_[Schaff],_EN.pdf accessed 22.11.12.) 1 35.
1215 *ST*, Ia-IIae, Q.24, Art.3.
1216 Pieper, *Fortitude and Temperance*, 23.
1217 Thucydides, *Peloponnesian War,* Bk 2, quoted in Pieper, *Fortitude and Temperance*, 26.

Temperance is “the virtue whose particular function is to restrain and check passion,” [1218] “a virtue of the appetitive part, by which men cease to desire bad sensual pleasures.”[1219] Strictly speaking, as we have seen, it is “a mean with regard to the bodily pleasures of touch.” [1220]

> To temperance belongs absence of admiration for the enjoyment of bodily pleasures, absence of desire for all base sensual enjoyment, fear of just ill repute, an ordered course of life, alike in small things and in great. And temperance is accompanied by discipline, orderliness, shame, caution.[1221] [1222]

Lack of self mastery in these areas carries serious implications, because as Aristotle argues, self indulgence is a more voluntary state than cowardice. Unlike pain, pleasure does not “upset and destroy the nature of the person who feels it.”[1223] We are more responsible for our actions when we are seeking pleasure than when we are fleeing fear and therefore failings in this area is all more blameworthy. We will be seeking for reasons, at the neural level, of this greater domination of the person, this greater obliteration of reason, caused by fear in comparison with intemperance.

Temperance is a *sine qua non* for the truly rational life, for a life that is able to show love for others effectively and with constancy. Aquinas writes of the inner peace, the tranquillity of right order, which is the fruit of temperance. Order is a mark of rationality; temperance as we have seen is “of the soul”. Aquinas says that a meaning of temperance is “serenity of spirit”.[1224]

[1218] Gilson, *The Christian Philosophy of St Thomas Aquinas*, 263.
[1219] Aristotle, *De Virtutibus et Vitiis*, 1250a30-37.
[1220] *NE*, 1117b24ff. Note that Aristotle includes taste as a form of touch.
[1221] Aristotle, *De Virtutibus et Vitiis,* 1250b7-11.
[1222] *NE*, II 8-9. “The habit of choosing the best course of action between the two extremes of overindulgence and impulsivity on the one hand, and of failure or inability to integrate one’s passions and emotions into one’s actions; it is the golden mean between self indulgence and insensibility.”
[1223] *NE*, 1119a25.
[1224] ST, IIa-IIae, Q.141, Art.2.2.

In the examples we have seen from the life of Nagai, these fruits of temperance are clearly seen. Pieper refers to inner order, a quality that shines through in Nagai's calm, self control:

> The purpose and goal of *temperantia* is man's inner order, from which alone … "serenity of spirit" can flow forth.[1225]

In other words, it is through the virtue of temperance that man is able to discover unity of life[1226].

> …The primary and essential meaning of *temperare*, therefore is this: to dispose various parts into one unified and ordered whole.[1227]

Temperance enables rationality to shine through, manifesting the order and serenity of soul. Without temperance these qualities will not surface; they require a bodily docility, a capacity of the organism to obey the judgements of reason.

4.2.7 Biophysical aspects of fortitude and temperance.

(Read in conjunction with **4.2.1 c** and **d**.)

a) Subordination to reason.

Moral virtue assists the sensitive aspect to "obey" reason.[1228] As we have already touched upon, Aristotle explains that the essence of this conformity of the sensitive aspect is the "royal" and voluntarily accepted obedience to the reason, as a king governs his subjects and as a man

[1225] Pieper, *Fortitude and Temperance*, 53.
[1226] Pieper writes, "Temperance is conceivable only on the basis of the fact that man has lost, together with his original sanctity, his integritas, his 'intactness', the self evident inner order of his nature." Pieper, *Fortitude and Temperance*, 12-13.
[1227] Pieper, *Fortitude and Temperance*, 53. Pieper writes, "Wherever forces of self preservation, self assertion, self fulfillment, destroy the structure of man's inner being, the discipline of temperance and the licence of intemperance come into play. The natural urge toward sensual enjoyment, manifested in delight in food and drink and sexual pleasure, is the echo and mirror of man's strongest natural forces of self preservation."
[1228] Sarah Broadie poses the question whether practice leads to expertise or addiction, and concludes that the answer is expertise, given the rationality inherent in the exercise of virtue bringing freedom of action. Broadie, *Ethics with Aristotle*, 71.

governs his children. Broadie elaborates at some length on this analogy of royal governance.[1229]It is “a hierarchical relationship but one between free people”.[1230] The will speaking, on all matters, “with the same voice as reason,”[1231]obeys reason “as one does one’s father”.[1232] It is a mistake, however, to think that an obedient child is only imperfectly or potentially in harmony with its parent. [1233]

Rather, the non rational part in the virtuous state is fully integrated with reason, including physically (the very point of this study), through part-constituents: “There is in human beings something capable of heeding reason even though not itself the rational source.”[1234]

While fortitude and temperance, in themselves, are essentially biophysical bodily qualities, they are ordered by reason and to reason. The “royal” governance of reason is facilitated by virtue.

> The irrational element ... appears to be two-fold. For the vegetative element in no way shares in a rational principle, but the appetitive and in general the desiring element in a sense shares in it, in so far as it listens to and obeys it.... that the irrational element is in some sense persuaded by a rational principle is indicated also by the giving of advice and by all reproof and exhortation. [1235]

It is clear that Aristotle views temperance and fortitude as irrational, and therefore, material in constitution. Nevertheless he emphasises their docility to reason and the role that reason has in their formation as habits.

[1229] Broadie, *Ethics with Aristotle*.
[1230] Aristotle, *Politics,* 1259a 37-41, and 10-17.
[1231] *NE*, 1102b28.
[1232] *NE*, 1103a1-4.
[1233] Broadie, *Ethics with Aristotle*, 65.
[1234] Broadie, *Ethics with Aristotle*, 65.
[1235] *NE*, 1102b28-34.

b) Biological perfections.

Fortitude and temperance are modifications at the biological level of our emotional circuitry; they level the playing field, so to speak, so that right reason is in the game. This will not involve a dampening of pain or of pleasure. Aristotle and Aquinas are intent on bringing the passions into right order with respect to reason, not with destroying them. Aquinas insists that a brave man is not who does not feel fear, but who, without losing his equanimity, can master that fear.

Aquinas explains that,

> The patient man is not the one who does not flee from evil, but the one who does not allow himself to be made inordinately sorrowful.[1236]

Similarly, temperance has not the aim of diminishing the intensity of sexual pleasure or of eating fine food, but of managing the pursuit of those activities according to reason.

Within the neural bases of fortitude and temperance we will be looking for evidence of cortical inhibition of emotional signalling, as well as pathways for cortical enrichment by emotional centres, and cortical executive function enriched by emotional input.

As there is no courage without prudence, at the neural level, we will be looking for forms of inhibition of emotional signalling from between regions and along pathways associated with fear, pathways and regions having rich connectivity to cortical regions identified as implicated in deliberation, memory, goal election, consideration of consequences, etc.

[1236] ST, IIa-IIae, Q.136, Art.4.2.
Teddy Roosevelt (1858-1919) captures this same admiration for the perseverance inherent in fortitude and courage: "It is not the critic who counts, nor the man who points how the strong man stumbled or where the doer of deeds could have done them better. The credit belongs to the man who is actually in the arena; whose face is marred by dust and sweat and blood; who strives valiantly."

> In conclusion, it is proposed at the neurobiological level, fortitude and temperance are perfections of specific biological structures that are necessarily associated with rationality in the embodied life. They are predispositions for rationally consistent responses to pain and to pleasure. In the first place they are habitual responses, which when established, allow a person more easily to manage fear of bodily danger and pain, and inappropriate attraction to sense pleasures of touch.

4.3 Unity of the virtues.

Aquinas explains that the four cardinal virtues cannot be isolated from each other; they form a unity. He asks whether the four (cardinal) virtues differ from one another, and goes on to explain, quoting Gregory the Great:[1237]

> There is no true prudence unless it be just temperate and brave; no perfect temperance that is not brave just and prudent; no sound fortitude that is not prudent, temperate and just; no real justice, without prudence, fortitude and temperance. [1238]

In the preceding section, in the light of an examination of virtue taking into account Aristotle's doctrine of pain and pleasure as primary motivations of action, I have argued for this unity of the virtues. I have suggested that fortitude and temperance, as habitual dispositions to pleasure and pain developed and guided in their activity by reason, contribute to every good human act. Further I have argued that justice, the habitual facility for assessing one's actions by their impact on others, is also necessarily integrated into every good human act. And of course, as sound judgement is required for an act to be good, prudence must also be

[1237] Gregory. *Moralia,* xxii 1.
[1238] *ST*, Ia-IIae, Q.61, Art.4.

integral. All four cardinal virtues perform different roles, and each is needed for the completion of a good action.[1239]

Only if the cardinal virtues act in concert can we account for fulfilment of the human person, as a unity of soul and body living in a community with others. Any view which deprives acts of individual virtue of the benefits of mutual enrichment by the other virtues cannot satisfy these three conditions for the flourishing of the human person:

- the interdependence of rationality and personal fulfilment (most associated with prudence)
- the interdependence of relationships, responsibility and personal fulfilment (most associated with justice)
- the interdependence of our bodily states and personal fulfilment (most associated with fortitude and temperance).

Further, we have seen that Aquinas insisted that each operation or faculty requires its appropriate disposing habit: for moral agency, a habit for the practical intellect, a habit for the rational intellect, and habits of the irascible and concupiscible appetites. Some who prefer not to take this text at its literal value ascribe a non-materiality to the habits of the sensitive appetites. I suggest that such an approach seems to question the role of the body in human fulfilment, and deprives the body itself of necessary habits.[1240]

4.3.1 The virtues are "integrated distinct elements"[1241] united in the person.

[1239] Should someone object to this position by arguing the possibility, for example, of man, unjust but endowed with the virtue of courage, I would answer that without the dispositions of justice his rationality is necessarily defective, and his courage therefore directionless and incapable of acting for a good end.

[1240] Of course, recent neuroscientific contributions to the biological understandings of passion, attention and learning, memory and habit formation all appear to emphasise the distinction between as well as the linkages between habits of mind and habits of body.

[1241] Broadie, *Ethics with Aristotle*, 65.

Freedom clearly resides in the rationality of the person himself, but truly rational decisions can be undermined if the cognitive power errs in preferring a lesser good, or if the appetitive power is not obedient to reason. Habitual dispositions are needed in both the cogitative and appetitive powers.[1242] Sarah Broadie reflects on the dilemma of applying a matter-form analysis of rational substance. She points out that without a clear Aristotelian understanding one can very easily confuse what are "integrated distinct elements, with mere uniform unity."[1243] The key lies in the understanding of "person" as the subject of action and of rationality.

In considering rationality, one can easily fall into one of diametrically opposed views: that either matter itself, or the mind, be the ultimate cause of rationality. Both are wide of the mark as discussed in **Chapter 1**. Nor is it a question of uniting in the person what is material with what is non-material: rather rational existence is a seamless integration of the material and the non-material. Rationality, by its nature, requires a whole new way of looking at substance. Aquinas writes, "Everything has unity in the same way that it has being."[1244]

4.4 Conclusions.

Section **4.1** and **4.2** have sought to separate biophysical qualities of virtue from that which is more directly in the rational domain. I have argued, within the hylomorphic understandings provided in **Chapter 1**, that prudence and justice, to the extent that they are dispositions of the rational powers, have only a contributory corporeal aspect, while fortitude and temperance are exclusively corporeal, though rational in cause. I have further argued, in **4.3**, for the unity of the virtues, that the cardinal virtues are all integral to good human acts.

[1242] *ST*, Ia, Q.83, Art.3.
"We must consider the nature of free will by considering the nature of choice. Now two things concur in choice: one on the part of the cognitive power, the other on the part of the appetitive power. On the part of the cognitive power, counsel is required, by which we judge one thing to be preferred to another; and on the part of the appetitive power, it is required that that the appetite should accept the judgement of counsel."
[1243] Broadie, *Ethics with Aristotle*, 65.
[1244] *ST*, Ia, Q.76, Art.2.2.

Some observations are pertinent.

i. A “restricted reading” view of the term “rational by participation”[1245] appears perfectly compatible with argument that virtues act in concert respecting the unity of the virtues. The view that fortitude and temperance are exclusively biophysical, though rational in cause, appears to significantly strengthen the case for the unity of the virtues.

ii. An understanding of the nature of, and the degree of, biological contribution to the particular virtues,[1246] accords adequate recognition to the hylomorphic constitution of the human person. Such recognition is essential if one is not to underestimate the importance of the contribution of the body and the biological to human activity, and ultimately if one is not to misrepresent human nature.

iii. There is a grandly satisfying logic evident if one links the unity of the virtues with the need for a notion of virtue which respects the composite view of human nature. This composite view will be, not only with respect to the composite nature of virtue in itself (having both rational and material aspects), but also in the way in which those virtues disposing rationality, operate in concert with the virtues disposing the sensitive appetites.

iv. A neurobiology of virtue appears to offer insights into fulfilment at the rational, the interrelational, and the biophysical levels. (See discussion in **6.2**.)

v. There are important conclusions at the level of parenting and self education. For example, the importance of training infants in behaviours reflecting temperance and fortitude and the need to emphasise to children the need for consideration of the needs and rights of others in every action, are noted.

[1245] *ST*, Ia-IIae, Q.50, Art.4.See also Q.59, Art.4 and Q.61, Art.2.

[1246] As has been constantly emphasized according to the hylomorphic understanding, discussion of the “material” or the “biological” in the human constitution must be understood an integral contributor to higher operations.

It has been argued that the distinct tasks of the specific cardinal virtues and their integrated role in each human act are necessary consequences of our hylomorphic constitution. These conclusions inform the tabulation of characteristics of virtue in following section and in turn will guide the neurobiological analysis in the next chapter.

4.4.1 Characteristics pertaining to the state of virtue.

In **Table 4.1** I refine the qualities identified in **Chapter 3**, in the light of the findings of **Chapter 4**, into distinct characteristics pertaining to the state of virtue and to the acquisition of virtue. Note that Nos 1 and 2 pertain to specific virtues.

Table 4.1
Characteristics pertaining to the state of virtue
As proposed by Aristotle and Aquinas (**3.2** & **3.3**) and cross referenced to qualities evident in Nagai's actions (**3.1.2**).

	Characteristics pertaining to the state of virtue	See **3.1.2**	See **3.2** & **3.3**
1	The virtues of prudence and justice dispose the practical reason and the intellectual appetite facilitating rationality and appropriate choices.	iii, iv, vi	3.2.1
2	The virtues of fortitude and temperance dispose the irascible and sensitive appetites to endure appropriate difficulties and to seek appropriate pleasure.	i, iv, v	3.2.1 3.2.1.1 3.3.7
3	A capacity for rational goal election is evident.	ii	3.2.1.2 3.2.2
4	"Virtues change us." The acquisition of virtue creates a state of character, a way of being, that tends to be permanent.	vii	3.2.4
5	The virtuous state is in keeping with our human nature.	iii, iv, v	3.2.5
6	In the exercise of virtue intrinsic motivation takes priority over extrinsic motivation. Virtue is motivated by that which is worthy to man's nature.	vii	3.3.9 3.2.5.1
7	Virtue facilitates effective action.	ii, viii	3.2.1.2 3.2.5.3
8	Virtue brings about ease of action.	viii	3.2.1.1 3.2.5.3

9	Virtue facilitates the flourishing of the person. Virtue brings about a state of excellence: an excellence of the person, inclusive necessarily of both neurobiological flourishing and the exercise of rationality. It is a state whereby reason and rationality are empowered to manage activity. It is a capacity for rationality that is reflective and emotionally enriched and able to be carried through into noble humane behaviours.	i, v, ix	3.2.5.2 3.2.5.3
	Characteristics of virtue in its acquisition Essential features pertaining to virtue in its acquisition.		
10	The virtuous state results from habituation and education.		3.3.1
11	Repetition, understood as critical practice, plays an essential role in the acquisition of virtue: repetition in appetitive responses, in responses manifesting noble sentiment and attentiveness to others, and in reasoning, deliberation and sound decision making.		3.3.4
12	Education specifically in wisdom and beauty is necessary in the formation of virtue.	vii	3.2.3 3.3.8
13	Effortful attention plays a significant role.		3.3.10
	Characteristics of virtue in its acquisition Features that may not necessarily be present in every case.		
14	Advantage must be taken of the early years both for training and provision of appropriate example.		3.3.2
15	Imitation of example is a key means for acquisition of behaviours.		3.3.3
16	Explicit teaching and guidance as to right and wrong, are needed.		3.3.6
17	Affection facilitates learning particularly in the family environment.		3.3.6

The aim in **Chapter 5** will be to propose for these characteristics, on the basis of current neuroscientific knowledge, neural part-constituents, biological elements that are integral to the exercise of virtue in the state of embodied soul.

Bearing in mind, as seen in **Chapter 2**, that neural processing in the brain is extremely complex, it would be simplistic to suggest that virtuous activity is localized and restricted to specific pathways and regions. Virtuous action, by definition, potentially embraces the whole range of human activity, and so it is clearly beyond the scope of any study to catalogue all the pathways and regions with *some* involvement in virtuous activity. We must seek to distil the essential neural components of virtuous action. In **Chapter 5** I will seek to identify the neural basis for these *essential* material components of virtuous activity.

Notwithstanding the caution with which one should nominate particular brain pathways and regions as implicated in activity of any moral type, to do so is consistent with a vast and expanding literature that implicates involvement of brain pathways and regions in the full range of human activities.

Although experimental verification of the neural substrates of virtue proposed in this study is beyond the scope of the work, it should be noted that the various sub-components of a neural “solution”, have already been verified experimentally in the many studies to which I refer. The approach of this study is to align these established jig saw pieces into a coherent and highly plausible view consistent with the proposed notion of virtue.

Chapter 5

The neural bases of virtue.

"A mind of moderate capacity which closely pursues one study
must infallibly arrive at great proficiency in that study."
Frankenstein; or, The Modern Prometheus
Mary Shelley

5.1 Reflections on the task being attempted.

There is scant literature referring explicitly to the role of neural structures in virtue. The most noteworthy attempt is by William Casebeer in an article published in *Nature Reviews Neuroscience* in 2003. Casebeer's paper provides a most valuable, broad brush endorsement of the task of identifying the neural bases of virtue. He considers the various approaches to ethics and in the broadest of terms suggests neuroscientific implications. He finds that because virtue is experience-based it is not only more suited to scientific investigation but also the ethical theory most likely to find correspondence in reality:

> The current evidence allows us to draw a tentative conclusion: the moral psychology required by virtue theory is the most neurobiologically plausible.[1247]

He suggests that the neural "solution" will involve rich interconnectivity between the cognitive and affective resources of the brain, and recruiting aspects of the brain implicated in memory and TOM.

> Empirically successful moral cognition on the part of an organism requires the appropriate coordination of multi-modal signals conjoined with appropriately cued executive systems that share rich connections with affective and conative brain

[1247] Casebeer, "Moral cognition and its neural constituents," 840-847.

> structures that draw on conditioned memories and insight into the minds of others, so as to think about and actually behave in a maximally functional manner. There is clear consilience between contemporary neuroethics and Aristotelian moral psychology.[1248]

Despite an ostensibly Aristotelian view of virtue, his focus is limited to "moral reasoning", and the role of virtue in supporting rationality remains implicit without either elaboration or explanation. "Virtue" remains undefined, and effectively there appears to be no appreciation of "habitus" nor of how good habits may be acquired or in what they might consist, nor is any any differentiation of the roles of virtue with respect to reasoning and sensitive appetites. Casebeer makes no reference to brain plasticity; and there are only single passing references to basal contribution and to "habit" itself.[1249] In short he demonstrates an impoverished understanding of virtue and consequently his speculation about the neural bases of virtue is unable to account for the actions and operations of virtue.

In addition there is a small but increasing number of studies which consider the neural substrate of isolated behaviours such as honesty, compassion, empathy and contemplation. Of these studies there appears to be none based on the Aristotelian-Thomistic notions of virtue and ensouled body, and therefore offering an articulated position with respect to human personality, autonomous behaviour, and for the capacity of persons to modify behaviours in response to environment, experience and their own choices.

In this chapter, I will argue for the existence of specific neural processes, brain areas, and pathways, constituting a complex of systems that are implicated in the development of virtue. My aim is to present a strong, inductive, empirical case for

[1248] Casebeer, "Moral cognition and its neural constituents," 843, suggests that the study of moral cognition can be divided into "three branches: the moral emotions, theory of mind and abstract moral reasoning."
[1249] He refers to "habits of character as informed by conditioned emotion and affect" (844).

the neural bases of virtue; a highly plausible mapping of current knowledge of neurobiology onto the characteristics of virtue identified in **Table 4.1**. Weight of evidence will argue that substantially differing neural bases are incompatible both with the neuroscience and with the Aristotelian and Thomistic notion of virtue. This study stands to make a timely contribution to the field and to give direction to research of an experimental nature.

This task, to my knowledge, has not been previously attempted.

5.1.1 Overview of this chapter.

First I draw insights from contemporary efforts to bridge the disciplines of neuroscience and moral anthropology, with respect to the neural bases of emotion and of morality. I discuss cross-current understandings of the neural bases of emotion in recent explorations of the relationship between emotion and reason by neuroscientists, Joseph LeDoux and Antonio Damasio, and philosophers, Nancy Sherman and Martha Nussbaum. These neuroscientific and philosophical approaches converge in the view that emotion and cognition are interacting, complementary and highly integrated systems.

Second I offer a compact overview of the neural bases of morality, and draw on the contemporary work in the discipline of psychopathology, by celebrated neuroscientist, Michael Gazzaniga. In **Table 5.1** I offer a summary of the neural sites activated in moral activity as many of these must also subserve virtuous activity. I note the increasing quantity of literature on the neural bases of moral behaviour, and tabulate a representative sample of findings which emphasise complexity of processing, and highly predictable centres of activation, results which are consistent with observations about cognitive function offered in **2.7**.

In **5.3** I propose neural bases for virtue.

As a starting point, I propose that the neural bases of virtue must be considered as a complex of interacting systems. I suggest that the neural complexity of the human act, and of virtue itself, is a reflection of the psychological complexity of the human act (as we have seen in **3.1.3**), moving from appetency and motivation at sense level, through evaluative reasoning to choice. I argue that, although particular brain areas are shown to be active in certain tasks, we must describe the neural dispositions of virtue in terms of neural interconnectivity and the activation of multiple brain areas and systems, predisposed by specific plastic development and thus able to work in highly elaborate concert. Only thus can we approach an understanding of the neural bases of the dispositions of virtue. I draw together in **Table 5.2** an outline of the interconnected systems at work in virtuous activity and then, drawing on the content of **Chapter 2**, I discuss the neural bases for the characteristics of virtue offered at the end of **Chapter 4** in **Table 4.1**.

In conclusion in **5.4**, as a model of the neural activity underpinning a specific act of virtue, I offer a neural analysis of Nagai's actions described **Scenario 3.** By analysis of a real life scenario, I demonstrate that the neural schema is highly plausible and readily applicable.

5.2 Insights from contemporary cross-disciplinary studies in emotion and morality.

5.2.1 Understanding emotion.

Neuroscientists and philosophers have focused in recent years on the relationship between emotion and reason/rationality. For the past twenty years, Joseph LeDoux has been at the forefront of research into the neural bases of emotion, most particularly of the emotion of fear.[1250] He shows that emotional reactions may be either regulated by higher cortical function or be direct and impulsive.

[1250] Joseph LeDoux, *The Emotional Brain*, (London: Phoenix, 1998).

Antonio Damasio argues that emotional somatic manifestations assist us in our cognitive response to the world, and that it is a mistake to separate mind and body. In common with philosophers, Nancy Sherman and Martha Nussbaum, these neuroscientists are in agreement that emotion can and should enrich decision making and that both emotion and reason possess biophysical correlates.

5.2.1.1 Joseph LeDoux

The work of Joseph LeDoux has provided some key lines of investigation for this study. He adopts a non-reductive approach, described by Nussbaum as "explicitly cognitive".[1251] LeDoux argues for emotion and cognition as separate but interacting mental functions mediated by separate but interacting brain systems.[1252] His interest is very much as a neuroscientist, and his focus is on the neural bases of emotion and regulation of emotion.

Of particular relevance for this study are these conclusions by LeDoux.

He suggests that reason and emotion should be harmonised; human biology, he argues, supports the view that emotion be moderated but not negated by reason.[1253] Because brain systems generating emotion are highly conserved, he argues that animal studies are valid indicators of the human brain systems associated with emotion:[1254] for example, by means of rat studies, LeDoux had highlighted the central role of the amygdala in fear conditioning and the role of the reciprocal cortico-amygdalic pathway in emotional regulation. [1255]

LeDoux observes that connections from emotion to the cognitive are denser and richer than connections from cognitive to emotional, allowing, he argues, for

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[1251] Nussbaum, *Upheavals of Thought,* 105.
[1252] LeDoux, *The Emotional Brain*, 69.
[1253] LeDoux, *The Emotional Brain*, 21.
[1254] LeDoux, *The Emotional Brain*, 17.
[1255] LeDoux, *The Emotional Brain*, 287.

emotions to flood consciousness.[1256] He found that areas of the amygdala project back to a wide variety of cortical areas (all cortical sensory areas, PFC, hippocampus) allowing the amygdala to influence higher order thought process, working and long term memories, ongoing perceptions, attention, mental imagery etc.[1257]

He identifies a "high road" of emotional response whereby the amygdala is informed of emotional content via the cortex, in preference to a "low road" of direct input to the amygdala via the thalamus, [1258] and concludes that cortical emotional regulation of fearful reactions requires reinforcement of this "high road" by means of use dependent plasticities.

He notes that the hippocampus plays a key role when there is cortical regulation of emotion and suggests that these hippocampal pathways require consolidation and reinforcement by means of use-dependent plasiticities. He also notes that the "high road" of cortical afferent to amygdala is informed by hippocampal memory,[1259] consistent with the view that the hippocampus is associated with conscious declarative memory and the implicit emotional memory associated with the amygdala (cf **Chapter 2**).[1260]

While LeDoux discusses pathways of emotional control, he does not directly address habits of emotional control. He does not discuss the interplay of reward pathways and emotion, but he does observe that emotions are powerful motivators of future behaviours.[1261]

5.2.1.2 Antonio Damasio

[1256] LeDoux, *The Emotional Brain*, 19.
[1257] LeDoux, *The Emotional Brain*, 287.
[1258] LeDoux, *The Emotional Brain*, 170.
[1259] LeDoux, *The Emotional Brain*, 199.
[1260] LeDoux, *The Emotional Brain*, 203.
[1261] LeDoux, *The Emotional Brain*, 19.

Another major figure in the contemporary dialogue between emotion and neuroscience is Antonio Damasio. In *Descartes' Error* (1994) he develops his somatic marker hypothesis by which he argues that emotional somatic reactions and consequent qualia assist reason. [1262] Most significantly he argues that emotion enriches cognition, and writes broadly of an integration of "brain systems that are jointly engaged in emotion and decision making" allowing management of social cognition and behaviour.[1263] Descartes' error, he says, was to divide body and mind.[1264]

In his 1999 text, *The Feeling of What Happens*, Damasio pursues this theme of integration of awareness and emotional response. He argues that consciousness and emotion are intimately related: consciousness as the conception that there is both a self and an external object; and emotion as the internal experience of change as a result of interaction with the external object, the "feeling of what happens". [1265]

In a more recent book, *Looking for Spinoza* (2003), Damasio further develops the theme of the unity of the organism. With Spinoza (and, as we have seen, in keeping with Aristotle's metaphysics) he argues that mind and body are manifestations of the same substance.[1266] "The body and the brain form an integrated organism and interact fully and mutually via chemical and neural pathways." [1267] Accordingly Nussbaum states that Damasio presents a non-reductionist, physiological account.[1268] Lacking explicit acknowledgement of the concept of person (for example, he writes only of "organism") his philosophy of mind is arguably impoverished. Damasio relies on assertions such as "(it is) unnecessarily incomplete and humanly unsatisfactory to reduce the mind to brain

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[1262] Antonio Damasio, *Descartes' Error* (London: Vintage, 1994), 174. Damasio writes, "Somatic markers are a special instance of feelings generated from secondary emotions. Those emotions and feelings have been connected by learning, to predicted future outcomes of certain scenarios."
[1263] Damasio, *Descartes' Error,* xix.
[1264] Antonio Damasio, *Descartes' Error* (London: Vintage, 1994) 249.
[1265] Damasio, *The Feeling of What Happens.*
[1266] Antonio Damasio, *Looking for Spinoza* (Orlando: Harvest, 2003) 12.
[1267] Damasio, *Looking for Spinoza*, 194.
[1268] Nussbaum, *Upheavals of Thought,* 114.

events." [1269] He attempts a non-reductive understanding of the unity of the organism, arguing,

> The truly embodied mind … does not relinquish its most refined levels of operation, those constituting its soul and spirit. … soul and spirit, with all their dignity and human scale, are now complex and unique states of an organism.[1270]

Yet ultimately, these statements are observations without metaphysical justification. "Person" is much richer a concept than "organism", capturing as it does the specific qualities of rationality and of a unifying principle beneath appearances.

Damasio's attempts, therefore, demonstrate the difficulty, perhaps impossibility, of defending specific metaphysiological conclusions about human nature in the absence of a concept of person. They demonstrate the need that mind-body speculation must be supported by a metaphysically rich anthropology.

Nevertheless, the work of Antonio Damasio positively provides assistance to, or verification for, this study in several important ways.

Like Aristotle (see **3.2.1.1**) he argues that all human motivations reduce to pain and pleasure in some form or other. "Pain and pleasure are the levers the organism requires for instinctual and acquired strategies to operate efficiently."[1271] Significantly, within his anthropology he includes the development of habits by which we manage our reactions to pain and pleasure: "our reactions

[1269] Damasio, *Descartes' Error,* 251.
[1270] Damasio, *Descartes' Error,* 252.
[1271] Damasio, *Descartes' Error,* 262. Damasio appears to draw much from Aristotle, albeit indirectly. For example, he quotes another aphorism from Spinoza: we are always moved by love (understood as appetite for what is pleasurable) in some form or other. "An affect cannot be restrained or neutralised except by a contrary affect that is stronger than the affect to be restrained."

to pain and pleasure can be modified by education".[1272] He offers neural substrates for sadness,[1273] and happiness[1274].

He is drawn to a series of insights of Spinoza in an exploration of human motivation and feelings.[1275] Importantly for this study he links pleasure with perfection of function, providing a rich avenue for eudaimonistic exploration. He argues that organisms strive to achieve "a greater perfection" of function and that Spinoza equated that perfection with joy. [1276] [1277] (See **6.2.1**.)

He describes emotion triggering sites as amygdala and VMPFC, and a further "frontal region in the supplementary motor area and cingulate".[1278] He writes of the basal forebrain, hypothalamus and nuclei of the brainstem as execution sites for emotion. He presents a number of significant clinical and research based observations about VMPFC.[1279] [1280] [1281] [1282] [1283] [1284] And he notes that the ACC

1272 Damasio, *Descartes' Error,* 262.

1273 Damasio quotes a case of a slightly misplaced electrode in the midbrain, possibly in the SN or the *periaqueductal gray region* PAG, evoking profound sadness.

1274 Representative studies: Richard Davidson et al., "Reciprocal limbic-cortical function and negative mood: converging PET findings in depression and normal sadness," *American Journal of Psychiatry* 156, (1999): 675-82; Richard Lane et al., "Neuroanatomical correlates of happiness, sadness and disgust," *American Journal of Psychiatry* 154, (1997): 926-33. Damasio also notes that stimulation in SMA (eg in mPFC and dorsal PFC and Anterior cingulate) was shown to evoke "genuine" laughter: Itzhak Fried, et al., "Electric current stimulates laughter," *Nature* 391, (1998): 650.

1275 Damasio, *Looking for Spinoza*, 12.

1276 Damasio, *Looking for Spinoza*, 12.

1277 Damasio, *Looking for Spinoza*, 11. His focus on Spinoza's comment "Love is nothing but a pleasurable state, joy, accompanied by the idea of an external cause" has the potential to connect motivation and pleasure with a role for justice.

1278 Damasio, *Looking for Spinoza*, 54.

1279 Hiroto Kawasaki, et al., "Single-unit responses to emotional visual stimuli recorded in human ventral prefrontal cortex," *Nature Neuroscience* 4, (2001): 15-16. Damasio notes the asymmetry is in keeping with Davidson's conclusion that right frontal cortices have a greater association with negative emotions. He points out that single cell studies show how specific different neurons in the right VMPFC in human subjects respond to pleasant and unpleasant visual stimuli.

1280 Damasio, *Looking for Spinoza*, 152. Damasio argues that the VMPFC and amygdala are critical areas of the PFC for reasoning/decision making and emotion/feeling.

1281 Damasio, *Descartes' Error,* 61.

1282 R.W. Sperry et al., "Interhemispheric relationships: the neocortical commissures; syndromes of their disconnection" in *Handbook of Clinical Neurology* Vol4, ed. P. J. Vinken and G. W. Bruyn (Amsterdam: North Holland, 1969), 273-90. Damasio's work confirms the right hemispheric dominance in emotion, and that damage to somatosensory cortices in the right hemisphere compromises reasoning/decision making and emotion/feeling as well as basic body signalling;

provides the location for intimate interaction between systems of reasoning/decision making and emotion/feeling leading to external action (movement) and thought animation and reasoning. [1285]

5.2.1.3 Nancy Sherman and Martha Nussbaum

Aristotle explains in the *Rhetoric* that anger will be towards somebody whom we think has caused us harm. Emotions are directed towards some object, according to the Aristotelian notion. Accordingly Nancy Sherman discusses emotions as "forms of intentional awareness".[1286]

Martha Nussbaum appears to build on this notion in her explorations of emotion in *Upheavals of Thought* which contains insights of significance to this study. She rejects any simplistic or negative view and defines emotions in a positive manner as:

> … appraisals or value judgements which ascribe to things and persons outside the person's own control great importance for that person's own flourishing.[1287]

[1283] Damasio, *Descartes' Error,* 71. Damasio confirms that DLPFC damage compromises reasoning/decision making on a broader scale and that DA driven reward systems are associated with pleasure and with motivation for emotion regulation.

[1284] Damasio, *Descartes' Error,* 180. He links VMPFC to autonomic nervous system effectors, able to trigger chemical responses from brain stem and hypothalamus.

[1285] Damasio, *Descartes' Error,* 72.

[1286] In *Making a Necessity of Virtue,* Nussbaum writes, "Emotions are about something that we represent in thought. Emotions are intentional states. As such they have cognitive content. They are identified by that content, by what we dwell on, whether it be fleeting or with concentrated attention… Such an account need not exclude other features of emotion, such as awareness of physiological and behavioural response or felt sensations. The claim is that these, when present, are dependent on cognitive (i.e. descriptive and evaluative content), and are directed toward that content." Sherman, *Making a Necessity of Virtue: Aristotle and Kant on Virtue*, 55. Insight from Ana C. Santiago, "A Study of Aristotelian Demands for Some Psychological Views of the Emotions" (PhD thesis, Duke University, 2009).

[1287] Nussbaum, *Upheavals of Thought,* 4. Nussbaum writes: "Emotions, I shall argue, involve judgements about important things, judgements in which, appraising an external object as salient for our own well being, we acknowledge our own neediness and incompleteness before parts of the world that we do not fully control."

She presents a eudaimonistic vision in which "Emotions appear to be eudaimonistic, that is, concerned with a person's flourishing".[1288] In further extension of this idea, she notes that Aristotle regards pleasure not as a feeling but as unimpeded action. [1289] Flourishing includes, therefore, the concept of mature biological development facilitating ease of action.

Of great value to this study also are a number of additional insights.[1290] She insists that "emotions are, like other mental processes, bodily."[1291] She also suggests that this vision of emotion offers clarity on the specific roles of the cardinal virtues; if emotion is essentially "thought of an object combined with thought of the object's salience or importance" this arguably lends a greater role to justice. Secondly, it accords perfectly with an initial presentation of desires and aversions (understood broadly as apprehensions evoking responses disposed by temperance and fortitude or their contrary habits).[1292]

She argues that it was Aristotle himself who integrated emotion into the cognitive world of the person, that Aristotle viewed pain as "pain at", "as an intentional state with cognitive content". [1293]

Discussing how particular representations in the mind make possible abstract eudaimonistic conclusions, she notes the significance of "rich particularising detail", the connection to the imagination that differentiates specific evaluations from abstract judgments. She writes that the imagining is "a vehicle for making a eudaimonistic connection with the object" allowing for example compassion, and downstream the exercise of justice.[1294]

[1288] Nussbaum, *Upheavals of Thought,* 22, 31
[1289] Nussbaum, *Upheavals of Thought,* 63
[1290] Nussbaum, *Upheavals of Thought,* 103 Of note also is her evaluation of Seligman's work as a non-reductionist account where internal mental representations construct intentionality.
[1291] Nussbaum, *Upheavals of Thought,* 25.
[1292] Nussbaum, *Upheavals of Thought,* 61.
[1293] Nussbaum, *Upheavals of Thought,* 63.
[1294] Nussbaum, *Upheavals of Thought,* 65.

Also of note in this study of virtue, considered as voluntary habit motivated less by external reward and more by intrinsic considerations, are her comments about the need to modify the S-R model to one of "S-Organism-R" [1295] consistent very much with the view raised in **Chapter 2** that voluntary habits can consist of A-O motivations replaced by S-R paradigms that are compatible with voluntary behaviour.[1296]

5.2.2 Research into the neural bases of morality.

5.2.2.1 Gillett's psychopathology.

a) **The field of psychopathology.**

Research into psychopathology can assist here, as it is a burgeoning field where neurobiology and consolidated moral behaviours, albeit negative behaviours, intersect. If one accepts the premise that through illness, environment or choice such people have underdeveloped dispositions of virtue, insights are possible into the neurobiology of virtue. For example, I have referred above (**4.2.1**.**d**) to studies that suggest an excessive dominance of fear in psychopathic individuals.

Studies emphasise time and again the functional and structural abnormalities of the the OFC, VMPFC and amygdala in psychopathic individuals.[1297] A *Nature* article in 2001 suggested that early imaging studies in this area suggested either that the dysfunctional OFC or dysfunctional amygdala are at the basis of psychopathic behaviour; the views may not be mutually exclusive.[1298] Yang et al. have now identified, by means of structural magnetic resonance imaging, marked deformations, including lower volumes, of the amygdala in individuals with psychopathy. They link these structural data to poor fear conditioning and poor

[1295] Nussbaum, *Upheavals of Thought,* 94.
[1296] Yin and Knowlton, "The role of the basal ganglia in habit formation," 465.
[1297] Walter Glannon, "Moral Responsibility and the Psychopath," *Neuroethics* 1, (2008): 158; Kiehl, et al., "Limbic abnormalities in affective processing by criminal psychopaths as revealed by fMRI".
[1298] Alison Abbott, "Into the mind of a killer," *Nature* 410 (2001): 296-298.

facial emotion recognition that are also present.[1299] Note the potential link between poor fear conditioning, and an inability, in developmental years, to develop normal emotional responses from the faces of parents.[1300] [1301]

"Empathetic dysfunction is one of the major features of psychopathology."[1302] James and Blair find that the empathetic dysfunction of psychopaths is associated with impaired processing of emotions of fear, sadness and possibly disgust, and manifest multiple signs of amygdala dysfunction. [1303] Most interestingly they argue that the lack of emotional empathy appears linked to dysfunction in "cortical and sub-cortical face processing routes" involving amygdala, insula and OFC and VMPFC. [1304] Potential for learning refined dispositions to pain and pleasure from the face of one's parents.

Another common thread of discussion in the literature is that of the apparent "rationality" of psychopaths. However Maibom finds that her studies affirm Damasio's argument for the essential role of emotion in practical rationality.[1305] She argues that the practical reason of psychopaths is impaired and that the basis of this appears two fold: an emotional impairment, with abnormal responses to fear, pain, guilt and empathy; and that are incapable of choosing means appropriate to ends. They are "constitutionally incapable of adopting and carrying out plans that affect the course of their lives in a pervasive and profound

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[1299] Y.Yang, et al. "Localization of deformations within the amygdala in individuals with psychopathy," *Archives of General Psychiatry* 66, 9 (2009), 986-994.

[1300] This is consistent with my argument that children learn and embody refined attitudes to pain and pleasure from the example of parents first of all. Psychopathic deficits possibly heightened by environmental factors, appear to impair this process in early years.

[1301] Other studies identify abnormalities in the corpus callosum: Adrian Raine et al. "Corpus Callosum Abnormalities in Psychopathic Antisocial Individuals," *Archives of General Psychiatry* 60, (2003): 1134-42.

[1302] R. James and R. Blair, "Empathic dysfunction in psychopathic individuals," in *Empathy in Mental Illness*, ed. Tom F. D. Farrow, (Cambridge: Cambridge University Press, 2007), 12.

[1303] James and Blair "Empathic dysfunction in psychopathic individuals," 12.

[1304] "If we could find means to increase the empathic reaction of children with psychopathic tendencies, we might be able to considerably improve the prognosis of this disorder." James and Blair "Empathic dysfunction in psychopathic individuals," 15.

[1305] Heidi Maibom, "Moral unreason: the case of psychopathy," *Mind and Language* 20, 2 (2005): 251.

manner."[1306] She suggests that psychopaths flout moral and social norms, but "experience no guilt or remorse, feel no empathy, and appear to be perfectly rational."[1307]

Lack of behavioural and emotional regulation also enters as an area of study. Corr suggests that deficits of behavioural inhibition are the basis of these aberrant behaviours. These deficits are associated with a consequent inflexibility with respect to cognitive activity, associated also with inattentiveness.[1308] Significantly he argues that there are multiple systems, an "amalgam of processes", that underpin normal behaviour, and that dysfunction in specific processes may account for the wide variations on psychopathology. He highlights for example failure of systems for appetitive anticipation.

An important study utilizing *diffusion tensor magnetic resonance imaging* (DT-MRI) shows neural underdevelopment in the limbic-cortical pathway connecting the OFC and amygdala.[1309] The authors found significantly reduced fractional anisotropy (suggesting reductions in fibre density, axonal diameter and myelination) in the right uncinate fasciculus (the major neural limbic-cortical neural pathway) of psychopaths in relation to matched controls.[1310]

In summary, studies into psychopathology appear to confirm dysfunction in several of the principal candidate systems and regions appearing to be at the basis of virtue. They draw attention to the role of attention, of regulation of emotion and appetency, of imitation, and in particular of the high level of mutual interaction required between limbic and cortical areas. Furthermore studies highlight the necessity of a multi-systemic approach in order to describe the neurobiological contribution to moral behaviour.

[1306] Maibom, "Moral unreason: the case of psychopathy," 243.
[1307] Maibom, "Moral unreason: the case of psychopathy," 237.
[1308] Philip J. Corr, "The The psychoticism–psychopathy continuum: A neuropsychological model of core deficits," *Personality and Individual Differences* 48, (2010): 695–703.
[1309] M. C. Craig, et al. "Altered connections on the road to psychopathy," *Molecular Psychiatry* (2009), 1–8.
[1310] Craig, et al. "Altered connections on the road to psychopathy," 5-6.

b) Gillett's work.

Grant Gillett's work builds on the clinical studies of psychopathology. In one recent paper, he introduces neo-Aristotelian notions of character, agency, and moral responsibility (in a consideration of Aristotle's account of practical reason in the light of Kant and Wittgenstein) and concludes "the will of the psychopath is pathological (in Kant's sense) because it is dominated by appetite and not truth...".[1311] This is a fascinating insight drawing on the internal features of the human act (**Table 3.1**) and emphasizing the importance of the virtues of prudence and justice. By the neurobiological features characterising the absence of the virtues, Gillett provides important insights about their neural bases.

Gillett presents a theory of action for psychopaths accounting for manifestly intentional behaviour that is disconnected from prudence and moral consideration.[1312] Ultimately, he finds that the psychopath is moved by self-oriented goals, and, lacking responsivity to others, lacks also responsibility. Often seeing others as less clever than himself, he suffers from a "pathologically restricted horizon of motivations" and "lacks the co-feeling and human connectivity that lie at the heart of moral voice and moral orientation."

Gillett suggests that moral responsibility according to a neo-Aristotelian understanding involves the subject choosing, using his rational powers, to obey or not to obey moral rules, and he sees these rules as pertaining not only to one's actions in the world in isolation from others, but also according to the demands

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[1311] Grant Gillett, "Intentional action, moral responsibility and psychopaths," (2012 publication pending), 10. Gillett's work on criminal psychopathology adopts a classic approach of neuroscience, that of learning about the brain by linking deficits of behaviour with anatomical observation.

[1312] A theory of action links psychology of the individual with an understanding of individual human beings as moral agents. The author suggests that action may be explained either by a Millean tradition, relying on prior causal events, or in the Nietzschean (neo-Aristotelian) vision of the individual acting on the world to enact his life story. The latter he combines with the identity-structure view of intention and action that sees action as the outward manifestation of the conception of the agent.

that arise from relationships with others. Within this framework, the role of pain in the form of disapproval, punishment, correction and discipline, is reviewed. Gillett notes that, during the acquisition phase of virtue, virtuous acts are not typically pleasant. Further he distinguishes between the cleverness of acting to achieve one's desired end, from the motivational sensitivity towards others that normally accompanies ethical formation.[1313]

His findings, drawing on various physiological and fMRI studies typified in the section above, highlight brain function in relation to poor choices, impulsivity, and lack of regard for others:

- Defective psychopathic response to fear based and aversive conditioning is situated (in the "limbic prefrontal circuit - amygdala, orbito-frontal cortex, insula, and anterior cingulate" areas of the brain.
- Severe social deprivation and abuse are consistent with unimpaired executive function and emotional intelligence.[1314] (His thesis is that deprivation and abuse impact most of all on practical reason.)
- Psychopathic activity appears unimpaired by secondary emotions of embarrassment and guilt.[1315]
- Certain amygdala dysfunction appears in studies of criminal psychopathic individuals.[1316]
- Defective responses in sensorimotor cortices as well as limbic and para-limbic structures appear implicated in pathologically diminished empathy.[1317] [1318]

[1313] Both are forms of rationality, but only the second contains a moral incentive. He argues that the psychopath acts with self-directed interest as opposed to "the natural human propensity for empathy and sensitivity to the suffering or negative emotions of others".

[1314] A. Raine, "Biosocial Studies of Antissocial and Violent Behaviour in Children and Adults: A Review," *Journal of Abnormal Child Psychology* 30, 4 (2002): 311-326.

[1315] A. Damasio, "A neural basis for sociopathy," *Archives of General Psychiatry* 57, (2000): 128-9.

[1316] K. A. Kiehl, et al., "Limbic abnormalities in affective processing by criminal psychopaths as revealed by fMRI" *Neuroimage* 11, 5 (2000), 677-684.

[1317] T. Singer, "The neuronal basis and ontogeny of empathy and mind reading: Review of literature and implications for future research' *Neuroscience and Biobehavioural Reviews* 30, (2006) 855-863.

[1318] Deely Q et al., "Facial emotion processing in criminal psychopathy," *British Journal of Psychiatry* 18 9, (2006): 533-539. Gillett also discusses psychopathic insensitivity to distress and negative emotion shown in other's faces.

Gillett concludes that “the physiological and fMRI studies show the findings that might be expected from the analysis of virtue and moral development found in Aristotle and Kant...”,[1319] that “our natural tendencies are transformed by socialisation in which we learn to moderate our tendencies by instruction and correction”.[1320]

Moreover he suggests that the advantageous pain, normally signalling undesirability of actions is somehow deficient in the psychopath. He suggests that “learned patterns of moral behaviour” can compensate for this deficiency.[1321] Moral education consists in this. “Necessarily, then, the character must be good or bad by its pursuit or avoidance of certain pleasures and pains.” [1322]

Gillett’s work is a cross disciplinary study reconciling aspects of Aristotelian psychology with neuroscience, and as such, serves as a useful precedent for this study. Furthermore, his identification of the involvement of specific neural structures in moral behaviour/psychopathology provides a valuable point of reference.

5.2.2.2 Gazzaniga and the neural bases of free will.

In the 2009 Gifford Lectures, neuroscientist Michael S. Gazzaniga explores the notion of free will. This topic is of importance to this study because a degree of freedom of agency is a necessity for the development of virtue, and for the operation of a rational being. Gazzaniga adopts a non-reductionist “strong emergent” paradigm in which the emergent “is more than the sum of its parts”.[1323] A number of aspects of his analysis of free agency are particularly useful for this study.

[1319] Gillett, “Intentional action, moral responsibility and psychopaths,” 13.
[1320] Gillett, “Intentional action, moral responsibility and psychopaths,” 14.
[1321] Gillett, “Intentional action, moral responsibility and psychopaths,” 14.
[1322] Aristotle, *Eudemian Ethics*, 1121b33.
[1323] Michael S. Gazzaniga, *Who’s in charge. Free will and the science of the brain* (NY: Harper Collins, 2011), 124. See my response to “emergent rationality” in **Appendix 1. A Response to the Claims of Emergent Rationality by Non-reductive Materialism.** However, because both

He argues that the integration of multiple brain systems underpins complex aspects of personality. “It is becoming increasingly clear that consciousness involves a multitude of widely distributed specialised systems and disunited processes.”[1324] I argue and summarise in **Table 5.2** that virtue may be seen as a type of macro system, a complex of systems, requiring multiple integrated brain systems for activation. Gazzaniga, by applying the concept to consciousness, provides a useful, highly credentialed precedent for such a view. It is the view of this study that such a “systems view”’ of virtue is appropriate to the extent that virtue is understood as a *biological* facilitation for rationality.[1325]

Secondly he offers an alternative model for brain activity, springing from his own research. He argues that “rampant” lateralisation of circuits is a mark of the human brain, and that within the left brain is the “interpreter module” that makes sense out of the literal view of reality presented by the right hemisphere. [1326]

He writes of studies that demonstrate that suppression of the right DLPFC increases self interest and self centred responses, and that VMPFC lesions impair moral judgement. This is consistent with views of the role of the DLPFC that have already been presented in **Chapter 2** and in **Table 5.1**.[1327]

5.2.2.3 Neural subdivisions implicated in moral behaviour.

In this section I note commonly identified neural bases activated in situations demanding a moral response, and complete the section with some comments also about the neural bases of immoral, psychopathic behaviour, as well as of spiritual

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hylomorphic and emergent rationalist approaches propose a single agent with rational and biophysical qualities, the conclusions of Gazzaniga, LeDoux, Damasio and others (with respect to neural bases, but not to anthropology nor metaphysics) transfer most readily to this study.

[1324] Gazzaniga, *Who’s in charge. Free will and the science of the brain*, 102.

[1325] That such a view should be applied also to consciousness is not so evident but discussion of this issue is well beyond the scope of this study.

[1326] Gazzaniga, *Who’s in charge. Free will and the science of the brain*, 35 and 86. This appears consistent with the notions in **2.3.4.1** and **2.5.3.1** that affect arousal is preferentially in areas of the right cortex, while emotional regulation pertains more to left VMPFC.

[1327] Gazzaniga, *Who’s in charge. Free will and the science of the brain*, 170 and 177.

and mystical experiences. These moral bases will further inform discussion in **5.3.3.2**.

Green and Haidt in a major review paper note that moral judgement appears to be based both on affect and reasoning, and that many brain areas contribute to moral judgement.[1328] Moll et al. find a "remarkably consistent network of brain regions … involved in moral cognition",[1329] far more consistent than the variability of activations for basic emotions of happiness, sadness, disgust, fear, and anger. He finds that complex emotions (compassion, embarrassment, indignation, guilt) show consistently to activate the same areas: ACC, aPFC, aTL, OFC , and STS.[1330] [1331]

A great number of studies have sought neural bases for social behaviour. A typical study, by Rilling et al., focused on altruistic cooperation. By means of fMRI scanning of 36 women playing the Prisoner's Dilemma Game a neural network associated with reciprocal altruism was identified.

> Mutual cooperation was associated with consistent activation in brain areas that have been linked with reward processing: nucleus accumbens, the caudate nucleus, ventromedial frontal/orbitofrontal cortex, and rostral anterior cingulate cortex. [1332]

Other studies have identified the key role of the *medial PFC* (MPFC) in studies concerning empathy, understanding for others, and the self-knowledge seen as a

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[1328] Joshua Green and Jonathan Haidt, "How (and where) does moral judgement work?" *Trends in Cognitive Sciences* 6, 12 (2002): 517-123.
[1329] Jorge Moll, et al., "The neural basis of human moral cognition," *Nature Reviews Neuroscience* 6, (2005): 799. Moll looked at the various models for moral cognitive neuroscience, and proposed the "EFEC (event–feature–emotion complex) framework", a model based on the integration of event knowledge, social perceptions, and basic emotional states. The authors argued that moral phenomena emerge "from the integration of contextual social knowledge, represented as event knowledge in the prefrontal cortex (PFC); social semantic knowledge, stored in the anterior and posterior temporal cortex; and motivational and basic emotional states, which depend on cortical–limbic circuits."
[1330] Jorge Moll, et al., "The neural basis of human moral cognition," 805.
[1331] Jorge Moll, et al., "The neural basis of human moral cognition," 799- 808.
[1332] James K. Rilling et al., "A Neural Basis for Social Cooperation," *Neuron* 35, (2002): 395–405.

prerequisite to moral responsibility. Furthermore, empathetic response to the pain of others appears to be mediated by the mPFC.[1333] [1334] [1335] Other studies consider the roles of memory and imagination in moral activity. It appears our judgements to trust others are processed on two different pathways, one bypassing memory and simply assessing the face, and the other accessing memory of behaviour of that person in the past.[1336] Some people draw on the personality trait information when judging trustworthiness others prefer to use facial information.

Self-control disorder studies in children using electroencephalogram (EEG) as well as fMRI of normal subjects, are consistent in linking the VMPFC and moral behaviour, in finding that the OFC cues for moral behaviour and also the acquisition of moral knowledge. ACC is linked to regulation of attention and emotion, and (with the NAc, caudate, and OFC) for cooperation respecting the rights of others.[1337] Moral cognition systems appear modulated by DA, 5-HT, NA and ACh. But "the proper operation of the system as a whole is crucial for effective moral judgement."[1338]

Persistent antisocial behaviours have long been a subject of interest. Forensic psychiatry like psychopathology is a large field offering insights into the neural bases of moral behaviour. Studies of violent offenders have demonstrated that

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[1333] Philip L. Jackson, Pierre Rainville, Jean Decety, "To what extent do we share the pain of others? Insight from the neural bases of pain empathy," *Pain* 125, (2006): 5–9.
[1334] Arnaud D'Argembeau and Eric Salmon, "The neural basis of semantic and episodic forms of self knowledge. Insights from Functional Neuroimaging," in *Sensing Systems in Nature*, ed. Carlos López-Larrea (Landes Bioscience and Springer Science+Business Media, 2011). The mPFC has been identified as playing "a key role in creating the mental model of the self that is displayed in our mind at a given moment."
[1335] Ruby P., Collette F., D'Argembeau A. et al., "Persons with Alzheimer disease did not recruit the mPFC when making judgments about themselves in perspective taking to assess self‐personality: what's modified in Alzheimer's disease?" *Neurobiology of Aging* 30, (2009): 1637‐1651. In persons with Alzheimer disease the mPFC appears inactive in judgements about self.
[1336] J. D. Rudoy and K. A. Paller, "Who can you trust? Behavioral and neural differences between perceptual and memory-based influences," *Frontiers of Human Neuroscience* 3, (2009): 1-6.
[1337] Casebeer, "Moral cognition and its neural constituents," 844.
[1338] Casebeer, "Moral cognition and its neural constituents," 843.

subjects have reduced grey matter in the PFC and patterns of abnormal limbic, prefrontal and temporal brain activation.[1339] (See also above, **5.2.2.1**.)

It is demonstrated that emotions play a role in moral judgement.[1340] A 2007 study by Michael Koenigs of six patients with VMPFC bilateral damage indicated that the subjects were more prone to utilitarian judgements on a certain type of moral dilemma, but that in other types their responses were normal. "The findings are consistent with a model in which a combination of intuitive/affective and conscious/rational mechanisms operate to produce moral judgements." [1341] [1342]

We must bear in mind the observation of Eric Kandel, Nobel laureate, that there is no single neural locus of command and coordination. He writes,

> "There is no single cortical area to which all other cortical areas report exclusively, either in the visual or in any other system. In sum, the cortex must be using a different strategy for generating the integrated visual image."[1343] [1344]

If the brain requires complex coordination strategies to present an "integrated visual image", how much more, then, will complex coordination of systems be needed for an integrated response to the world, for recognition of truth and moral action. Yet, universal human experience is that in moral matters, as in behaviours of moral insignificance, human responses can be unified and

[1339] H. Soderstrom, et al., "Reduced frontotemporal perfusion in psychopathic personality" *Psychiatry Res* 114, (2002): 81–94.
[1340] Michael Koenigs et al., "Damage to the prefrontal cortex increases utilitarian moral judgements," *Nature* 446, (2007): 908-911.
[1341] Koenigs et al., "Damage to the prefrontal cortex increases utilitarian moral judgements," 910.
[1342] Darcia Narvaez, "Triune ethics: the neurobiological roots of our multiple moralities," *New Ideas in Psychology* 26 (2008): 95-119. Narvaez provides a useful summary of the neural bases of moral behaviour within her "triune ethics theory". She draws together neuroscientific evidence in support of the three stages: security, engagement and imagination. Rather than a top down, cognitively initiative view, she adopts a bottom up approach based on motivational orientations, and so her work is complementary to this study; she understands appetitive systems in the body as fundamental, a view consistent, as we shall see with the Aristotelian understanding of motivation. The article also provides an excellent overview of key literature on the role of affection in gene transcription.
[1343] Eric R. Kandel and Robert H. Wurtz, "Constructing the visual image" in Eric R. Kandel et al. *Principles of Neural Science*, 4th ed. (NY: McGraw, 2000), 340.
[1344] Bear, *Neuroscience. Exploring the Brain,* 731.

purposeful despite the varied systems involved. Again, let us remind ourselves that neural excitation cannot make moral decisions, persons do.

Table 5.1 draws together findings from some dozen authors whose work involves the neural bases of moral responsibility. The listing of areas and roles is by no means exhaustive, but it is representative of the complex integration of neural areas in moral action.

5.3 Neural bases.

5.3.1 A complex of systems.

The complexity of the brain is inescapable: the sheer extension of the neural network, the intricate cooperation of mechanisms at the molecular, genetic and cellular levels underpinning a grand collaboration of systems, and the possibilities for connectivity blessed with the potential for a virtual infinitude of subtle variations of synaptic strengths and neuromodulation. Indeed in 1949 Donald Hebb had suggested that thoughts and memories were dependent on "cell assemblies", networks of neurons. He postulated that changes in cell connections were the basis of learning, and that memory is both localised and distributed. Commonly in the current literature we meet terms such as "vast neuronal array"[1345], and "neural pools"[1346] to discuss the means by which networking complexity of the brain contributes to mental processes. Susan Greenfield proposes that "subsecond assemblies of 10s or 100s of millions of neurons lasting a fraction of a second determine *depth* of consciousness."[1347] One need not fully accord with the conclusion to appreciate the complexity of neural operations.

[1345] Susan Greenfield, *I.D. The Quest for identity in the 21st Century* (London: Sceptre, 2008).
[1346] Saladin, *Anatomy and Physiology*, 5th ed., 471.
[1347] Susan Greenfield, *I.D. The Quest for identity in the 21st Century,* 127. "Determine" however is a word that carries unwanted connotations; use of "contribute to" or "subserve" would avoid the suggestion that materiality could be the ultimate cause of free action. (See **6.4.2.2**.)

There is recognition that individual systems in the brain operate with astonishing breadth and complexity. Note for example this recent description of the motivational system:

> All of this being said, what should a *neural* mechanism of motivation look like? According to the account pieced-together in this dissertation, motivational mechanisms should look like pulsating synaptic cascades across vast breadths of neural tissue. From a seed of rhythmic activity, perhaps in orbitofrontal cortex and the hypothalamus, motivation would reach through planning mechanisms in dorsolateral prefrontal cortex, posterior parietal cortex, the cerebellum and motor cortex, and all of the loops connecting these areas through the basal ganglia and thalamus. Basically a motivation mechanism should extend through most of the brain.[1348]

Other brain systems offer similar complexity.

Neuroscientist Mario Beauregard in *The Spiritual Brain* argues that various brain systems are integrated in the performance of the highest rational functions, an intricate cooperation of neural systems, areas and mechanisms facilitating actions of the person. He says that transcendent experiences are

> …implemented via a spatially extended neural circuit encompassing brain regions involved in attention, body representation, visual imagery, emotion (physiological and subjective aspects) and self consciousness.[1349]

LeDoux makes an important point that the contribution of components in a system is derived from the fact that the system exists. Individual components are of this conditional value. Hence he writes of the system of emotional

[1348] Anthony Landreth, "Far Beyond Driven: On the Neural Mechanisms of Motivation" (PhD thesis, University of Cincinnati, 2007), 186.
[1349] Mario Beauregard and Denyse O'Leary, *The Spiritual Brain. A Neuroscientist's Case for the Existence of the Soul* (New York: Harper One, 2007), 37. Beauregard writes, "The brain has a neurological substrate that enables it to experience a spiritual state". (39)

management, “The amygdala is certainly crucial, but we must not lose sight of the fact that its functions exist only by virtue of the system to which it belongs.”[1350]

Something analogous happens with respect to virtue. By applying this principle to the systems underpinning virtue, we gain a greater appreciation of the whole. There is no doubt that the PFC and the BG, and numerous other individual brain regions are intimately involved in the expression of virtue, but the whole is greater than the parts. It is the soul that is the principle of unity and the principle of virtuous action; when the soul departs the orchestra falls silent. The performers go their separate ways. The music ends. Virtue may be understood as a complex integration and orchestration of organic elements.

George Orwell said that good prose is like a window… you see straight through it to the ideas it communicates; it does not draw attention to itself. Analogously, for all the complexity of the underlying neural orchestration, it is the beauty of virtue that is seen. We have seen that it is in his actions that the greatness of soul of Takashi Nagai shines out.

The state of virtue will be underpinned at the neurobiological level by mechanisms and pathways within the multiple systems of the brain that integrate neural function under the agency of the person. These neurobiological bases dispose for rational virtuous activity.

5.3.2 The principal brain systems contributing to the development and exercise of virtue.

Our focus is not only on systems operating in isolation, but on “multiple neural systems” which in turn are integrated in a highly coordinated manner. Grossberg and Versace offer an fascinating integrative view of brain function accounting for

[1350] J. LeDoux, “Emotion, Memory and the Brain,” *Scientific American* 270, (1994): 50-57. 56

cortico-thalamic learning.[1351] Furthermore parallel systems operate and compete.[1352] Pollak develops the idea of grand neural systems made up of contributory systems; he writes,[1353]

> Attachment, attention, emotion regulation, are likely to be constellations of processes that emerge as output from multiple neural systems… (and so it is necessary to seek) biologically plausible models of the mental processes in question. [1354]

Such a level of integration and coordinated complexity suggests that the state of virtue itself may be understood as complex of other systems, or several complexes of interlinked systems (pertaining to the different virtues), operating across the whole organism. It is the position of this study that the state of virtue may be classified as a system because numerous somatic areas and subsystems contribute, the process may be described scientifically, and results are replicable. Ultimately it is a system that is ordained to the flourishing of the human person, not only at the personal level, but at the biological level as well. This macro system however, does not operate beyond personal control (such as autonomic systems); rather it is a system over which the individual exercises considerable

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[1351] Stephen Grossberg and Massimiliano Versace, "Spikes, synchrony, and attentive learning by laminar thalamocortical circuits," *Brain Research* 1218 (2008): 278-312. In their Synchronous Matching Adaptive Resonance Theory (SMART) model they argue that there is high level of coordination between brain regions, dependent upon arousal, attention, memory, learning, and expectation brain systems, and mediated by plasticities generated by resonance and synchrony.
[1352] A. J. Gruber and R. J. McDonald, "Context, emotion, and the strategic pursuit of goals: interactions among multiple brain systems controlling motivated behavior," *Frontiers in Behavioural Neuroscience 6, (*2012): 50. "Multiple brain systems acquire information in parallel and either cooperate or compete for behavioral control. We propose a conceptual model of systems interaction wherein a ventral emotional memory network involving ventral striatum (VS), amygdala, ventral hippocampus, and ventromedial prefrontal cortex triages behavioral responding to stimuli according to their associated affective outcomes."
[1353] Pollak, "Early adversity and mechanisms of plasticity Integrating affective neuroscience with developmental approaches to psychopathology," 735.
[1354] Cf. Gruber and McDonald, "Context, emotion, and the strategic pursuit of goals: interactions among multiple brain systems controlling motivated behavior," 50. Adding a new degree of complexity, Gruber and McDonald (2012) comment on their finding that multiple brain systems appear to compete in pursuit of goals. They discuss a ventral emotional memory network that is constituted by ventral striatum (VS), amygdala, ventral hippocampus, and VMPFC.

autonomous control (directly, and through participatory systems such as the attentional systems and systems for learning).

It is reasonable to suggest that neural systems operate in support of moral actions. Casebeer notes multiple cognitive sub-processes involved in moral cognition, "a highly distributed, whole brain affair".[1355] Greene and Haidt also draw attention to the distributed nature of the neural bases of moral cognition.[1356] In a perceptive analysis of self reports of loss of will power by EL patients Paul Foley argues that it is necessary to view the brain as "an integrated whole" rather than separating out the psychic and the neurological elements. Within that view he finds that the biological basis of the loss of willpower in EL patients appeared to derive from dysfunction in the affective and motor centres of the BG, with interference to connection between thalamus and pallidum.[1357]

Notably there is evidence that developmental maturation is associated with the phenomenon of increased connectivity and coordinated systems in the brain. Converging evidence suggests that, during development to adulthood, there is a lessening of immediate functional connections to adjacent regions, and an increase of connection between regions distant in the brain. "These novel network-level findings bolster the claim that cognitive maturation occurs not in unitary structures but in the connectivity and interactions between structures."[1358]

[1355] Casebeer, "Moral cognition and its neural constituents," 841 and 846. **"**Socio-moral behaviour is rooted in the brainstem/limbic axis and PFC, with input and recurrent connections to and from sensory and multimodal cortices and frontal lobe areas: so it involves more-or-less the entire brain."

[1356] Greene and Haidt, "How (and where) does moral judgment work?" 517–523.

[1357] Foley, "The Encephalitis Lethargica Patient as a Window on the Soul," 184-214.

[1358] Somerville and Casey, "Developmental neurobiology of cognitive control and motivational systems," 236-241; see also M. C. Stevens, et al., "Age-related cognitive gains are mediated by the effects of white matter development on brain network integration," in *Neuroimage* 48, (2009): 738–746; Beatriz Luna et al., "What has fMRI told us about the Development of Cognitive Control through Adolescence?" *Brain and Cognition* 72, 1 (2010): 101. The authors write: "The transition from adolescence to adulthood therefore can be seen as a change in *mode of operation* from initially relying on more regionalized processing, such as in the PFC, earlier in development to relying on a broader network of regions that share processing in an efficient and flexible manner at the systems level."

And what are the neural systems that subserve the state of virtue? At the most elemental level we find the systems and mechanisms of plasticity and learning. Learning may be understood as our capacity to change in response to experience. We can be conscious of some of these changes, and even direct them by our choices; others will be at a subconscious level. The state of virtue denotes the conscious possession of learned moral habits. Plasticity and learning, then, are the two foundational systems for the construction of virtue. We have seen that mechanisms of plasticity are virtually ubiquitous across all areas of the brain.[1359] Plasticity is triggered by a wide array of developmental, environmental and experiential factors, and these mechanisms of plasticity are acknowledged to be decisive in all learning and memory. We have seen that plasticities associated with intracellular calcium and gene expression underpin structural changes resulting in long term memory, consolidated learning of new behaviours, etc. The brain's capacity for plastic change is at the core of a neural explanation for the phenomenon of habit, [1360] and, this study suggests, of virtue itself.

Higher "component" systems of the state of virtue utilise the mechanisms of plasticity and learning. These are the systems of memory, attention, reward and motivation, emotion regulation, habit formation, goal election, executive execution of motor commands and cognition, consideration of consequences, planning, and executive direction. In addition there are various subsystems assisting specifically in the development of virtue: systems for empathy and imitation, and systems disposing to sensitive periods of development.

Table 5.2 summarises the principal brain systems and mechanisms contributing to the state and exercise of virtue, referring to summary tables associated with neuroscientific systems discussed in **Chapter 2.**

5.3.3 The neural substrates of virtue. The state of virtue reflects a state of neural and systemic maturity.

[1359] Butz, et al.,"Activity dependent structural plasticity," 287-305.
[1360] Typical of the literature: Graybiel, "Habits, Rituals, and the Evaluative Brain," 359-87.

Having proposed that the state of virtue may be understood, at the neural level, to operate as a system perfecting the various associated systems of the brain (in **5.3.1** and **5.3.2**), and having identified the principal brain systems contributing to the development and exercise of virtue (in summary form in **Table 4.2**, and in more detail throughout **Chapter 2**) it now remains to set out the neural substrates of virtue in some detail.

I do this in two stages. In **5.3.3.1** I lay out systematically the argument for what I call the "neural excellence" view of virtue in the brain noting in summary form the neural bases; in **5.3.3.2** I draw on neuroscientific understanding to account for the 17 characteristics of virtue identified in **Table 4.1**.

5.3.3.1 A "neural excellence" understanding of the neural bases of virtue.

a) **A successful identification of the neural substrate of virtue and of the individual cardinal virtues requires clarification of the terms virtue, prudence, justice, fortitude, and temperance**. The virtues of prudence and justice are materially manifested as perfections of certain neural structures that are necessarily associated with rationality and choice in the embodied life. The virtues of fortitude and temperance are perfections of certain biological structures constituting dispositions of the irascible and sensitive appetites to endure appropriate difficulties and to seek appropriate pleasure; thus we can say they are <u>pre</u>dispositions for rationality and choice. In simple terms, the practical reason is understood, as the human capacity to elect appropriate means and ends for action; the rational appetite chooses what is good for oneself taking into account the good of others; the irascible appetite chooses goods that are difficult to pursue; the sensitive appetite chooses what is pleasurable. 'Appropriate' and 'good' refer to choices that are in keeping with the needs of human nature. The view of this study, in line with Aristotelian and Thomistic notions, is that all mental activity in the embodied life has a biophysical correlate, and therefore the dispositions of these four capacities have neural substrates. These substrates may be identified. (For detailed argumentation see **Chapters 1, 3 and 4**.) Furthermore the notion of the unity of the virtues has been argued: in all virtuous human actions the dispositions corresponding to all four virtues will be active. The fact that acts disposed by fortitude and temperance require rational guidance disposed by prudence and justice serves to clarify the distinctive neural tasks of each of these virtues. (For detailed argumentation see **Chapters 1, 3 and 4**.)

b) **Virtue is a state of neural and systemic maturity**. (See **Chapter 5.3.1** and **5.3.2**) It is evident that this maturity corresponds to the biological flourishing of the organism. (See **Chapter 6**.) The state of virtue is revealed as a macro system: the result of a highly complex interplay of systems, brain areas, mechanisms and pathways (neural, neurotransmitter and neuromodulatory, etc). The flourishing of the organism as a consequence of virtuous dispositions is seen in the mature development and integration of organic "components". The high levels of specific interconnectivity and cooperation between systems, and fine tuning of mechanisms make possible, as material causes, the rational operations of knowing reality and loving other persons. In fact every experience leaves a trace of neural changes in our brain; it will only be neural modifications serving these deepest goods of our nature, of knowing and loving, that are associated with virtue.

c) **Virtue consists, structurally, in the constellation of neural modifications reflecting maturity, at the genetic, synaptic, and cellular levels, in areas of the brain and in its pathways, across all neural systems serving rational action**. These neural modifications facilitate, at a material level, conscious and intentional action carried out for reasons of intrinsic motivation, and include receptivity for neuromodulation associated with reward pathways associated with pleasure inherent in virtuous action.

d) We have seen in **Chapter 2** and **Tables 5.1**, and **5.2** that **a great range of brain areas and structures are involved in the formation of virtue**.

Developmentally-dependent (initially) and use-dependent plastic changes in these areas and structures bring into being a material facilitation for rational activity; they are the neural signature of the state of virtue. Knowledge of the brain, while still advancing rapidly, has reached the point that it is possible to discuss with some clarity the contribution of discrete brain areas and how discrete areas contribute to the functioning of the whole.[1361] Principal areas of the brain in which will be found the mature modifications of virtue include most areas of the PFC, areas of the other cortical lobes associated with memory, deliberation, goal election, consideration of consequences of action, moral judgement, attention, imitation, response and delivery of affectivity, and for motor execution. The BG, limbic and paralimbic structures, the neural pathways between interconnecting these areas with the cortex, and the pathways for neuromodulation reaching cortical and subcortical areas are also intimately involved. In particular the pathways of emotional regulation, of reward, motivation and goal election, and of habit formation are of great significance.

e) Analysis of the exercise of virtue, or more properly of the various virtues, is additionally complex because of its integration into the steps of the human act itself. (See **Chapter 3.1.3**.) **The analysis of the human act assists in identifying the distinctive roles of fortitude and temperance (disposing rationally appropriate appetitive representations prior to the commencement of the act) and the roles of prudence and justice (disposing the deliberations between intellect and rational appetite that constitute the act itself)**.

f) Virtue is acquired by experience. "The human brain is inscribed (or carries traces) that make its microprocessing structure the record of an unfolding reality" writes Gillett.[1362] (See **Chapter 3.1.3**.) **The various mechanisms of**

[1361] Owing to advances in imaging techniques, the last two decades have brought a great increase in knowledge of the functioning brain. Furthermore, as many neural mechanisms and systems are highly conserved across species, animal studies add greatly to knowledge of the human organism.
[1362] Quoted in: Stephen Lyng, "Brain, body, and society: bioethical reflections on socio-historical neuroscience and neuro-corporeal social science," American Journal of Bioethics 9, 9 (2009): 25-6.

plasticity, making possible learning from sensory experience: explicit tuition, environment, experience (guided and otherwise), and repetition,[1363] **bring about the requisite neural changes**. Plasticity explains the capacity for the human neural system to modify structurally, and functionally, disposing to new behaviours in a stable way. (**Chapter 2 and 5.3**.)

g) **The material manifestion of the state of virtue may be described as the sum of the perfections of neural structures necessarily associated with rationality and choice in the embodied life.**

h) We have seen that human motivation may reduce to seeking pleasure and avoiding pain. The practice of virtue then is closely supported by a healthy reward system, assisting motivation and goal election; a system that is balanced with rationally cued, aversive responses when appropriate: "Much of our behaviour is shaped by learned associations between stimuli, our responses to them, and the rewards and punishments that result."[1364] Virtuous action is motivated by pleasures appropriate to our rational nature, and by the forbearance of difficulties for the sake of a noble reason. (See **Chapters 1, 3 and 4**.) In fact, **the virtues of fortitude and temperance dispose the human reward systems, and closely associated systems of emotional regulation, to good health**. It is patently not healthful for the organism to pursue rewards and exercise emotional responses which are detrimental to the wellbeing of the whole organism; therefore it is necessary that reward choices and emotional regulation are subject to cognitive processing. Fortitude and temperance dispose, at the neural level, the reward and emotion systems towards cognitive processing. Reward systems in the brain commence with sensory and somatosensory feedback to the OFC and limbic areas which are interconnected. Centres for both gratification and aversion are present in most limbic system structures. Aversional stimulation, for example in the

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[1363] D. Narvaez and J. L. Vaydich, "Moral development and behaviour under the spotlight of the neurobiological sciences," *Journal of Moral Education* 37, 3 (2008): 289-312.
[1364] Saladin, *Anatomy and Physiology*, 6th ed., 540.

amygdala, produces unpleasant sensations such as fear and sorrow, consciously registered through the amygdalic pathways via medial thalamus to the cortex, and by somatosensory cortices registering bodily reactions triggered by amygdalic output to the hypothalamus; [1365] in contrast a sense of pleasure or reward is associated with gratification, notably mediated by the NAc,[1366] pallidum and amygdala, and associated with μ-opioid and phasic DA signalling. [1367] Furthermore, limbic structures and the OFC inform the ventral striatum and the hypothalamus as well as the VTA and SN which reciprocally deliver DA to the OFC, amygdala, ventral striatum and hypothalamus.[1368] Directly, and in a second pathway through the ventral pallidum, the ventral striatum also inputs the medial thalamus via a pathway returning to the OFC.[1369] (See **2.6** for more detail.) This reward system is triggered in the OFC and amygdala by sense input. Arguably the due calibration of these areas is a major focus of the virtues of fortitude and temperance; but, as a system is only as strong as its weakest link, a healthy reward system requires all components and linkages to be calibrated to respond to pleasures with moderation and maintain a degree of equanimity in the face of dangers of one form or another.

i) **Maturity in virtue is evidenced by implicit motivation as opposed to extrinsic rewards**. In the development phase of virtue, neural reward systems (mediated principally by DA) are implicated as goals for A-O paradigms. This shift from A-O to S-deliberation-R paradigms involves increased activity in the dorsal BG, a transition to intrinsic motivation and ease of action, and decreased cortical activity. [1370]

> Some types of instrumental learning result in a strong association between a stimulus and an action that becomes resistant to reward devaluation. This kind of

[1365] Saladin, *Anatomy and Physiology*, 6th ed., 540.
[1366] Saladin, *Anatomy and Physiology*, 6th ed., 534.
[1367] Leknes and Tracey, "A common neurobiology for pain and pleasure," 317-8.
[1368] The ventral striatum is reciprocally connected also to the VTA and SN.
[1369] Saladin, *Anatomy and Physiology*, 6th ed., 428.
[1370] Yin and Knowlton, "The role of the basal ganglia in habit formation," 472.

associative memory, in which the stimulus becomes stronger than the outcome to trigger the response, is called habit….The more this associative memory becomes represented by a larger number of associative units, the more difficult it will be to erase them when the reward outcome or the novelty decreases. [1371]

Note that outcome devaluation affects neither habit nor virtue. [1372] (See **2.6.4**)

j) The exercise of virtue requires cortical emotional regulation. Emotional regulation is closely associated with the conscious perception of reward expectations. **Training in temperance and fortitude** (see below **p**. and **q.**) **consists in what could be described as the "plastic calibration" of the amygdala, and other limbic, basal and cortical structures associated with aversion and reward, in line with Aristotle's insistence that children be trained to seek appropriate pleasures**. A further aspect of emotional regulation is the reinforcement of pathways from amygdala to the PFC.[1373] [1374] Cortical processing alone, however, is insufficient for virtue. **Cortical processing, in turn, must be disposed by prudence and justice**. (See below **n**. and **o.** and also **Table 5.2**)

k) The practice of virtue requires explicit involvement of systems for goal election, a consequence of effective presentation and processing of rewards, and of emotion regulation. **Goal election, in its final phases, is a cognitive process disposed by prudence and justice**. (See **Table 5.2**) Neural modifications during the acquisition of virtue will be dependent upon goals that are self-elected, or goals, as in the case of a young child for example, that are elected by another. In both cases, virtuous goal election

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[1371] Da Cunha, et al. "Learning processing in the basal ganglia: a mosaic of broken mirrors," 166.
[1372] Da Cunha, et al. "Learning processing in the basal ganglia: a mosaic of broken mirrors," 166.
[1373] Saladin, *Anatomy and Physiology*, 6th ed., 540.
[1374] LeDoux, *The Emotional Brain*, 170. Sense input received in the amygdala is infused with emotional content. Thence, output will be either to hypothalamus (for bodily reactions to emotional stimulus), which is "the low road" identified by LeDoux, or areas of PFC implicated in conscious control and emotional expression, aspects of "the high road".

is a task of rationality, therefore disposed either by one's own prudence and justice, or by the prudence and justice of the guide whom one obeys.

l) Virtue is a form of learning characterised by the acquisition of habits. **The development of habitual behaviours is attributable to mechanisms of plasticity in brain areas and in brain pathways. Certain habits associated with virtue initially appear cognitively based (eg a habit of deliberation before acting), while others appear more procedural in the strict sense, with a striatal basis (eg the habit of courteously smiling to each new person one meets).** Cognitive habits however will not simply be mediated by cortical plasticity. Striatally mediated habits are not restricted to subconscious procedural activities; automaticity may develop in formerly goal directed actions mediated by striatal changes. [1375] Cortically elicited DA release (from VTA and SN), in both PFC and striatum, reinforces goal election and mediates, by repetition, striatally based habit learning: "Habit learning is achieved after overtraining in the striatum."[1376] Graybiel suggests that oscillatory activity in the cortico-basal loops is involved in establishing the habit, and that that chunking of behaviours, of action repertoires, is evidence for a neuronal shift from limbic to regions of motor and cognitive output. "Thus the relation between habits and the evaluative brain is that habits are an endpoint in the evaluation process."[1377] (See **2.4.5**) Note that as habits are acquired, reward mediation in the ventral striatum gives way to dorsal automatisation. (See above **i.**)

m) **Systems responsive to sensitive periods and to affection, and systems of imitation play significant roles** in acquiring behaviours particularly during developmental periods. (See **Table 5.2**)

n) **Prudence** is characterised by rich and reciprocal connectivity primarily between the DLPFC and other with cortical areas serving memory and somatic and sensory input, with the OFC, DMPFC, BG, and amygdala

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[1375] Wickens, "Synaptic plasticity in the basal ganglia," 125.
[1376] Da Cunha, et al. "Learning processing in the basal ganglia: a mosaic of broken mirrors," 166.
[1377] Graybiel, "Habits, Rituals, and the Evaluative Brain," 378.

serving emotion regulation, with the ventral striatum assisting in goal setting and motivation. (For more detail see **Tables 5.1** and **5.2,** and **5.3.2**)

o) **Justice** is characterised by habitual understanding for others, consideration of the impact of one's actions on others, empathy, and considerations of fairness, capacities mediated primarily by the aPFC, mPFC, VMPFC, OFC (especially medial OFC), ACC (especially rostal ACC), insula, limbic and paralimbic areas, and the BG. (For more detail see **Tables 5.1** and **5.2,** and **5.3.2**)

p) **Fortitude** is mediated first of all by the BG-thalamo-cortical loop and enriched connectivity between the OFC and the amygdala. At its most elementary level, the expression of fortitude may be understood as a capacity for rational, habitual suppression of debilitating responses to fear or pain. The various pathways of emotional regulation are also implicated. Various brain regions are shown to be active including OFC, DLPFC, VMPFC, areas of the amygdala and of the BG. The close association of pain and pleasure systems in the brain allowing balanced cognitive judgements has also been noted. (For more detail see **Tables 5.1** and **5.2,** and **5.3.2**).

q) **Temperance** is mediated primarily by the DLPFC and ACC, and by the various pathways of emotional regulation associated with the OFC, DMPFC, BG, with the ventral striatum assisting in goal setting and motivation. (For more detail see **Tables 5.1** and **5.2,** and **5.3.2**)

r) Exercise of these four virtues will also be subserved by ready access to memory. Many forms of plasticity dependent learning and memory are implicated in the development of virtue. **Deliberations implicit to cognition, consideration of consequences, planning, and goal election require activation of both long and short term declarative memory, as well as procedural memory and emotional memory.** (See **Table 5.2**.) Consolidation and plasticity in memory pathways is a necessity for virtuous judgement. Activation of declarative memory is necessary in evaluating the value of actions.

s) **Acquisition of the four virtues will be served particularly by mechanisms of imitation** priming responses in accord with the exemplar. (For more detail see **Tables 5.1** and **5.2,** and **5.3.2**)

t) The state of virtue should be seen as the endpoint of neural development, of a developmental sequence of behaviours associated with the ordered biological dispositions of fortitude and temperance informing right judgement. It involves an ongoing interplay between biological development, practical reason, experience, consideration for others, and the repetition of positive goal directed behaviours. The state of virtue makes use of the constellation of mechanisms and processes operating in across the various brain regions and pathways between them. Habit provides a mechanism for the organism to act more efficiently at the neuronal level, allowing the diversion of attention elsewhere and absorbing fewer cerebral resources. During the period of acquisition, both implicit procedural memories and virtue, move from the explicit to the automatised. [1378] Both are acquired by a process initially involving attentive, voluntary and repetitive action and explicit knowledge. During the human act and therefore the process of acquisition of virtue, concrete representations are present in mind.

u) Finally, **happiness as 'the reward of virtue'**[1379] **can be identified on various levels**.

    i. Choices associated with appetite are rewarded indiscriminately by the body's hedonic reward systems. As we have seen this is a normal concommitant to human acts. In biological terms this will be reflected in mechanisms of μ-opioid and phasic DA signalling and 5-HT uptake inhibition.

    ii. Pleasure enjoyed with self control is more enjoyable because it is longer lasting, and because it is enriched by the joy of knowledge of benefits to others, and is free of any bitter aftertaste of self interest.

[1378] See **Chapter 2** for referencing.
[1379] *NE*, 1099b16.

Such reward satisfaction following upon intrinsic motivations has been discussed. This will also be reflected in DA and opioid signaling.

iii. Via thalamic pathways from the striatum to the OFC that allow cognitive modification of PFC to upregulate DA release, rewards are modified to reflect the conviction to that proposed virtuous actions are rationally desirable; a source of reward reserved for what is perceived as a rational choice.

iv. Virtue empowers the functional flourishing of the organism. (See **b.** immediately above.) This state requires the efficient interconnection of the cortical, sub cortical, limbic, and brain stem regions, and the mature development of the full array of biophysiological attributes of the human being.

v. Virtue empowers the functional flourishing of the person, facilitating openness to reality and the capacity to love other persons.[1380] (See **b.** immediately above.) This is facilitated not only by rich connectivity between sensory cortices and the PFC but enriched brain activity supporting just action (see **p.** above), and prudent action (see **o.** above), supported by effective emotional regulation at the service of rationality.

vi. Virtue empowers the teleological flourishing of the person. The endpoint is *eudaimonia*, a state of general flourishing marked by effective self-management mediated by the neurophysiological dispositions of prudence, justice, temperance and fortitude. It satisfies two conditions for the presence of virtue – on the one hand mature neurobiological development, integration of systems, efficiency and an emotionally enriched life; and on the other a rationality that is disposed to seek and recognise truth and to love others. The wellbeing of the human person requires effective integration of the rational and physiological, the complete harmonisation of body and soul. This is the

[1380] Affective experience in turn feeds back into the paradigm of virtue development, facilitating peace of heart and motivating further positive behaviours.

ultimate meaning of *eudaimonia*. (There will be further discussion of flourishing in **Chapter 6**.)

5.3.3.2 The neural bases of virtue

I will now map the neural substrates of virtue to the characteristics of virtue established in **Chapters 3** and **4**. The state of virtue is understood as a state of excellence at the neural biophysical level for each of the characteristics.

This section proposes neural features for the 17 characteristics of virtue identified in **Table 4.1**. These 17 characteristics are divided, as per the original table, into three categories according to their association with the acquisition of virtue. For each point I offer brief philosophical clarifications of the characteristic under discussion (relating findings of **Chapters 3** and **4** to the neurological domain) and then I summarise the proposed neural signature for the characteristic under discussion. Finally, for each characteristic, I list the neural systems (see **Table 5.2**) associated, thus emphasizing the underpinning systemic integration. Tables summarizing discrete neural systems and their *prima facie* linkage to virtue are included in the endnotes.

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A. CHARACTERISTICS PERTAINING TO THE STATE OF VIRTUE

1. The virtues of prudence and justice dispose the practical reason and the intellectual appetite facilitating rationality and appropriate choices.

<u>Philosophical clarifications.</u>

- **The different virtues exhibit distinctive biological features.** In the Aristotelian/ Thomistic understanding, the human person *is* the animated body. Rational activity is conducted by a body animated by a human soul. As has been reviewed in **Chapter 4**, four cardinal virtues are necessary to account for operations and activities of an embodied soul. On this basis it is necessary for the four cardinal virtues to have distinctive neural signatures. Hence, the virtues of prudence and justice are materially manifested as perfections of certain neural structures that are necessarily associated with rationality and choice in the embodied life.

- **Prudence**[1381] **and justice**[1382] contribute habits perfecting the rational faculties,[1383] and therefore directing choices consequent upon the presentation of arduous goods and pleasurable goods to the intellect and will by the habits of the sensitive appetites.[1384]
- **Rationality** and **rational choice** as we have seen in **Chapters 1, 3 and 4**, while not reducible to the biological, possess and are manifested by means of sensible, neurobiological concomitants.
- Furthermore, (as has been argued in **Chapter 4**) in a state of virtue the unity of the virtues holds: **all virtues are present and their action is fully integrated**. Not only will the virtues of prudence and justice, here described, be enlisted in the direction of actions disposed by fortitude and temperance, but the self-dominion accompanying fortitude and temperance (described in the section immediately

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[1381] The virtue disposing the practical intellect is prudence**.** As we have seen in **Chapter 4**, prudence may be understood as the habitual disposition of the practical intellect to be of right counsel, to judge well and to command well. Aquinas argues that prudence is needed "to perfect the reason, and make it suitably affected towards things ordained to the end". (*ST*, Ia-IIae, Q.57, Art.5.) It is "right reason about things to be done," (*ST*, Ia-IIae, Q.58, Art.3.1) the habitual disposition of the practical intellect to be of right counsel, to judgement well and to command well. The starting point of prudence is knowledge of reality. Furthermore, "memory, experience, tact, good judgement, and sagacity" all either arise from prudence or accompany it. (Aristotle *De Virtutibus et Vitiis*, 1250a30-37) It is "well trained reason, capable of working out the particulars of a problem, of foreseeing the probable consequences of an act, of using powers of circumspection, of weighing the individual circumstances of a situation, of exercising caution lest good intentions ultimately do more harm than good. Reasoning, foresight, watchfulness, precaution are all essential elements of prudence, and there is no real prudence without them." (Gilson, *The Christian Philosophy of St Thomas Aquinas*, 288.)

[1382] As we have seen in **Chapter 4**, Justice is the virtue which disposes the rational will to act with due respect to the rights of others. Aquinas argues that justice is the state of character that makes people disposed to do what is just, and makes them act justly and wish for what is just. (*NE*, 1129a7ff.) Strict reciprocity of duty but also extending to duties of religion and of filial gratitude.

[1383] Aquinas writes of virtue as the "perfection of reason" in *ST*, II-II, 51,1.

[1384] The intellectual appetite is understood as the attraction to abstract pleasurable goals brought about by reward mechanisms in the brain responding to particular representations of goods associated with those abstract goals.

below) make prudent and just action possible. Hence, the neural signature of the virtues disposing a single human act will reflect the presence not only of the virtues disposing the intellect and rational appetite, but also those disposing the irascible and sensitive appetites.

- **We must keep present that it is the person who is rational, not particular brain cells.** Although it is the case that the PFC, and higher cortical areas in general, are more active in supporting the dispositions of prudence and justice, it would be an unwarranted conclusion that man's intellectual life, his capacities to grasp the truth of things or to love rationally, have their bases solely in activity in the higher cortical areas. This position would have no philosophical justification in keeping with the views of Aristotle and Aquinas. Beyond the highly complex integration of all brain areas, including limbic and basal structures, accompanying all activity in the cortex, activity in the brain itself is supported by the organic life of the organism, respiration, nutrition and circulation. Our microfocus on neural structures and pathways and mechanisms must be balanced by acknowledgement of the functional, existential, and objective unity of the person.

Neural bases

At the neurobiological level, prudence and justice are perfections of specific biological structures that are necessarily associated with rationality in the embodied life. They are established by plasticity-elicited changes to neural structures, which optimise neural and biological efficiency and are essentially mechanisms for use-induced establishment and reinforcement of neural pathways.

These perfections of bodily structures are essentially neuronal facilitations of the following biophysical tasks. These tasks together account for the roles of counsel, judgement, command, and the disposition to accommodate the good of others, as required by the virtues of prudence and justice.[1385]

- A facilitation for (hereafter described as "capacity for") **processing of sensory data** as a prerequisite for grasping the reality of the context for decision making. This processing will be directed by the lateral PFC informed by the accurate cortical somatosensory feedback via PNS and lower brain areas that is required for effective cortical processing.
- Capacity for planning and foresight, and for **consideration of consequences** of impact on others. This latter role is primarily a task of the VMPFC,[1386] [1387] the ACC and the OFC. Areas of the PFC are active in consideration of possible future outcomes.[1388] [1389] [1390] Contribution of the right DLPFC has been noted. It is believed that the PFC, and in particular the OFC, is the site of appreciation of moral consequences of behaviour.[1391]
- Capacity for cognitive **processing of emotional content, and particular reward representations** reaching PFC via OFC (input from cortico-striatal, and cortico-limbic pathways). Clinical studies show time and again that frontal cortical inhibitory zones suppress lower

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[1385] Counsel may be understood as a having a sound grasp of reality and duty in both physical and ethical dimensions. Judgement implies the capacity to evaluate the intrinsic and extrinsic benefits of an action taking into account the good of others. Command implies the executive capacity to carry decisions into action.

[1386] Davidson, "Affective style, psychopathology, and resilience: Brain mechanisms and plasticity," 1196-1214. It was the medial PFC that suffered damage in the case of Phineas Gage.

[1387] Lee, et al., "Regulation of human behaviours," 190.

[1388] J. M. Fuster, *The prefrontal cortex*, (New York: Raven Press, 1989).

[1389] J. Grafman,"Alternative frameworks for the conceptualisation of prefrontal functions" in *Handbook of Neuropsychology*, ed. F. Boller and J. Grafman (Amsterdam: Elsevier, 1994), 187.

[1390] R. Passingham, *The frontal lobes and voluntary action*, (Oxford: OUP, 1993). Passingham is recognised as a decisive pioneer of an understanding of PFC function and its role in support of decision making.

[1391] Note that damage to the medial PFC and frontal cortex leads to socially inappropriate behaviour, disinhibition, emotional impairment, difficulty in planning, and impaired working memory, as noted above in the celebrated case in 1848 of Phineas Gage but borne out by many animal studies and human case studies. Cf Gazzaniga, *Who's in charge. Free will and the science of the brain*.

order behaviours. [1392] [1393] Emotional and reward representations are generated in the medial PFC in conjunction with the BG via reciprocal pathways. BG are also active in concert with the PFC, enlisting limbic structures for processing emotional content and memory. [1394] Cognitive processing of emotional representations channeled through the OFC via limbic-cortical pathways is primarily in DLPFC, VMPFC, and OFC itself. [1395] [1396] [1397] This will be assisted by generation of representations in the memory (primarily distributed in cortex and in amygdala), as required for the representation of the anticipated goods. Note that, via striatal pathways, the medial PFC is capable of upstream modification on ACh and DA release, further modifying reward and emotional representations. [1398] [1399] Plasticity in spindle cells understood to facilitate goal directed behaviour and self control.[1400] There is evidence that emotional and reward election management requires the PFC areas to be in rich reciprocal communication with the amygdala and striatum. [1401]

- Capacity for **associated deliberation about abstract goods** (again primarily in the PFC) represented by the above particular reward representations. This cognitive activity directed by the lateral PFC will be facilitated by recruitment of memory (principally cortical-declarative, emotional memory via the limbic pathways, and hippocampal memory) which "supports the capacity to make

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[1392] M. R. Bennett, "The prefrontal-limbic network in depression: Modulation by hypothalamus, basal ganglia and midbrain," 483.
[1393] Zotev et al., "Self-Regulation of Amygdala Activation Using Real-Time fMRI Neurofeedback".
[1394] Koch, "Consciousness," 1220.
[1395] Davidson, "Affective style, psychopathology, and resilience: Brain mechanisms and plasticity," 1196-1214.
[1396] Barbas and Zikopoulos, "Sequential and parallel circuits for emotional processing in primate orbitofrontal cortex," 57.
[1397] Balbernie, "Circuits and circumstances. The neurobiological consequences of early relationship experiences and how they shape later behavior," 237-255.
1398 Pollak, "Early adversity and mechanisms of plasticity Integrating affective neuroscience with developmental approaches to psychopathology,"747.
[1399] Yin and Knowlton, "The role of the basal ganglia in habit formation," 470.
[1400] Arden and Linford, *Brain-based therapy with children and adults*, 104-105.
[1401] Ray and Zald, "Anatomical insights into the interaction of emotion and cognition in the PFC," 479-501.

generalisations and inferences from memory”.[1402] [1403] Recruitment of various forms of short and long term memory at cortical, limbic, and striatal sites in particular, facilitate recall of contextual particular information, emotional cues, and also abstract rules of right and wrong. The BG also play a direct role in the task of deliberation: areas of BG interconnected with PFC are implicated in intentional behaviour, learning and decision making. [1404]

- Capacity for **consequent generation of an intention** is supported by mechanisms of reward and goal election. As we have seen, goal election and cognition of reward representations appear to be closely associated functions. Rational intention will be informed by medial PFC emotional processing balanced by laterally directed deliberation.[1405] [1406] Input from the BG, modifying the PFC via thalamic pathways, is also considered a key regulator of voluntary behaviour.[1407] Capacity for deliberation is an integrating cognitive task directed by the lateral cortex. [1408] [1409] Active brain areas are diverse but feature strong connectivity. [1410] Memory in the striatum not only appears to instruct the PFC with respect to procedural patterns of behaviour,[1411] but the striatum contributes to an

[1402] Manns and Hichenbaum, “Learning and memory: brain systems,” 1165.
[1403] Marieb, Elaine N. and Katja Hoehn. *Human anatomy and physiology*. 8th ed. San Francisco: Pearson, 2010, 459. Declarative memory pathways involve sensory input carried to the association cortex; information is then sent to the medial temporal lobe, including the hippocampus and proximate temporal cortical areas that link to the PFC and the thalamus. ACh from the basal forebrain released into the PFC and the medial temporal lobe is believed to trigger memory formation.
[1404] Wickens, (2009) “Synaptic plasticity in the basal ganglia,”119.
[1405] Markowitsch, et al., “Brain circuits for the retrieval of sad and happy autobiographic episodes,” 643-665.
[1406] Arden and Linford, *Brain-based therapy with children and adults*, 104-105.
[1407] Yin and Knowlton, “The role of the basal ganglia in habit formation,” 464.
[1408] Miller and Wallis, “The prefrontal cortex and executive brain functions,” 1201.
[1409] Arden and Linford, *Brain-based therapy with children and adults*, 88.
[1410] Lee, et al., “Regulation of human behaviours,” 189-199.
[1411] Pasupathy and Miller, “Different time courses of learning related activity in the prefrontal cortex and striatum,” 873-876.

emphasis on intentional behaviour, learning and decision making. [1412] [1413]

- **Executive command** is a task of the lateral cortex enlisting motor cortices, the cortico-BG-thalamocortical loop, the BG, and the cerebellum. [1414] [1415] [1416] [1417] [1418] (See **No. 7** in this section.) This will be complemented by the **capacity to carry through executive commands to appropriate execution**.
- **Capacity to utilise language** as a vehicle for thought. For this the PFC links extensively to Broca's Area also in the frontal cortex.
- **See also n. – q.** in **5.3.3.1** outlining the particular neural features of each of the four cardinal virtues considered individually.

Note that in the performance of a single human act, these tasks are seamlessly **integrated**.[1419]

Prudence consists in appropriately formed neural structures that assist the intellect in reaching correct conclusions about ends and means. The lateral PFC is the principal site active in deliberation about consequences and means, planning and foresight. Lateral and medial PFC are densely interconnected and facilitate human volitional activity,[1420] and cognitive deliberation about emotional content.[1421]

[1412] Wickens, (2009) "Synaptic plasticity in the basal ganglia,"119.
[1413] Yin and Knowlton, "The role of the basal ganglia in habit formation," 465.
[1414] Doyon, et al., "Contributions of the basal ganglia and functionally related brain structures to motor learning," 62.
[1415] Kaas and Stepniewska, "Motor cortex," 159.
[1416] Barbas and Zikopoulos, "Sequential and parallel circuits for emotional processing in primate orbitofrontal cortex," 73.
[1417] Wickens, (2009) "Synaptic plasticity in the basal ganglia,"119.
[1418] Nolte, *The human brain. An introduction to its functional anatomy*, 5th ed., 473.
[1419] The analysis of the constituent parts of the human act (**3.1.3**) provides essential knowledge for the correct sequencing of activities at a somatosensory level and at the rational level. It provides a clear understanding of the distinctions between counsel, judgment and command, and of the roles of prudence and justice in informing these actions. Importantly also, it provides an understanding of the reciprocating deliberation between the intellect and the rational appetite prior to command. For example, an appreciation that particular reward representations precede to-and-fro deliberations between parts of the cortex prior to a single completed human act is essential the if the neural signature of the virtues disposing that human act are to correctly be identified.
[1420] Lee, et al., "Regulation of human behaviours," 189-199.

Justice consists in appropriately formed neural structures that assist the rational will in choosing correctly. Neural structures include aspects of those aspects of **b-e** which are related to affective appreciation and evaluation, and emotion-cued reward representations. In particular, areas of medial and orbital PFC are centrally implicated. These are the principal cortical sites for emotional processing, reward evaluation, deliberation about positive and negative affective consequences and means, and planning and foresight, most particularly with respect to the impact proposed actions will have on others. Recruitment of systems for empathy (including mirror neurons) to assist in understanding consequences of actions on others is also required. Areas of BG also, interconnected with amygdala, and PFC assist in deliberation about rewards with emotional content. Furthermore, a habit of expectations of cortical (ie conscious) DA reward in response to appropriate consideration for the impact of actions on others will be a further indicator of possession of the virtue.

In summary, the PFC should be considered the most significant brain area associated with the virtues of prudence and justice, although various other brain areas are directly implicated, most significantly other cortical areas, the BG, the limbic system, and the pathways connecting these. The neural activity associated with prudence and justice takes place in a highly integrated and coordinated manner across multiple areas of the brain.

Associated systems

Plasticity. Systems for learning. Attentional systems. Memory systems. Systems of emotional management. Reward and motivational systems. Systems for habit

[1421] Source for information in this section on the frontal cortex is, unless otherwise specified: Lee, et al., "Regulation of human behaviours," 190.

formation. Cognition, consideration of consequences, planning, goal election, and executive direction.

2. **The virtues of fortitude and temperance dispose the irascible and sensitive appetites to endure appropriate difficulties and to seek appropriate pleasure.[1422]**

<u>Philosophical clarifications.</u>

- Virtue consists in appropriate (ie rational) response in respect to pleasure and pain. Regulation of emotion is at the heart of virtue. Fortitude and temperance dispose for the effective management of emotion. Rational guidance systems, disposed by prudence and justice, then are able to act.
- **Fortitude[1423] and temperance[1424]** are essentially perfections of biological structures of the body, directly associated with management of emotional life, which facilitate the presentation of appropriate arduous goods and pleasurable goods to the intellect and will. It has been argued that fortitude and temperance are, in total, ordered biophysical qualities of the human person; they facilitate rational action in the same way that a well-trained animal obeys the rationality of its master, eg by eating only when permitted, defending the master's interests by fighting, etc.

[1422] The irascible and sensitive appetites, are understood as the attraction to concrete pleasurable goals brought about by reward mechanisms in the brain responding to particular representations or sensory input. Fortitude disposes the irascible appetite to endure difficulties in pursuit of difficult goods. Temperance disposes the sensitive appetite to obey reason in moderating pursuit of pleasures.

[1423] Fortitude is a particular quality of self management; the right management of one's fear and its concomitant sorrow is at the heart of the virtue. The essence of the virtue of courage is mastery over one's emotions of fear with readiness in necessity to put one's life knowingly and calmly on the line. "The man of fortitude relinquishes, in self forgetfulness, his own possessions and his life." Pieper, *Fortitude and Temperance*, 54.

[1424] Temperance is "the virtue whose particular function is to restrain and check passion" (Gilson, *The Christian Philosophy of St Thomas Aquinas*, 263). It is "a virtue of the appetitive part, by which men cease to desire bad sensual pleasures" (Aristotle *De Virtutibus et Vitiis* 1250a30-37). In the strict sense it is "a mean with regard to the bodily pleasures of touch" (*NE*, 1117b24ff). "To temperance belongs absence of admiration for the enjoyment of bodily pleasures, absence of desire for all base sensual enjoyment, fear of just ill repute, an ordered course of life, alike in small things and in great. And temperance is accompanied by discipline, orderliness, shame, caution."

- We have seen that with respect to temperance Aristotle understood that virtue consists in finding pleasure in the right things for the right reason to the right degree. Thus we should look for the temperance in the changes and dispositions in the pathways triggering pleasure as well as in the cognitive reassessment and adjustment of sense pleasure, a reassessment of fitting sources of pleasure.
- We have seen that with respect to fortitude Aristotle understood that virtue consists in enduring difficulties in the right things for the right reason and to the right degree. Thus we should look for the fortitude in the changes and dispositions in the pathways triggering fear as well as in the cognitive reassessment and adjustment of fear, a "recalibration" of what makes us fearful.
- Note that, the points which follow should be read most particularly in conjunction with the **No. 1** in this section outlining the common neural bases of prudence and justice, and **n. – q.** in **5.3.3.1** outlining the particular neural features of each of the four cardinal virtues considered individually. This is discussed in **No. 1**, immediately above, according to the understanding of the unity of the virtues.[1425]

<u>Neural bases</u>

At the neurobiological level, the virtues of fortitude and temperance consist in plasticity elicited changes to neural structures. These changes are brought about by mechanisms for use-induced establishment and reinforcement of neural pathways and they serve to optimise neural and biological efficiency. These perfections of bodily structures are essentially neuronal facilitations, plasticity elicited predispositions for rationally consistent responses to pain and to pleasure. They serve to enable rational action. In the restricted sense they consist of habitual responses, which when acquired, allow a person more easily to manage

[1425] Note that an understanding of the unity of the virtues leads to the conclusion that the work of the virtues is highly integrated, and points to the difficulty of precisely delineating at what point the work of fortitude and temperance is completed, and where the work of prudence, most particularly, commences.

fear of bodily danger and inappropriate attraction to sense pleasures of touch. In a broader sense they refer to habitual responses of patience and determination in the face of difficulties, and to habitual responses of appropriate moderation of pleasurable activities.

They are constituted by integrated activity in neural bases below. Activity is primarily in interconnected areas of the PFC, limbic system, and BG, dedicated to emotional regulation, bearing in mind that the various emotions are represented, as would be expected, at differing locations in the brain.

Fortitude and temperance, as we have seen, are brought about by "training" according to Aristotle, in a way analogous to training an animal. As such they may be viewed as varieties of "conditioned response", itself a broad term denoting learning brought about by some form of incentive. These conditioned responses are compatible with, and facilitate, conscious rational goal election.

The points below must be read in conjunction with **No.1** above. In the light of the above proviso, **the common neural bases** for fortitude and temperance follow.

- **Areas of the PFC (OFC, medial PFC, and lateral PFC) and areas of the amygdala and of the BG** are the key structures in management of fear and pleasure. The capacity of the PFC to elicit conscious representations of emotion, and to assess affective consequences of actions is at the heart of this emotional regulation.[1426] The PFC has projections to and from the forebrain systems associated with sensory data, with voluntary motor movement, with long term memory, and with systems processing affect and motivational state.

[1426] Davidson, "Affective style, psychopathology, and resilience: Brain mechanisms and plasticity," 1196-1214.

It is also interconnected to brain areas processing external information (linked to sensory systems/cortical and subcortical motor systems), as well as internal information (limbic and midbrain involving affect, memory and reward).

- Cognitive processing of emotional representations reaching the OFC via limbically modified thalamocortical pathways is primarily in **DLPFC, VMPFC and OFC**, those areas of the cortex adjacent to the limbic areas, and are believed to regulate emotional response.[1427] [1428] [1429] [1430] Conscious regulation of emotion utilizes both the DLPFC and VMPFC. It is believed that the DLPFC recruits input from the VMPFC (which includes the OFC) when there are conflicting emotional situations.[1431]
- The **OFC** is regarded as the limbic gateway to the cortex. OFC inhibition of subcortical areas such as the amygdala is a key to affect regulation.[1432] Neuroplastic remodelling of the frontal lobes is at the core of improved affect regulation in the PFC, allowing the OFC to effectively inhibit activation of subcortical areas such as the amygdala.[1433]
- The **ACC**, within the medial PFC, has been called the "major outflow of the limbic system" and is active in the experience of pain and distress. [1434] With the OFC it plays a central role in cortical regulation of emotion.[1435] The ACC appears to play a role in inhibiting impulsive

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[1427] Guyton and Hall, *Textbook of Medical Physiology*, 11th ed., 738.
[1428] Arden and Linford, *Brain-based therapy with children and adults*, 88.
[1429] Barbas and Zikopoulos, "Sequential and parallel circuits for emotional processing in primate orbitofrontal cortex," 57.
[1430] Davidson, "Affective style, psychopathology, and resilience: Brain mechanisms and plasticity," 1196-1214.
[1431] Arden and Linford, *Brain-based therapy with children and adults*, 88.
[1432] Arden and Linford, *Brain-based therapy with children and adults*.
[1433] Arden and Linford, *Brain-based therapy with children and adults*.
[1434] Posner and Rothbart, "Developing mechanisms of self regulation," 429.
[1435] Balbernie, "Circuits and circumstances. The neurobiological consequences of early relationship experiences and how they shape later behavior," 237-255.

behaviours and in generating goal-directed behaviours.[1436] There is evidence that it plays a role in analysing conflicting options.[1437]

- **The BG** informs the limbic loop of emotional management and plays a significant role in regulation of emotional responses.[1438] [1439] [1440] This finding supported by clinical observation that dysfunction of basal ganglia-limbic circuitry leads to schizophrenia and severe anxiety.[1441]
- The **amygdala** projects back to virtually all areas of the cortex influencing not only responses to fear, but higher order thought process, working and long term memories, ongoing perceptions, attention, mental imagery, principally in assistance to emotional regulation. [1442] [1443]
- **Pathways for emotional regulation** are found in the BG-thalamo-cortical loop importantly already associated with habit formation, and in the limbic-OFC-ACC loop. [1444] Limbic modulation requires rich reciprocal connections with the OFC. [1445] [1446] Significantly, the NAc in the BG is adjacent to the OFC and rich interconnections exist between them. Limbic modulation also requires interconnectivity to memory centres. OFC links to other cortical memory centres and to subcortical memory centres including amygdala and hippocampus. The lateral OFC, the OFC, and medial PFC are interconnected and

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[1436] Markowitsch, et al.,"Brain circuits for the retrieval of sad and happy autobiographic episodes," 643-665.
[1437] Arden and Linford, *Brain-based therapy with children and adults*, 88.
[1438] Martin, *Neuroanatomy: Text and Atlas*, 3rd ed., 347.
[1439] Heatherton and Wagner, "Cognitive Neuroscience of Self-Regulation Failure," 132-139.
[1440] Michael W. Shiflett and Bernard W. Balleine, "Molecular substrates of action control in cortico-striatal circuits," *Progress in Neurobiology* 95, 1 (2011): 1–13. "How the striatum controls the influence of reward learning on the cognitive control of action selection and initiation at a cellular and molecular level is an area of active research."
[1441] Tortora and Derrickson, *Principles of Anatomy and Physiology,* 11th ed., 493-494.
[1442] LeDoux, *The Emotional Brain*, 287.
[1443] Hamann, et al., "Ecstasy and agony: activation of the human amygdala inpositive and negative emotion," 135–141.
[1444] Pare et al., "New vistas on amygdala networks in conditioned fear," 1-9.
[1445] Heatherton and Wagner, "Cognitive Neuroscience of Self-Regulation Failure," 132-139.
[1446] Somerville and Casey, "Developmental neurobiology of cognitive control and motivational systems," 236-241. Cortico-striatal pathways appear crucial for cognitive control.

play a critical role in cognitive and emotional processing and in the formation of motivation for the selection of behaviours.[1447] DA modulation of reward pathways is well established. [1448] [1449] [1450]

- **Various forms of memory** are recruited in support of emotional regulation. Consideration of the perceived good of emotional regulation is associated with recruitment of memory (principally by hippocampal-cortical memory systems informed by the amygdala) the generation of reward representations associated with a pleasurable good, and associated DA and opioid signaling.

Fortitude consists in appropriately formed neural structures that assist the irascible appetite to obey rationality. These are essentially learned dispositions at the neural level regulating fear responses and aversive responses to pain.

As fortitude involves the rational management of fear, it is necessary to describe the neural bases of the experience of fear in order to better understand the neural bases of fortitude. To describe the **neural bases of the experience of fear** I draw, among others, from the work of Joseph LeDoux:

- The PFC is active in conscious representations of emotion, and in assessing affective consequences of actions.[1451] The presence of fear, the capacity to experience fear, indicates the maturation of working memory and in particular the OFC, linking temporal lobe limbic areas (amygdala and temporal pole cortex), the subcortical drive centres (in hypothalamus), and the DA neurons in reward

[1447] Barbas and Zikopoulos, "Sequential and parallel circuits for emotional processing in primate orbitofrontal cortex," 57.
[1448] Pine, et al., "Dopamine, Time, and Impulsivity in Humans," 8888-8896.
[1449] Buitelaar, "Adolescence as a turning point: for better and worse," 357.
[1450] Floresco, "Dopaminergic regulation of limbic-striatal interplay," 400–411.
[1451] Davidson, "Affective style, psychopathology, and resilience: Brain mechanisms and plasticity," 1196-1214.

centres of VTA.[1452] ACh is responsible for the mediation of vivid fearful memories. [1453]

- The amygdala is active in the experience of fear, mediates emotional influences on attention and perception, and regulates emotional responses. Mechanisms of synaptic enhancement are linked to emotional memory in studies of amygdala circuits that mediate fear. [1454] Emotional memory seems associated with the BLA which includes the lateral, basolateral, and basomedial nuclei, and the CEA.[1455] The lateral nucleus area tags memories with emotional "markers".[1456] Recall of these memories is mediated by hippocampus.[1457]
- The BLA seems key in development of an aversion, of fear conditioning. BLA draws input from widespread cortical areas, and from the sensory nuclei of the thalamus, with reciprocal connections to hippocampal and striatal memory systems. Outputs also extend from BLA to CEA and thence to subcortical areas controlling fear related responses such as heart rate, blood pressure, sweating, hormone release, etc. [1458]
- Emotional arousal appears to promote synaptic plasticity (for memory and learning) by various mechanisms including release of NE.[1459] The emotional circuitry is also modulated in an excitatory way by ACh from the gigantocellular neurons of the reticular excitatory area.[1460] [1461]

[1452] Schore, "Effects of a secure attachment relationship on right brain development, affect regulation and infant mental health," 7-66.
[1453] LeDoux, "Emotion circuits in the brain," 155-184.
[1454] Byrne, "Learning and memory: basic mechanisms," 1141.
[1455] LeDoux, "Emotion circuits in the brain," 155-184.
[1456] Davidson, "Affective style, psychopathology, and resilience: Brain mechanisms and plasticity," 1196-1214.
[1457] McGaugh, "The amygdala modulates the consolidation of memories of emotionally arousing experiences," 1-28.
[1458] LeDoux, "Emotion circuits in the brain," 155-184.
[1459] Kessels and Malinow, "Synaptic AMPA Receptor Plasticity and Behaviour," 344.
[1460] Bear, *Neuroscience. Exploring the Brain,* 581.
[1461] Guyton and Hall, *Textbook of Medical Physiology*, 11th ed., 730.

- Cortisol, adrenaline, and noradrenaline are triggered from the adrenal glands in times of stress that may or may not accompany fear.[1462]

Neural regions associated with the apprehension of pain are widespread and include the lateral PFC, anterior and posteria insula, the OFC, the MPFC, the anterior cingulate gyrus, areas of the BG, the thalamus, amygdala, hippocampus and various other subcortical regions. [1463]

It is proposed that **the specific neural bases of fortitude** are essentially to be found in neural modifications in the above pathways, most particularly in the following ways:

- Cortical processing of pain and fear responses is facilitated by the cortico-basal ganglia-thalamocortical loop which permits complex cognitive-emotional interaction, and offer insights into processes of planning, goal selection, self-regulation, attention and motivation. There are dense interconnections between the OFC and the amygdala, and between the amygdala, the hippocampus, and the ventral striatum.[1464] Furthermore, it is shown that motivation and meaning are analgesic factors. [1465] Therefore plastic modification of reward and goal setting pathways can effect changes in the pain threshold.
- The VMPFC and the amygdala are the key brain areas implicated in fear and its management. The VMPFC, the DLPFC, the hippocampus, and amygdala constitute the core elements of the neural circuit (the

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[1462] Sunderland, *The Science of Parenting,* 40. "Brain scans show that early stess can cause the HPA axis (the stress response system in the body) to become permanently wired for oversensitivity." "When a child experiences prolonged, uncomforted distress, the hypothalamus releases *corticotrophin releasing factor* (CRF)", which in turn stimulates the pituitary gland to release the hormone *adrenocorticotropin* (ACTH) which travels to the adrenal glands (on top of each kidney) which produce cortisol which in the short term "can help us to respond to stress by boosting the level of glucose in the blood." However continued exposure to high levels of cortisol is detrimental to neurons. (p87)

[1463] Leknes and Tracey, "A common neurobiology for pain and pleasure," Figure 2, 317.

[1464] Nolte, *The human brain. An introduction to its functional anatomy*, 5th ed., 469.

[1465] Leknes and Tracey, "A common neurobiology for pain and pleasure," Figure 2, 317.

cortico-amygdalic pathways) critical for deactivating conditioned fears. [1466]

- Neurotransmitters modulate the individual's emotional responses,[1467] We have seen, for example, 5-HT released into the hypothalamus and limbic structures inhibits aggression. [1468] [1469]
- Emotional inhibition makes use of inhibitory pathways in the brain. GABA is the major inhibitory transmitter in the mammalian brain further modified by the presence of steroids (denoting stress) and testosterone. [1470] [1471] GABA and GABAergic genes are seen as key mediators of learning and memory in anxiety, and in specific in the amygdala and hippocampus, regions of the brain involved in memory and anxiety. [1472]
- Consciousness of wellbeing and inner peacefulness as a consequence of release of opioids from the hypothalamus,[1473] and release of cortical (ie conscious) DA reward in response to appropriate endurance of difficulties will be further possible indicators of virtue.

Temperance consists in appropriately formed neural structures that condition the sensitive appetite to obey rationality. These are

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[1466] Morgan et al., "Extinction of emotional learning: contribution of medial prefrontal cortex". In rats it is the mPFC that plays a significant role for fear extinction in rats; this area corresponds to the DLPFC in humans.
[1467] Depue andCollins, "Neurobiology of the structure of personality: Dopamine, facilitation of incentive motivation, and extraversion," 514.
[1468] Bear, *Neuroscience. Exploring the Brain,* 581.
[1469] Guyton and Hall, *Textbook of Medical Physiology*, 11th ed., 730.
[1470] Siegal and Sapru, *Essential neuroscience*, 124. Note that inhibitory refers to the effect at the synapse and that therefore inhibitory pathways do not necessarily result in inhibition of actual behaviours. Sometimes the opposite result is obtained by the mechanism.
[1471] Arden and Linford, *Brain-based therapy with children and adults*. 204. Note reference to the work of LeDoux in this area. Sunderland writes that GABA naturally inhibits high levels of cortisol and calms the amygdala. "Research shows that if young mammals are left alone or in a prolonged state of distress, this can have a marked influence on how the genes for GABA unfold in the brain. This can alter the brain's sensitivity to stress, resulting in an agitated attitude to life for much of the time." Sunderland, *The Science of Parenting,* 44.
[1472] Kalueff, "Neurobiology of memory and anxiety From genes to behaviour. (Review)".
[1473] Sunderland, *The Science of Parenting,* 87. Endorphins for the relief of pain are "endogenous morphine"; oxytocin, released in the pituitary gland brings about feelings of comfort and well being and inhibits the triggering of the body's stress response system. Opioid receptors are ubiquitous in the brain.

essentially learned dispositions at the neural level regulating formation of pleasure representations, and response to these representations.

The **neural bases for the experience of sense pleasure** consist in:

- Basic sexual drives associated the hypothalamus in association with somatosensory feedback pathways trigger neurochemical and hormonal release. DA, originating in the VTN and SN, is sent via reward pathways, to the striatum, medial PFC and some twenty other locations.
- Equivalent pathways associated with sense pleasures with respect to food and drink.
- Emotional memories are laid down in the BLA, reward and procedural memories in the striatum, and associated declarative memories distributed through the cortex.

It is proposed that **the specific neural bases of temperance** are essentially to be found in certain neural dispositions. Hence the neural bases for temperance consist in the following:

- The facilitation of cortically moderated responses to basic sexual drives associated the hypothalamus, and reward representations in the medial PFC and the striatum, following pleasurable stimuli. Reinforcement of appropriate emotional memory, procedural memory and declarative memories will be take place in association with this.
- Facilitation for conscious management of lustful feelings in DLPFC and ACC, which have been shown to be activated in suppression of sexual response.[1474] The DLPFC, interacting with VLPFC and ACC, becomes active in choosing to resist feelings deemed inappropriate.[1475]

[1474] Beauregard, et al., "Neural correlates of Conscious Self-Regulation of Emotion," 1-6. Noted in Nolte, *The human brain. An introduction to its functional anatom* , 6th ed., 605.
[1475] Lee, et al., "Regulation of human behaviours," 190.

- Established pathways of habituated responses to pleasure in keeping with rational choice, in association with cognitive pathways regulating reward responses, assessing impact on others, and assessing proposed behaviours against moral learning.
- DA modulation of appropriate reward representations in the striatum exerts in turn a major modulatory effect on cortical output via the cortico-striatal connection and the via the thalamolimbic pathway. [1476] Cortico-basal-thalamic loops lead to further modulation and reinforcement of appropriate pathways.
- Consciousness of wellbeing and inner peacefulness as a consequence of release of opioids from the hypothalamus,[1477] and release of cortical (ie conscious) DA reward in response to appropriate sense pleasure, will be further possible indicators of virtue.

In **4.2.6** I asked why fear has the capacity to obliterate reason more easily than sense pleasure. The neural bases for these two responses are distinct, and it would appear possible that the central role of the amygdala, and direct interconnectivity with the hypothalamus, offer an explanation for this enhanced function.[1478] The studies of LeDoux demonstrate that fear responses are highly phylogenetically conserved; for evolutionary reasons, the sympathetic, fight or flight responses triggered by the amygdala, have an override capacity.**[1479]** Cortical processing comes second. It would seem too that pathways for the experience of sense pleasure to some extent are more cortically driven, a result of choice rather than of chance encounter in the environment requiring split second response. For this evolutionary reason too, it would seem that response to fear is more dominating and subrational.

<u>Associated systems</u>

[1476] Da Cunha, "Learning processing in the basal ganglia: a mosaic of broken mirrors," 158.
[1477] Sunderland, *The Science of Parenting,* 87. See also preceding Sunderland note.
[1478] Nolte, *The human brain. An introduction to its functional anatomy*, 5th ed., 469.
[1479] For an introduction to the anatomy and physiology of the brain: Larry W. Swanson, "Basic plan of the nervous system" in Squire, Larry et al. *Fundamental Neuroscience*. 3rd ed. Burlington, MA: Elsevier, 2008. Chapter 2.

Plasticity. Systems for learning. A-O paradigms giving way to S-R paradigms. Attentional systems. Memory systems. Systems of emotional management. Reward and motivational systems. Systems for habit formation. Cognition, consideration of consequences, planning, goal election, and executive direction. Systems for imitation and empathy.

3. A capacity for rational goal election is evident.

<u>Philosophical clarifications.</u>

In this section we look more closely at the neural basis for cognitive management of goal election. Cognitive management of goal election is a necessary but insufficient condition for the presence of virtue. Cognitive choices must not only be present but also disposed by prudence and justice (as discussed in **No.1** above). Vice is none other than the deliberate choice of harmful behaviours.

We have seen in **No.2** that fortitude and temperance may be developed by incentive learning. In such a paradigm will be found rational goal election, supported by reward incentives for appropriate behaviours.

In addition what can be called an **intellectual or spiritual joy** is effected by harmonious rational activity. This may be understood as the peace, comprehended rationally, and further rewarded by the body's reward systems, derived from due order in one's emotional and passionate life, and from an appreciation of the good accruing to others because of one's virtuous activity.

The **pleasure associated with virtuous action** is first of all a consequence of the reward systems and pathways. These reward systems operate at two levels: as a motivation to act, and as a further reward for virtuous action.

Neural bases

Our focus in this section is on the reward systems of the human organism, associated with goal election and motivation; our focus is on how these, in themselves, are subject to the neural facilitation of virtue. Reward systems may either be subject to cognitive direction, or (in the case of impulsive behaviour) over-ride effective cognitive direction. It is shown for example, that subcortical sensory inputs to the amygdala can drive emotional responses that precede cortical awareness, thereby circumventing executive direction. [1480]

Neural modifications associated with virtue will dispose reward systems to cognitive deliberations thereby offering the satisfaction of greater self management attuned to the integrated flourishing of the entire organism.

The **neural bases for the human reward systems** involve:

- The exciting DA driven, and the blissful endorphin driven systems. DA release is the principal mechanism of reward activation and, as we have seen, is interdependent on opioid signalling. The hormone oxytocin manufactured in hypothalamus provides specialised reward incentive, upregulating mood. A further type of reward activation involves 5-HT release into the limbic area and hypothalamus. [1481] [1482]5-HT receptors are found in nerve endings throughout brain. [1483]
- Areas of the amygdala, BG, and OFC are major reward "centres" of the brain. [1484] [1485] They are richly interconnected. Cue-reward learning and synaptic plasticity in the amygdala, more particularly,

[1480] Pare D, Quirk GJ, and LeDoux JE 2004 New vistas on amygdala networks in conditioned fear. *Journal of Neurophysiology* 92:1-9
[1481] Bear, *Neuroscience. Exploring the Brain,* 581.
[1482] Guyton and Hall, *Textbook of Medical Physiology*, 11th ed., 730.
[1483] Deutch, Ariel Y, and Roth, Robert H. "Neurotransmitters" Chapter 7 in Squire, Larry et al. *Fundamental Neuroscience*. 3rd ed. Burlington, MA: Elsevier, 2008.
[1484] Schultz and Tremblay, "Involvement of primate orbitofrontal neurons in reward, uncertainty and learning," 194.
[1485] Wagner and Silber, *Physiological Psychology*, 193.

the LA appears to be a decisive mechanism underpinning goal directed behaviour. Note that goal directed behaviour does not necessarily imply consciously elected action.

- Hedonic reward has been long believed to be mediated by DA projections from the VTA of the basal forebrain.[1486] Midbrain DA systems appear to provide reward signals to the PFC strengthening specific connections for particular behaviours.[1487] [1488]
- We have seen that there are two major DA systems in the brain: one projecting from the SNpc to the caudate and the putamen in the striatum and in a minor way to the NAc;[1489] another, the mesocorticolimbic DA system originating in the VTA and innervating the NAc, the amygdala and the various parts of the cortex, particularly the PFC. [1490] This second system is regarded as central to the brain's reward circuit,[1491] [1492] and critical in facilitation of incentive motivation.[1493]
- These DA systems, triggered by cortico-limbic afferents,[1494] in response to novel reward stimuli are the principal reward signals acting on the PFC to strengthen specific connections for particular behaviours.[1495] [1496]

[1486] Di Filippo et al., "Short term and long-term plasticity at corticostriatal synapses: implications for learning and memory,"116.

[1487] Miller, E. K., and Cohen, J. D. "An integrative theory of prefrontal function" *Annual Review of Neuroscience*. 24 (2001): 167-202.

[1488] Wagner and Silber, *Physiological Psychology*, 213.

[1489] Linked to laying down of procedural memory, and possibly to higher order personality traits

[1490] McCormick, David A. "Membrane potential and action potential" Chapter 6 in Squire, Larry et al. *Fundamental Neuroscience*. 3rd ed. Burlington, MA: Elsevier, 2008. DA is diffused in cortex with 80% of the DA concentrated in the corpus striatum. DA release is the condition for synaptic plasticity in the BG synapses between corticostriatal neurons and MSNs, possibly involving reverberation in the cortico-striatal loop.

[1491] Martin, *Neuroanatomy: Text and Atlas*, 3rd ed., 390.

[1492] Bear, *Neuroscience. Exploring the Brain,* 526.

[1493] Depue andCollins, "Neurobiology of the structure of personality: Dopamine, facilitation of incentive motivation, and extraversion," 500.

[1494] Pollak, "Early adversity and mechanisms of plasticity Integrating affective neuroscience with developmental approaches to psychopathology,"747.

[1495] Miller, E. K., and Cohen, J. D. "An integrative theory of prefrontal function" *Annual Review of Neuroscience*. 24 (2001): 167-202.

[1496] Da Cunha, "Learning processing in the basal ganglia: a mosaic of broken mirrors," 166.

- The BG play a major role in learning owing to their plasticity, presence in the reward and emotional regulation pathways, and efferent neuronal pathways to sensory cortices allowing somatic and sensory feedback.[1497] Closed cortical (lateral PFC, OFC, and the premotor cortex) - striatal loops appear to enable PFC to link complex anticipated behaviours with rewards, relying on rapid plasticities of the striatum.[1498]
- The NAc is topographically linked to basolateral amygdala and is a major terminal area for DA release in the reward pathways. The role of the striatum is essential in reward and motivation, organising somatosensory representations in a topographic manner. It draws cortical inputs from many areas of cerebral cortex.[1499]

T**he neural bases facilitating virtuous activity in association with the human reward systems** will facilitate activity in the following structures and pathways.

- **Plasticity in the OFC** enables cortical processing of reward representations. The OFC is the key area for volitional goal election. Reward representations in the OFC are associated with goal-directed, conscious choices of action.[1500] The OFC permits association information to access representational memory promoting "voluntary, cognitive, and goal directed (not stimulus driven) behaviour and facilitating new learning."[1501] It is activated by tasks where processing of rewarding or emotional information is required,[1502] [1503] [1504]and where information about rewards and punishments is integrated with their predictors to select goals for

[1497] Squire et al., *Fundamental Neuroscience*. 3rd ed.
[1498] Koch, "Consciousness," 1220.
[1499] Manns and Hichenbaum, "Learning and memory: brain systems," 1165.
[1500] O'Doherty and Dolan "The role of the human orbitofrontal cortex," 276.
[1501] Roesch and Schoenbaum, "OFC as gateway," 229.
[1502] Wagner and Silber, *Physiological Psychology*, 193.
[1503] Davidson, "Affective style, psychopathology, and resilience: Brain mechanisms and plasticity," 1196-1214.
[1504] Roberts and Parkinson, "Functions of primate orbitalfrontal cortex, 250.

action. [1505] [1506] Medial OFC appears implicated in reward and the lateral OFC in punishment. [1507]

- The OFC through its rich reciprocal connections to the limbic system and to the striatum plays a major integrating role. [1508] The OFC (particularly area MOC13) integrates both stimuli and responses with complex associations of reinforcement.[1509] MOC 13 is believed to integrate appetitive and aversive factors that are environmentally dependent."[1510]
- **Plasticity in the DA pathways and uptake in the PFC** facilitates cortical processing of reward representations. A large proportion of PFC neurons assisted by DA release, encode rewards linking behaviours to goal directed consequences. [1511] It is postulated that DA neurons in the midbrain respond when a reward seems imminent. [1512]
- **Plasticity in areas of the BG** facilitates conscious reward processing. [1513] Like the OFC, the striatum is activated in association with movement for an expected reward. [1514] [1515] The BG contain inhibitory GABAergic neurons, [1516] requiring strong and coherent excitatory cortical inputs from almost all cortical areas to become

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[1505] Roesch and Schoenbaum, "OFC as gateway," 201.
[1506] O'Doherty and Dolan "The role of the human orbitofrontal cortex,"266.
[1507] O'Doherty and Dolan "The role of the human orbitofrontal cortex,"269.
[1508] Price, "Connections of the orbitofrontal cortex,"39 and 52.
[1509] Depue andCollins, "Neurobiology of the structure of personality: Dopamine, facilitation of incentive motivation, and extraversion," 501.
[1510] Depue andCollins, "Neurobiology of the structure of personality: Dopamine, facilitation of incentive motivation, and extraversion," 491-517.
[1511] Miller and Wallis, "The prefrontal cortex and executive brain functions," 1217.
[1512] Miller and Wallis, "The prefrontal cortex and executive brain functions," 1217.
[1513] Yin and Knowlton, "The role of the basal ganglia in habit formation," 465. Animal studies have offered much light about the role of the BG in reward systems. Lesions of the BG affected the instrumentality of actions so that tested animals have been no longer able act for reward to avert adverse outcome.
[1514] Barbas and Zikopoulos, "Sequential and parallel circuits for emotional processing in primate orbitofrontal cortex," 64.
[1515] Wickens, "Synaptic plasticity in the basal ganglia," 120.
[1516] 95% of neurons in striatum are GABAergic MSNs according to Da Cunha, "Learning processing in the basal ganglia: a mosaic of broken mirrors," 159.

active. [1517] Over time A-O behaviours activating the ventral striatum give way to S-R behaviours.[1518] [1519] As has been discussed, S-R behaviours can also be volitional.[1520]

- **Plasticity in connectivity between the BG and the OFC is crucial** to the body's reward system, and hence to systems for goal election. Cells of the striatum become active in anticipation of reward, mirroring reward coding in the OFC.[1521] [1522] DA is released into the striatum leading to further limbic modification of neural transmission. DA modulation in the BG in turn brings about a decisive modulatory effect back on the cortex via the cortical-BG-cortical pathways. Striatal DA depletion is shown to lead to severe disruption of learned movement sequences.[1523] This further supports the view that there is an interconnection, at the level of the BG, between reward pathways and learned sequential behaviours. The DA system acts as a learning signal for behavioural reinforcement but also may well be involved in attention and motivation before all important events, both positive and negative. Its action is facilitated by neural loops. [1524]

[1517] Yin and Knowlton, "The role of the basal ganglia in habit formation, " 464.
[1518] Wickens, "Synaptic plasticity in the basal ganglia," 125.
[1519] Graybiel, "Habits, Rituals, and the Evaluative Brain," 364. Ventrally based limbic reward becomes less significant; the dorsal striatum characterised by habit formation and addictions becomes associated with management pathways of actions.
[1520] Beretta et al., "Synaptic plasticity in the basal ganglia: A similar code for physiological and pathological conditions," 349. Activities carried out with the ease of habit, either of a purely motor variety such as a tennis forehand, or with an ethical dimension such as habitual courteous greetings to strangers, may of course be fully intended and free, despite their intrinsic motivation.
[1521] Horvitz, "Stimulus-response and response outcome learning mechanisms in the striatum," 133.
[1522] Horvitz, "Stimulus-response and response outcome learning mechanisms in the striatum," 133. There is a close association between the striatum and the OFC by observation of differences between the sustained activity in striatal cells in comparison with the hundreds of millisecond activations of DA cells of the midbrain. The striatal-cortical reciprocal pathways connect reward centres in the BG and PFC and play a major role in goal election. DA, a principal mediator of plasticity, is decisive in development of habits of goal directed action.
[1523] Horvitz, "Stimulus-response and response outcome learning mechanisms in the striatum," 135.
[1524] Pollak, "Early adversity and mechanisms of plasticity Integrating affective neuroscience with developmental approaches to psychopathology," 747. In relation to this point, Pollak cites Schultz (1998), and Pruessner et al. (2004).

- Consciousness of wellbeing and inner peacefulness as a consequence of release of opioids from the hypothalamus,[1525] and release of cortical (ie conscious) DA reward will be further possible indicators of virtue.

<u>Associated systems</u>

Plasticity. Systems for learning. Attentional systems. Memory systems. Reward and motivational systems. Systems for habit formation. Cognition, consideration of consequences, planning, goal election, and executive direction.

4. "Virtues change us." The acquisition of virtue creates a state of character, a way of being that tends to be permanent..

<u>Philosophical clarifications.</u>

At a secondary level, it is universally recognised that **the habits we develop change us as people**: good habits, virtues, change us for the better; bad habits, vices, for worse. Habit formation may be seen to consist in, at the neural level, of plasticities that facilitate certain ways of acting and thinking.

Here I look at character, understood as a stable way of being that is associated with and denoted by qualities that have been acquired or developed. My focus is on habits that are acquired, the stable behaviours that define character.

<u>Neural bases</u>

- Explanation for the quasi permanent nature of character changes in the virtuous state is found at its foundation in the brain's capacity to incorporate **use-induced structural plasticities** which elicit

[1525] Sunderland, *The Science of Parenting,* 87.

permanent structural changes at the neural level, predisposing thereby to changed behaviours.[1526]

- **Cortical and BG plasticities** appear central to the stable, characteristic ways of acting and thinking that constitute personality and that are evident in emotional management systems, reward evaluation, systems for cognition and deliberation, and in the facility to act.
- The cumulative effect of genetically transcripted changes on personality is profound.[1527] In fact structural plasticities may have more permanent and lasting forms. For example, hippocampal plasticity is supplanted by cortical plasticity over time that is mediated by the striatum. [1528] [1529]
- There is a compelling case supporting the view that the BG are a key component in the development of **stable voluntary habits**.[1530] [1531] In conjunction with the PFC, the BG are now increasingly regarded as a key brain area for reward and emotion processing, cognition and voluntary goal election, and for behaviour changing modulatory input to the cortex. BG are now seen as a centre, not only for subconscious facilitation of habits, but also mediating deliberate attention, and limbic modulation of cognition and action.[1532] (see **2.6**)
- **The BG are now recognised as an area critical for learning, cognition and behavioural control**. [1533] [1534] Furthermore, the role of the BG,

[1526] Butz, et al., "Activity dependent structural plasticity," 287-305. As we have seen, plasticity is now known to be virtually ubiquitous in the human brain.
[1527] Malenka and Bear, "LTP and LTD: an embarrassment of riches," 5-12. This is despite the fact that LTD is the mechanism whereby LTP can be reversed in the neocortex.
[1528] Pasupathy and Miller, "Different time courses of learning related activity in the prefrontal cortex and striatum," 873-876.
[1529] For distinct forms of memory systems and the story of their discovery, the principal source of material that follows: Manns and Hichenbaum, "Learning and memory: brain systems," 488.
[1530] Manns and Hichenbaum, "Learning and memory: brain systems," 1165. The role of the BG in modifying cortical motor representations is well documented.
[1531] Floyer-Lea and Matthews, "Distinguishable Brain Activation Networks for Short- and Long-Term Motor Skill Learning," 517.
[1532] Martin, *Neuroanatomy: Text and Atlas*, 3rd ed., 327.
[1533] Martin, *Neuroanatomy: Text and Atlas*, 3rd ed., 327.

and of the cortico-striatal pathways, in conscious goal election is increasingly well understood. [1535]

- It has become clear in recent years that the PFC-basal pathways sustain voluntary movement, whereas the motor cortex-basal ganglionic modules underlie more automatic movements.[1536] The role of the BG in instructing the cortex in S-R situations is well understood.[1537] Now it is becoming clear that S-R habituation need not necessarily be subconscious nor, per se, non-volitional. BG pathways appear integral to the pursuit of complex, purposeful, behaviour patterns,[1538] It may be argued that individual goal directed behaviours on repetition become automated and less reward dependent, but nevertheless they remain purposeful, thereby fulfilling requirements for virtuous action.[1539]

<u>Associated systems</u>

Plasticity. Attentional systems. Memory systems. Systems of emotional management. Reward and motivational systems. Systems for habit formation. Cognition, consideration of consequences, planning, goal election, and executive direction. Systems for effective execution of motor commands. Systems for imitation and empathy.

5. The virtuous state is in keeping with our human nature.

<u>Philosophical clarifications.</u>

[1534] Beretta et al., "Synaptic plasticity in the basal ganglia: A similar code for physiological and pathological conditions," 349. "It is well known that the cortico-striatal network controls functionally heterogeneous decision making processes, including goal directed actions, susceptible to reward feedback, and stimulus linked actions, largely automatic or habitual."

[1535] Beretta et al., "Synaptic plasticity in the basal ganglia: A similar code for physiological and pathological conditions," 349.

[1536] Wise and Shadmehr, "Motor control," 153.

[1537] See for example: Yin and Knowlton, "The role of the basal ganglia in habit formation"; Da Cunha, "Learning processing in the basal ganglia: a mosaic of broken mirrors".

[1538] Beretta, Nicola et al. "Synaptic plasticity in the basal ganglia: A similar code for physiological and pathological conditions" in *Progress in Neurobiology* 84 (2008): 345-346.

[1539] Beretta et al., "Synaptic plasticity in the basal ganglia: A similar code for physiological and pathological conditions," 349.

Virtue assists human beings to flourish by disposing us to rational action.[1540] The virtuous state, in keeping with our human nature, facilitates the fulfilment of our needs as human beings, understood by some as the goods of human flourishing (**6.2**), and promotes the complete realisation of personal potential (ie both at the biological level and at the level of the transcendental fulfilment by truth and love). Virtue offers us the capacity to be open both to the truth of experience and to transcendent truth, to elect reasonable goals for pursuit without interior hindrance, and to respond with love in interpersonal relationships.

<u>Neural bases</u>

- Virtue fosters the complete realisation of personal potential at the biological level. The development of virtue is manifestly a state of integration of brain systems, and a realisation of the capacity to learn most effectively from experience. The integration of the brain systems harnessed for the possession and expression of virtue is suggested by **Table 5.1** and is central to this proposal for the neural bases of virtue. The capacity to learn from experience is a consequence of mechanisms of plasticity in conjunction with the somatosensory system, and systems for imitative learning.

- Biological flourishing of the organism may be understood as the maturity of neural development. It implies the highest degree of development and specialization of individual neural components, mechanisms and systems, together with the development of interconnectivities (of all cortical, sub cortical, limbic, brain stem regions and PNS, together with the full development of

[1540] *NE*, 1106a15. "That which makes its possessor good and his work good likewise". The good may be understood that which is most fulfilling according to one's nature; rationality is ordered to choice of what is good.

neuromodulatory pathways). Thus is enabled the most complete integration and contribution of all elements at the service of emotional direction and enrichment, and which, in turn, is at the service of efficient, rationally directed action that takes the rights of others into full account.

- Virtue offers the complete realisation of personal potential at the transcendental level by fostering an integration of emotional and rational life. Through a disposition to rational action, one is empowered to know and to love in an habitual way.
- See **No. 1** above for an overview of the neural manifestations of rational action.
- Note also that the development of neuronal maturity in the support of rational operations is a gradual process. Neonates manifest little activity in the cerebral cortex and this accords with the Aristotelian view that infants and children, because they do not possess full rationality, are incapable of perfect virtue.[1541]
- See also **6.2.1**.

Associated systems

Plasticity. Systems for learning. Attentional systems. Memory systems. Systems of emotional management. Reward and motivational systems. Systems for habit formation. Cognition, consideration of consequences, planning, goal election, and executive direction. Systems for effective execution of motor commands. Systems for imitation and empathy. Sensitive periods of development.

6. In the exercise of virtue intrinsic motivation takes priority over extrinsic motivation. Virtue is motivated by that which is worthy of man's nature.

Neural bases

[1541] Byrne, "Learning and memory: basic mechanisms," 1142.

Intrinsic motivation leading to virtuous activity is present in several ways:

- As has been discussed, once a disposition is acquired, A-O paradigms give way to S-R paradigms (possibly operating below the threshold of consciousness), leading to intrinsic reward associated with μ-opioid and phasic DA signalling in the BG, NAc, pallidum and PFC.[1542] (It is argued that S-R paradigms are compatible with rational action.[1543])
- Actions disposed by virtue will be intrinsically rewarding, a trigger in themselves for the contentment mediated by reward systems.
- By the exercise of the virtue of justice (see **No. 1** above) which is always present in virtuous action, actions are disposed to take into account the good of others. This may be understood as a form of intrinsic motivation because there is no conscious hedonic benefit sought by the protagonist in interpersonal relationships. Persons may never be instrumentalised for personal gain or reward.

<u>Associated systems</u>

Plasticity. Systems for learning. Attentional systems. Memory systems. Systems of emotional management. Reward and motivational systems. Systems for habit formation. Cognition, consideration of consequences, planning, goal election, and executive direction. Systems for imitation and empathy.

7. Virtue facilitates effective action.

<u>Philosophical clarifications.</u>

While not all virtuous action need manifest in external activity, external activity that does result is rationally directed, taking the needs of others into account, addressing one's own needs, having both sound intention and prudent selection of means.

[1542] Leknes and Tracey, "A common neurobiology for pain and pleasure," 314-320.
[1543] Yin and Knowlton, "The role of the basal ganglia in habit formation," 465. The speed of development however is striking. In the first four years of life, cerebral neuronal metabolic activity increases to twice adult levels, thereafter declining to adult levels by age 15.

- See **No. 1** for actions originating in the intellectual appetite.
- See **No. 2** above for actions originating in the sensitive appetite.
- The virtue of prudence will underpin selection of ends and means. (See **5.3.3.1.n.**)
- The virtue of justice takes account of the impact of actions on others. (See **5.3.3.1.o.**)

Effective direction of habitual external behaviours is effected by complex pathways involving primarily the PFC, the motor cortices and the BG.

<u>Neural bases.</u>

We have seen in **No.1** above, the role of executive command in the virtue of prudence. This was described as a task of the lateral cortex enlisting motor cortices, subserved by systems for action selection or goal election, and motor pathways utilizing the BG-thalamo-cortical loop, the BG, and the cerebellum, complemented by the capacity to carry through executive commands to appropriate execution. [1544] [1545] [1546] [1547] [1548] Here I focus on the facilitation specifically of these tasks. This is a further characteristic that is necessary, but in isolation insufficient, for the presence of virtue.

The facilitation of execution of intended action requires integration of the various sectors of the frontal lobe (most specifically the lateral PFC, an area oriented to action[1549], and the motor cortices), enlistment of the

[1544] Doyon, et al., "Contributions of the basal ganglia and functionally related brain structures to motor learning," 62.
[1545] Kaas and Stepniewska, "Motor cortex," 159.
[1546] Barbas and Zikopoulos, "Sequential and parallel circuits for emotional processing in primate orbitofrontal cortex," 73.
[1547] Wickens, (2009) "Synaptic plasticity in the basal ganglia,"119.
[1548] Nolte, *The human brain. An introduction to its functional anatomy*, 5th ed., 473.
[1549] Barbas and Zikopoulos, "Sequential and parallel circuits for emotional processing in primate orbitofrontal cortex," 73.

BG and cerebellum (for procedural facilitation), and directed neural activity in subsequent pathways via brain stem to execution in the PNS .

Plasticity in these motor pathways is well documented. ACh is the principal excitatory mediating agent at the neuromuscular synapse, opening ion channels and triggering the phenomenon of muscular memory. Epi also plays a role.[1550] AMPA trafficking is the mechanism appearing to underlie the formation of neuronal pathways, and behaviour modification itself.[1551] Activity at the motor synapse can be self reinforcing with synapse pruning serving to optimise the connection,[1552] [1553] causing the synapse to be responsive to the specific environment of the individual. [1554]

The neural facilitation for effective action will consist in the following aspects:

- The **PFC** itself is richly endowed with connections for conscious motor management to motor cortices, the primary motor cortex, the premotor and supplementary motor areas and Broca's area. In addition to "anatomical loops" between the PFC and the BG , there is rich interconnectivity between the functional sectors of the frontal lobe, the cerebellum, the BG, and lower brain structures enabling execution of cortical commands. The medial PFC "provides goal directed motor plans selected within the NAc on the basis of contextual and emotional associations from both the hippocampus and the amygdala".[1555]

[1550] Bear, *Neuroscience. Exploring the Brain,* 707.
[1551] Kessels and Malinow, "Synaptic AMPA Receptor Plasticity and Behaviour," 340.
[1552] Tapia, Juan C and Lichtman, Jeff W. "Synapse Elimination" Chapter 20 in Squire, Larry et al. *Fundamental Neuroscience*. 3rd ed. Burlington, MA: Elsevier, 2008. p470
[1553] Nolte, *The human brain. An introduction to its functional anatomy*, 5th ed., 610.
[1554] Tapia, Juan C and Lichtman, Jeff W. "Synapse Elimination" Chapter 20 in Squire, Larry et al. *Fundamental Neuroscience*. 3rd ed. Burlington, MA: Elsevier, 2008. p475
[1555] Quoted in Pollak, "Early adversity and mechanisms of plasticity Integrating affective neuroscience with developmental approaches to psychopathology,"738.

- Multiple **memory** systems are associated with execution of goal directed motor plans.[1556] The **premotor cortex** holds motor activity in memory. [1557] Motor memories and learning are triggered in the premotor cortex by ACh released from the basal forebrain. [1558] The **dorsal striatum** lays down memory for the long-term storage of well-learned movement sequences and motor habits. [1559] The **cerebellum** holds movement programming.[1560] Hippocampal plasticity and memory are evident in the development phase of habits in the striatum, and in the formulation of goal directed motor plans.[1561].
- Long term **storage of explicit motor knowledge is in the PFC and associated parts of the BG**, while storage of intermediate term explicit motor knowledge is in the MTL. [1562]
- The **BG** are most involved not only in cortical management of emotion, and habit formation, but also in motor management. The dorsal striatum lays down memory for motor habits and instructs the PFC in S-R situations.[1563] The putamen receives input from motor and somatosensory cortical areas. [1564] Processing of motor commands takes place here and in the GP.[1565] BG outputs directly affect activity of motor areas in the cortex,[1566] operating "mainly to modify cortical motor representations rather than control behaviour through direct motor inputs".[1567] The GP and the SN of the BG also play a major role

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[1556] Manns and Hichenbaum, "Learning and memory: brain systems," 1174.
[1557] Marieb and Hoehn, *Human anatomy and physiology*, 8th ed., 437.
[1558] Siegal and Sapru, *Essential neuroscience*, 124.
[1559] Floyer-Lea and Matthews, "Distinguishable Brain Activation Networks for Short- and Long-Term Motor Skill Learning," 517.
[1560] Marieb and Hoehn, *Human anatomy and physiology*, 8th ed., 458-459.
[1561] Pollak, "Early adversity and mechanisms of plasticity Integrating affective neuroscience with developmental approaches to psychopathology," 747.
[1562] Wise and Shadmehr, "Motor control," 137-157.
[1563] Squire et al., *Fundamental Neuroscience*. 3rd ed.
[1564] Nolte, *The human brain. An introduction to its functional anatomy*, 5th ed., 469.
[1565] Martini, *Fundamentals of Anatomy and Physiology*, 6th ed., 486.
[1566] Nolte, *The human brain. An introduction to its functional anatomy*, 5th ed., 469.
[1567] Manns and Hichenbaum, "Learning and memory: brain systems," 1165.

in motor control, [1568] selecting patterns of cortical activity, and ultimately selecting and reinforcing chosen motor programs.[1569]

- The **BG-thalamo-cortical loop** processes subsequent motor commands. Motor learning involves a "functional interplay... between cortico-striatal, cortico-cerebellar, and limbic systems." [1570]
- The **cerebellum** assists in movement and motor habits and is now recognised to have a likely role in formation of cognitive habits.[1571] [1572] [1573] Furthermore, there is now evidence that the cerebellum and the BG are far more interconnected ,via a cerebello-thalamo-striatal pathway, and are therefore interactive, than has been long thought.[1574]
- **Axonal myelination** facilitates speed of sensory and motor messaging through much of the PNS and CNS.
- See also **6.2.1.2.**

Associated systems.

Plasticity. Systems for learning. Reward and motivational systems. Systems for habit formation. Memory systems. Cognition, consideration of consequences, planning, goal election, and executive direction. Systems for effective execution of motor commands.

8. Virtue brings about ease of action.

Philosophical clarifications.

[1568] Kaas and Stepniewska, "Motor cortex," 159.
[1569] Petersen, *Human physiology,* 205.
[1570] Doyon, et al., "Contributions of the basal ganglia and functionally related brain structures to motor learning," 62.
[1571] James W. Kalat, *Biological Psychology*, 7th ed. (Belmont CA: Wadsworth, 2001), 238.
[1572] Ito, M. "Cerebellar long term depression: Characterisation, signal transduction, and functional roles" 1143-1195. There is strong evidence that LTD is the mechanism by which learning is encoded in cerebellum.
[1573] Patrick R. Hof, et al., "Cellular components of nervous tissue," in Larry Squire, et al., *Fundamental Neuroscience*, 3rd ed. (Burlington, MA: Elsevier, 2008), Chapter 3. NE is distributed to the cerebellum and other areas from noradrenergic nucleus, the locus coeruleus, within the pons.
[1574] E. Hoshi, et al., "The cerebellum communicates with the basal ganglia," *Nature Neuroscience* 8, (2005): 1491–93.

The easy repeatability of behaviours associated with virtue is immediately seen, for example in habitual courtesies, habits of getting up when the alarm goes off, habits of reacting to difficulties with patience, etc.

<u>Neural bases</u>**.**

Here we focus on the development of habit, automaticity, in good behaviours. Ease of action is primarily a result of a number of neuronal mechanisms and loci of facilitation:

- Preferential pathways are established by mechanisms of **plasticity**: in the pathways of the CNS and PNS, in motor, emotional and deliberative areas and pathways, in the various seats of memory, etc.
- Mechanisms of habit learning, of **automatisation,** offer an explanation for the phenomenon of behaviours that appear to remain robust in the absence of immediate rewards. A-O paradigms give way to S-R paradigms with lower cortical demand: action becomes more efficient as action moves from high levels of cortical activation to simpler patterns of activation that are associated with automaticity.
- The **BG** mediate subconscious facilitation of habits, cognition and action.[1575] Hence they are now recognised as areas contributing to conscious control of established behaviours. The putamen, an area of the sensorimotor striatum, [1576] involved in learning and movement initiation and neuromodulated by DA from the SNpc, is also enriched by reward pathways.[1577]
- See **6.2.1.2**.

[1575] Martin, *Neuroanatomy: Text and Atlas*, 3rd ed., 327.
[1576] Yin and Knowlton, "The role of the basal ganglia in habit formation," 468.
[1577] The BG become increasingly, or at least more efficiently, involved in the process of learning as actions become more automatic. Complex striatal habit formation involves cortical management via the striatal-cortical pathway. The striatum is functionally linked to SN which is richly interconnected to midbrain, STN, and VTA. In the dorsal striatum, which as we have seen is most active once actions are automatized, the caudate nucleus receives inputs from association cortices (and appears more implicated in A-O learning); the putamen has primarily sensorimotor connections (associated more with S-R learning).

Associated systems.

Plasticity. Systems for learning. Attentional systems. Memory systems. Systems for habit formation. Systems for effective execution of motor commands.

9. **Virtue facilitates the flourishing of the person. Virtue brings about a state of excellence: an excellence of the person, inclusive necessarily of both neurobiological flourishing and the exercise of rationality. It is a state whereby reason and rationality are empowered to manage activity. Capacity for rationality that is reflective and emotionally enriched and able to be carried through into noble humane behaviours.**

Philosophical clarifications.

- Flourishing, those habits "by which a person acts well",[1578] is in effect the "reward of virtue".[1579] It denotes a state in which autonomy and agency, mastery over one's operations and activities, are enhanced. Autonomy is a consequence of enhanced rationality and an enhanced capacity to bring one's plans to fruition. See also **No.5.**
- See also **6.2.1.2** where I argue that flourishing may be understood on at least three levels: affective, functional and teleological (directly facilitating of the final end of the person).

Neural bases.

- **Nos. 1 and 2** above, focused on the capacity for the person to act in a truly rational and emotionally enriched way are the heart of *eudaimonia*. The high degree of integration of systems required, in support of emotional regulation and cognitive goal selection directed

[1578] *ST*, Ia-IIae, Q.55, Art.3.
[1579] *NE*, 1099b16.

towards moral behaviour, is well established and increasingly acknowleged.[1580]

- **Nos. 7 and 8** above, focused on ease and efficiency of action, enhancing further to the autonomy of the person, contribute further to his functional flourishing. Functional flourishing requires structural maturity at the cellular and systemic levels, as well as functional integration. Essentially these processes are driven by developmental gene transcription triggered by internal processes and appropriate sense inputs. As the person matures after infancy, the subject's own goal choices increasingly direct experiential inputs that consolidate pathways facilitating future behaviours. Development becomes increasingly self regulated, or at least offers the potential for this to be so.[1581]
- Learning pathways need to be both efficient and cognitively directed: a result of plasticity and well developed mechanisms supported by habitual management of attentional systems.

Associated systems.

Systems for learning. Attentional systems. Memory systems. Systems of emotional management. Reward and motivational systems. Systems for habit formation. Cognition, consideration of consequences, planning, goal election, and executive direction. Systems for effective execution of motor commands. Systems for imitation and empathy. Sensitive periods of development.

[1580] A representative sample of supporting papers: Casebeer, "Moral cognition and its neural constituents," 841-849**;** Grossberg and Versace, "Spikes, synchrony, and attentive learning by laminar thalamocortical circuits," 278-312; Greene and Haidt, "How (and where) does moral judgment work?" 517–523; Somerville and Casey, "Developmental neurobiology of cognitive control and motivational systems," 236-241. Also see Stevens, et al., "Age-related cognitive gains are mediated by the effects of white matter development on brain network integration," 738–746; Luna, et al., "What has fMRI told us about the Development of Cognitive Control through Adolescence?" 101.

[1581] The work of Wolf Singer is of relevance. His work focuses on how the brain is modified by experience, and on the synaptic modifications underpinning the neurobiological basis of learning and memory. At the Pontifical Academy of the Sciences gathering of experts in Human Neuroplasticity and Education in October 2010, he spoke of the "massive rearrangement of functional networks" in adolescence, and of the "second chance" to reconstitute one's neural structures in a way more conducive to personal fulfilment. Note reference to Singer in **Table 1.1. A hylomorphic critique of 20th century currents in philosophy of mind.**

B. CHARACTERISTICS OF VIRTUE IN ITS ACQUISITION

Essential features pertaining to virtue in its acquisition.

10. The virtuous state results from habituation and education.

Philosophical clarifications.

Habituation in the Aristotelian sense consists of training from one's earliest years, primarily in the behaviours appropriate to fortitude and temperance. Education, in Aristotelian sense, consists both in the learning of appropriate information (for example, of right and wrong in accord with nature) and the acquisition of appropriate experiences. In both, guided experience, imitation of good example, aspiration to what is good, true, and beautiful, and appropriate correction of erring behaviours are essential. Education also requires explicit ethical and behavioural instruction, carried out in a practical and contextual manner.

Neural bases.

- The neural bases for mechanisms of **habituation** are a result primarily of the plasticities, primarily use-induced, present in mechanisms of learning associated with the virtues of fortitude and temperance (see **No. 2** above). These are complemented by the explicit development of habits and automaticity in specific behaviours (see **No. 8** above.).
- The neural bases for mechanisms of **education** are a result primarily of the plasticities, primarily use-induced, present in mechanisms of learning associated with the virtues of prudence and justice (see **No. 1** above.) These will be complemented by mechanisms of imitation inspired by exposure to what is good, true and beautiful (see **No. 12** below), and explicit ethical instruction (see **No. 16** below).

Mechanisms of attention need to be engaged in order to facilitate learning (see **No. 13** below).

Associated systems.

Plasticity. Systems for learning. Attentional systems. Memory systems. Systems of emotional management. Reward and motivational systems. Systems for habit formation. Cognition, consideration of consequences, planning, goal election, and executive direction. Systems for effective execution of motor commands. Systems for imitation and empathy. Sensitive periods of development.

11. Repetition, understood as critical practice, plays an essential role in the acquisition of virtue: repetition in appetitive responses, in responses manifesting noble sentiment and attentiveness to others, and in reasoning, deliberation and sound decision making.

Neural bases.

- Use-induced plasticities and pathways operate across most brain areas and pathways, established by Hebbian laws, underpin the synaptic strengthening that results from repetition of neural firing. (See **2.2** and **Tables 2.3** and **2.15**)
- Other forms of learning also contribute. The possibility of self induced and parentally guided conditioning has been discussed.
- DA reinforcement of goal directed activity underpins a broad spectrum voluntary plastic reinforcement of behaviours.

Associated systems.

Plasticity. Systems for learning. Attentional systems. Systems of emotional management. Reward and motivational systems. Systems for habit formation. Cognition, consideration of consequences, planning, goal election, and executive direction. Systems for effective execution of motor commands. Systems for imitation and empathy. Sensitive periods of development.

12. Education specifically in wisdom and beauty is necessary in the formation of virtue.

<u>Neural bases.</u>

All experience leaves neural changes. Education in wisdom and beauty is acquired, in the Aristotelian view, by exposure to appropriately true and beautiful experience. Experiences where there is effortful attention, positive emotional association, repetition, or novelty are shown to have greater potential to effect neural change. Mechanisms of cognitive learning and memory, as well as use-induced plasticities, will be implicated.

Neural facilitation of these pathways of learning consists in plastic modification of neural structures associated with:

- Attentional control. (See **No. 13** below, and **Tables 2.9** and **4.2** Attentional Systems.)
- Mechanisms for learning. (See **No. 16** below, and **Tables 2.4** and **4.2** Systems for learning.)
- Pathways for empathy. (See **No. 15** below, and **Tables 2.6** and **4.2** Systems for imitation and empathy.) This will be most relevant in ease of adoption of behavioural example of parents, siblings, mentors and friends.
- Pathways responsive to positive emotional context and affection. (See **No. 17** below, and **Tables 2.2** and **4.2** Sensitive periods of development.)

<u>Associated systems.</u>

Plasticity. Systems for learning. Attentional systems. Memory systems. Systems of emotional management. Reward and motivational systems. Systems for habit formation. Cognition, consideration of consequences, planning, goal election, and executive direction. Systems for imitation and empathy.

13. Effortful attention plays a significant role.

Philosophical clarifications.

Human beings have some capacity to reflect on the direction and level of attention operating in their sensory systems (most significantly the visual system). They have some capacity to redirect or focus that attention if they so choose. If the activity pursued is virtuous, the choice to focus one's attention must also be virtuous as it is integral and necessary for the intended act. The relationship between willpower (which, if rational and effective, will with due regard to the unity of the virtues involve the spectrum of established virtues) and attention has been noted.

Neural bases.

Effortful attention appears to be a prerequisite for much of the learning associated with the development of virtue. This is so for at least two major reasons:

- The attentional system is a key to self-directed brain plasticity, and as such is a key to free and volitional behaviour.
- Effortful attention would appear to be present in all learning from sensory input (consider for example a small child learning by observing). The nucleus basalis, and the attention system in which it plays a critical part, have the capacity to guide plastic development.[1582]

In the learning stages of habit development there are much higher levels of attention evident in the cortex, than when the behaviour has

[1582] Doidge, *The brain that changes itself*, 84-88.

been incorporated as habit, at which time procedural mechanisms dominate.

Neural facilitation in attentional systems will consist in the following:

- Plasticity in the fronto-parietal attentional control system is the core mechanism for attention. [1583] [1584]
- Learning related and use-dependent plasticities in the nucleus basalis, the parietal lobes, the ACC, and the BG. Each plays a key role in attentional learning. In these cases the actions will be constituted at the neural level by an integrated constellation of neural activities, similar to those outlined in **Nos. 1 and 2** above.
- The BG play an integral role in attention regulation, [1585] [1586] [1587] [1588] and in attentional loops.[1589]
- ACC involvement in attentional systems, appears necessary for learning, and a prerequisite for goal election and executive command. [1590]
- Note that **No. 13** refers to the attention required for learning to take place.

<u>Associated systems.</u>

Plasticity. Systems for learning. Attentional systems.

C. CHARACTERISTICS OF VIRTUE IN ITS ACQUISITION

Features that may not necessarily be present in every case.

[1583] Froemke, et al., "A synaptic memory trace for cortical receptive field plasticity," 425-429.
[1584] Doidge, *The brain that changes itself*, 84-88.
[1585] Hole Jnr., *Human Anatomy and Physiology*. 2nd ed.
[1586] Markowitsch, et al.,"Brain circuits for the retrieval of sad and happy autobiographic episodes," 643-665.
[1587] Doidge, *The brain that changes itself*, 84-88.
[1588] Kaas and Stepniewska, "Motor cortex," 167.
[1589] Doidge, *The brain that changes itself*, 84-88.
[1590] Markowitsch, et al.,"Brain circuits for the retrieval of sad and happy autobiographic episodes," 643-665.

14. Advantage must be taken of the early years both for training and provision of appropriate example.

Philosophical clarifications.

Considerations under this heading will account for the effectiveness of early experience noting Aristotle's dictum: "We like best what we first experience," and his imperative to form habits while children are very young. [1591]

Neural bases.

Mechanisms for enhanced learning in early years take advantage of periods of greater sensitivity, constituted at the neural level by enhanced developmental and activity induced plasticities. Learning in critical periods is comparatively effortless because of activity in the nucleus basalis.[1592]

The relationship between sensitive periods and cortical development is now shown.[1593] [1594] [1595] (See also **No.17.**)

- Attentive mothering leads to gene transcripted cellular changes in the hippocampus reducing basal levels of glucocorticoids, abolishing thereby anxiety and fearfulness, and facilitating learning.[1596]
- Emotional arousal, for example in the positive affect produced by sound mothering, appears to promote synaptic plasticity. This

[1591] Aristotle, 1103b.
[1592] Doidge, *The brain that changes itself*, 84-88.
[1593] In the case of imprinting, neurons in intermediate and *medial mesopalium* (IMM) become responsive and selective for the stimulus; there are local increases in NMDA receptors, an increased size in certain synapses, and a transitory surge in inhibitory activity. While imprinting is not directly a mechanism of virtue development, in a sense it may be regarded as a prerequisite mechanism laying necessary foundations for affection facilitated plasticity, etc. Systems associated with responsiveness to affection are directly implicated in sensitive periods
[1594] Coon, *Essentials of psychology*, 7th ed, 115.
[1595] Laura E. Berk, *Development through the lifespan*, 4th ed. (Boston: Allyn and Bacon, 2007), 126.
[1596] Core content here derived from Knudson, "Early experience and sensitive periods," 525.

promotes learning by various mechanisms including release of NE.[1597]

- The end of sensitive period is triggered sensory input and possibly by myelination.

A wide range of mechanisms are directly involved in the plasticities of sensitive periods and developmental periods. Some of the more significant include:

- As with other occasions when plasticity is at work, NMDA receptors triggering gene transcription associated with LTP and LTD are integral to the mechanisms of the sensitive periods and developmental learning.
- Attentional mechanisms operate in conjunction with the great range of mechanisms of plasticity are associated with sensitive periods of development. Hence attentional learning plays a significant role here also. (See also **No.13**)
- Guidance mechanisms are particularly active during this time: astrocyte, and associated molecular guidance cues of migrating neurons and production of growth (trophic) factors.[1598]
- The amygdala is particularly active in mediating early attachment relationships, and reaction to stress and nonconscious emotional memories.[1599]
- Hypothalamic oxytocin is also implicated; the oxytocin bonding pathways are active in periods of attentive mothering.
- DA plays a key role in cortical information processing around puberty. [1600]

[1597] Kessels and Malinow, "Synaptic AMPA Receptor Plasticity and Behaviour," 344.
[1598] Stevens, "Neuron-astrocyte signalling in the development and plasticity of neural circuits," 278-288. Neurotrophins such as BDNF can also play an essential role in anatomical remodelling.
[1599] Arden and Linford, *Brain-based therapy with children and adults*, 3, 36.
[1600] Rapp and Bachevalier, "Cognitive development and aging," Chapter 45.

- Up to the age of 20, there is a gradual decline in synaptic density, a refinement and clarification of pathways; cortical myelination appears to continue to the fourth decade of life. [1601] [1602]
- It appears that changes in dendritic architecture, and abnormalities in the myelination of axons are at the basis of aging in the prefrontal cortex, rather than neuron death and a simple decline in PFC synapses.[1603]

Associated systems.

Plasticity. Systems for learning. Attentional systems. Memory systems. Systems of emotional management. Reward and motivational systems. Systems for habit formation. Systems for imitation and empathy. Sensitive periods of development.

15. Imitation of example is a key means for acquisition of behaviours.

Neural bases.

- Imitative learning is effective because plastic changes in neuronal structures are triggered, allowing the adoption of new behaviours. Mechanisms for learning behaviours, for learning moral behaviours and attitudes, and for learning empathy, through imitation consist in the activation of mirror neurons present in areas of the cortex, most particularly in the left frontal operculum area (Broca's area), the right anterior parietal cortex,[1604] Imitative mechanisms involve activity in the fronto-parietal and the superior temporal cortex, the amygdala, and insula.[1605]
- An important aspect of imitation is the capacity to empathise, to read the feelings of others. There is widespread association of mirror

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[1601] Rapp and Bachevalier, "Cognitive development and aging," Chapter 45.
[1602] Principal source for this section: Knudson, "Early experience and sensitive periods," 525.
[1603] A. Peters, et al., "Are neurons lost from the primate cerebral cortex during normal aging?" in *Cerebral Cortex* 8, (1998): 295-300.
[1604] Iacoboni, et al. "Cortical Mechanisms of Human Imitation," 2526-2528.
[1605] Carr, et al.,"Neural mechanisms of empathy in humans: a relay from neural systems for imitation to limbic areas," 5497-5502.

neurons with the development of empathy. In addition, the **OFC** is regarded as having a major role in processing the "interpersonal signals necessary for the initiation of social interactions between individuals". The OFC operates in a limbic circuit comprising OFC,[1606] [1607] AC gyrus, amygdala and temporal pole. It would appear too that right orbitofrontal and right anterior insula cortices are components of a pathway that integrating bodily responses with attentional and emotional states. [1608]

- **VMPFC and OFC** are needed for associating incoming information with existing response contingencies, linking information to motivational importance, and for working memory... plasticity in these areas is necessary for object reward association memory, and contextual fear conditioning. The medial PFC, especially the ACC, has abundant links to limbic system via the hippocampus, the shell region of the NAc and the amygdala. There is a likely contribution of this pathway to DA and 5-HT modulation of cortical socioemotional areas.[1609]
- The **PFC** and the complex integration of brain areas, including lateral and medial PFC, are associated with deliberation about emotional content is also involved. Effective emotional modulation of deliberation is essential for sound reasoning particularly in areas requiring empathy with others, understanding of others' viewpoints etc.[1610]
- The **BG** are known to play a role in anticipating movement.[1611] [1612]

[1606] Nitschke et al., "Orbitofrontal cortex tracks positive mood in mothers' viewing pictures of their newborn infants," 583-592.
[1607] Arden and Linford, *Brain-based therapy with children and adults*, 103.
[1608] Schore, "Effects of a secure attachment relationship on right brain development, affect regulation and infant mental health," 7-66.
[1609] Pollak, "Early adversity and mechanisms of plasticity Integrating affective neuroscience with developmental approaches to psychopathology," 747. In primate studies, the amygdala has been shown to project directly to medial thalamic nucleus and thence to VMPFC, facilitating involvement in processing social information requiring plasticity dependent learning and memory.
[1610] This is a very strong take home message from Nussbaum, *Upheavals of Thought.*
[1611] Tortora and Derrickson, *Principles of Anatomy and Physiology*, 11th ed., 493-494.

Associated systems.

Plasticity. Systems for learning. Attentional systems. Memory systems. Systems of emotional management. Reward and motivational systems. Systems for habit formation. Cognition, consideration of consequences, planning, goal election, and executive direction. Systems for effective execution of motor commands. Systems for imitation and empathy. Sensitive periods of development.

16. Explicit teaching and guidance as to right and wrong, are needed.

Philosophical clarifications.

Guidance as to right and wrong will include, when appropriate, appropriate correction to assist in reforming behaviour.[1613]

Neural bases.

Neural facilitation in pathways of cognitive learning consists in plastic modification of neural structures associated with:

- **Attentional control**. (See **No. 13** above, and **Table 2.9** Attentional Systems, and **Table 5.2**.)
- **Imitation** of example is a powerful means of inculcating ethical values. (See **No. 15** above.)
- **Correction** communicating affection and empathy is shown to be more effective in bringing about neural restructuring than methods motivated by fear. A moderate degree of stress promotes neural restructuring; excessive stress paralyses.[1614]
- Cognitive learning requires particularly **intense activation of learning mechanisms** (See **Table 2.4** Systems for learning, and **Table 5.2**.)

[1612] Graybiel, "Habits, Rituals, and the Evaluative Brain," 379. In this way the BG are acknowledged to have a key role in control and modulation of social behaviours and may be integral to a progressive evaluation process of behaviours.

[1613] Correction will normally take the form of admonition that enlightens. Aquinas insists that even punishment must be medicinal – restoring justice, and bringing a wrong doer to the point of recognising his or her error.

[1614] cf Sunderland, *The Science of Parenting,* 38.

Learning usually involves strengthening and consolidation at the synapse, and associated changes in the dendritic tree. Learning associated with LTP and LTD is mediated by NMDA receptors, coexisting with AMPA receptors, activated by L-Glutamate.[1615]

- **Memory** in the cortex is plastically responsive to experience.[1616] (See **Tables 2.5** and **5.2** Memory systems.)
- DA, 5-HT, NA and ACh appear to modulate the **moral cognition** systems. OFC cues for moral behaviour and also moral knowledge acquisition. [1617] Activation of stored memories depends on hippocampus and the PFC – temporal cortex connection.[1618]
- **Declarative memory** features the explicit recall required in cognitive learning**.** Hippocampus initially acts as retrieval system for information in widespread areas of neocortex. Over time, the hippocampus reactivates the neocortical representations (by repetition and rehearsal, etc), bringing about plasticity in cortico-cortical connections. [1619]
- The **PFC** (focusing on acquisition of new rules) and the **BG** (focusing selection of rules appropriate to the situation) play complementary roles in rule learning.[1620]

Associated systems.

Plasticity. Systems for learning. Attentional systems. Memory systems. Reward and motivational systems. Systems of emotional management. Systems for habit formation. Cognition, consideration of consequences, planning, goal election, and executive direction. Systems for effective execution of motor commands. Systems for imitation and empathy. Sensitive periods of development.

[1615] See discussion in Waxham,“Neurotransmitter receptors, ” Chapter 9.
[1616] Manns and Hichenbaum, “Learning and memory: brain systems,” 1174.
[1617] Casebeer,“Moral cognition and its neural constituents,”843.
[1618] Tomita, et al. “Top down signal from prefrontal cortex in executive control of memory retrieval,” 699-703.
[1619] For distinct forms of memory systems and the story of their discovery, the principal source of material that follows: Manns and Hichenbaum, “Learning and memory: brain systems,” 488.
[1620] Wise, et al.,“The frontal-basal ganglia system in primates,” 317-356.

17. Affection facilitates learning particularly in the family environment.

Philosophical clarifications.

Family and social culture, as well as appropriate laws and rules are needed.

Neural bases.

The capacity to respond to affection is shown to be developmentally sensitive, and is centred in the emotion responsive areas of the PFC: the VMPFC and the OFC. [1621] Furthermore affectionate mothering and affectionate teaching style facilitates learning and associated plasticities.

- Cortical development is shown to positively correlate to the presence of affection, and consequent perfusion of hypothalamic oxytocin.[1622] [1623]
- Attachment and positive maternal affect are linked to DA mediated reward arousal in the right brain of the infant[1624].
- Emotion laden events cause release of Epi and glucocorticoids by adrenal glands leading onto release of NE in amygdala, increasing its activity and thereby consolidating memory in other parts of the brain (direct by connections to striatum, hippocampus or cortex; and indirect by connections with nucleus basalis which innervates much of cortex). [1625]

[1621] Arden and Linford, *Brain-based therapy with children and adults*, 103.
[1622] Core content here derived from Knudson, "Early experience and sensitive periods," 525.
[1623] Arden and Linford, *Brain-based therapy with children and adults*, 8.
[1624] Schore, "Effects of a secure attachment relationship on right brain development, affect regulation and infant mental health," 24
[1625] For distinct forms of memory systems and the story of their discovery, the principal source of material that follows: Manns and Hichenbaum, "Learning and memory: brain systems," 488.

- Unless intense arousal is involved, emotional arousal appears to promote synaptic plasticity in memory promoting learning. [1626] Mechanisms include release of NE.[1627]
- Left side PFC has been shown to play a role in maintaining positive affect. Medial insula and the anterior cingulated cortex also mediate affective feelings. [1628]
- Reduced affect leads to underactive OFC. OFC function is relative to the individual's reaction to emotional laden events in the environment.[1629] [1630]

Associated systems.

Plasticity. Systems for learning. Attentional systems. Memory systems. Systems of emotional management. Reward and motivational systems. Systems for habit formation. Cognition, consideration of consequences, planning, goal election, and executive direction. Systems for imitation and empathy. Sensitive periods of development.

5.4 A case study: a simplified neural analysis of a virtuous action performed by Takashi Nagai

In conclusion to this chapter the analyses of **5.3.3.2** are applied to one of the case studies from **Chapter 3**, the moment when Nagai reads and rereads an American leaflet claiming that Japan's defeat is inevitable. (See **Scenario 3**)

[1626] Bechara, et al.,"Emotion, Decision Making and the Orbitofrontal Cortex," 295-307. See Cahill et al., "The amygdala and emotional memory," 295-296.
[1627] Kessels and Malinow, "Synaptic AMPA Receptor Plasticity and Behaviour," 344.
[1628] Davidson, "Affective style, psychopathology, and resilience: Brain mechanisms and plasticity," 1196-1214; Sunderland, *The Science of Parenting.* Identification with family or culture heightens positive affect and desire to learn, and neural restructuring. Clarity of expectation and communication, with explicit input and positive affection promotes effective cognitive learning.
[1629] Roesch and Schoenbaum, "OFC as gateway," 202.
[1630] Arden and Linford, *Brain-based therapy with children and adults*, 8. We have seen that imaging studies of orphans (See **2.4.4 Early Experience and Sensitive Periods**) reveal abnormalities that are consistent with the behaviours that appear to follow upon being raised in environments of social deprivation, in particular, the manifestation of an underactive OFC in comparison with normal children.

This exercise serves as illustration but also as a form of validation for the results presented in this chapter. It is a demonstration that the proposed model of virtue and neuroscience accommodates a real life case study of a virtuous act, as described in precise psychological observations by the subject himself.

Table 5.3
A simplified neural analysis of Scenario 3.
For complete description of scenario see **Chapter 3.1.2 Scenario 3.**

Action (**3.1.2 Scenario 3**)	**Virtue commentary** (**3.1.2 Scenario 3 Commentary; 3.1.3 Virtue and the human act.**)	**Neural analysis** Note that it can be only the person as the subject of the action when we are considering a human act. However when we are not referring to a human act, but to unconscious responses by parts of the body (eg ACh heightens attentiveness) or to the action of part of the body (eg my eye blinked, my amygdala responded to emotional input) there is no problem specifying non personal subject.
"The chief nurse came running up and handed me a sheet of paper"	Nagai has already demonstrated that he has finely attuned responsibilities to those he leads, and habitual courtesy. He takes the leaflet from the nurse, conscious of his duties towards her. It is reasonable to surmise that this sense of responsibility as well as his training in scientific objectivity assisted him in applying sufficient deliberation before committing himself to judgement. Justice will dispose Nagai to take his duties to the nurse and to the survivors into account, giving appropriate example and reaching a final deliberation in the best interests of the entire community he finds himself leading. An unspoken principle he clearly follows is that	Prior learning of duty and courtesy, both disposed by justice, lead Nagai to respond to the nurse's implicit request to read the leaflet. Nagai is extremely drained and exhausted as it is the day after the bomb has exploded. He has suffered much blood loss and has lost consciousness at least on one occasion. The need to care for the wounded has given him little rest. He is also fatigued from the responsibility of leading the growing group of survivors. Exhaustion will be manifested in lower levels of attention, a heightened capacity for emotionally initiated representations (an overactive imagination), and difficulty in suppressing goal irrelevant sensory inputs. When Nagai is approached by the nurse and becomes aware of the American leaflet, his fronto-parietal attentional system is triggered. ACh from the nucleus basalis is released into the thalamus and into areas of the parietal, frontal and cingulated cortices, heightening attentiveness. Attentional loops between the BG and the cortex are established. DA, a facilitator of attention, is also activated for emotional and reward responses.

	truth, no matter how unpalatable, must be faced… and for a leader to do so is necessary.	
Nagais' initial glance at the leaflet revealed the cause of the catastrophe as an atomic blast. Nagai writes, "In the depth of my being I felt a tremendous shock. The atom bomb has been perfected! Japan is defeated!"	Nagai's description of how his passionate reaction subsides on successive readings of the leaflet gives us a remarkable insight into how deliberation can enable mastery of passion. What is initially less obvious is the interior battle that Nagai has fights in order to respond rationally to the news. There is an initial movement of complacency towards the truth. He comprehends the American claim and reacts initially dispassionately.	As Nagai glances at the leaflet initial visual input is channelled to the BLA from the sensory nuclei of the thalamus which has filtered out other inputs allowing his full attention on the leaflet. A degree of fear conditioning will be evident in the BLA given the suffering that Nagai has endured. There is an initial numbness, a lack of cortical response associated with a welling sadness (perhaps reflecting a left VMPFC that is underactive in managing right side negative affect), but Nagai falls back, perhaps heightened through his training as a scientist, on an established habit of seeking knowledge. He reads in the text a confirmation of his suspicions of a nuclear blast. His scientific knowledge gives him virtually an intuitive grasp of the potential of the bomb. Cortical representations of sadness for his country and people, and disgust at the Americans, flood his cortical memory and a negative emotional state overwhelms reason. Even in a state of physical and psychological exhaustion, Nagai's learned self mastery is sufficient for him to utilise cognitive pathways to gain some management of passionate predisposition, reacting with deliberation, and consideration of consequences.
"… Conflicting emotions churned in my mind and heart as I surveyed the appalling atomic wasteland around me. … A bamboo spear lay on the ground. I kicked it fiercely and it made a dull, hollow sound. Grasping it in my hand, I raised it to the sky, as tears rolled down my cheeks. The	Conflicting emotions well up within him, of frustration, sadness, anger, patriotism and shame at defeat. He deliberates briefly about the prospects of victory for Japan in the face of a nuclear power and concludes there is no hope of victory. At some point there is a rejection of blind passionate assertion. Prudence disposes his readiness to apply himself diligently to assess the truth of the American claims. Justice ensures	We are witnessing a "low road" emotional response unmediated by the cortex. Although there is consciousness in the PFC of the response, there is little cortical processing. A further surge of emotional memory inputs flood into the BLA via reciprocal connections to the hippocampal and striatal memory systems. There are neural activations of fear, sadness, anger and disgust (in the anterior insula). Outputs from the BLA trigger a rage response in the dorsomedial nucleus of the hypothalamus. This hypothalamic response directs rage related motor patterns. The various limbic aversion centres also activate. Limbic afferents to the PFC via the OFC trigger consciousness of the emotional response and provide an initial justification based hippocampal call up of DA mediated conscious short term memories of the

bamboo spear against the atomic bomb! What a tragic comedy this war was! This was no longer a war. Would we Japanese be forced to stand on our shores and be annihilated without a word of protest?”	that does not dismiss the American claims out of hand.	suffering witnessed in association with the bomb. These representations are in the PFC. The reward system is activated and Nagai seeks gratification in the pointless action of kicking the bamboo spear. DA floods the NAc in anticipation. GP and the SN select patterns of cortical activity and motor programs for action drawing on movement sequencers in the dorsal striatum. Hippocampus is enlisted for goal direction. The BG instruct the motor areas of the PFC via the BG-thalamo-cortical loop. PFC and motor cortices deliver executive command. The bamboo is kicked. The BLA is now drawing input from widespread cortical areas, and from, and from cortical, hippocampal and striatal memory systems. Nagai shows a greater awareness of his current state, looking around and reflecting on his situation. Attempts to articulate the situation serve to mitigate his passionate reaction. Nagai indulges in a flight of imagination calling up a succession of cortical representations of future scenarios, and this diverts his attention away from sensory input and into deliberation. Effectively is buying time for cortical processing of the overwhelming emotion. The initial surge of passion, corresponding to a neuromodulating flood of ACh and DA, dissipates somewhat and he is able to adopt a more cognitive response. His training in self-discipline can now take effect. Also he is conscious that he has an audience. His desires to give good example, despite an absence of evident reward, are mediated by overlearned S-R responses in the ventral striatum. His prior training has brought about this mechanism.
“I read the leaflet once and was stunned.”	By learned pathways of reflection Nagai sets about the task of reaching the truth of the situation. Quickly Nagai refocusses on reaching the truth or falsehood of the American claim. Very swiftly has Nagai moved through steps of the human act concerning ends and means (**Table 3.1.** Steps 1-7.). His end is to reach the	Nagai’s self mastery is characterised by habitual obedience of the emotional realm to rational command. Goals and rewards are not needed as incentives. S-deliberation-R pathways have taken over. Input to the PFC via the BG-thalamo-cortical loop reestablishes higher cortical, as opposed to emotion driven, management. Emotional thalamic and limbic centres are now redisposed to cortical override**.** Prior learning of fortitude and temperance have established pathways moderating emotional responses so they are obedient

	truth. The means is to weigh the message of the leaflet with his own assessment. Prior to the commencement of his deliberative reading there is a moment of "election" towards the means to reach the chosen good: by reading and calm consideration he decides he will reach the truth. (**Table 3.1.** Step 8 of the human act. See also **3.1.3 Virtue and the human act**.) Despite his impeding emotion he shows determination to face truth no matter how unpalatable it may be. (**Table 3.1.** Steps 9 to 11.) He makes a judgement that the truth can be reached by suppressing immoderate emotion and then applies himself rereading the leaflet weighing its assertions against his own knowledge and estimations.	to rational direction. The habit of fortitude will be present in preferential pathways in the BG-thalamo-cortical loop, and strengthened top-down connections between the OFC and the amygdala. The prior habituation of temperance will be present in mediation primarily by the DLPFC and ACC. In the past it is likely that this habituation was associated with DA rewards that consolidated the pathways of self control. In this current scenario, with the habit established, it is unnecessary for DA perfusion to take place. Various brain regions now coordinate to regulate emotional reaction: OFC, DLPFC, VMPFC, further areas of the amygdala and of the BG. Emotional regulation leads to cortical direction of reward expectations. Emotional representations are consciously suppressed. Cortical management is consolidated via action plans involving rereading. Even though it is unlikely that this is a conscious strategy, nevertheless it is likely to be a learned strategy… to divert oneself into a cognitive task in order to take the heat out of emotion.
"I read it a second time and felt they were making fools of us."	Nagai's established dispositions to moderate and divert excessive emotional representations and expressions are the result of prior learning. The actions of these dispositions permit cortical deliberation to occupy his attention. Nagai's response in this situation, and his character in general, is built on previously established behaviours and convictions upon which he can draw.	Nagai's habit of application at the task until the desired outcome is achieved is a consequence of prior training. His election of the goal to read and reread involves deliberative evaluation utilising numerous cortical areas, drawing particularly on episodic memory, self knowledge, scientific knowledge and skills of critical assessment. Intrinsic motivations have come to the fore: of commitment to the truth, and that one's duty to others must be fulfilled. These appear to be the result of cortical neuronal pathways established and consolidated by prior experience and DA reinforcement, originating in the VTA and SN and mediated by the ventral striatum, by childhood and military training and in happier times. The prior habituation of prudence will be present in this rich and reciprocal connectivity, primarily to and from the DLPFC, with other cortical areas serving memory and somatic and sensory input, with the OFC, DMPFC, BG, and amygdala

		serving emotion regulation, with the ventral striatum assisting in goal setting and motivation. Similarly the prior habituation of justice consists of consolidated pathways in the aPFC, mPFC, VMPFC, OFC (especially medial OFC), ACC (especially rostal ACC), insula, limbic and paralimbic areas, and the BG. These rich connections serve to give preferential traffic to deliberations about understanding of others, consideration of the impact of one's actions on others, empathy, and considerations of fairness, etc. It is possible to detect in this change of behaviour the classic pattern noted by Graybiel:[1631] a passing from reward mediation in the ventral striatum (Nagai's kicking fruitlessly against the goad), associated with the emotional gratification, to a dorsal automatisation, carrying out duty as he has trained himself to do (Nagai's determination to grapple with the truth and face it). Such an automatisation is consistent with our knowledge of the character of this wonderful man.
"I read it a third time and was enraged at their impudence."	In the analysis of the human act (**3.1.3**) it was noted that sense appetite acts upon the will particularly at Steps 2,4,6, and 8; that "undue sense appetition can negate effective use of the intellect".	In neural terms this means that the person is aware of cortical representations of attractive or aversive sense objects, and that reward systems provide neuromodulatory incentive for preferential attention to, and pursuit of these goals via appropriate action plans. Cognition and the capacity to reach the truth can be overwhelmed by the presentation of attractive or aversive cortical representations. This is the battle that Nagai fights in the first, second and third reading. However by holding to his action plan of rereading he is able to regulate the emotion sufficiently to allow deliberation and a final judgement as to the truth of the American message. As we are discussing aversional content, direct involvement of reward systems is minimal. However, during prior learning the habits of prudence, justice, fortitude and temperance were established; during this time the reward systems were greatly active, leading to DA mediated

[1631] Graybiel, "Habits, Rituals, and the Evaluative Brain," 378.

		reinforcement of regulatory pathways triggered in the OFC and amygdala by sense representations. These pathways are available now for Nagai's use in coping with this particularly difficult situation.
"But when I read it a fourth time I changed my mind and began to think it was reasonable."	Nagai has reached the point a judgement about the trustworthiness of the American leaflet.	In the course of moral evaluations and judgements there is a complex integration of numerous neural subdivisions which show significantly consistent activation across numerous studies. (See **Table 5.1** and **Table 5.2.**) Therefore it is possible to predict that, in this case, Nagai's neural activity is likely to include heightened activation in numerous areas: • DLPFC, ACC, the ventral striatum, and amygdala will reveal principal activation. • Above baseline activation will also be evident in mPFC, VMPFC, OFC, the posterior cingulate/retrosplenial cortex, superior temporal cortex, STS, the temporo-parietal junction, medial hypothalamus, and insula. • LPFC and Right OFC will be active in the suppression of sadness. • Considerations of the social norms of patriotism and of cultural expectations of a leader will involve further integration of areas such as the VMPFC, lateral OFC, and aTL, assisted by storage of social perceptual representations in the temporal lobes, • In addition, reflecting Nagai's frustration at the shame of defeat and empathy with the pain of others, the rostral ACC, and the anterior insula will show activity. • Posterior cingulate, and inferior parietal lobe will show activity during the Nagai's brief catastrophising.
"But when I read it a fourth time I changed my mind and began to think it was reasonable. After reading it a fifth time I knew that this was not a propaganda stunt but the	He gives his assent to the assertion of the leaflet. The word "sober" indicates his attainment of "quies". (**Table 3.1.** Step 12 of the human act. See **3.1.3 Virtue and the human act**.) This achievement of *quies* contrasts with Nagai's fierce kick to the bamboo spear: destructive, impulsive, futile, and	In Nagai's reading of the flyer, in this single human act seeking the truth of the issue, we have witnessed a highly complex interplay of systems (memory, emotional management, deliberation, goal election, consideration of consequences of action, moral judgement, attention, reward to some extent, and motor execution), of brain areas, of mechanisms and of pathways. The end result has been the harmonisation of the emotional life with the rational life. The disorder of actions carried out without

sober truth."[1632]	pointless. Acquiescence to the truth implies also a degree of self mastery.	cognitive approval and direction, is replaced by an admission of the truth and a quieting of wayward passion.

This exercise has also served to clarify certain understandings of virtue in action.

Reason and judgement, and the virtues of prudence and justice, are exercised in what we could call a "biophysical dimension" that incorporates duration. As Nagai explores the truth of the American claims his deliberations are protracted in time.

Examples drawn from actual life argue strongly for the unity of the virtues. Nagai's struggle against his emotional reaction is quietened only when he admits that the American leaflet reflects truth. Emotional management is a necessary though insufficient condition for virtue. Management of passionate responses and the disposition to acquire and accept the truth pertain to different virtues. Virtues that directly dispose rational operations as well as virtues that enable emotions to correctly inform, or respond to, rational command are both needed.

The contributory work of the virtues of fortitude and temperance is prior to the deliberations of the human act. In this case, the contributory involvement is manifested in the rereadings and evaluations of the leaflet's content. The action of these virtues is ongoing during the reading in response to the tenacity of the emotional reactions he experiences. It is fascinating to note that, at the point where Nagai admits the truth, the violent emotional responses subside. (They are replaced by a sadness and lethargy which will require a further virtuous response from Nagai.)

Automatised habituated dispositions for positive action are able to come to the fore once the flood of passion passes. Of course, should there be no habituated

[1632] Nagai, *The Bells of Nagasaki*, 52-3.

positive habits, or should there be vices, the flood of passion will not be diverted but may stand in even greater relief.

5.5 Conclusion.

A highly probable model for the neural bases of virtue has now been described on the basis of an hylomorphic anthropology. I have presented arguments supporting the view that virtue, as understood by Aristotle and Aquinas, is embodied, I have described the distinctive nature of that embodiment as it pertains to the cardinal virtues, and I have identified 17 characteristics that capture the nature of virtue. For each one of these characteristics I have identified processes that account for, at the neurobiological level, the specific contributory task that I have identified. I have noted the capacity of the brain to operate multiple processes, concurrently and in concert, in support of goals of the person's own choosing, and that this view of virtue, as a complex of systems, is highly consistent with that view.

This approach respects the soul as principle of being, unity and function; it accounts for rationality of the person and human freedom; it supports the view that neural bases are necessary for, but alone cannot account for, human operations.

In mapping the discrete characteristics of virtue against the neuroscience, I have identified supporting neural structures, pathways and mechanisms. In summary:

i. <u>Human motivation and goal election</u> are supported by the reward structures of the brain that are in reciprocal communication with cortical structures.
ii. <u>Emotional regulation</u> is supported by limbic-cortical connectivity permitting bottom up modification of cortical "decision making", and top-down direction and regulation. I have argued that neuroscience and philosophy converge in describing the complementary roles of emotion and reason in a balanced happy life. The very presence of reciprocal

substantial neural pathways is firm evidence of both cortical direction and subcortical modification of regulation and decision making. A neural reality, consistently presented in this study, is that neuronal pathways develop when used, but atrophy in disuse. I have distinguished between the relative roles of the OFC, the DLPFC and the VMPFC in emotional regulation, with implications for motivation.

iii. It has been shown that the established <u>cognitive activity of the PFC requires the complement of subcortical structures of the limbic system and the BG</u> for these activities of emotion regulation and goal election. I have further argued that the involvement of the BG is crucial, not only by its implication in emotion and reward pathways but also because the BG are the principal seat of automaticity of actions. It has been shown that such automaticity is not necessarily opposed to conscious, voluntary goal election.

iv. The "second nature", the ease of use that characterises virtue, is attributable primarily to <u>mechanisms of structural plasticity</u> in both cortical and subcortical regions and in the relevant communicating neural pathways. Plasticity in the structures of the BG underpinning automaticity is a further source of the facility for ready action that we find in actions disposed by virtue.

v. <u>The notion of a complex of systems</u> is supported by a weight of current neuroscientific opinion. I have argued that the systems of reward evaluation, of goal setting, of motivation, and of emotional regulation are supported by "upstream" systems of plasticity, learning and memory, and capacities for attention, critical learning, and imitation and empathy.

vi. In support for the notion of the unity of the virtues and of the <u>distinctive neural "signatures" for each of the cardinal virtues</u> I have reviewed the complexity of the human act and noted the necessary and consequent neural complexity of any virtuous act. In particular, I have noted the activity of the sensitive appetites prior to every rational choice and noted the distinctive pathways involved in each of the cardinal virtues.

vii. Cognition centres in the PFC (assisted by other cortical and lower areas primarily implicated in reward and emotional assessment, sense apprehension, memory, attention, and motor planning and command) support the integrating capacity of rationality and the reflection and reasoning that are manifestations of prudence.

viii. Cortical pathways and brain areas are demonstrably implicated in cortical assessment of the consequences of actions on others. These too are in reciprocal connection both by DA pathways, and BG-thalamo-cortical loops, with the reward systems and centres, providing further incentive for action. I have argued that the virtue of justice resides most typically in the habitual activation of these areas.

ix. I have argued that human actions commence with sensitive appetitive responses to perceptions or imaginative representations in the memory (but not necessarily of specific past events) of pleasure and aversion, and that the essence of virtue is to find pleasure in what is in keeping with our nature, along with a readiness to endure difficulties to obtain those things that we know to be good for us. In essence, neural dispositions in our reward processing and in our responses to fear support temperance and fortitude.

In **Chapter 6** I will turn my focus to a eudaimonic analysis of what we have seen at the neural level. At the beginning of this current chapter, I noted Casebeer's observation that the virtuous life will be characterized by neural elements operating in a "maximally functional manner".[1633] I will focus on this notion of functional fulfilment along with affective and teleological fulfilment. In conclusion, **Chapter 6** will also offer neuroscientific, philosophical and pedagogical conclusions relevant to this study.

[1633] Casebeer, "Moral cognition and its neural constituents," 843.

Chapter 6

Flourishing

"A human being in perfection ought always to preserve a calm and peaceful mind and never to allow passion or a transitory desire to disturb his tranquility."
Frankenstein; or, The Modern Prometheus
Mary Shelley

6.1 This study proposes a necessary role for virtue in human flourishing.

Elizabeth Anscombe proclaimed the need to get the psychology right if we are to do moral philosophy (see **1.6.1**).[1634] This study insists that we must get the biology right too. Psychology and neurobiology must be in sync. It is appropriate to investigate whether virtues are all that Aristotle, Aquinas, and their followers claim them to be; if they are truly the key to human fulfilment and wellbeing, and if hylomorphic anthropology reflects reality, then it is appropriate to expect this to be evident at the biological level.

So, in **Table 4.1**, a major characteristic of virtue was identified as follows:

> Virtue facilitates the functional flourishing of the person. Virtue brings about a state of excellence: an excellence of the person, inclusive necessarily of both neurobiological flourishing and the exercise of rationality. It is a state whereby reason and rationality are empowered to manage activity well. It is a capacity for rationality that is reflective and emotionally enriched and able to be carried through into noble, humane behaviours.

Evidence presented in **Chapter 5** has supported the view that virtue has a material foundation in the neural structures of the brain and that this material structure can be identified. I argue that these neural structures manifest, in their maturity

[1634] Anscombe, "Modern Moral Philosophy", 26-44.

of expression and integration across the entire brain, the role that virtue plays in human fulfilment itself, and that there is a biological aptitude and *predisposition* in human beings for the development of virtue.

That the neurobiology of virtue may be described, and more importantly, that it constitutes a state of a neurobiological perfection must carry far reaching implications for the study of ethics. Aristotle proclaimed, "Happiness is the reward of virtue",[1635] with happiness understood as human fulfilment, flourishing, *eudaimonia*. In this concluding chapter we examine the evidence to support the view that happiness, understood as flourishing, is indeed a consequence of the neurobiological presence of virtue.

The identification of the neural structures of virtue and of a biological aptitude for the development of virtue, for the *necessary* role of virtue in flourishing, must serve to strengthen the recognition of virtue ethics as superior to consequentialist and deontological approaches in offering a model for human wellbeing.

It will be noted below that the work of Martin Seligman supports the view, as predicted by rational psychology, that virtues are demonstrably conducive of human wellbeing at the clinical level. That these clinical phenomena may be shown to be supported by a neurobiology of virtue necessarily constitutes a far reaching ratification not only of Seligman's position but of hylomorphic anthropology, as a true model of the human being and human flourishing. This necessarily carries profound critical consequences both for the evaluation of current theories of philosophy of mind and of moral development, and for practical approaches to pedagogy and parenting.

6.1.1. Reflecting on the structure of this study.

[1635] *NE*, 1099b16.

After offering a *prima facie* case for the profound integration of the rational and the physical in the human person, **Chapter 1** situated the philosophical dimensions of this study within contemporary approaches to philosophy of mind and ethics and within ethical theory. The significance of the hylomorphic foundation for this study has been discussed - the profound unity of material and non-material aspects in the human person, to the extent that human neurobiology participates in rationality and in every rational action.[1636]

Chapters 2 presented a representative overview of current research into six lines of investigation that it is reasonable to associate with the acquisition and exercise of virtue: plasticity, learning and memory, habit formation, emotional regulation, goal election and reward, and cognition and executive function.

The principal task of **Chapter 3** and **4** was to identify key characteristics of virtue. Against a panorama of differing and opposing definitions of virtue, it is necessary to adopt a robust understanding of positive, dispositions of character acquired by repetition and practice. A broad Aristotelian understanding of virtue has been proposed, founded on Aristotelian and Thomistic rational psychology and an understanding of the hylomorphic view of substance, and attuned to *eudaimonia,* a notion derived from Aristotle and found in the work of prominent virtue ethicists.

My essential methodology was, in the light of clear examples of virtuous action present in real life case studies and with the aid of insights from contemporary virtue ethicists, to distil from seminal Aristotelian/Thomistic texts the characteristics of virtue. Controversial questions were largely avoided, as outside the scope of this study, except that a restricted reading was offered for the notion of rationality "by participation" of the moral virtues of the sensitive appetites: fortitude and temperance were proposed as ordered biophysical qualities of the human person. In turn this led to greater clarification about the characteristics of

[1636] As we have seen, Aquinas however distinguishes between powers "common to the soul and body", and other powers "exceeding the entire power of the body" (*ST*, Ia, Q.76, Art.8.4).

the specific cardinal virtues and their distinctive contributions within the broad notion of virtue. Arguments were presented for the unity of the virtues. An analysis was offered of the distinct functions of the four cardinal virtues in disposing a virtuous human act as described by Aquinas. I argued that such a coherent understanding of the contribution of each of the four virtues to the one human act is a prerequisite to any proposal for the neural bases of virtues. In conclusion, **Table 4.1** was presented, listing key characteristics of virtue.

Chapter 5 married the characteristics of virtue with the neuroscience against a backdrop of recent cross-disciplinary work in regulation of emotion and moral action. The model offered suggests that, in the acting person, virtuous dispositions of thought and action are constituted at the neural level by highly integrated contributory brain systems (emotional regulation, reward, attention, memory and learning, habit formation, cognition and command) supported by a range of mechanisms of plasticity allowing a certain permanence and durability. These established ways of thinking and behaving thus become characteristics of the personality of the subject.

Ultimately I have sought to capture the complexity of the exercise of virtue and its reflection in neurobiology. I have wished to apply the real knowledge we have of the brain into the formation of a coherent picture for the development, exercise and state of virtue. I have proposed, by means of an integrative analysis of current research into brain function, a highly plausible model for the neural bases of virtue understood in the Aristotelian and Thomistic sense.

It is highly conceivable that the accuracy of this model could, in time, be experimentally tested. By highlighting, at the biological level, the integrative nature of rationality, and by drawing cross disciplinary insights from rational psychology, I hope to stimulate interest in what presents as an important field for further exploration.

6.1.2 The task of Chapter 6.

On the first page of this study I proposed four central questions for investigation:

- To develop a methodology by which I can identify the core characteristics of the Aristotelian-Thomistic view of moral virtue.
- To identify, on the basis of current neuroscientific knowledge, the neural substrates that may be reasonably demonstrated to play a substantial role in the acquisition and exercise of virtue.
- In the light of neurobiological evidence, to draw conclusions about the role of virtue in human flourishing.
- To consider wider implications of these findings, with particular respect to philosophy of mind, ethics and parenting.

The first and second of these questions have been addressed in detail in preceding chapters; brief concluding reflections are offered below in **6.3**. The primary task of this chapter is to present conclusions with respect to the third and fourth of these questions. Eudaimonic conclusions will be discussed in **6.2** with brief critical reflections also offered in reference to *Flourish*, a 2011 text by Martin Seligman which draws the notion of *eudaimonia* into the domain of clinical psychology;[1637] neuroscientific conclusions will be summarised in **6.3**; philosophical conclusions in **6.4** will include brief reflections on philosophy of mind; and pedagogical conclusions bring both the chapter and the study to a close.

6.2 Eudaimonic conclusions

This study proposes that man has a biological aptitude or predisposition for virtue, and that virtue is required for human flourishing. I argue that the brain is biologically disposed to the development of virtue. As it were, the conduits for virtue are already laid in the brain by way of genetic predisposition and participation in rationality; however the wiring will need to be installed by the

[1637] Martin Seligman *Flourish: a new understanding of happiness and well-being and how to achieve them*. (London: Nicholas Brealey, 2011).

user himself through experience and repetition of actions, guided by rational goal setting.

Human flourishing necessarily includes flourishing of the brain... the full and integrated development of the brain and its capacity to mediate a self-determined life. The argument of this study is that this biological aptitude for flourishing extends to the neurological domain: that the concept of human flourishing should properly include brain development along those lines of development to which the organism is biologically predisposed.

I argue that man's biological aptitude for flourishing is found in his ability to develop to the full his natural powers along the predisposed lines for the development of the human organism. This is also consistent with the view of Aquinas that virtue disposes man to perfection according to his nature.[1638]

These lines of predisposed development incorporate the constellation of pathways and mechanisms that underpin virtue development. Further, I argue that, as virtue develops there is an extensive integration of the neural resources of the person (cognitive, executive, emotional and sensorimotor systems, and pathways facilitating habitual action); an integration that empowers man for rational self-management and necessarily implicit to human flourishing.

My discussion of eudaimonic conclusions will focus first on this biological aspect – that the full development of the organism is indeed a form of flourishing, and then on the broader issue of fulfilment of the person, and in specific the *eudaimonia* of virtue.[1639]

[1638] "Whatever is lacking for a thing's natural perfection may be called a vice." *ST*, Ia-IIae, Q.71, Art.1.quoting Augustine, *De Libero Arbitrio*, iii.

[1639] Note that the following sections contain material most relevant to this section: **1.6.4** (This study is situated under the umbrella of eudaimonist virtue ethics), **2.4** (Habit formation), **2.5** (Neural bases for emotional control), **2.6** (Neural bases for goal directed behaviours and reward activation), **2.7** (Cognition and executive function), **3.2.5** (Virtues accord with the natural perfecting of the person), **3.2.5.3** (Virtue brings about human fulfilment**), 3.3.7** (Development of virtue requires formation in what is appropriate in respect to pleasure and pain… emotional education.), **3.3.12** (Education specifically in wisdom and beauty is necessary in the formation of

6.2.1 Flourishing at the biological level.

Nobel laureate Kandel noted above (**5.2.2.3**) what could be called a principle of decentralisation that operates in the brain, that there is no central command centre in the brain.[1640] This reflects Hebb's prophetic insight in 1949 that a cell assembly, all the activated cortical cells, provide the internal representation of a stimulus distributed through the brain.[1641] Such a highly distributed model requires advanced interconnection for effective function. Facilitated interconnectivity is also required for effective cortical, or top down, governance of emotional and motivational life.

In keeping with these observations I have suggested that the state of virtue presents as a highly developed facility for interconnection between brain regions and systems making use of the constellation of pathways, mechanisms and processes operating across the various brain regions and pathways between them. It is founded upon principles of use-induced plastic reinforcement of neural connections. Habit provides a further mechanism for the organism to act more efficiently at the neuronal level, allowing the diversion of attention elsewhere and absorbing fewer cerebral resources. During the period of acquisition, both implicit procedural memories and virtue, move from the explicit to the automatised.[1642]

It is a state of systemic maturity. The state of virtue manifests as the endpoint of neural development, of a developmental sequence of behaviours associated with the ordered biological dispositions of fortitude and temperance informing right judgement. It involves an ongoing interplay between biological development,

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virtue), **3.3.9** (The development of virtue takes place over time and respects the development of the body), **4.1.2.7** (Rather than of "acts of isolated virtues" it appears more appropriate to think in terms of "moral operations performed with the integral involvement of multiple virtues"), **5.3** (The neural bases of virtue), **6.1** (This study proposes a necessary role for virtue in human flourishing), **6.2** (Neuroscientific conclusions), **6.3** (Philosophical conclusions).

[1640] Kandel and Wurtz,"Constructing the visual image," 340.

[1641] Bear, *Neuroscience. Exploring the Brain,* 731.

[1642] See **Chapter 2** for referencing.

practical reason, experience, consideration for others, and the repetition of positive goal directed behaviours.

6.2.1.1 Rational operations in the present state of life are conducted with sensible knowledge and sensitive appetites as their "material cause".[1643] Therefore neural development that forms the biological basis of virtue is a "material cause" for *eudaimonia* of the person.

Aquinas says that sensible knowledge is, in a way, "the material cause" of intellectual knowledge. "It cannot be said that sensible knowledge is the total and perfect cause of intellectual knowledge, but rather it is in a way the material cause."[1644]

If, along the same lines, we can argue that the sensitive appetites (presenting aspects of pain and pleasure to the intellect and will) are, in a way, the material cause of the human act (Step 2 **Table 3.1**), then we can also say that the sensitive appetites disposed by the virtues of fortitude and temperance are the material cause of good human acts.

Therefore, the virtues of fortitude and temperance in their neural bases (see argument in **4.1**), are the material cause of *eudaimonia*, if *eudaimonia* is to be understood as a state brought about by consistently good human actions. By extension we could also argue that the neural part constituents of prudence and justice should also be included as material causes of *eudaimonia*.

Ultimately, it is this state of advanced interconnection and systemic integration underpinning virtue is the "material cause" of *eudaimonia* in the person.

[1643] *ST*, Ia, Q.84, Art.6.
[1644] *ST*, Ia, Q.84, Art.6.

Aristotle taught that "The soul in a certain way requires the body for its operation."[1645] He explained the key role of the material:

> No one can learn or understand anything in the absence of sense, and when the mind is actively aware of anything, it is necessarily aware of it along with an image.[1646]

The word "necessarily" is important: in the state of body and soul united, all understanding not only starts in the senses but is dependent upon the presentation of the phantasm.

He explains that suspension of the sensitive powers (eg during sleep) hinders the judgement of the intellect; [1647] [1648]that, "The corruptible body is a load upon the soul, because it hinders the use of reason even in those matters which belong to man at all ages."[1649]

He says that cooperation of the body is necessary for acquisition of new knowledge and necessary for application of acquired knowledge, [1650]and insists that the cooperation of the body as material cause for rational operations is according to human nature.

> It is as natural for the soul to understand by turning to the phantasms as it is to be joined to the body; but to be separated from the body is not in accordance with its nature, and likewise

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[1645] *ST*, Ia, Q.75, Art.7.3.

[1646] *DA,* 431b. In Book 3 of *De Anima* Aristotle affirms that the soul understands nothing without a phantasm.

[1647] *ST*, Ia, Q.84, Art.8.

[1648] *ST*, Ia, Q.101, Art.2. "... the state of reason depends in a certain manner on the use of the sensitive powers; wherefore, while the senses are tied and the interior sensitive powers hampered, man has not the perfect use of reason, as we see in those who are asleep or delirious. Now the sensitive powers are situate in corporeal organs; and therefore, so long as the latter are hindered, the action of the former is necessarily hindered also; and likewise, consequently, the use of reason."

[1649] *ST*, Ia, Q.101, Art.2.1.

[1650] *ST*, Ia, Q.84, Art.7. "...not only when it acquires fresh knowledge, but also when it applies knowledge already acquired, there is need for the act of the imagination and of the other powers. For when the act of the imagination is hindered by a lesion of the corporeal organ, for instance, in the case of a frenzy; or when the act of the memory is hindered, as in the case of lethargy, we see that a man is hindered from actually understanding things of which he had previous knowledge.... when we wish to help someone understand something we lay before him examples from which he forms phantasms."

> to understand without turning to phantasms is not natural to it; and hence it is united to the body in order that it may have an existence and an operation suitable to its nature.[1651]

The implication is, consequent on the theological principle that grace respects nature, that the embodied soul will *only* operate in a way suitable to its nature, ie. utilizing the neural structures of the body.

Consonant with this view, Aquinas holds that, "(The human soul) reaches an understanding of truth by arguing, with a certain amount of reasoning and movement."[1652] Now elsewhere he explains, "The nerves," we are told, "are instruments of movement."[1653] Hence it is compatible with these texts to conclude that Aquinas anticipated a neural part-constituent for the operations of the intellect.

6.2.1.2 Rational operations in the present state of life are conducted with the body as their final cause.

In **3.2.5.3** above, it has been argued that virtue perfects not only the soul but also the body.

Aquinas writes,

> ...the function of virtue (is)... to make (the sensitive appetite) execute the commands of reason, by exercising (its) proper acts. Whereby just as virtue directs the bodily limbs to their due external acts, so does it direct the sensitive appetite to its proper regulated movement.[1654]

In other words, through rationality, manifested as virtue, the person flourishes.

In keeping with the view that the soul united to the body "perfects the soul", it is further argued also that virtue realises

[1651] *ST*, Ia, Q.89, Art.1.
[1652] *ST*, Ia, Q.79, Art.4.
[1653] *ST*, Ia, Q.99, Art.1.
[1654] *ST*, Ia-IIae, Q.59, Art.5.

> the perfected structure of the body. Hence there is an aspect of final causality also present. [1655]

This final causality derives from the fact that the body is integral to the person and the development of virtue, with all the bodily ramifications is according, as Aquinas says, to the "due disposition" of the person. We read, "Virtue implies not only a perfection of power, the principle of action; but also the due disposition of its subject."[1656] Note that this concept of "due disposition" is consistent with the view that virtue is not any arbitrary ordering, but a "right ordering", of neural connections.

Note that this notion is relevant also with respect to the unity of virtues. Precisely *because* the various virtues act in integrated concert, each with its requisite disposition of the materiality of the body, that the flourishing of the person is achieved. Virtue not only disposes the organism to rationality (because there is no virtue without rationality in the first place), but also rationality we can say disposes the human organism to fulfilment.

6.2.2 The neurobiology of *eudaimonia*.

<u>The notion of *eudaimonia* in this study</u>

In **1.6.3** mention was made of the variety of positions adopted by virtue ethicists with respect to *eudaimonia*. Not only do Aristotle and Aquinas have differing concepts of *eudaimonia*, but how *eudaimonia* is to be understood in Aristotle has been the subject of various schools of thought. Hence, prior to drawing eudaimonic conclusions, it is necessary to offer further brief clarifications about the position adopted in this study.

[1655] Aquinas, *Questions on the Soul*, trans. James Robb (Milwaukee, WI: Marquette University Press, 1984), 59,62. Cited in Ramsay, *Beyond Virtue Integrity and Morality*, 137.

[1656] *ST*, Ia-IIae, Q.71, Art.1.

Nagel identifies two accounts of *eudaimonia* in the *Nicomachean Ethics*: the intellectualist (ie a state of contemplation) and the comprehensive account in which fulfilment is to be found in the "full range of human life and action".[1657] Nagel proceeds to argue, "This (second) view connects *eudaimonia* with the conception of human nature as composite, that is, as involving the interaction of reason, emotion, perception, and action in an ensouled body." [1658] This study considers *eudaimonia* in this second, arguably richer, category. It is a view that perfectly accommodates considerations about the neural bases of virtue and evidence for flourishing at the biological level.

Rorty also addresses this issue and appears to accord with this second view. She proposes an integrated account: that the contemplative life (the fruit of the intellectual virtues) and the active life (fruit of the moral virtues) are compatible in the fulfilled life.[1659] She argues, "For a human being, Aristotle says, to live well is to perceive well and to think well. These are natural *energeiai*:[1660] their exercise is paradigmatically pleasurable (1170a16-20)."

Other commentators also argue for this integrative account that embraces both intellectual and moral realms. In **1.6.3** we saw that the positions of Hursthouse and Swanton are broadly aligned with the view that the fulfilment of the person is integrated with the development of virtue.

Hursthouse draws attention to the importance of *phronesis* (wisdom) in the development and exercise of virtue. She argues that Aristotle saw virtue and *phronesis* as two aspects of the same thing; and that it is impossible to have one

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[1657] Thomas Nagel, "Aristotle on Eudaimonia in Aristotle's Ethics" in *Essays on Aristotle's Ethics*, ed. Amelie Oksenberg Rorty (Berkeley: University of California Press, 1980), 7. McDowell too reflects this view, suggesting that Aristotle proposes two possible views on the meaning of eudaimonia: an intellectualist view, and the view that accommodates moral virtue. John McDowell, "The role of eudaimonia in Aristotle's Ethics" in *Essays on Aristotle's Ethics*, ed. Amelie Oksenberg Rorty (Berkeley: University of California Press, 1980), 373, note ii.
[1658] Nagel, "Aristotle on Eudaimonia in Aristotle's Ethics," 7.
[1659] Amelie O. Rorty, "The place of contemplation in Aristotle's Nicomachean Ethics" in *Essays on Aristotle's Ethics*, ed. Amelie Oksenberg Rorty (Berkeley: University of California Press, 1980), 378.
[1660] e*nergeiai*: a unified self contained whole.

without the other.[1661] For example, Aristotle explains that both wise and villainous people can be called clever. "Wisdom is not the same as (cleverness) though it does involve it. ... A wise person is able to deliberate well about the sorts of things that conduce to the good life in general, ie *eudaimonia*."[1662] Hursthouse highlights the role that *phronesis* plays in virtue and in human flourishing. She says, "Like *arête* … *phronesis* was an almost unrecognised concept in modern moral philosophy until the virtue ethicists brought it back."[1663]

These contrasting positions of Hursthouse and Swanton with respect to eudaimonism are enlightening. Hursthouse develops a moderate position, closely reflecting Aristotle's own thought and bridging the teleological and the non teleological accounts. Swanton on the other hand highlights deficiencies, or perhaps gaps, in Aristotle's treatment of *eudaimonia*, and articulates the essential nature of virtue as a responsiveness to being, thus defending the primacy of virtue ethics over other ethical systems.[1664]

In contrast with Aristotle, Aquinas utilises the word *beatitudo* in place of *eudaimonia*. Aquinas considers the happiness of *beatitudo* to be "complete fulfilment to which nothing can be added by way of improvement or

[1661] Hursthouse, "Virtue Theory," 51.
[1662] *NE*, 1140a24-29.
[1663] Hursthouse, "Virtue Theory"; and Swanton, *Virtue Ethics: A Pluralistic View*, 51. Swanton takes issue with "monistic" approaches found in proponents of relationship ethics and some versions of Aristotelian eudaimonistic ethics "according to which, the rationale of all the virtues is their being needed for the flourishing (good) of the agent". She argues for a "pluralistic" approach, "moral responsiveness" requiring a variety of modes: love, respect, creativity, promotion etc. "What I call the profile of a virtue is that constellation of modes of moral responsiveness or acknowledgement which comprise the virtuous disposition." Swanton (in *Virtue Ethics: A Pluralistic View*, 48) argues against what she regards as a "monoculture of consequentialist thought". Swanton insists that virtue cannot be instrumental in pursuit of goods such as love, friendship and pleasure as these goods are not independent of virtue and that it is misleading to consider goods as having an absolute value. For example, the value of particular goods may be derived from the relationship to the agent himself. She seeks to "combine eudaimonism and naturalism through the unifying idea of the perfection of our rational nature"(54). The point, as for Aristotle, is that the notion of virtue derives from the very nature of the person.
[1664] Swanton's debt to Aristotle is evident, though she advocates a somewhat more eclectic approach to virtue ethics and moral psychology, drawing even on notions derived from Nietzsche's theory of self love, in order to emphasise that she regards virtue as integral to the natural wellbeing of the subject.

variation",[1665] and contrasts it with *felicitas*, earthly experiences of happiness. He regarded man's ultimate good as the perfection of the intellect by means of what he calls *beatitudo*, which is often translated as happiness. To live the good life knowledge however is insufficient; he argued that the acquisition of virtues is necessary. These qualities enable us to make effective use of moral knowledge.[1666] Implicit to *beatitudo* is the notion, far beyond Aristotelian understandings, of blissful union with God. Nevertheless, *beatitudo* as 'the perfection of the totality of a well lived human life'[1667] bears much in common with the comprehensive account offered by Aristotle. Both are the outcome of a fully realised life according to nature, as each distinctively defines it. Both argued for the necessity of rationality for life directing choices and happiness, and that it is virtues that perfect rationality and human action. They see the development of virtue as a response to being, a requirement for happiness.

In conclusion this study adopts a moderate eudaimonistic approach that considers virtue, following Aristotle and Aquinas, to be constitutive of and enabling of human flourishing understood as the development of our natural faculties.

<u>A notional distribution of the neural bases of *eudaimonia*.</u>

The explicit reference to *eudaimonia* in **No.9** in **Table 4.1** leaves much still to be elaborated about the relationship between part-constituents of the characteristics of virtue and *eudaimonia*. To some extent the immediate affective outcomes will be reflected in the intrinsic reward outcomes associated with **Nos.2** and **6**, and functional aspects certainly enter into **Nos. 7** and **8**. While functional flourishing may include everything from efficiencies of transmission of neural commands, to facilitated emotional regulation, there are also major objective positive outcomes such as enhanced freedom of action, augmented capacity to love others, which deserve acknowledgement as functional advantages. **No. 9** focuses very much on

[1665] Brian Davies, "Happiness" in *The Oxford Handbook of Aquinas*, ed. B. Davies and E. Stump (Oxford: OUP 2012), 232. 227-237

[1666] For a useful useful primer on Aquinas' thought: Peter S. Eardley and Carl N. Still, *Aquinas: A guide for the perplexed* (London: Continuum, 2010).

[1667] Brian Davies "Happiness," 227-237.

teleological flourishing: that the rational operations of the organism are directly facilitated. In fact, it appears that the notion of *eudaimonia* is associated with all the characteristics in some way or other.

In **Table 6.1** I consider the neural bases of the characteristics of virtue in the light of affective, functional, and teleological categories of fulfilment. Detail concerning the relevant neural bases is found in **5.3**. This division follows upon simple analysis of the nature of these characteristics: some are more associated with feelings of pleasure and contentment, others reflect the nature of virtue as a facilitation of action, and the third category most reflects the rationality of virtuous action, that it is performed for an evident end.

Table 6.1
A notional distribution of neural bases of *eudaimonia*.

	Indicative categories of fulfilment		
	Affective	**Functional**	**Teleological**
Characteristics of the state of virtue having neural bases. For description of the neural bases of characteristics refer to **5.3.**	Conducive to subjective feelings of contentment.	Directly associated with satisfaction derived from this neural and cognitive efficiency.	Directly facilitating rationality and therefore directly enabling virtuous moral choices.
1. The virtues of prudence and justice dispose the practical reason and the intellectual appetite facilitating rationality and appropriate choices.	✓	✓	✓
2. The virtues of fortitude and temperance dispose the irascible and sensitive appetites to endure appropriate difficulties and to seek appropriate pleasure.	✓	✓	
3. A capacity for rational goal election is evident.			✓
4. “Virtues change us.” The acquisition of virtue creates a state of character, a way of being that tends to be permanent.		✓	✓
5. The virtuous state is in keeping with			✓

our human nature.			
6. In the exercise of virtue intrinsic motivation takes priority over extrinsic motivation. Virtue is motivated by that which is worthy to man’s nature.	✓	✓	✓
7. Virtue facilitates effective action.		✓	
8. Virtue brings about ease of action.		✓	
9. Virtue facilitates the flourishing of the person. Virtue brings about a state of excellence: an excellence of the person, inclusive necessarily of both neurobiological flourishing and the exercise of rationality. It is a state whereby reason and rationality are empowered to manage activity. It is a capacity for rationality that is reflective and emotionally enriched and able to be carried through into noble humane behaviours.	✓	✓	✓
Characteristics of virtue in its acquisition For description of the neural bases of characteristics refer to **5.3.**			
10. The virtuous state results from habituation and education.		✓	
11. Repetition, understood as critical practice, plays an essential role in the acquisition of virtue: repetition in appetitive responses, in responses manifesting noble sentiment and attentiveness to others, and in reasoning, deliberation and sound decision making.		✓	
12. Education specifically in wisdom and beauty is necessary in the formation of virtue.	✓	✓	
13. Effortful attention plays a significant role.		✓	
Characteristics of virtue in its acquisition For description of the neural bases of characteristics refer to **5.3.**			
14. Advantage must be taken of the early years both for training and provision of appropriate example.	✓	✓	
15. Imitation of example is a key means for acquisition of behaviours.		✓	
16. Explicit teaching and guidance as to right and wrong, are needed.		✓	
17. Affection facilitates learning particularly in the family environment.	✓	✓	

Note that all three aspects of fulfilment should be present in an enriched understanding of embodied *eudaimonia*. *Affective* pertains to those characteristics directly conducive to subjective feelings of contentment. *Functional* pertains to aspects of neural efficiency at the behavioural level. *Teleological* includes those characteristics more directly facilitating rationality and therefore directly enabling virtuous moral choices.

We should be mindful that these characteristics all pertain to differing facts of virtue itself. A definitive categorization is not possible; rather, the notional distribution of characteristics of virtue across indicative categories serves to highlight the complexity of the neural bases of *eudaimonia*.

The sections immediately following comment on the neural bases for the affective, functional and teleological aspects of *eudaimonia*.

6.2.2.1 Affective fulfilment. Discussion of the neural bases for the feelings of contentment associated with virtue.

Our focus here is not on arbitrary feelings of wellbeing, but on wellbeing directly associated with the state, exercise or acquisition of virtue.

A convincing case may be presented that the dispositions of virtue lead to heightened positive affect. While choices associated with appetite are rewarded indiscriminately by the body's hedonic reward systems and this is a normal precursor to human acts, it is reasonable to suggest that pleasure enjoyed with self-control is more enjoyable because it is longer lasting, and because it is enriched by the joy of knowledge of benefits to others, and is free of any bitter aftertaste of self-interest.

So, feelings of contentment will manifest at the neural level first of all in mechanisms of DA regulation, μ-opioid messaging and 5-HT uptake inhibition, but also via thalamic pathways from the striatum to the OFC (allowing cognitive modification of PFC to upregulate DA from the VTA and SN). Thus reward signalling is modified to reflect the conviction that proposed virtuous actions are rationally desirable; a source of reward reserved for what is perceived as a rational choice.

Cognitive memory in association with emotional memory facilitates recall of positive experiences in a manner exemplified in Wordsworth's "Daffodils". In this way, in addition to intrinsic functional benefits towards facility for preferred actions, we find that ease of action, clarity of deliberation, and so on, engender the experience of rational joy.

Peace and wellbeing, appreciated at the emotional level as a freedom from fear and a feeling of contentment, should also be included at this point. The capacity for self-management, and ultimately of happiness, is intrinsically dependent upon the successful management of one's emotional life (see **5.3.3.2 No 2** for neural bases). It is said of Alexander the Great that he had in his power all things except his passions, unaware that the greatest of empires is to possess dominion over oneself.

6.2.2.2 Functional fulfilment. Discussion of neural and cognitive efficiencies. The intrinsic functional benefits of virtue.

Autonomy and ease of action are directly a result of virtue. Virtue requires enriched neural connectivity and well developed neural pathways, a neural perfection in some way analogous to physical fitness, empowering a person to act more freely.

Neural and cognitive efficiencies, offered by the neural characteristics of virtue, may be identified at various levels. Flourishing of the organism is a state denoted by mature development of neural systems and mature integration of brain systems; freedom to live an emotionally enriched life constitutes a further important dimension of organic functionality.

Neural bases for the intrinsic functional benefits of virtue appear to consist in the following:

i. Systemic integration that characterises the state and operations of virtue. This integration exhibits the benefits that result from integrative processes: efficiencies, and an end result beyond the reach of individual contributions (in this case the various contributing systems, brain regions and pathways.)

ii. This systemic integration facilitates a self-regulation that is characterised by intrinsic motivation, a rich emotional life, and effective motor command. Emotional life is passionately felt, and passionately appreciated at the cognitive level, with a heightened aesthetic sense. Nevertheless, in a state of virtue, internal emotional expression does not eclipse cognitive deliberation. Such a situation would directly result in internal neural inefficiencies of loss of objectivity in interpreting sense data leading to poor decision making, and confusion or a loss of internal peace as a consequence of anxiety at not being in control, or as a result of not acting in one's best rational interests. This rich emotional life complemented by an inner peace has been noted in the life of Takashi Nagai in **3.1.1** and demonstrated in **Table 5.3.**

iii. As virtue develops cortical activity is enriched by duly moderated, emotional responses. Reward representations and emotional responses have been calibrated by training in that which is most apt for human nature in pleasure and pain. Emotional regulation must not be understood as a circumventing of emotion leaving redundant "circuitry" and superfluous systems. As virtuous behaviours are acquired, direct limbic routes remain for fast response if needed. As virtue is acquired, pathways between limbic centres and cortical processing areas are established and consolidated, allowing both cortical regulation to some extent of emotional responses, and also permitting emotional enrichment of cortical understanding.

iv. Loops and oscillatory messaging appear to offer the neural efficiencies of amplification of transmission, distillation of the core messages by filtering out of noise. Emotional processing via loops offers such efficiencies of circuitry.

Well calibrated perfusion of neuromodulation, in coordination with such reverberation and oscilliatory messaging appears to offer insights into the neural bases supporting a constant state of mind, and possibly even playing a role in peace of mind. [1668]

v. Neural efficiencies as a result of mechanisms of habit formation are present. Neural resources are optimised. As habits are consolidated, and fewer cortical resources are enlisted in the performance of actions,[1669] attention can be focused elsewhere. "The brain is constantly trying to automate processes, thereby dispelling them from consciousness; in this way, its work will be completed faster, more effectively and at a lower metabolic level. Consciousness, on the other hand, is slow, subject to error and 'expensive'."[1670]

vi. Neural resources dedicated to emotional self regulation are reduced as virtue is acquired. There are natural developmental analogies for this.

> Voluntary suppression of a primary emotion, such as sadness, requires more prefrontal work in children than in adults. Conscious and voluntary self regulation of emotion is more challenging (cognitively and affectively) in children than in adults because the maturation of the connections linking the prefrontal cortex and the limbic structures is not yet completed. [1671]

Similarly, the effort to be cheerful in children exhibited increased PFC activation. [1672]

[1668] The basal-thalamo-cortical loop appears most relevant here. Da Cunha, "Learning processing in the basal ganglia: a mosaic of broken mirrors," 163.

[1669] For example, Solso finds that experts use less energy in their brains responding to stimuli in their domain. R. L. Solso and D. W. Massaro, *The science of the mind: 2001 and beyond*, (Oxford: OUP, 1995).

[1670] Gerhard Roth, "The Quest to Find Consciousness," Scientific American Mind, January-February, 2004.

[1671] Beauregard and O'Leary, *The Spiritual Brain. A Neuroscientist's Case for the Existence of the Soul*, 136.

[1672] Beauregard and O'Leary, *The Spiritual Brain. A Neuroscientist's Case for the Existence of the Soul*, 136. Increased activation is noted in lateral PFC, OFC (just above the optic nerve input), mPFC and rostral ACC.

vii. Stable intrinsic motivations replace the unreliability of extrinsic reward. As habits are formed behaviours become increasingly resilient against reward devaluation and efficiencies of intrinsic reward take dominance. Motivation becomes independent of extrinsic reward. This accelerates further use-induced synaptic stabilisation: reinforcing behaviours are repeated more readily once motivation is internalised.

viii. The proximity of brain regions with key involvement adds further efficiencies of interconnectivity. PFC, BG and limbic structures, with their interconnections and loops, have been identified as key brain areas associated with the state of virtue. These systems are adjacent in the architecture of the brain offering a considerable neural efficiency for interconnectivity. This efficiency is further enhanced by the fact that the BG and the limbic systems, enjoying rich neuromodulator infusion, are adjacent to temporal lobes which are themselves richly interconnected to the PFC and active in cortical memory, and are situated between the autonomic systems linked to the brainstem and cortical regulation.

ix. Structural neuronal plasticity is a major cause of functional efficiency. Structural changes facilitate pathways for preferred reward and emotional responses, for deliberation, and for preferred motor outcomes. The stability of virtue and of associated personality is accounted for, at the neurobiological level, by structural plastic change as a consequence of gene expression mediated by processes such as LTP and LTD. For example: preferred reward outcomes could include intrinsic rewards for helping another; preferred emotional responses could include remaining calm in a crisis; preferred motor outcomes could include ready courtesies of smiling, etc. Mechanisms of neuroplasticity offer greater speed, accuracy and efficiency in replicating behaviours, by means of established pathways of motivation, processing, command, and execution. Experience-based, Hebbian learning associated with forms of LTP and LTD appears to play a major role in these mechanisms, accounting for enhanced interconnectivity upon which procedural sequences involved in virtuous actions are founded.

x. Sensitive periods and affection induced plasticities offer further efficiencies. Guided by the reason of parent or caregiver, a child's sound early development of likes and dislikes, the precursor behaviours to fortitude and temperance, are assisted by sensitive periods of responsiveness and by care-giver affection.

xi. Mechanisms of imitation lead to direct incorporation of emotional responses. This is manifested most particularly, though not exclusively, in younger children. This facilitates parental and caregiver guidance in what, according to reason, should be sought as pleasurable and what should be avoided.

xii. The experience based paradigm of learning which underpins virtue development brings a grand efficiency. Every experience carries potential for learning not only at the cognitive level, but by inducing direct biological modifications below the threshold of consciousness.

xiii. In the development of the neural bases of virtue, a law of increasing returns operates. Arden and Linford explain, "On the macro level: the more often we do something, the more likely we are to do it again."[1673] Choices to act virtuously serve to encourage future choices along the same lines. The neural basis for this is found in use-induced plastic reinforcement of pathways of preferred behaviours; simultaneously, unused and little used pathways are pruned away.

6.2.2.3 Teleological fulfilment. The neurobiology of *eudaimonia* at the teleological level.

In **5.3.3.1 u.** teleologically oriented *eudaimonia* was described as:

> A state of general flourishing marked by effective self-management mediated by the neurophysiological dispositions of prudence, justice, temperance and fortitude.
> …(underpinning) a rationality that is disposed to seek and recognise truth and to love others.

[1673] Arden and Linford, *Brain-based therapy with children and adults*, 21.

In this section I consider *eudaimonia*, at the teleological level, under this aspect. We saw (**1.4.1.a)** that flourishing, fullness of potentiality, is necessarily associated with final causality; here we discuss flourishing of the person with respect to his proper ends: truth and love.

Man is empowered for truth and love by the integrated action of the virtues disposing his acts for perfection. Virtue facilitates inhibition of impulsivity towards inappropriate and harmful pleasures, assists in mastery of timidity and moderation of rashness (see **3.4.3.5-7** and **5.3.3.2 No.2**), inclines towards a spirit of relationship and respect for others, and assists in the dominion of reason. There is compelling inductive argument that the state of virtue is a state of natural happiness, and that therefore that the neural part-constituents of virtue are aspects of the natural developmental trajectory of the human being, although this natural development can be frustrated by the individual.

As we have seen (**4.2.2**) man's capacity to grasp truth is perfected by prudence. His capacity to moderate his own goods in relation to the goods of others is perfected by the dispositions of justice (**4.2.3,** and **5.3.3.2. No.1** for neural bases of both virtues). Virtue empowers the person for openness to reality, accuracy in evaluating reality, planning, sincerity about reality; it empowers man for right deliberation about means and goals, and about abstract goods.

On the basis of truths grasped and knowledge of one's own end, it is possible to make rational choices to choose rightly, to be in "good shape for self determination".[1674]

Furthermore, life is "relational" starting even at the synapse itself. Our capacity to move ourselves towards the goals we understand to be good for ourselves

[1674] John Finnis, *Natural Law and Natural Rights* (Oxford: Clarendon Press, 1980), 86. Finnis argues that human flourishing is dependent on the possession of various goods, among them the basic good of life is characterised by the capacity for self determination. Other goods such as practical reasonableness necessitate the presence of virtue.

necessarily requires the capacity to grasp the truth of things or people: I will love another whom I understand to be a good for me. Hence, flourishing at the personal level includes an openness to another in a personal relationship to the degree that that person is understood as a good for oneself. It is common experience that happiness in life is dependent on the experience of these loving relationships.[1675] In turn these positive experiences facilitate further positive behaviours, nourishing human maturity. Reciprocally, it is shown that the quality of relationships experienced by a child will affect brain development.

Biological processes facilitate a state disposed to knowing and loving. It seems natural to human beings to love with all their being, with full integration of the biological. Knowing too requires full integration of the biological. Without this vision, knowing and loving remain as ancilliary activities to man, failing to enlist one's entire being, optional fulfilments for limited aspects only of human nature. It would in fact be self-contradictory to argue that human beings are fulfilled by knowing and loving were these operations not carried out with the integrated involvement of the body.[1676] Virtue may be understood as the neurophysical disposition enabling rational operation, and is the key to our knowing and loving in a fully integrated way. The perfection of the body must be integral to the perfection of the person in a permanent way.[1677]

[1675] Cf John Paul II, *Redemptor Hominis*, (1979), 10. "Man cannot live without love. He remains a being that is incomprehensible for himself, his life is senseless, if love is not revealed to him, if he does not encounter love, if he does not experience it and make it his own, if he does not participate intimately in it."
(http://www.vatican.va/holy_father/john_paul_ii/encyclicals/documents/hf_jp-ii_enc_04031979_redemptor-hominis_en.html)

[1676] Norman Doidge regards oxytocin as the neural substrate for love and commitment, creating a calm and warm mood and triggering trust between couples and between mothers and children. He christens it "the commitment neuromodulator"(119), and suggests that as a neuromodulator it is more able to "enhance or diminish the overall effectiveness of the synaptic connections and bring about enduring change" (118). Doidge is of the view that oxytocin assists imitation of another's intentions and perceptions, and counters self-centredness. (119) He quotes Walter J Freemen of Berkeley who argues there to be two massive neuronal organisational times: falling in love and parenting. Doidge, *The brain that changes itself*, see discussion 116-121.

[1677] The very perfection of the risen Christ reveals, to a Christian, that bodily perfectibility is permanent, and that how we are hereafter is proportionate to how we become now.

I am fulfilled by knowing and loving with all my being, without holding back, a complete giving in which all my senses, internal senses, memories, desires, planning and deliberations are enlisted and present. This understanding is in accord with a definition of love that embraces complete self-giving. (See also Woytyla's enriched understanding of person, and fulfilment in loving relationships in **1.4.3**.) To love with all my heart is to love not only the "movement" of love towards the good that is loved, but, in interpersonal love, the mutual possession of the beloved and complete self-giving of the beloved. This is true flourishing. Virtue is the only path. It is the biological key.[1678]

Happiness normally also accompanies the capacity for autonomous action that is necessarily a feature of human maturity. It is also common experience that happiness depends upon peace of heart, that quality of character reflecting the capacity to direct oneself to the goals one holds to be of greatest value in life. It may be argued that good habits, habits following upon choices of what we perceive as deeply good for us, bring this peace. A further case may be presented that habitual dispositions for meditation, reflection, and contemplation of beauty are also implicated in happiness.

Note that while peace of heart may appear to be a subjective element, there is a manifestly objective basis in the due order in one's life and in one's neurobiology.[1679]

6.2.3 Fulfilment through virtue.

Links between virtue and fulfilment are found in two prominent contemporary professors of psychology whose work is largely consistent with the Aristotelian/Thomistic view of virtue as a source of fulfilment for man. Both venture into the neuroscience.

[1678] For this reason, for a Christian, Christ is the model of human activity; a man who knows and loves "in" his very being.

[1679] "The peace of all things lies in the tranquility of order; and order is the disposition of equal and unequal things in such a way as to give to each its proper place" Augustine XIX.13, p. 938.

The work of Samuel Franklin openly attempts to demonstrate that a greater part of the anthropological wisdom, and biological accuracy, of current psychology may be traced back to Aristotle's teachings about virtue. The other is the initiator of the Positive Psychology movement, Martin Seligman, who presents the view that at the clinical level (and therefore at the level of biological structures) that virtue perfects the nature of man. Seligman's most recent text, *Flourish*, presents his current thought on the topic.

6.2.3.1 Samuel Franklin

With the intention of building a bridge between contemporary biopsychology and Aristotle, Samuel Franklin has published in 2010 *The Psychology of Happiness. A good human life*. He discusses "the physiological basis of virtue".[1680]

> Aristotle suggested that virtue is the moderation of emotion by reason. Although it took 2,500 years, we now have neurological evidence that he was right. [1681]

Drawing on the work of LeDoux, he outlines a simple model for the implication of biological structures in the operation of virtue. At the core of his insight is the contrast between a longer cortical route for emotional processing, involving eye – thalamus – visual cortex – amygdala – PFC – emotional reaction, with a more direct route: eye – thalamus – amygdala – emotional reaction; [1682] he argues that the longer cortical route is integral to virtue. He holds that the capacities for "executive control" lie in prefrontal areas.[1683] He argues for the instrumentality of the PFC in executive control and self awareness and result in foresight, judgement, social graces, creativity, empathy, reasoning, and reliability,[1684]and

[1680] Franklin, *The Psychology of Happiness. A good human life*, Chapter 12.
[1681] Franklin, *The Psychology of Happiness. A good human life*, 117.
[1682] Franklin, *The Psychology of Happiness. A good human life*, 117.
[1683] Franklin, *The Psychology of Happiness. A good human life*, 119.
[1684] Franklin, *The Psychology of Happiness. A good human life*, 119.

suggests that both humans and primates suffering damage to the prefrontal areas (think of Phineas Gage) lose these capacities.

> Here lay the capacities for "executive control", the ability to make reasonable decisions, to inhibit when appropriate, and to say and do the right thing. The prefrontal lobes appear to be the centres where visual images become meaningful and where reason and emotion join together.[1685]

The absence of any discussion whatsoever touching on the hylomorphic makeup of the human person is a serious omission from the perspective of this study. He suggests, incorrectly from an Aristotelian perspective: "The prefrontal lobes ... may be the seat of our humanness, our ergon."[1686]

6.2.3.2 Martin Seligman

Martin Seligman, Professor at University of Pennsylvania and a recent past President of the American Psychological Association, is a giant of contemporary psychology. Having won acclaim for his groundbreaking work on resilience for young people, in 2004 he coauthored with Christopher Peterson *Character Strengths and Virtues,* an analytical framework for discussion of character defined as a composite of positive traits or habits.

Their avowed aim was to "reclaim the study of character and virtue as legitimate topics of psychological inquiry and societal discourse", seeking to elevate discussion of virtues to a clinical basis through an *evidence-based* methodology. They stated, "We believe good character can be cultivated, but to do so we need conceptual and empirical tools to craft and evaluate interventions." This confirmation of the role of virtue and particularly of its contribution to flourishing is timely.

[1685] Franklin, *The Psychology of Happiness. A good human life*, 119.
[1686] Franklin, *The Psychology of Happiness. A good human life*, 120.

Seligman and Peterson through an exhaustive process identified six umbrella abstract virtues: wisdom, courage, justice, temperance, humanity and transcendence and a further list of character strengths subordinate to the virtues. Their list of virtues bears resemblance to core virtues of the various traditions of man.

Under the six headings the authors drill down to twenty four character strengths, or stable traits of character; for example wisdom is the umbrella virtue for creativity, curiosity, open-mindedness, love of learning, and perspective. The authors suggest that one can further descend to what they call “situational themes”, habits manifesting the character strengths in specific circumstances. The whole process is thus from the abstract to the specific habits that manifest the virtues. Pleasingly Aristotelian.

They are at pains to remind us that theirs is not the final word, but the work is most impressive nonetheless. Major sections in the book discuss aims and methodology of the project, the character strengths in detail, and assessment processes. Chapters on each character strength are the work of contributing experts in their own specific fields. Discussion of each strength follows a standard template: definitions, traditional approaches, measures, benefits, manifestations, cross-gender and cross-cultural variations, interventions for fostering, areas for future study, and bibliography.

Early in the work, Seligman and Peterson review understandings of virtue through the great cultural traditions of the east and the west. It is most of all in the writings of the great Greek philosophers that Seligman and Peterson find their inspiration. The four cardinal virtues closely align with five of the six of Seligman and Peterson. Only *transcendence* at first sight is not easily categorized yet Socrates and his followers would no doubt have included a transcendence within the speculative virtue of wisdom. Not only does the actual articulation of the virtues essentially correspond, but the vision of a virtue as a good habit closely aligns. Seligman has now built upon this work, taking it an overtly eudaimonistic direction… "strengths of character that make the good life possible."

Building on his earlier work, Seligman has now published *Flourish*. The new work broadens his definition of happiness. He proposes five indicators of flourishing: positive emotion, engagement, relationships, meaning and accomplishment. Relationships and accomplishment receive more emphasis than in his past works.[1687] Nevertheless his analysis appears to have compatibility neither with that of Aristotle nor with the basic human goods as outlined by John Finnis and others.[1688]

An attempt to align the three perspectives suggests that Seligman's divisions are based on a subjective perspective: for example, Seligman overtly discusses positive emotion and the experience of meaning and accomplishment, whereas both Aristotle and Finnis prefer to limit their analysis to objective context. I suggest this reveals a significant difference in approach. Ultimately Seligman prefers to discuss the subjective experience of virtue and the subjective experience of happiness, rather than the existential reality of virtue. While this is understandable given his clinical emphasis it is perhaps inevitable given Seligman's lack of a metaphysical anthropology. This does not, however, detract from the value of Seligman's findings on the necessity of virtue for human flourishing. The power of clinical findings is in their objective basis in evidence; it is Seligman's analysis that adds the note of subjectivity.

6.3 Neuroscientific conclusions

6.3.1 Reflections on the model that has been proposed.

[1687] Seligman *Flourish: a new understanding of happiness and well-being and how to achieve them*.
[1688] In **3.2.8** we saw that Aristotle regarded virtue as necessary though not sufficient for happiness and he enumerated requirements for happiness.

During my investigations there have been moments of significant insight that have given shape to this study. An understanding of these stepping stones will provide an appropriate lead-in to a summary of neuroscientific conclusions, and may stand my key findings in greater clarity.

The role of virtues as factors that promote wellbeing has been most evident to me in my professional life. I am still in close touch with a great number of students, some now in their late 30s, whom I knew very well through a decade of their school lives. Many are flourishing and some are struggling. It has become patently clear to me that that our habits will either pull us through or, if they are bad habits, come back to bite us.

A *Time* article fifteen years ago about the developmental windows in a child's brain got me thinking about a project describing the neural basis of virtue understood as good habits, and that it could be possible to demonstrate scientifically the benefit of virtues.[1689]

Once I started on the project, it became very clear that the solution needed to embrace the unity of the virtues. When I dissected the actions of Nagai it became clear that good actions in real life consistently require the dispositions of most, if not all, of the cardinal virtues. Rereading the *Nicomachean Ethics* in the light of the task I was undertaking, I was struck by Aristotle's remarkable insights about pain and pleasure as human motivations, and of the virtues of temperance and fortitude disposing for appropriate pain and pleasure. The role of temperance and fortitude fell into place as necessary dispositions prior to *every* human act.

When I was considering the possibility of neural bases for prudence and justice, it became apparent that, during the process of deliberation, reasoning requires the ongoing support of phantasms drawn from memory (and imagination, which is a form of composite memory). This fact and the description in **Scenario 3** where

[1689] J. Madeleine Nash, "Fertile minds," *Time Magazine*, 3 February, 1997.

Nagai reads and reads again the pamphlet dropped from the plane *before* he comes to a conclusion, made it clear to me that embodied rational deliberation has duration and is conducted with the ongoing assistance of, is disposed by, neural structures.

The observation of trained dogs that obey their owners's commands to sit at kerbs (even when, as in the suburb where I live, dogs receive instruction in a foreign language!), accorded remarkably with the observation of Aristotle that acts disposed by fortitude and temperance in a small child must follow the reason *of the parent*. This led me to the view that fortitude and temperance must *essentially* be neurobiological features.

When the discovery of mirror neurons received publicity, initially I could see a possible role of this neural mechanism in assisting the uptake of parental example. I then read of Aristotle's insistence that parents must teach refined attitudes to pleasure and pain, by example and body language in an ongoing emotional education, and thus teach emotional regulation. The mirror neuron thus offers a mechanism not only to assist in imitation of example and development of empathy but for the very core business of emotional education: children are able to embody their parent's emotional reactions to pain and pleasure … again for better or for worse.

At a comparatively early stage in this project, an integral role for the BG struck me as necessary.

i. In my readings in neuroscience on habit formation in the brain, I was struck by the recent expanding understandings of the function of the BG (extending to involvement in reward and emotion processing, and cognitive support for decision making and goalsetting). I had come seeking a neural basis for good habits, and it was felicitously coincidental that the area most associated with automaticity enjoyed rich *reciprocal* interconnectivity with the PFC and with the limbic areas. It struck me that the Hebbian principle brings with it a corollary: connections are not only built *by* activity, but the existence of connections *indicates* activity, and dense interconnection indicates a virtual information highway.Furthermore, the physical location of the BG also struck me as highly conducive to an integral role.

ii. Addiction studies brought to my attention the pathways in the BG for the transformation of reward related behaviours to habitual behaviours, with corresponding reduction in reward significance. This struck me as a significant parallel to the reward independent intrinsically motivated behaviours of mature virtue, most especially given the presence once again of the BG in the equation. The reality of reward incentivation for small children (and puppy dogs) during stages of habit formation further suggested to me a role for the BG in mature virtue.

iii. Furthermore, addiction studies note the coexistence of BG addiction pathways with clear-headed, calculating rationality in the addict. This suggested that positive BG habits could also have a rational dimension. That there are no motor pathways directly from the BG demonstrates that the role of the BG is to modify motor commands not to issue them. In principle, the abundant basal-cortical connectivity can support positive reflective habits, not only unconscious habit and addictive behaviours.

My attendance at the *Persons and their Brains* conference at Oxford in July 2012 and subsequent meetings and correspondence with several figures writing in philosophy of mind and neuroscience have given me greater clarity of understanding concerning the shortcomings of the notion of emergence and of the need to repackage the hylomorphic view in terms that can engage with neuroscience. A chance meeting with a professor of Thomistic philosophy helped me refine my view of the unitive and functional role of the soul.[1690] [1691]

[1690] Discussions and correspondence with Professor Antonio Malo of the University of the Holy Cross, Rome.

[1691] These insights are presented in **Appendix 1. A Response to the Claims of Emergent Rationality by Non-reductive Materialism** and in several articles I have penned in subsequent months. Several online pieces I have contributed to MercatorNet website, http://www.mercatornet.com/:"The battle to reclaim free will," 6 July 2012; "Stephen Covey: reviving the forgotten notion of virtue," 22 August 2012; "What's the matter with Analytic Philosophy," 4 September 2012.

6.3.2. A summary of neuroscientific conclusions.

I have argued that the neural bases of virtue (as have been presented in **5.3 and in Table 5.2**) consist in the highly coordinated integration of higher neural systems at both the functional and structural levels, subserved by the lower neural structures and other bodily systems (sustaining life and supporting physical activity). These neural bases manifest the plasticity that is virtually ubiquitous across the neuronal pathways of the human brain; this plasticity, and the systems of learning, memory, habit formation, emotional regulation and goal election offer the primary mechanisms to assist in the stabilisation and reinforcement of behaviour by repetition and in response to environmental inputs.

In the normal course of events consolidated neural pathways are a use-induced consequence of repeated choices disposed by the virtues of prudence and justice (and therefore with full respect for duties towards others), free from the negative consequences of emotion driven choices (through the dispositions of temperance), and from unreasonable fears of external obstacles (though the dispositions of courage). In other words, it is rational and virtuous choices themselves that further consolidate stable dispositions of virtue in a marvellously efficient paradigm of development; the very neural circuitry involved in individual virtuous acts becomes over time a flexible myriad of expressways and flyovers for ease of action (pathways facilitating attention to others, intrinsic reward, emotional management, consideration of consequences to others, critical judgement, prior planning, decisiveness, etc). In complement to each virtuous action, preferential recall in cortical memory systems and reward circuitry, is further consolidated by each virtuous action: preferential priority for subsequent behaviours is accorded to practised behaviours. This will be true for practised positive behaviours (eg sincerity, service to others, patience, a capacity to endure discomfort for a reasonable motive, etc) but also for negative behaviours (eg laziness, reactions of disrespect, surrender to anger, etc).

The state of virtue manifests at the neural level as a systemic harmonisation, a grand integration of the mental resources of the human being. An ongoing interplay is required between biological development, practical reason, experience, consideration for others, and the repetition of positive goal directed behaviours. Established interconnections facilitate, most importantly, higher cortical management of a person's emotional life and of deepest motivations for action. For this reason as we have seen (See **5.2.2.2**), the development of the neural dispositions for virtue may be seen as a flourishing of the human organism at the biological level.

Furthermore this complex systemic integration is ordained to the fulfilment of the person at the holistic level, to *eudaimonia* in the most complete sense of the word. (See **5.2.2.3**) The development of the neural structures supporting virtue is manifestly the end point of a developmental process that is, so fittingly given our yearning for rational self-determination, autonomous. Freely elected life experiences and free responses to environmental and experiential inputs are the raw material from which virtues are formed. The state of virtue is a state of neural and systemic maturity, but one which, in some way, one constructs oneself.

6.3.3 Associated insights into brain structure and function.

In **Chapter 1** I suggested that this study has the potential to contribute to our understanding of the human brain. The following insights appear particularly noteworthy:

i. In keeping with the evolutionary preference for increasing efficiency in organisms and organic systems, this study holds that increased integration and interconnectivity of brain areas and brain systems are manifestations of normal developmental processes. This is suggested, for example, in the clarification of interconnections between brain regions brought about by synaptic pruning (see **2.2.4**, **2.2.5** and **Table**

2.15) with resulting greater efficiencies of connectivity, and found also in descriptors of the Templeton research grants (**2.1.1.2**). [1692]

ii. This study supports the view, gaining greater traction with improved imaging, that deep cortical structures play a more significant role in cortical and cognitive activity than had been previously understood.

iii. The BG appear to play a most significant integrative role by facilitating cognitive processing of emotion, reward considerations and habit formation.

iv. Note that plasticity denotes not only flexibility for change, but paradoxically the capacity to become and remain in a different configuration. This capacity, first to be responsive to remoulding, and then for the "concrete to set" is at the heart of the stabilized pathways that are manifested in virtue. It was noted in **Chapter 2** that the capacity to lock in behaviours is "the forgotten … aspect of plasticity".[1693] The essence of this quality of plasticity appears to be found most of all in permanent changes associated with gene expression brought about by structural reconfigurations at the level of the dendrite. Hebbian paradigms of synaptic strengthening govern the development of brain structures that reflect procedures of behaviour and associations between environmental stimuli.

v. The necessary integration in cognitive learning of systems of attention has particular significance in the development of the virtues of prudence and justice, which rely less on early training and more on explicit guidance. Attentional difficulties in adolescence must be a significant hindrance to moral development.

vi. In the model of virtue proposed, neurotransmitter perfusion most particularly of DA in response to cognitive reward perception plays a

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[1692] Note too, that in descriptors of the Templeton research grants, (**2.1.1.2**) accord with the view that virtue manifests in high levels of integration and interconnectivity between neural systems: most particularly in the integration of the brain's emotion and reward/motivation/goal election systems, with systems of cognition, planning and executive management. Note, for example, that the rational moderation of pleasure and rational endurance of pain for a proportionate good, necessarily present in acts of temperance and fortitude, requires a high level of neural interconnectivity between reward, emotion, emotional memory, cognition and executive centres.

[1693] N. Doidge, *The brain that changes itself*, 276.

most significant motivational role, most certainly in the early stages of acquisition of the virtue. But also, on the basis that the body possesses mechanisms to reward activities that are perceived as enjoyable with DA, 5-HT and opiates,[1694] these pathways are also likely to constitute the basis of intrinsic reward associated with virtue.[1695]

vii. In the model of virtue proposed, the lack of resilience, shown in the virtual epidemic of depression and anxiety present in young people, would appear to consist in a heightened sensitivity to conditioned fears, and a corresponding lack of development cortical management pathways.

viii. The ready facility found in young people for the development of habits is also shown to be grounded in the neuroscience: it is proposed that structural plasticity at the neuronal level provides the mechanism underpinning the long-term changes which characterise virtue. It is also proposed that mechanisms of structural plasticity provide the neural substrate for the necessary rational elements that underpin true virtue. It is argued that structural plasticity is also implicated in the greater self management of emotional life that virtue affords... and in the experience of happiness and peace that self management provides.

ix. I have presented neurobiological evidence that we human beings have the evident ability to bring about, by our own choices, the neural development of our brain systems that are necessarily conducive to the exercise of rationality and emotional regulation across the spectrum of virtuous behaviours. I suggest that this neural development may be understood, because of excellence of cognitive-emotional integration and connectivity it entails, as the pathway *par excellence* for our maturity as human persons.

x. Ultimately this study into the neural bases of virtues is a further witness that the material is integral to our humanity. A state of virtue is

[1694] Addiction studies of video gamers show this.
[1695] The research into the bases of intrinsic reward under the Templeton research grants offers the possibility of early clarification of this model.

a stable disposition to know and to love, and is ordered to our deep fulfilment. To program ourselves for happiness we need to build up, by dint of constant choices and effort, a repertoire of positive behaviours; as we consolidate them, these experiences change us. Functional change leads to permanent change both neuronally and personally. Virtue based approaches remind us that rationality and matter are profoundly integrated.

6.4 Philosophical conclusions.

In **6.4** I draw together conclusions, in the light of the neuroscience and hylomorphic theory, with respect to:

i. Anthropology – In addition to the points raised in **6.1** and **6.2** concerning *eudaimonia*, I offer reflections arising from this marriage of neurobiology and hylomorphism. I consider the unity of the virtues and offer brief reflections on the distinction between virtue and vice.
ii. Philosopy of mind – I consider the comparative advantages, in the light of an identification of the biophysical part-constituents, of the hylomorphic approach to philosophy of mind. I suggest that a notion of soul as principle of being, unity, and function of the person accords to hylomorphism the language to engage more successfully with contemporary currents in philosophy of mind and demonstrate a patently superior approach to materialist and dualist understandings.
iii. Virtue ethics – This study suggests that virtue ethics, because of a demonstrated relationship to human biophysiology, is superior to consequentialist and deontological approaches.
iv. Hylomorphism itself – I consider the insights that the hylomorphic account of human freedom and rationality stands to gain from a deeper understanding of neuroscience.

6.4.1 Anthropology. Understanding of the human person. Advantages of an hylomorphic approach.

By describing the neurobiological basis for acquired character traits, this study offers a heightened appreciation of the effect that choices and behaviours, experiences and environment play in defining who we are.

Plutarch wrote that character is inured habit.[1696] For better or for worse this is true. Our personality is sooner or later defined by our habitual behaviours. The traction obtained by repeated negative or positive behaviours is founded in the biological basis of virtue. Matter brings determination; in the case of virtue, a self-elected determination. A comprehensive model has been offered, consistent with both the identified characteristics of virtue and with the neuroscientific data, describing how emotion and processes of goal election may either hijack rationality or reinforce decision making.

6.4.1.1 Unity of the virtues reveals itself as a biological necessity.

This study serves to considerably strengthen the case for the unity of the virtues.

In **4.3** I argued for the complementary and integral activity of the cardinal virtues in every human act. My approach consisted of the following: I offered observations of the apparent complex integration of the various virtues in real scenarios; in concert, I argued that an analysis of the human act (**Table 3.1**) reveals composition by various elements each requiring the distinctive perfection of the various virtues; then, noting Aquinas's argument that each virtue must play a distinctive role, and on the basis of a close reading of Thomistic texts, I offered a "restricted understanding of Aquinas' "reason is the form of the virtues". In summary I have argued that all four cardinal virtues are present in actions of perfect virtue because the four cardinal virtues each perform different roles, disposing the sensitive appetites, the intellectual appetite and the intellect. All are needed for the completion of the good action.

[1696] Plutarch, *On the education of children.*

When these arguments based on observation, dissection of the human act, and deduction from an understanding of the differing roles of the virtues based on analysis of Aristotelian and Thomistic texts, are complemented in **5.3.3** by identification of highly plausible neural bases of each of the cardinal virtues, a compelling argument crystallises: it would seem that the unity of the virtues be a biological necessity.

6.4.1.2 Some thoughts on the nature of vice.

Vice is understood popularly as the antonym of virtue. In **3.3.13** the nature of vice was discussed. Vice is a disposition to give free rein to a passion, following one's sensitive nature "contrary to the order of reason".[1697] It stands in contrast to both virtue which, generally speaking, is the habitual rational choice of a good that is in keeping with one's nature, and to incontinence in which the action against nature is contrary to the express will of the agent who lacks the mastery that would be accorded by possession of the virtues of justice, fortitude or temperance.

The neural analysis of **Chapter 2** serves to highlight that vice and virtue are not simple alternatives. Vice is a habit of complacent abrogation of rational deliberation and so is most harmful for the subject. Vices are best understood as an absence, accompanied by rational justification, of neural circuitry facilitating adequate evaluation of goals.

Vice and virtue are not simple alternative trajectories of development; vice is a privation of neural development. A correctly formed understanding of vice leads us to understand that bad habits are not a simple alternative to good habits; there is a world of difference both in function – rationality informed by appropriate ends- and structure – vice must necessarily exhibit defective pathways of

[1697] *ST*, Ia-IIae, Q.71, Art.2.

deliberation and/or evaluation of consequences of one's actions, accompanied also possibly by impoverished emotional regulation.

Vice is a self-imposed privation of rationality. Neurally it will be constituted by direct pathways between passion and behaviour, bypassing due deliberation. As it is a complacent attitude, it will be accompanied by higher cortical reward representations denoting awareness and enjoyment of one's actions. There will be no consequent activity in brain centres for sadness and guilt. The bottom line is that the person in the grip of vice is content to underutilise the human capacity to deliberate effectively about ends. Such underutilisation becomes neurally reinforced, through strengthening of direct, non reflective routes, the more the relevant behaviours are pursued.

6.4.2 The benefits of a non-reductionist, hylomorphic approach to philosophy of mind.

In **Chapter 1** notions of anti-reductionism, rationality and person were introduced as essential to the Aristotelian view of virtue. In Section **1.5**, I adopted Haldane's advocacy of a "return to form", and proposed the suitability of an hylomorphic solution to the mind-body problem. A convincing, non-reductionist position appears impossible without the concept of person as agent. Here I further conclude that the anti-reductionist position and notions of person, rationality, and virtue, are further supported by an enriched understanding of causality (**6.4.2.1**) and by an understanding of soul that is adequate to underpin human freedom (**6.4.2.3,** and **Appendix 1**). Thus, in the first case, I further distance hylomorphism from any taint of substance dualism, and in the second, I avoid a narrow and deterministic definition of causality that considers only material cause.

We have seen that contemporary philosophy of mind, in seeking to account for human behaviour and material causality, is dominated either by reductionist-materialist approaches on the one hand, essentially denying freedom, or anti-reductionist approaches on the other. Within the latter, this study proposes that only an approach founded on the Aristotelian-Thomistic vision of the human person succeeds in accounting for both causality and freedom. We have seen that the other principal non-reductionist approach to philosophy of mind has looked either to substance dualism in one form or another for a solution accounting for human freedom, or to a paradigm of emergent rationality.

Ultimately, free human action is *as* inconceivable in a model of human nature that proposes a dual substance solution *as* in one that is purely material. The first, in affirming freedom disposes of a single human subject, and the second is incapable of offering a rationally satisfying accommodation for freedom within the determination of matter. The hylomorphic solution, is however, as we have seen, a "non dualist, dual aspect, ontological anti-reductionist" approach to the human person; an approach that reconciles human freedom with the notions of material causality essential to neuroscientific method.[1698]

6.4.2.1 The importance of an hylomorphic understanding of brain function and structure.

What if someone should ask whether there is any *practical* difference between a materialist (reductionist or non-reductionist) understanding of the brain and an hylomorphic understanding? In the first, matter is the agent; in the second animated matter operates. Does this difference have any real significance? Could it be that agency resides ultimately in neural structures and neurochemicals? Could it be that hylomorphism is simply an act of faith that preserves a realm of immateriality?

On the contrary, this study argues that rationality *is only possible* if the hylomorphic understanding of matter holds. Rational understanding and rational choices to move ourselves towards what we know is suitable for ourselves seem only explicable within a paradigm of participation ungoverned by the

[1698] A classification suggested by Haldane, "A return to form in the philosophy of mind".

determination of matter. A materialist explanation of human beings is not rationally satisfying.

There is undeniable evidence of the human capacity to transcend the material. Human beings can transcend from the concrete and the immediately perceived; they can acquire wisdom, understanding about what things are and their purpose. Human beings can choose; they can elect to dedicate themselves to the pursuit of goods that they believe will enrich them even on a non-tangible level; also a human being can form interpersonal relationships whereby he or she dedicate themselves to carry out the will of another seeing this as for their own fulfilment in some way.[1699]

Because this evidence of man's capacity to operate at a transcendent level is undeniable, and because materialist accounts cannot explain non-material realities, material explanations for man's nature are *necessarily* inadequate. And once the inadequacy of the material agency is established, the notion of "person" as moral agent is a necessary further conclusion on the basis of unity of being. Note that the conclusions first of the hylomorphic constitution of man, and of his personhood are both based on observation of the real nature of things. Take away the hylomorphic constitution of man and he is denied personhood.

There are only five possible explanations for the presence of rationality of human beings.

i. That human beings are <u>puppets of a rational principle beyond themselves</u>. This is manifest nonsense as it removes every skerrick of agency from mature human beings.
ii. A <u>reductive materialism</u> that defines matter as the functioning agent, and argues that all human behaviour has its explanation in cells, currents, neurotransmitters, etc. This is a deterministic position and is

[1699] cf Ansombe's observations abou the non materiality of man's spiritual nature.

ultimately a denial of rationality; an assertion that rationality and human freedom are essentially illusory.

iii. A substance dualism that defines the soul as the functioning agent, leading to insuperable contradictions in accounting for causation and for interaction between human beings and physical experience.

iv. A non-reductive materialism arguing that rationality emerges from matter itself. Yet an emergent rationality must be tied to the determinism inherent in matter; it cannot explain the capacity to grasp universal truth, nor human freedom. As both of these are manifest realities, non-reductive materialism is ultimately a self-contradictory position. The term "emergent" appears to be an unscientific sleight of hand. Furthermore, to resort to "chaos" and "quantum", as some do, to explain personhood and freedom either misunderstands rationality or takes refuge in a mysticism that is ultimately irrational.

v. The hylomorphic solution which is more subtle and satisfying, arguing that there must be another principle for human activity beyond matter but intrinsic to the human being. This special quality cannot emerge from the matter itself nor be a separate substance to the body. It is a principle animating the body itself but must be received from beyond the body. This principle of activity is the rational soul. The hylomorphic solution is founded on the observation that an animated human body is essentially of a different order from a living animal or a non-living thing.

The prevailing position in neuroscience is that of materialism, either reductive or non-reductive, but either way materialism. It is my hope that this cross-disciplinary study, in subjecting the assumptions of neuroscience to a rigorous philosophical critique, assists in bringing to this exciting field the depth of an hylomorphic understanding of man.

Without a broader acceptance of hylomorphism in the community of neuroscience, it would appear that the neurobiology of abstraction, of human freedom, of personal agency and interpersonal relationships must remain undervalued and possibly understudied. Without acknowledgement of rich complexity of the human person, and the role of truth and dedicated interpersonal love in human fulfilment these fields will remain uncultivated in neuroscience. There are of course noteworthy exceptions of persons currently working in these fields. Because, in the hylomorphic scheme of things, virtue opens the door to truth and interpersonal commitments, it is my hope that neural studies of virtue, in the light of hylomorphism, open the door to neural studies of human flourishing at an even broader level.

6.4.2.2 An enriched understanding of causality accords with the anti-reductionist view and permits dialogue between scientific and philosophical explorations.

In this task of applying neuroscience to an anthropology that respects human freedom, an enriched, essentially Aristotelian, understanding of causality is necessary, that discriminates between material, formal and final causes at the neural level. Without such discrimination it would appear impossible to accommodate both biological materialism and the human freedom manifested in the rational development of virtue ordered to the flourishing of the person. Without such an enriched understanding it would various appear impossible to reconcile man's freedom with the determinism inherent in matter.

Therefore I propose that these investigations into the neural bases of virtue, indeed all neuroscientific endeavours attending to human subjects, must respect the following notions of causality:

i. Experimental method understands an <u>efficient</u> causality operating at the material level. The cause of water turning to steam is the Bunsen burner. The cause of the accident is the drunk driver. A key mistake of reductive understandings of neuroscience is that causality is simplistically reduced to one category: efficient/material causality. This is an impoverished view of causality;[1700] in the development of virtue, I suggest that appropriate experience is the efficient cause of the development of habit. There are clearly other factors in play, but no good habit can exist without appropriate experience.

ii. Good habits in their neurobiological bases are the <u>material</u> cause of virtue. Good habits are truly embodied. The body is a necessary co-constituting factor of good habits in the embodied state. In our embodied state all human activity in the rational, moral, conscious order, not only has manifestations in man's physical being, but is mediated through the physical.

iii. Although rationality is mediated through the physical it is not reducible to the physical. It is the person who is rational, not his or her brain. Biochemical mechanisms alone are insufficient to account for free action. Human development and human behaviours cannot be reduced to actions subject to a material determination. Through our rationality we become masters of our own development. Hence, rationality, is the <u>formal</u> cause of all virtue.[1701] An understanding of this concept has discussed at length in **Chapter 3**.

iv. Good habits are characteristics, not merely of biology, but of the person. Indeed as was presented in **5.2.1.2**, it is argued that the flourishing of the person is the <u>final</u> cause of virtue, that good habits, with all of the biological embodiment that this implies, are the means by which a state of human flourishing is achieved.

Without this enriched appreciation of causality, I suggest it is not possible to reconcile neuroscientific understandings with human behaviour, nor to reach findings of significance both to philosophy and neuroscience.

[1700] Formal and final causality are neglected completely.

[1701] Not only does Aquinas affirm this principle, but Haldane as we have seen, argues that a return to an understanding of formal cause is absolutely necessary if we are to find a way forward in philosophy of mind, if we are to reconcile man's evident, albeit limited, freedom of action, with notions of causality in the physical world.

6.4.2.3 Functionalist approaches to hylomorphism.

a) Rationality is functionally integrative.

An enriched understanding of causality offers a solution satisfactory to both neuroscience and to an anthropology protective of rationality and freedom. We have seen in particular that it is essential to embrace notions of formal and final causality if one is to reach an accommodation satisfying to both.

I argue here for a "functional" understanding of rationality. By this I mean the view that rationality is the principle of being, unity and function for the person; it offers a path by which physicalist understandings of matter may be moderated by non physical factors. Without such an understanding of rationality there seems to be no possibility of a dialogue between physicalism and metaphysics. Once rationality is dismissed as a physically dependent element in the constitution of the person, there would appear to be no longer any room for human freedom. The notion of an emergent freedom ultimately appears self contradictory, grounded as it is in physical laws.

We have seen that rationality, ultimately, is not simply something one does, nor a reflection of physically constitutive parts; it is something of one's very being. Activity follows upon nature; function is a reflection of being. A functional approach therefore readily accommodates the Aristotelian notion of the rational soul as a principle of activity in the entire body. Consider Aristotle's text: "As pupil and sight *are* the eye, so, in our case, soul and body *are* the animal".[1702] A profoundly functional understanding of the soul is proposed; sight for the eye is analogous to rationality for the body. Furthermore, Aquinas considers rationality to be an overarching operative power; an emphasis once again on function as a descriptor of what it means to be and act as a human being.[1703] He noted also (see

[1702] *DA*, 413a.
[1703] *ST*, Ia, Q.48, Art.5.

1.4.1.b) that the soul "perfects each part of the organism"[1704] and that it is "whole in each part".[1705]

It follows that rationality is "functionally integrative". It is indeed helpful to identify functions of the mind in order to discuss structures of thought (see **3.1.3**), but, in discussing, for example, the parts of the human act or notions such as "agent intellect"and "operations of the soul",[1706] we must not obscure the fact that the acting person is the agent, that emotional life intimately enriches personal judgements, and that rightly ordered appetitive responses to pain and pleasure are necessary for sound, embodied, rational choices. It is an affirmation that acquisition of accurate sense data, moderation of emotional response and of reward anticipation are as valuable to the act of thinking rationally as the conclusion itself. A "functionally integrative" view of rationality assists in such synthesis. It is patently faithful to Aristotle and Aquinas but presented in language

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[1704] *ST*, Ia-IIae, Q.22, Art.2, Art.76.8.

[1705] *SCG*, II.72.1485.

[1706] Although beyond the scope of this study, I suggest that it is not helpful from a Christian perspective either to talk of the soul as agent in preference to the embodied soul, or the ensouled body. It is completely compatible with the Christian understanding of the substantiality of the soul, to affirm that, in embodied life, rational expression could be said to be the very task of the animated body. The view that rationality is a fitting operation for neural part-constituents respects the theological principle that grace respects nature. Commentaries, as well as Aquinas himself, write of the soul as agent of various activities, but a close, cross-referenced reading of Thomas always clarifies the understanding that the person, the ensouled body, is the agent. Nevertheless such an emphasis on soul as agent can lead not only to dualist turns of phrase but to dualist ways of thinking. A failure to emphasize the "ensouled body" as agent, can lead to the conclusion that the operations of the soul are independent from the body at least as far as their "intellectual activities" go. Take for example this current metaphysics instructional text:

> It is at this highest point of animal life that intellectual knowledge comes into play in human knowledge. For, it is by the co-working of the imagination (as a cognitive instrument) and the intellectual (abstractive) power of the spiritual soul (as principal agent) that the essential character of the accidental forms expressed in the imagination, reaching to the substantial forms of the things so represented, are opened up, whereby they can be known and understood by the intellect. This abstraction (and illumination) is not the activity of knowledge. It simply puts the forms (by a spiritual impression) into the understanding intellect, which is where the immanent activity of knowledge occurs. This is the beginning of human knowledge as it is intellectual or spiritual. There remains, as all are conscious of, a long and arduous process of intellectual work (reasoning) still to do before any degree of full human knowledge is achieved. This course is part of that work-in progress. (www.cts.org.au accessed 26/10/12).

Note, that for the sake of "clarity" the author is making *soul*, *intellect*, and *abstraction* the subjects of actions. Yet in the process, an impression is created that activities at this level are conducted without the complicity and assistance of the ensouled body. One could almost conclude that association with the body bespeaks an unworthiness for these higher functions.

accessible to contemporary philosophy of mind, familiar with the various currents of functionalism.[1707] (See: **6.4.2.3.c**.)

In confirmation of this, recent work on emotion suggests that emotion has a place in rational decision making.[1708] In a paradigm where function pertains to the acting person such a view presents no problem. In the light of an hylomorphic understanding of animated flesh, an ensouled body, it is reasonable to suggest that the emotional responses and reward apprehensions initiating the human act, provided they are moderated by fortitude and temperance and provided they are in keeping with principles of justice, are themselves *integral* to rationality.

In summary, a functional view of rationality appears better able to engage with contemporary intellectual currents, and it resists any narrowing of the concept of rationality in a way that would undervalue the integral contribution of the body.

b) A response to prevailing physicalism.

Yet materialist conceptions dominate the neuroscience. Larry Squire, author of a standard neuroscience text asserts that all behaviour and all of mental life have their "origin in the structure and function of the nervous system".[1709] Stephen Lyng captures the determinism of contemporary neuroscience in acknowledging the work of Grant Gillett: "Countering the prevailing neurophilosophical view of human action as a product of largely unconscious brain events, Gillett employs his relational model to dispel the notion that free will is only an illusion".[1710]

These materialist conceptions dominate also in contemporary philosophy of mind, perhaps for want of a more closely considered philosophical position. For

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[1707] Although well beyond the scope of this study, I would think also that such language is more accessible to the expectations of analytic philosophy.

[1708] The work of Nussbaum and Damasio has been noted above. Nussbaum, *Upheavals of Thought;* Antonio Damasio, *Descartes' Error.*

[1709] Larry Squire, et al. *Fundamental Neuroscience*, 3rd ed. (Burlington, MA: Elsevier, 2008). Introduction to Section 1.

[1710] Lyng "Brain, body, and society: bioethical reflections on socio-historical neuroscience and neuro-corporeal social science," 25.

example, words from Kandel, dismissive of human freedom, were quoted in **1.3**: "All biological phenomena are properties of matter".[1711] Tellingly he acknowledged only two possible approaches to philosophy of mind: physicalist or dualist. Hylomorphism was completely off his radar.

Contemporary currents in neuroscience seek to account for human freedom either by emergentism, which is a form of non-reductive physicalism, or by dualism. Both appear logically flawed.

Emergentism suggests that non-material realities can emerge from purely material origins. For example, Susan Greenfield argues that the brain is "personalized through a unique and ceaselessly changing configuration of neuronal connections". Yet, ultimately, human freedom cannot exist in a being which is wholly material and therefore determined. Nor is it logical to take refuge in qualia, one's "inner sanctum",[1712] as in some last bastion against materialism. How could qualia escape the determinism of their origins? The emergent views of Joseph LeDoux (**5.2.1.1**), Antonio Damasio (**5.2.1.2**), and Michael Gazzaniga (**5.2.2.2**) seem similarly problematic. [1713] (See **Table 1.1**, and **Appendix 1.**)

Various forms of contemporary dualism and epiphenomenalism deny causality between the real and mental worlds, leave it as unexplained, or resort to fanciful theories. Schwartz, for example, insists that mental events can precede biological events in the brain. [1714] Yet dualism is not a rational option: in its modern forms an immaterial mind controls the body (yet is paradoxically derived from and therefore ultimately dependent upon matter), or two orders of being are

[1711] Kandel et al., *Principles of Neural Science*, 4th edition, 1317.
[1712] Greenfield, *I.D. The Quest for identity in the 21st Century*, 168 and 132.
[1713] Gazzaniga *Who's in charge. Free will and the science of the brain*, 124.
[1714] Schwartz and Begley, *The Mind and the Brain*, 319. "There are no rational grounds for denying that conscious mental effort plays a causal role in the cerebral changes observed in OCD patients." On the one hand Schwartz denies causality as we know it by invoking Quantum theory as an explanation for non-material realities; on the other he enlists causality in asserting that mental events are distinct from physical events: "thinking creates pathways".

proposed without any causal interaction from the mental to the physical.[1715] (See **Table 1.1**)

Hylomorphism has been proposed as the "third way" (**1.4**). Openness to the hylomorphic solution can free neuroscientists from determinism and from dualism. There are indications that both Schwartz and Greenfield would be open to such a resolution as they preserve person as agent, and this agent enjoys a freedom subject to certain physical limitations. In addition, Susan Greenfield (differing from Schwartz) affirms the hylomorphic principle that the mental and the physical are not separate events. Schwartz writes: "There are no rational grounds for denying that conscious mental effort plays a causal role in the cerebral changes observed in OCD patients",[1716] but Susan Greenfield insists that for every thought there is "a physical correlate".[1717] It would appear that neither Schwartz nor Greenfield are, *per se*, committed materialists; simply that, perhaps like Eric Kandel, they had not conceived of a third way and had opted, one for an emergent approach and the other for dualism, for the best theories on offer.[1718] (See further discussion in **Appendix 1**. **e**.)

c) Bridges to contemporary philosophy of mind.

Hylomorphism provides a pathway to reconcile human freedom with the determinism of physical laws. Martha Nussbaum and Grant Gillett are two philosophers in the Aristotelian tradition who have sought to marry hylomorphism with neuroscience. To do so they have emphasised variations on a functionalist approach. These insights are of value to this study.

[1715] We have seen above (**1.5**) the criticisms that highlight the "crypto-cartesianism" of contemporary materialism that posits a matter which appears to be none other than the matter of dualism. Such crypto-cartesian thinking constitutes a further category of dualism.
[1716] Schwartz and Begley, *The Mind and the Brain*, 319.
[1717] Greenfield, *I.D. The Quest for identity in the 21st Century*), 50.
[1718] To take this observation a little further: Greenfield, from a background of neuropharmacology, emphasises the brain chemistry; psychiatrist Schwartz seeks a way to preserve the power of cognitive based therapies. Hylomorphism offers a bridge between the hard sciences and cognitive clinicians.

Nussbaum adopts a functionalist hylomorphic solution in order to answer the materialist philosophies of mind often associated with neuroscience and the substance dualism that is sometimes proposed as an unconvincing response to determinism. Nussbaum champions the work of the functionalist Hillary Putnam as compatible with hylomorphism,[1719] and takes issue with Burnyeat's suggestion that "Aristotle's philosophy of mind is no longer credible because Aristotelian physics is no longer credible".[1720]

She argues that certain contemporary functionalist approaches are indeed Aristotelian. Burnyeat had sought to force a wedge between Aristotle and Putnam by arguing, "the whole point of functionalism is to free our mental life from any particular material setup"[1721]. Nussbaum responds, drawing on the *Metaphysics:*[1722]

> The soul is not an "it" housed in the body but a functional structure in and out of matter. Matter is, in its very nature, just the thing to constitute the functions of life (it is not a thing to which these functions of life can be reduced). [1723]

She concludes, "As Aristotelians we do not discover something behind something else, a hidden reality behind the complex unity that we see and are. We find what we are in the appearances. And Aristotle tells us that if we attend properly to the appearances the dualists' questions never get going." [1724]

> It is not appropriate to inquire whether the soul and the body are one – just as it is not appropriate in the case of wax and its shape, and in general the matter of each thing and that of

[1719] See especially Martha Nussbaum and Hilary Putnam, "Changing Aristotle's mind" in *Essays on Aristotle's De Anima*, ed. Martha Nussbaum and Amelie Oksenberg Rorty (Oxford: Clarendon, 1992), 27-56. This compendium of essays contains further useful sources.
[1720] M. F. Burnyeat, "Is an Aristotelian Philosophy of Mind still credible (A draft)" in *Essays on Aristotle's De Anima*, ed. Martha Nussbaum and Amelie Oksenberg Rorty (Oxford: Clarendon, 1992), 15-26. Quotation from p16.
[1721] M. F. Burnyeat, "Is an Aristotelian Philosophy of Mind still credible (A draft)," 16.
[1722] "Some things are just are this or in this, or these parts ordered in such and such a way.' *M,* 1036b22ff.
[1723] Martha Nussbaum and Hilary Putnam, "Changing Aristotle's mind," 56.
[1724] Martha Nussbaum and Hilary Putnam, "Changing Aristotle's mind," 56.

> which it is the matter.... If you attend in the appropriate way to the complex materiality of living things, if you understand the common conception of what it is to be a living thing, you will not ask that question.[1725]

Whilst Nussbaum does not enter discussion about neural substrates, she (as also John Haldane, noted in **Chapter 1**) establishes an hylomorphic response to the mind-body problem, and reaffirms authoritatively that discussion of a biophysical substrate for mental activity is indeed valid within a Aristotelian-Thomistic approach.

A recent paper by Grant Gillett also presents a modified hylomorphic understanding of human beings in which, he writes, “both matter and form (or body and subjectivity) are important”.[1726] In assessing the ethics of psychosurgery, Gillett suggests that form is “not just a configuration of matter but a holistic, subjective, relational and embodied reality: the person who exists in our midst as a being-in-the-world-with-others”.[1727]

He takes Aristotle’s dictum “If the eye were an animal, then the sight would be its soul” and develops a multifaceted view of the soul that “involves” relatedness with others, “an identity that evolves over time”, “a stream of conscious experience”, and a moral standing as a socially situated agent whose life story is lived out and elaborated among (others)”.[1728] In particular, he rejects a focus on narrow cognitive functions, insisting that the human psyche (the soul) is shaped primarily by interaction with others. In seeking to summarise Aristotle’s view of the soul, he offers five principles, including: that the soul is shaped by life among others, that it is “the expression of patterns of activity laid down in the brain”, and

[1725] DA 412b6-9
[1726] Grant Gillett, “The gold-plated leucotomy standard and deep brain stimulation,” *Bioethical Inquiry* 8, (2011): 35.
[1727] Gillett, “The gold-plated leucotomy standard and deep brain stimulation,” 35.
[1728] Gillett, “The gold-plated leucotomy standard and deep brain stimulation,” 35.

that it is a “unique, interactional configuration of brain function shaped by a segment of the human life world.” [1729]

While it is in keeping with Aristotle’s view of the embodied soul that the soul is, while not exclusively, “the expression of patterns of activity laid down in the brain”, it does seem open to misinterpretation to describe the soul as “interactional brain function”. Surely Aristotle, in discussing the soul, would have us focus on the functions of the embodied person rather on functions of the brain alone. For Aristotle, a human brain without a human soul is inconceivable. It is the soul which gives the brain its meaning, not vice versa. I think rationally because of my soul; the soul must not be reduced to intellectual activity let alone to brain function.

However Gillett’s emphasis on the interactional, and therefore the functional, as essential to the definition of the human psyche, provides us with a rich line of eudaimonistic exploration, building the case for the essential distinction that necessitates the virtue of justice, and integrating that virtue into a vision for human flourishing.

A functionalist approach is also found in Mario Beauregard who defines mind not as substance but as a collection of mental processes and events.[1730] In effect this opens the door to the existence of an underlying substance or person, but without attempting any metaphysical explanation of the assertion. The merit of Nussbaum’s and Gillett’s functionalist paradigm stands out clearly when one compares their approach with that of Jeffrey Schwartz, the “non-materialist UCLA neuropsychiatrist”[1731] who, as we have seen, argues that minds change brains. Without a functional, non-reductive emphasis, efforts to accommodate human

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[1729] Gillett, “The gold-plated leucotomy standard and deep brain stimulation,” 36.
[1730] Beauregard and O’Leary, *The Spiritual Brain. A Neuroscientist’s Case for the Existence of the Soul*, 315.
[1731] Beauregard and O’Leary, *The Spiritual Brain. A Neuroscientist’s Case for the Existence of the Soul*, xiii

freedom by arguing that the non-material substance of the mind acts on the material substance of the brain, must drift towards the substance dualism.

d) Conclusions.

The hylomorphic solution provides the subtle philosophical conception of reality that is required for logical consistency. We have seen that the soul, rather than a substance in its own right,[1732] must be the principle of being and function of the subject. Furthermore, as this principle of rationality may not be derived from matter it must in some way be received. There are no other options.

This "principle-received", neither derived from matter nor a substance in its own right, must be a sharing in some manner or other. As Martha Nussbaum has said, we must attend carefully to the "complex materiality of things". [1733] The answers are all there. In Thomistic terms, this sharing is a participation in the being of God; it is participation in perfect "act" (refer to **1.4.1.a**), participation in the being of God himself. The evidence of human freedom leads inexorably to the conclusion that the soul is a gift of functional participation in the divine act of being. (See **Appendix 1. A Response the Claims of Emergent Rationality**.)

Only a "received" rational principle can explain both rationality and the necessary unity of the subject. Only perfect "act" can offer the possibility of such "functional" participation. The conclusions extend beyond neuroscience, yet I suggest they provide the only possible path forward to provide a philosophy of mind that is rationally satisfying.

Functionalist explanations therefore appear to demonstrate convincingly how the "return to form"[1734] advocated by Haldane can marry with neuroscientific

[1732] Notwithstanding the term "substantial form" applied to the soul (**1.4.1),** I refer to the soul in the embodied life as not a "substance in its own right". I suggest that the term "substantial form" offers a glimpse into the dignity of participated rationality, personhood.
[1733] Martha Nussbaum and Hilary Putnam, "Changing Aristotle's mind," 56.
[1734] Haldane, "A return to form in the philosophy of mind".

evidence that would otherwise appear deterministic. Of course it is not only Nussbaum and Gillett who are focussed on function. It is Aristotle himself who argues for the necessity of four virtues on the basis of the four appetitive *functions* they perform. Observation of function leads to metaphysical conclusions. Aristotle is the original functionalist.[1735]

6.4.3 Advantages of a virtue based approach to ethics over consequentialist and deontological approaches.

I have argued that the understanding of virtue is more in keeping with the complexity of human nature itself. According to the Aristotelian-Thomistic notion of virtue, virtue possesses both sensitive (exclusively biological) and rational dimensions. Aristotle and Aquinas propose that sense memory, imagination and appetite, and processes such as imitation and habit development, are in complex interplay with the knowing and choosing which are inherent in all fully human action. I have argued that the contribution of these various processes in accord with what is for the good of the subject, are supported at the biophysical level. Virtue, so long regarded as essential component of human flourishing in the philosophical tradition of Aristotle and Aquinas, is now demonstrably so by the findings of contemporary neuroscience.

On this basis it is possible to argue for the superiority of a virtue based paradigm evaluating human behaviour. Virtue ethics stands in contrast with rule and duty based ethical systems and consequentialist approaches, all of which are theory based and give little significance to human experience and to an anthropology where rationality and matter are intrinsically integrated (see also **1.6**).[1736] These approaches find less support in the neuroscience: as ethical systems they are learned and applied cognitively, whereas virtue development is acquired principally by profound experiential modification of the organism itself. In short, it

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[1735] Dermot Moran ed., *The Routledge Companion to Twentieth Century Philosophy*, (Abingdon: Routledge, 2008), 977. “It is often said that Aristotle is the founder of functionalism because of his view that the function of an entity determines its form.”
[1736] For this reason, Robert Louden writes of virtue ethics as “anti-theory”.

would appear that virtue based development best accords with a view of man where bodily development is integral to his very nature.[1737] Along this line a strong inductive case may be mounted in support of a rich, virtue-based, moral development of the person, and such an inductive case is necessarily strengthened by the identification of physical bases for virtue.

6.4.3.1 A contemporary validation of virtue ethics in the light of neuroscientific evidence.

I noted in **1.7** that contemporary accounts of moral behaviour fall broadly into consequentialist, deontological or virtue based approaches. In **3.1.5** an analysis was offered demonstrating that virtue ethics appears superior to consequentialist and deontological paradigms in accounting for the behaviour of Takashi Nagai.

A number of arguments were offered. There is an undeniable causality operating, present in Nagai's own worldview and born out in his actions over a substantial period of his life, demonstrating that actions effectively flow from settled states of character. Furthermore, there is a striking correspondence between specific behaviours (eg the role of passion and deliberation, the presence of intrinsic motivation, and the evidence of happiness subsequent to virtuous action) predicted by virtue theory and Nagai's own self description of moral actions. It is evident too that virtue theory offers the capacity to accommodate the human freedom and rationality that are apparent aspects of human nature. These qualities of the virtue based account contrast with the apparent inability for rule based and consequentialist paradigms to account for Nagai's behaviour.

It is hoped that a biological validation of virtue ethics will serve to focus moral education on virtue development, heightening the political, popular and clinical

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[1737] Casebeer, "Moral cognition and its neural constituents," 844. Casebeer notes the experience based nature of virtue development, "It is a practice affair". He suggests that althought "moral reasoning and action are "whole psychology, whole brain' affairs", the neurobiology of a Kantian position would have a frontal emphasis in Kant, and a pre-frontal, limbic and sensory emphasis in Mill, but would be the "properly coordinated action of all" in Aristotelian approaches.

recognition of the role of virtues in moral development. It will also serve to publicise in neuroscientific circles the possibilities of an hylomorphic anthropology, focussing on the human person, and permitting an analysis of human action that embraces the rational.

We have seen that the focus accorded by the Templeton Foundation, and the clinical work of Seligman and Peterson. (**1.2.3.1** and **6.2.2.2**) [1738] promise a contemporary neuroscientific *validation* of virtue based approaches. Also, a biological validation of virtue ethics would be a significant contribution to the burgeoning field of neuroethics, a field exhibiting a most diverse and at times contradictory range of views, from the physicalist perspectives typified by Neil Levy[1739] to Darcia Narvaez's defence of moral education.[1740] Physical evidence for the neural bases underpinning the development and acquisition of virtue, based on an hylomorphic understanding of the human person, would be a significant challenge to purely physicalist approaches. It would offer a way forward for an enriched scientific view of the human being.[1741]

6.4.3.2 Understandings of neurobiology assist the discipline of virtue ethics.

[1738] Seligman and Peterson, *Character Strengths and Virtues*. See also: Martin Seligman, *Authentic Happiness* (NY: Free Press, 2002).

[1739] Neil Levy, *Neuroethics* (Cambridge: Cambridge University Press, 2007).

[1740] Darcia Narvaez, "Human Flourishing and Moral Development: Cognitive and Neurobiological Perspectives of Virtue Development" in *Handbook of Moral and Character Education*, ed. L. P. Nucci and D. Narvaez (NY: Routledge, 2008).

[1741] If moral virtues are essentially neural structures established ultimately at the promptings of reason (one's own or one's parents'), what are "infused virtues"? This thought experiment is appropriate here and it sheds light on the nature of moral virtue and the importance of truth and moral conviction as prerequisites for virtue. Infused virtue is a form of virtue that comes as a divine gift. (cf Aquinas, *Disputed Questions on Virtue*, Q.1, a.10.) It seems unlikely however that infused virtues have a neural signature: this would require a miraculous biophysical reconfiguration. Furthermore, the theological understanding of infused virtue is that without good will to exercise the infused virtue there can be no apparent effect; this would not be the case were there a neural presence which must deliver some degree of permanent impact on behaviour. Therefore it would appear that, just as moral virtue disposes for particular actions, infused virtues are graces that also dispose for particular actions. They appear to be the promise that stable, actual graces will be available to assist the person to act in specific positive ways and so build up the actual moral virtues. I propose that these graces consist essentially in an infused enlightenment; a clear perception of a truth. For example, infused justice may consist in such a conviction that all men and women are brothers and sisters to me. Antonio Malo accorded with my view of this in a personal discussion in July 2012.

This study has the potential to clarify apparent imprecisions in contemporary writing in virtue ethics.

In much contemporary writing in virtue ethics itself, discussion of virtue as a form of habit seems largely unexplored. One finds virtue defined or described in terminology such as "dispositions of responsiveness" and "the expression of fine inner states",[1742] "being well endowed with respect to the agent's actions, desires, and emotions"[1743], "powerful and enduring concern"[1744] "substantive dispositions to choose what is right".[1745] These approaches, while admittedly not seeking neurobiological precision, lack the benefit of insights that neurobiological studies can provide. Outside of the discipline of virtue ethics, the range of understandings of the term virtue drifts further from a conception of virtue as the spectrum of positive habitual behaviours: Rawls, for example, defines virtues relatively narrowly as "strong and normally effective desires to act on the basic principles of right".[1746] A neurobiology of virtue will assist in standardising approaches by anchoring definitions in physical reality.

A neurobiological lens on the notion of virtue offers the possibility of a deeper appreciation of:

i. The processes and pathways for habitual management of emotion, demonstrating that they fall in the trajectory of human maturation, and are not a line of development merely parallel to impulse challenged personalities.
ii. The distinction between habits, on the one hand, and on the other, less neurobiologically precise terms such as states, enduring concerns, and normally effective desires. These latter suggest phenomena rather than stable features of personality that are demonstrably established and

[1742] Swanton, *Virtue Ethics: A Pluralistic View*, 5.
[1743] Rosalind Hursthouse as presented by Swanton, *Virtue Ethics: A Pluralistic View*, 94.
[1744] Philippa Foote as presented by Swanton, *Virtue Ethics: A Pluralistic View*, 94. Cf Philippa Foote, *Virtues and Vices*, (Berkeley: University of California Press, 1978).
[1745] Statman, "Introduction to Virtue Ethics," 49. Statman presents this a the moderately pluralistic view held by certain virtue ethicists.
[1746] Rawls, *A theory of justice*, 436.

enduring, and are oriented towards action through the integration and consolidation of neural pathways for emotional and reward oriented responses, moderated by brain systems performing tasks of emotional management and goal election.

iii. The neurobiological attentional processes which we utilise for directing our concentration which are arguably implicated in the neural systems for will and choice. An understanding of these systems can facilitate greater self awareness and consequent greater self management, as well as more effective cognitive therapies.

6.4.4 Fine tuning the hylomorphic approach.

This study also presents an opportunity to refine explanations of Aristotelian-Thomistic psychology, allowing it to engage more effectively with contemporary neuroscience. Just as the Copernican revolution changed understanding without changing the philosophical essentials of cosmology, so too, accommodating the new evidence, it is possible that there can be insights into traditional understandings of reason, virtue, vice, etc.

Although the notion of person as an ensouled body is extremely well developed philosophically, there is little written from the Aristotelian perspective (we have looked at two notable exceptions in Nussbaum and Gillett) that considers how the lens of neuroscience can assist Aristotelian philosophy and illuminate aspects of rational psychology, embodied rationality, and the very notion of fulfilment itself. Reflections on the nature of, and fulfilment for, embodied rationality can provide a valuable contribute to this field.

I have suggested that a study of neuroscience in the light of hylomorphism throws into relief several key principles:

i. The importance of a view of the soul as principle of being and function. As we have seen, this is a view of rationality highlighted by Putnam and Nussbaum in the 1990s in response to physicalist theories.

ii. A view that the unity of the virtues is a biological necessity.

iii. An understanding of vice, not as a parallel alternative to virtue, but as a privation of biophysical development.

iv. The possibilities for a language, accessible to neuroscience and to contemporary philosophy of mind, better able to explain the tenets of hylomorphism. (cf discussion in **6.4.2.3.a**.)

There are further observations that can be made.

An understanding of the human biophysical constitution leads to a deeper appreciation of the trajectory of human maturation, and of what is required for human beings to flourish. Modification of the biophysical that is implicit to the Thomistic account is "fleshed out" so to speak, and in so doing implications become evident. For example, the need for enriched Aristotelian notions of human flourishing becomes apparent: the interplay of neural structures and human freedom necessitates the Thomistic development of "participation in being".[1747] And in turn this leads to a further argument for the objective basis of human flourishing: we know ourselves as sharers, participants, in rational life, and know moreover that our greatest fulfilment is in accepting the invitation to seek truth, and to respond to that Loving One who invites us to share being. (See **6.4.2.3.d** and especially **Appendix 1. A Response the Claims of Emergent Rationality**.)

An understanding of neural involvement in mind function must lead to a deeper appreciation, in accord with basic hylomorphic tenets, that knowing and loving can only take place in this embodied life with the biophysical as material cause.

[1747] "St. Thomas...grasped from the very beginning the theoretical significance of the opposition between Plato and Aristotle and the absolute need to overcome it by bringing their fundamental principles and conclusions into agreement. This he did by elaborating his own notion of participation. This notion, in contrast with the Neoplatonic concordism, presents an entirely new concept and principle: it is the concept of *esse* as *actus essendi*, not to be confused with the *existentia* of Augustinianism and of rationalism. It is from the concept of *esse* as ground-laying first act that Thomas develops his own notion of participation and his entire metaphysics." Cornelio Fabro, "The Intensive Hermeneutics of Thomistic Philosophy: The Notion of Participation," *Review of Metaphysics* 27, (1974): 451-457.

Every action and every choice dispose us either for, or away from, excellence in knowledge and love. The vision of man that has been proposed is complex. The human being is understood as a person, an embodied soul, an animated body, with rational powers, and therefore fulfilled not only by sense knowledge and pleasure, nutrition and security, and movement and emotional life, but also by activities in the rational order of knowing truth and choosing, and ultimately by the free gift of self in loving relationships.[1748]

An understanding of neural involvement in mind function has the potential to clarify Aristotelian/Thomistic notions of the nature of intellectual life itself. For example, should we distinguish, on their biophysical characteristics, the *deliberations* that lead to rational outcomes from the rational insights and choices themselves? Clearly deliberations of reason, underpinning what we could call the "process" of the human act, manifest a biological substrate. They have duration, they involve brain areas for attention, for reward apprehension, for cognitive and emotional memory, for assessment of consequences, for issuing commands, etc. Yet it is clear, too, that even the instantaneous events of grasping a truth, and making a choice, are biology dependent; at the most elementary level, for example, there can be no conviction of truth or choosing of goods in this life without consciousness. Yet even the very moment of flash of insight into the nature of things or the very moment of choice (and the inner life of the person cannot reduce to just these moments) will nevertheless be accompanied by neural correlates- not only accompanying emotional surges and heightened attention, but neural activity directly associated with the knowing and the choosing.

[1748] Scruton argues that unhappiness is driven by lack of truth and lack of relation to others; ultimately perhaps by a lack of virtues of sincerity, compassion, and generosity. Roger Scruton, "Connecting Catholic Anthropology to a Secular Culture," *Edification* 3, 1 (2009): 80-82. Scuton writes: "I think particularly of the need to persuade people that one of the principal causes of unhappiness in modern societies is the 'self delusion', about which Vitz (1994) has written in other terms: the delusion that what I truly am is this inner thing that is hidden from the world, and that my happiness consists in nurturing it and taking from others what is needed to supply it with its needs. That delusion is the opposite of the truth. Happiness comes from forgetting the self; from thinking of others; from seeking to give and not to take – and that idea, which is of course contained in the doctrine of Christian charity, can be phrased in secular terms that make it immediately apparent to the ordinary agnostic that therapy based in the Christian faith might be exactly what people suffering from the self delusion require."

Strictly speaking the operations of the embodied intellect are the capacity to grasp the true nature of things, and the choice to move oneself towards what one has grasped as a good.

Within the flesh and blood human being it is absurd to suggest two acting substances. In a psychologically balanced human being there should be no wrestle for agency between the operations of rationality and the activities of the body, notwithstanding our excursion into psychopathologies which demonstrated that, when the body is not functioning as it should, the pathologies may drive behaviour rather than the agent himself. Operations of rationality are carried out in the ensouled body, on this count *capax* for intellectual activity; the soul is a principle of function and unity, not a separate functioning agent.

And what then of the human capacity to abstract from the concrete to universals? Was this not Aristotle's proof for the immateriality of the soul? Surely abstraction to universals takes place beyond the reach of matter? No again. The wrong question is being asked. Rather we should ask: What is special about human beings empowering them to see the truth of things? It is the person that acts: an animated body capable of abstracting to universals, of seeing the truth of things and of seeking unreservedly that which, or that whom, it perceives as good for itself. Hence we see that reflections on the biophysical constitution of human beings have the potential to clarify perhaps popular misconceptions about Aristotelian and Thomistic thought.

6.5 Pedagogical conclusions

In **1.7.1** it was suggested that virtue ethics is superior to other paradigms of ethics in its understanding of the principles of education. It offers three clear advantages.

i. At the most fundamental level, the focus of virtue ethics is on the qualities of the agent rather than his actions; it offers a more incisive understanding of education because it is empowering of the agent. Ultimately, a virtue based view of education emphasises the primacy of formation of character, what we could call the “sacred” formation of character.

ii. Virtue is a more effective model for moral and skills development because it is experience based and thus takes into account the anatomical realities of plastic change as a result of experience. All that we choose to do, all that we consent to experience, all that we enshrine as desires in our hearts, all that we elect as convictions in our minds – all these things sculpt our personalities. Every experience has the potential to change us, to consolidate ways of acting and thinking. This sacred and exquisite sensitivity to experience is well captured in a passage by Mitch Albom:

> All parents damage their children. It cannot be helped. Youth, like pristine glass absorbs the prints of its handlers. Some parents smudge, others crack, a few shatter childhoods completely into little jagged pieces, beyond repair.[1749]

iii. There is a grand interplay between the emotional and cognitive realms; the underpinning educational psychology presents a harmony between emotion and reason. Emotions guide us in selecting the experiences that we know will change us. Sound emotional responses help us make sense of the environment, responding with appetency or rejection. Temperance and fortitude may be understood as acquired emotional responses to the environment; to be nurtured in a child through training, and when complemented by prudence and justice bestowing self management experiences and environment.

6.5.1 Ineffective moral pedagogies.

The report card for moral education initiatives, at least in the USA, is less than flattering. In 2010 the results of a major study of *Social and Character*

[1749] Mitch Albom, *The five people you meet in Heaven,* (London: Little Brown Book Group, 2004).

Development (SACD) programs were released. The study found that SACD programs produced *no* improvement against control schools on measures of emotional and social competence, nor in behaviour or academic performance.[1750]

This need for a coherent framework upon which to structure character education programs is also apparent from a 2011 *Science* review of intervention programs to improve executive function (designated as a range of personal qualities summarised by "creativity, flexibility, self control, and discipline"[1751] and therefore including what we have discussed as emotion regulation). The authors assessed a range of current programs. In response, I make the following observations:

i. The variation between the character education approaches was substantial: computerised and other games based training for working memory, speed and reasoning, aerobic exercises, martial arts, meditation, role play games, Montessori culture, heightened expectations and reinforcement for behaviour, and conscious training in self control strategies.
ii. The variations however were the result of intuitive, rather than analytically argued, lines of investigation. The programs offered broad alignment with the view that emotional regulation and repeated practice must lie at the basis of effective approaches.
iii. Interventions, except for the Montessori program and, to some extent, the PACT program which teaches self control strategies, did not place an explicit priority on respect for others, ie the virtue of justice.
iv. Interventions generally did not seek to empower students in *conscious* self management, even though this is a *sine qua non* of adult self regulation and necessary for skills of personal assessment and refined goal setting. In general there was a lack of appreciation that the virtues disposing for

[1750] The Institute of Education Sciences, U.S. Department of Education, "Efficacy of Schoolwide Programs to Promote Social and Character Development and Reduce Problem Behavior in Elementary School Children", October 2010, http://ies.ed.gov/ncer/pubs/20112001/pdf/20112001.pdf.
[1751] A. Diamond and K. Lee, "Interventions shown to aid executive function development in children 4-12 years old," *Science* 333, (2011): 959-964.

rationality would be crucial in personal goal setting, and therefore in ensuring transfer of skills.

v. In the design of the programs, there appeared little appreciation of the neural bases for attention, personal goal setting for arduous tasks.

vi. The ineffectiveness of the programs appears to reflect the lack of comprehensive rationale behind them. Gains were modest at best, and mostly manifested at the lower performance end of the scale. In most cases there was a low level of transfer of skills learned to tasks beyond the immediate exercise, "Executive function training appears to transfer, but the transfer is narrow."

Kevin Ryan, founder and Professor Emeritus of the Center for the Advancement of Ethics and Character at Boston University, ascribes this undeniable failure to the poor understanding, by designers of programs, of what constitutes human character and human flourishing, and a public policy that emphasises the role of the state over that of the family.[1752]

These worrying conclusions suggest that important insights for moral and character education and intervention programs may be gleaned from this study into the neural bases of virtue. Design of improved programs, although beyond the scope of this study, should incorporate the systematic anthropology that has underpinned this study:

i. Parental efforts require all support and facilitation.

ii. The programs must be designed on the basis of a rich psychological understanding of the developing person, endowed with a range of specific powers (intellect, rational appetite, sensitive and irascible appetites) each requiring nurture.

iii. Appreciation of the unity of the virtues must be an essential element. Programs must seek the integrated development of sound judgement, respect for others, resolution in the face of difficulties, and self control.

[1752] Kevin Ryan, "The failure of modern character education," prepublication draft in personal correspondence, 2 November, 2012.

iv. In particular considerations of justice and habits of cognitive assessment must be present in all human acts, if young persons are to be empowered to set goals effectively.

6.5.2 Insights from the neuroscience.

In the section that follows, I restrict discussion to insights that may be gained from a study of the neural bases of virtue, although these insights will have wider pedagogical application, for example, into the design of teaching programs or in guiding one's own children.

a) Principles of plasticity.

i. We have noted the Hebbian principle. <u>Neural electrical activity</u> builds more permanent connections. Consequently it is clear that both our conscious and unconscious thoughts and behaviours are self reinforcing; they effectively change our brain by synaptic strengthening along specific neural pathways, facilitating like thoughts and behaviours that utilize these pathways. (See extensive references to use-induced plasticity, especially **2.2**.)

ii. <u>Vivid experience</u> is shown to be linked to learning. It is human experience that novel, sense laden and dramatic experiences (for example war, sex, drugs, loud music, first exposure to something truly surprising) are not only indelibly etched in memory, but also that this retention of vivid experience is more easily revisited, acquiring a certain addictive quality (for example studies show that pornography "changes our brains",[1753] or of the phenomenon of

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[1753] Judith A. Reisman, "The psychopharmacology of pictorial pornography restructuring brain, mind and memory and subverting freedom of speech," (http://www.drjudithreisman.com/archives/brain.pdf; accessed March 2009).
G. J. Meerkerk, et al., "Predicting compulsive Internet use: it's all about sex!" *Cyberpsychology and Behaviour* 9, 1 (2006): 95-103; Patrick F. Fagan, "The effects of pornography on individuals, marriage, family and community," in *Research Synthesis*, Family Research Council, (December 2009). In the last document note testimony about pornography addiction by Mary Anne Layden of Centre for Cognitive Therapy, University of Pennsylvania (Testimony for US Senate Committee on Commerce, Science and Transportation, 18 November, 2004).

soldiers seeking repeated tours of duty, or of the addictive behaviour of serial killers). [1754]

iii. Emotional engagement has been shown to be closely linked to learning, to the development of new pathways in the brain. (**Table 2.2**)

b) Habit formation as learning.

i. Consolidation of learning normally requires repetition and takes place over time. Therefore it may be concluded that material processes are involved and that neural configurations and connections are facilitating the learning process. People who exhibit virtues (such as cheerfulness, self control, or courage), or vices (such as dishonesty, laziness, or insincerity) exhibit these behaviours repeatedly… character traits exhibit stability and are sound predictors of future behaviour. A neuroscientific understanding is that ease of repetition suggests established circuitry. Ease of repetition suggests an established pathway in the brain, and so too an inability to retain flexibility is a sign of an established pathway. (See **2.2**, **2.4** and **3.3.4.**)

ii. The repetition required in learning and unlearning is arduous. This is found for example in the application of mental discipline to build up some desired capability – in the time it takes to build up intellectual habits such as planning ahead and problem solving, habits of emotional management of anger or appetite, or even intentionally performed motor skills such as a tennis forehand. That it is arduous to develop habits suggests also a material process where patience is required but eventually is rewarded.

iii. There are windows for learning that correspond to developmental stages in the biological make up of the human being. Windows of opportunity that are age related, and the intractability of

[1754] See discussion: Difede and Cukor, "Evidence-Based Long-Term Treatment of Mental Health Consequences of Disaste among Adults," 336-339.

behaviours outside of those windows, despite all good intentions to change them, bespeak a material physiological foundation for learning. There is a timeline of development for the human organism; there are windows of opportunity, sensitive periods, for the development of various capacities. These windows of development embrace not only the development of sensory powers (such as sight and hearing), but also mechanisms of emotional expression, and of emotional management, virtues. (See **Table 2.2**.)

iv. It is recognized that <u>first experiences are particularly powerful</u> in the development of neural pathways. The neural basis for this appears associated with the principle that guides sensitive periods of development: reception of appropriate experience closes off the sensitive period. (See **2.2.4**) The applicability of this phenomenon to parenting is immediately apparent.

v. <u>Concomitant physical activity</u> has been shown to be associated with increased capacity to form new connections and to learn.

c) Pathways of habit formation.

i. <u>Habits also short circuit the need for cognitive processing</u>; take for example the action of a touch typist who has no need to reflect on each key stroke. (**Table 2.7**.)

ii. At the moral level, <u>habit formation may be positive (virtues) or negative (vices)</u>. Such habits can seem virtually “hardwired” and be very difficult to change, with simple intentions insufficient; we see people with such good intentions, but unable to put their desires into action. Emotion driven behaviours take up residence and become the default behaviours; another dynamic is at work suggesting a more permanent change has taken place in the organism. Repetition builds habits and dependency upon those habits; for example, established sleeping and eating patterns can be hard to break, just as pattern of poor self control can also be resistant to efforts to change.(**Table 2.7**) But also, when good habits are embodied, these learned, emotionally attuned, positive behaviours will carry us through periods of tiredness, illness or stress.[1755]

iii. The mechanisms of synaptic modification and modulation of transmission provide an excellent explanation not only for the construction of habits but for habits of varying intensity. (**Tables 2.3**, **2.4**, **2.5** and **2.15**.)

iv. The popular adage reminds us, 'The best predictor of future behaviour is past behaviour'. Thought and behaviour are closely interconnected; past behaviours fuel our expectations, goal setting, and action plans. Habitual behaviours fuel our thoughts; behaviours very much make us who we are. (**Table 2.14**.)

d) Principles of memory.

i. Certain thinking and acting processes include a physical component: we see that some memories can be affected by time, either diminishing in intensity, or actually become more vivid as we obsessively "rewrite" them focusing on specific perceptions. Again, these phenomena are consistent with changes at the neural level. (**Tables 2.3**, **2.4** and **2.5.**)

ii. Dementia also gives us insight into the material mechanisms of memory. A person, suffering from the neural degeneration that characterises dementia, can lose memories or reaccess memories dormant for decades in the subconscious. This suggests that memories are tied very much to material mechanisms, mechanisms now increasingly well described. (**Table 2.5**.)

[1755] An example: a friend explains that he returned exhausted from an overseas trip, and "failing to keep his mouth shut", found himself in a destructive, domestic argument that led to a decision to leave the marriage. The same man, 30 minutes later, still tired but drawing on established humility and sincerity, found the strength and self control to make his apologies and turn around a potentially tragic situation.

e) Principles of imitation.

i. The experience of imitation leads directly to learning without the necessity of cognitive involvement. It will be seen that imitation is a key factor in the acquisition of behaviours underpinning virtue. The relevance to parenting and the moral education of younger children is immediately apparent. (**Table 2.6**.)

ii. An understanding of the function of mirror neurons offers heightened appreciation of the mechanisms whereby our own experience, including sense experience, profoundly dyes our behaviours. For example, one who has not experienced love, will be unable to put love into his actions. (**Table 2.6**.)

f) Interplay between emotion and learning.

i. Emotions are demonstrably bodily functions; yet the chemical messages at the heart of appetite, desire and passion, can initiate processes that conclude in more or less free choices.[1756] (**Tables 2.8 and 2.11**.)

ii. It is shown that the emotional centres of the brain, in particular the amygdala, are richly connected via the limbic pathways both to the PFC and to the BG, and play a key role in the generation of habitual behaviours. This study proposes that these areas, among others, are substantially implicated in the acquisition of virtues. (**Tables 2.8** and **2.13**.)

g) Healthy body; healthy mind.

i. Damage to the PFC leads to compromise of what are normally regarded as moral behaviours. This outcome is consistent with poor moral choices under analogous situations when the biology has been compromised, for example in moments of utter exhaustion,

[1756] US pro-life activist, Terri Herring, cites scriptural references to Christ “moved by compassion”, and argues that human beings can draw the energy to act from attention to, and reflection on, appropriate emotional stimuli. (Oral presentation at Redfield College, Sydney, 2004.)

under extreme stress, in dementia, etc. It would appear that learned, emotion-driven, negative behaviours can surface when inhibitory decision making is impeded. (See **2.7**.)

6.5.3 Parenting conclusions

If neuroscientific knowledge confirms the role of virtue in human flourishing it is all the more imperative that we refocus on the necessity of positive input in the lives of impressionable children, that we help parents maximise their effectiveness by sound neuroscientific insights, that we shield children from negative inputs that have the potential to profoundly change them for life, and that we actively promote the development of personality underpinned by habitual strengths of character.

A biological validation of virtue based moral education carries far reaching implications at theoretical and practical levels. Virtue ethics in the tradition of Aristotle and Aquinas itself receives validation as an ethical system most suited to human flourishing. The model of human flourishing that, prior to some decades ago, underpinned character education in the West for two and a half millennia, is revalidated.

There is currently much confusion in educational circles about the importance that should be given to virtue development in moral education. Some would replace virtues with *values*, failing to understand that good intentions while important are far from being good habits. Others use the terminology of values and virtues, sometimes remarkably interchangeably,[1757] yet because they fail to ground virtue in what befits man's nature, they cannot escape a relativistic framework.[1758] Others resort to fragmented suggestions of varied worth without a

[1757] This appears to be a fault in the much publicized *The Book of Virtues* by the former US Secretary for Education: William Bennett, *The Book of Virtues* (Melbourne: Bookman Press, 1994).
[1758] The National Values Framework created by the Howard Government in 2004, seemingly founded on consequentialist and relativist approaches to virtue ethics, appears to be inspired by these approaches.

foundation in an adequate understanding of man.[1759] A relatively small proportion of parenting authors do adopt a virtue building approach. Notable are Thomas Lickona[1760], James Stenson[1761], and Stephen Covey[1762] in the USA, Donald De Marco[1763] in Canada, and David Isaacs[1764] in Europe. *Parenting for Character* also features a virtue-based rationale.[1765] This current study offers a scientific justification for the practical strategies found in these works. It provides an evidence-based verification of the approach these authors take; and this is a necessity if virtue-based moral education is to gain traction in contemporary society.

The neuroscientific evidence supports parenting approaches that foster the development of virtue. I argue that this study in fact confirms virtue development as a scientifically sound approach to moral development. It is an urgent task to identify neuroscientific insights that assist parenting. This is beyond the scope of this current study, however below I briefly identify parenting practices which, in the light of current neuroscience, would serve to facilitate children's moral development.

Furthermore, it is hoped that this project may contribute to a popular reassessment of the importance of virtue in moral education and parenting. Despite the fact that virtue ethics is a dynamic field of philosophical study with an enduring presence also in moral theology,[1766] and despite the fact that for some two and a half thousand years the development of virtue has been regarded in the

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[1759] For example, Steve Biddulph's writing appears to lack an adequate underpinning psychology.
[1760] Thomas Lickona, *Character Matters: How to Help Our Children Develop Good Judgment, Integrity, and Other Essential Virtues* (New York: Simon and Schuster, 2004) is one of Dr Lickona's more recent works.
[1761] James B. Stenson, *Upbringing: A Handbook for Parents of Young Children* (New York: Scepter, 1992).
[1762] Stephen Covey, *The 7 Habits of Highly Effective Families* (New York: Allen & Unwin, 1997).
[1763] Donald DeMarco, *The Heart of Virtue* (San Francisco: Ignatius, 1996).
[1764] David Isaacs, *Character Building: A guide for parents and teachers,* 2nd ed. (Dublin: Four Courts Press, 2001).
[1765] Andrew Mullins, *Parenting for Character* (Sydney: Finch Publishing, 2005).
[1766] For example: Peter Kreeft, *Back to Virtue; Traditional Moral Wisdom for Modern Moral Confusion* (San Francisco: Ignatius Press,1986); Pieper, *The Four Cardinal Virtues* ; Pius XI, *On the Christian Education of Youth* (Encyclical, 1929).

West as the foundation for moral education, virtue is now much misunderstood and marginalised in both public policy and in contemporary writing on parenting.

6.5.3.1 Applications to parenting

The goal of the morally educative dimension of parenting is to foster the sound capacity for reflection and action facilitated by the virtues. Maturity of character and the freedom to act autonomously result from the development of virtue.
A parenting model consistent with the neuroscience presents strategies for fostering virtues, and for the management with meticulous care of inputs entering into the life of the child. It is so right that parents focus on habits, manifest behaviours, that help a child develop a healthy autonomy with inbuilt safeguards against physical and psychological compulsion by external forces, but also empowering them to avoid debilitating internal faults of laziness, self centredness, timidity, etc.

Environment and experience are decisive in development of character. The parent-child relationship, founded on mechanisms of bonding, fueled by parental care and affection, and conducted in an atmosphere where selfless service between family members is the norm, provides a natural venue for moral growth.

Elements of a parenting model consistent with the neuroscience include:

i. Acknowledgement that parental responsibility for the formation of moral character in an impressionable child includes decisive guidance in the early years in development of fortitude and temperance, and in the years when rationality becomes active in the child, of prudence and justice. Environment, critical practice, explicit advice and correction all contribute.
ii. Acknowledgement of the role of early training in teaching moderation according to reason of what is pleasurable and what pains are worth enduring for a sound reason. Parental facial expressions and body language are beneficial or corrosive. As the child grows, obedience to

parental reason in these matters transfers to obedience to their own reason. Parental guidance gives way to self education and self-talk.

iii. Attention to the quality of parent child habitual interaction and communication as a prerequisite for moral learning.

iv. Acknowledgement that early exposure to what is good, true and beautiful is beneficial. A consequent appreciation of the urgency of proactive parenting.

v. Expertise in identifying incipient patterns of behaviour, both positive and negative, in children, and readiness to intervene in the case of negative patterns that can lead to bad habits and, with complacency, to vices.

vi. Management of non parental inputs coming into the life of the child such as technologies and peer group. Expertise in identifying, evaluating, and if necessary intervening in response to, character traits apparent in those with whom the child spends time. Parents are facing a great deal of competition in raising their children, competition from peer group, from media, from bad example of role models in society. If they do not manage those inputs and actively build good habits their children will suffer.

vii. The role of high but realistic parental expectations allowing a child to strive for behaviours that are achievable and enriching. The importance of accountability for those expectations.

viii. A conviction that human beings need to focus not only on their own needs, and that it is virtues that dispose us to good deeds. Good intentions are not enough. Children without virtue lack the wherewithal to do good in their lives. The end point of all parenting is that young people act well and freely from their own dearly cherished convictions. So, the essential challenge in teenage years is to help a young person internalize the values they have learned. Good values must lead to a good heart, to habitually good choices, and to self management. "It is no profit to have learnt well, if we neglect to do well," wrote Publilius Syrus sometime during the 1st century BC. Virtues give habits of acting[1767]. Furthermore, virtues enable a person to take responsibility in a democratic society. Virtues affirm the concept of personal responsibility... that in normal circumstances, I am responsible for what I do, or for what I have decided. A society which denies personal responsibility will be doomed to mediocrity and then to decline.

ix. Strategies for the formation of good habits through consistent expectations, imitation and repetition, correction, guided practice, reflection, and reinforcement of recent experiences given that the common experience of human beings is that they can more readily repeat recent actions than those further in the past. [1768]

x. Responsibility for a positive home environment. An understanding of the role of habitual parental affection, specific emotional reinforcement, praise, positive emotional associations, emotional engagement, etc, in learning and the development of virtue. An understanding that parental emotion is "contagious".

xi. An understanding that focused attention is required for cognitive learning.

xii. An understanding that non cognitive learning leading to imitation of behaviours and emotional states can be sub cognitive.

xiii. An understanding that strategies such as visualisations and rehearsal of physical actions assist in building virtues; thought facilitates behaviour, and behaviour can facilitate intention.

xiv. An understanding of virtues, brings an appreciation of the debilitating effects of bad habits, vices. "A young person's character is like wax for the growth of bad habits,"[1769] observed the old Roman soldier poet Horace.

xv. Appreciation that the family is the natural environment *par excellence* for fostering virtue. Virtues are best learned in a family, where an overriding

[1767] The Dale Carnegie saying, "If you want to be enthusiastic, act enthusiastic" suggests a subtle dynamic between modeling actions and incorporating them fully into our personality. This is another version of the A.A. motto: "Fake it till you make it."
[1768] Joel Kupperman insists on the importance of "longitudinal close looks at the reality of human lives" through history, stories and biographical studies. His book *Character* contains a very useful appendix of strategies for moral education. J. Kupperman, *Character* (Oxford: OUP, 1995).
[1769] Horace, *Letters* "To the Pisos", 153.

motivation is the welfare of the other members. In such an environment the motive for action is love. In the family, love is unconditional; a failure to exercise virtue is corrected. Institutions can also assist in fostering virtue, provided the culture is right: respect for others; high but realistic expectations; a positive philosophy of education where mistakes are part of the process of learning and problems are not disasters because they bring the underlying cause into relief so that it can be addressed.

xvi. Recognition for the virtually indelible nature of first experiences and their role in maximizing learning. Habits are most easily formed in childhood.[1770] First impressions can be virtually indelible: "We are by nature most tenacious of childish impressions...further it is the worst impressions that are most durable."[1771] Because, as Aristotle observed, "We (human beings) always like best whatever we first experience" parents do well to put great care into the early experiences of children and focus on habits built in the younger years. Experts talk of windows of opportunity for building particular virtues[1772]; a child who has not learned the importance of truthfulness by the middle of primary school, at the latest, is likely to have real difficulties in facing reality, etc.

xvii. Acknowledgement of the need to pass on to children an understanding of rational anthropology, including an understanding of the integration of rationality and emotional life, what virtues are, how they are acquired, and the role of virtue in human flourishing.

xviii. An understanding of virtues makes parenting much more effective. Parents become much more aware of the need to establish good habits, to provide consistent routines, to follow up misbehaviour before it becomes entrenched, to help a child work against temperamental weaknesses such as timidity, impulsivity, etc.

[1770] Bennett, *The Book of Virtues.*

[1771] Quintilian, *Institutio Oratoria,* trans. HE Butler (Loeb Classical Library). (Cambridge MA: Harvard University Press, 1920), I, I, 1-7.

[1772] Professor David Isaacs displays a chart in his *Character Building* which shows the most appropriate virtues to focus on in the various stages of childhood.

xix. Commitment to meticulous parental example. A necessary consequence of this priority is that parents themselves strive to develop virtues in their own character and to eliminate bad habits. Of the two forms of virtue formation – training and education in childhood, or free, conscious, self imposed, perhaps arduous, habit formation in adult life – the second applies to parents. When parents grasp also that their own parenting comes down to a collection of habits… good and bad, they can then improve their parenting practices more easily. It is important for parents to identify their own character defects and mistakes in order to minimize negative example. A parent's poor relationship, a habit of over-management, unresolved dependencies on drugs and alcohol, experience of abuse, etc, have the potential to wreak intergenerational havoc. Unless parents strive for virtue, they will not pass on a love for virtue as a source and prerequisite of fulfilment. Key parental virtues include:

- Sincerity about the deepest values that underpin one's behaviours.
- Sound judgement. Consistent and clear headed prioritizing.
- Generosity: loving dedication to one's spouse and family, and a capacity to model solidarity and compassion for those in need.
- Fortitude and self control: a demandingness on oneself. John Paul II said of his own father, "He never had to be demanding on me, he was so demanding on himself."
- The virtues of humility, human warmth and approachability, and the capacity to show affection and understand others.

xx. Understanding of strategies parents may employ to change their own behaviours may include:

- The necessity of sincere acknowledgement of mistakes.
- The necessity of reflective sorrow for impulsive or self centred behaviours – sorrow and shame will act subliminally as disincentives for the repetition of negative future behaviours.
- The role of making realistic commitments in order to put changes in train (eg structured anger management programs, monitored action plans on paper).

- Readiness to accept the support of others, including one's spouse, in order to change one's behaviour.
- Appreciation of constant performance of targeted concrete actions such as getting up on time, eating the right foods, carrying out acts of service to others, smiling when tired, etc, thereby overlaying old habits with new preferred behaviours.

xxi. Appreciation of the ultimate goal of parenting for virtue, that children develop:

- The capacity to manage themselves – "Children have the right to learn how to solve their own problems in life."[1773] This refers to the virtue of prudence.
- Readiness to care for others – "Children grow up when they are able to care for others, and want to."[1774] Here I refer to the virtue of justice, underpinning charity. Augustine says that charity contains all the cardinal virtues.[1775] The capacity to truly love others is a consequence of character with a well rounded development of virtues. Virtues make love possible.[1776]

xxii. An appreciation of the following neurobiological insights:

- A basic understanding of virtues (see **3.2**) includes a taxonomy of moral virtue though an schema such as that of the cardinal virtues.
- The priority of the cardinal virtues as essential character strengths.
- We like best what we first experience. We can be easily attracted to what we have already experienced. We have a natural fondness for the familiar.
- All our behaviours are essentially self reinforcing, for better or for worse according to the law of association. "Neurons that fire together wire together."

[1773] This gem comes from the late Rafael Pich, father of sixteen, and driving force behind the Family Education movement in Catalonia.
[1774] Jim Stenson.
[1775] Augustine, *Epistles* CLXVII PL33 738.
[1776] DeMarco, *The Heart of Virtue.*

- Time can resolve many issues; passions can dissipate. Remove oneself from the situation; don't raise the emotional stakes, take time to reflect, etc.
- The law of attenuation, "Use it or lose it", also sometimes applies to things we have learned, and to abilities and skills. If we do not practise them we lose the facility.
- When we give our attention, we learn.
- Where we provide emotional reinforcement we facilitate learning.
- An appreciation of the relationship between virtue formation, autonomy and self management, and human flourishing.
- An understanding of the processes of emotional control and of formation of habits (including habits of mind under the umbrella of prudence).
- Mastery of the range of strategies for virtue formation (see **3.3**).

6.6 The last word.

This study commenced with a quotation from Mary Shelley's *Frankenstein*. Notwithstanding its ghoulish spawn over almost two centuries, the tale stands as a moral and metaphysical reflection on human existence. The creature asks:

> "Who was I? What was I? Whence did I come? What was
> my destination? These questions continually recurred,…
> but I was unable to solve them"[1777]

Much more than a gothic thriller, *Frankenstein* is a warning that science must know its boundaries. It is also a reminder, from the youngest of women, that while knowledge may bestow power, power must be exercised responsibly within objective limits. Our rationality is grandly disproportionate to the nerves and sinews which compose us. She reminds us too, in the tragic denoument of the tale, of the stark contrast between human flourishing and its grim alternatives.

[1777] Mary Shelley, *Frankenstein; or, The Modern Prometheus*, The Pennsylvania Electronic Edition, ed. Stuaart Curran, (http://knarf.english.upenn.edu/index.html; accessed 28 November 2012) 128.

Einstein wrote, “Everything must be made as simple as possible. But not simpler.” It is the very stuff of a corporeal existence to appreciate that a whole is made of parts. I have explored the detail, not to get lost amongst the dendritic trees, but to better appreciate the wood as a whole. In describing the biophysical basis and developmental pathways for virtue, I have endeavoured to show that if we step back from the complexity of the pathways and processes and multiplicity of systems and brain areas that are involved, a grand picture emerges of a state of being that offers heightened autonomy, functional efficiency, and affective and contemplative peace of heart, true *eudaimonia*.

After first identifying characteristics of virtue in a close reading of Aristotelian and Thomistic texts, supported by analysis of the human act and real life scenarios, I proposed specific and identifiable neural elements underpinning these characteristics. I suggested that they are integral to, and necessary conditions for, the formation of virtue in the embodied life. I have described them as the material causes of virtue. In the process, I proposed distinct biophysical part-constituents for each of the cardinal virtues arguing that each virtue plays a necessary role in every virtuous human action.

I have proposed that the state of virtue is demonstrably a state of systemic and neural maturity, essentially an apogee of neurobiological development. It is a state of grand coordination and integration of neural systems, directed primarily to the harmonisation of the emotional and cognitive domains and thus, at the service of personal fulfilment.

We must not miss the wood for the trees. Most importantly, not only is virtue a disposition for good action, but human beings have a disposition to virtue itself. There is an evident, genetic predisposition in human beings to the development of virtue. Aristotle touches on this when he writes:

> There are three things which make a man good and virtuous: these are nature, habit, rational principle; these must be in harmony with one another. [1778]

To be virtuous is of our very "nature". By "habit" Aristotle refers to dispositions of the sensitive appetites that we have developed, or allowed to develop, in our characters.[1779] Aristotle links the harmony intrinsic to *eudaimonia* with the training of the appetites and free rational choices. Such elevated physical development of an organism is inconceivable without specific biological predispositions at the genetic level. Our characters are the outcome of nature (genes), nurture (upbringing) and our own choices.

The virtuous person is thus endowed with a capacity for self-realisation, a key to his flourishing. The development of virtue, provided we do not frustrate the process by wayward appetitive habituation, consists in rational choices resulting in the development of certain stable neural structures to which we are predisposed. In turn these stable neural structures support ongoing rational behaviours. There is a grand efficiency operating; one's progress is not thwarted by occasional mistakes. This optimisation of past efforts contributes to a sense of fulfilment even during the acquisition stage of virtue.[1780] Repeated good acts, over time, build up a stability of virtue. "To him who has, more will be given."

The dispositions of mature virtue guide us along the pathways of calm self-management, bestowing peace in the face of difficulties and self-control in the face of temptation or provocation. Think of Nagai. Virtue directly facilitates rationality, by disposing us to accept reality and act well by freeing us from unreasonable attachments to pleasure and from unreasonable fears. Such an

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[1778] Aristotle, *Politics*, 1332a39. "The rational principle" refers to the principle of rationality and free choice;

[1779] According to Sherman's understanding of habit as "non-rational training of desires towards appropriate objects", habit then refers to the trained sensible desires, biophysical pathways. Nancy Sherman, "The Habituation of Character" in *Aristotle's Ethics* ed. Nancy Sherman (New York: Rowman and Littlefield, 1999), 231.

[1780] Add to this the reality that habits acquired during the sensitive period of childhood may be reactivated after lying dormant for years more easily than if they had to be established from scratch.

outcome is dependent both on actual development of the biological pathways and on rational choices to act in ways disposed by those pathways.

The ramifications of this study are significant. Most importantly science itself is now seen to validate the notion of virtue and fulfilment through virtue. Science demonstrates that *eudaimonia* is dependent upon the development of specific neurobiological qualities that are experience dependent in a dynamic process whereby positive behaviours predispose to increased facility for action and greater reward. The virtuous man is empowered to flourish: "In this life, nothing is more precious than the virtues."[1781]

And as a corollary, I argue that the alternative approaches to ethics, according to deontological and consequentialist notions, are manifestly inferior to the rich account of affective, functional and teleological fulfilment implicit in the eudaimonist virtue based paradigm. Embodied reality trumps theory every time. Our diligent response to the neural dispositions of our bodies makes for our happiness in the deepest sense. Robert Browning captured this:

> "All good things
> Are ours, nor soul helps flesh more
> Now, than flesh helps soul."[1782]

Philosophy of mind requires a return to the notions of form and being. I am convinced that it is realistically possible to articulate hylomorphic and Thomistic arguments able to better engage with contemporary philosophy of mind. Such arguments will be grounded in direct observation of reality, offering an appreciation of contingency and participation in being, an enriched understanding of causality, and avoid the unnecessary misunderstandings that can arise in response to the concept of subsistent soul.

[1781] St Thomas Aquinas, *Meditations for Lent*, trans. Philip Hughes (London: Sheed and Ward, 1935), Passion Wednesday.
[1782] Robert Browning, "Rabbi Ben Ezra"

Noting the current confusion in the field of moral pedagogy, I have touched but briefly on the potential for this study to offer clarity of methodology to pedagogy and parenting. Extensive repercussions for public policy, for research into further specification of the neural bases, and formulation of psychological applications in education and counselling remain largely implicit.

It is my hope that this study assists in a rediscovery of virtue as an intrinsic necessity for moral development, happiness and abiding peace of heart. On this note of intrinsic fulfilment I finish. I offer the final word to Antonio Damasio who for two decades has been at the forefront of neuroscientific explorations of cortical management of emotion, an articulate advocate for the importance of a rich human emotional life and an opponent of dualistic understandings that would deny a physical correlate to mental events or the possibility of an integration of rationality and human passion.

> Happiness is the power to be free of the tyranny of negative emotions. Happiness is not a reward for virtue: it is virtue itself.[1783]

[1783] Damasio, *Looking for Spinoza*, 175.

Appendicies

Appendix 1

A Response to the Claims of Emergent Rationality by Non-reductive Materialism.[1784]

a) Non reductive materialism asks the wrong question.

The advocates of emergence pose the questions "What is a human being?" and "How did human beings become like this?" Both questions focus on the assumption that the central questions are essential rather than existential.

The emergent approach adopts a scientific method and therefore takes existence as a given. But human existence is demonstrably contingent so we cannot dodge the existential question.

Therefore these questions are mistakenly framed. They ought to ask "What is a human being?" and "In what way do human beings have existence?" The first question is essential; the second existential.

b) "What is a human being?"

The advocates of emergence presuppose that human rationality is on a continuum of development with the intelligence of animals. Yet the more evident the gap between human beings and the highest animals, the more difficult it is to accept the non-reductive materialist presupposition.[1785] We do well to listen to Martha Nussbaum's advice to attend carefully "to the complex materiality of living things." [1786] Human rationality is of a patently different order to the intelligence of

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[1784] This non reductive materialist position is compatible with a belief in a theistic creation. Theistic, non reductive, materialism asserts nevertheless that all that man is now, including his existing now, comes to him by an evolutionary pathway.

[1785] In conversation with me in October 2012 Tim Chappell agreed with this. Chappell holds a theistic, non-reductive, materialist position.

[1786] Martha Nussbaum and Hilary Putnam, "Changing Aristotle's mind," 56.

animals and it appears unscientific to support the view that human rationality emerges from matter.

We human beings know ourselves and understand the world in which we find ourselves because of our capacity to know universal ideas and reason with them. We can both act in the world and stand above that world. Our agency is of a different order to the limited freedom that animals enjoy; our choices can be motivated by intangibles. We can respond to what is not immediate and sensible; no animal has this capacity. Moreover our capacity to find fulfilment in idealistic dedication to another is not instinctual but a choice. In a similar way, our capacity to fulfil the will of another is not the result of training alone but of training and choice. We are our own masters. This phenomenon is without parallel in the animal world.

It is sometimes argued that our capacity for language is a sophisticated development of the language of animals, that our capacity for communication reached a tipping point and that human development from that point forwards accelerated. Yet the gulf between animals and humans remains, and even if the bridge were crossed, the apparent contingency of our being creates a further and insuperable challenge.

c) "In what way do human beings have existence?"

All that we see around us is contingent. Contingent things cannot be self explanatory so how is it that they exist? How is it that they come into existence and are sustained in existence?

It is a very different thing to ask how a planet was made, from asking for an explanation of how a planet has existence. To focus just on how things *became* can miss the significance of the fact of current existence. Contingency requires an abiding existential causality.

Contingent living things seem to be a further category of existent, [1787] but human life appears to be of another order all together. Aristotle argued that the human capacity for knowledge and for love based on informed choice bespeaks a dimension in human nature of non-materiality.

Rationality can neither be possessed by matter nor be bestowed by matter. Both would be dualistic solutions failing to explain the profound unity in human nature. Therefore the only alternative is that human nature participates in a principle of being. Aristotle called this the “rational principle”. There can be no other solution. Aquinas concluded that this non-materiality consists in a personal, abiding, participation in rational life. Human beings enjoy a personal, rational identity, something that matter cannot bestow.

The inevitable conclusion is that human participation in being is of a different order to that of animals. Human beings have the capacity to understand their world, and at the same time, to stand above it, to seek fulfilment in elective, loving relationships with other rational beings. Rationality transcends the material world. It can neither be derived from it nor find fulfilment in the merely material.

Our capacity for rational life, to make love-choices about what we know, characterises the very being in which we share. Again apply the Martha Nussbaum principle of close observation of reality. Because we share in this capacity to love, inescapably we must conclude that we have been created by a personal being who knows and loves us, and furthermore that, with our abiding participation in rational life, we are invited to respond to this Loving One.

As our principle of rational identity is not derived from matter, it would appear that we transcend death although how this will happen is unclear. Aristotle suggested that the soul is immortal but that man loses his personal identity after

[1787] Nevertheless there seems to be no rational objection to the statement that vegetative and non-human animate life are emergent from matter.

death. Aquinas however concluded that this individuated, rational participation continues after decomposition of the body.

The view that we participate in being should not be understand as an artificial construct, an inadequate model that raises more questions than it answers. It seems clear that neither an emergent solution nor a dual substance solution provide satisfactory answers. The big question of existence may be answered only by close attention to reality. [1788] (See also **5.4.2.3**.)

d) The question of fulfilment.

There is a third question that must be asked: "What fulfils human beings?"

The answer to this question must be utterly different depending on whether one just asks essential questions, or whether one asks also the existential question.

Advocates of emergent rationality who ask the essential questions define human beings as free agents, able to know themselves, to know the world, and to choose *whatever* course is preferred. The emergent view *bestows* purpose on life. It is difficult, from this position, to demonstrate an objective purpose in life.

But if we answer the existential question we *discover* the purpose in life by knowing ourselves to share in the life of one who knows and loves us. This is an acceptance of the truth of participated being, a recognition that one cannot be fulfilled in isolation, and that one is fulfilled by the use of rationality to know and love other persons, first of all in knowing and loving the Loving One in whose being one shares and to whom one owes one's all.[1789]

[1788] Martha Nussbaum and Hilary Putnam, "Changing Aristotle's mind," 56.

[1789] This view underpins the philosophical writing of Benedict XVI."Our nature is constituted not only by matter but also by spirit and as such is endowed with transcendental meaning and aspiration." Benedict XVI, *Charity in Truth* (original title: *Caritas in Veritate*), (San Francisco: Ignatius, 2005), 48.

In the Aristotelian and Thomistic understanding, virtue is a necessary means to objective wellbeing. The personal excellence of virtue is ordered to fulfilment in personal love. When fulfilment is framed in purely subjective terms, when relationships with other persons becomes an optional extra and unabashed self interest a viable alternative, there can be little room for virtue.

e) Why has the existential question been neglected?

I argue that the existential answer is the most important answer of all. If so much hinges on correctly framing and answering the existential question then the current debate in philosophy of mind must rediscover the existential question. It is essential to identify issues which cloud the discussion. I suggest causes for neglect of the existential question, and the seeds of its reemphasis, lie in the following:

- Aquinas, writing for another age where the Pauline vision of participated existence "in him we live and move and have our being"[1790] was not questioned, gave great emphasis to the soul even in the embodied state. Perhaps this was because primarily he was writing theology, and so gave importance to man's transcendence of the material world, and to personal responsibility for one's soul. Nevertheless, emphasis on soul as an entity in itself rather than as a principle of participation in rational life, has served to mask Aquinas's doctrine of participation and has possibly contributed to a widespread misunderstanding of the notion of form.
- Kant argued that existence is not a property: "Being is evidently not a real predicate, that is, a conception of something which is added to the conception of some other thing."[1791] This has dissuaded philosophers from engaging with the question of existence, yet Kant fails to consider contingence as such, as well as notions of being and participated being.

[1790] Acts 17:28.

[1791] I. Kant, *The Critique of Pure Reason, Chapter 12.* He states, "All our knowledge of existence belongs entirely to the sphere of experience."

[1792] He appears to consider whether being can be considered a quality of a substance but is silent on being as the principle of existence.

- In contemporary analytical circles there has been a Wittgensteinian bias against metaphysics. The simple logic that underpins the conclusion of participated being must be affirmed.
- Certain teachings of Aquinas have been misinterpreted by his commentators. At times English translations have not helped either.[1793] Only in recent decades have modern commentators rediscovered the primacy of existence in Aquinas, emphasised his doctrine of participation, and given recognition to the Platonic sources of much of his thought. [1794]
- In major sectors of the fragmented, contemporary, Christian world there is a distrust of philosophy in the service of faith: Orthodox theology was bypassed by the insights of Aquinas, and the reformers in emphasising faith unintentionally contributed to a distrust of human reason. Philosophers have failed to recognise that participation in existence is a crucial underpinning for an anthropology accommodating Christian belief.
- Modern philosophy has largely bypassed the existential question caught up with the pressing challenges of idealism, materialism, and dualism.
- The growth of scientism has opened the door to a non critical acceptance of physicalist constraints of thought.[1795]
- Physicalist solutions dominate in contemporary neuroscience and evolutionary biology.

[1792] Roger Scruton writes, "I always have trouble with the concept of being (being tempted by Kant's view that it is not a concept) and so these Thomistic arguments don't always spark off assent in me. However, I do agree that there is a problem about accounting for rationality and the general difference between man and the other animals, and that in the end we need some kind of teleological metaphysics to make sense of our condition." Personal correspondence, 3 November 2012.

[1793] For example, *esse* was often translated in works of Jacques Maritain as "existence" rather than "act of existence".

[1794] Note for example, the rediscovery of *The primacy of existence in Thomas Aquinas* by Dominic Banez (1528-1604), and the work of Etienne Gilson in *Being and some philosophers*, (Toronto, 1952), of Cornelio Fabro in *La nozione metafisica di partecipazione secondo S. Tommaso d'Aquino* (Milan, 1939), and A. Little in *The Platonic Heritage of Thomism* (Dublin, 1949).

[1795] Scientism: a term used by John Paul II denoting the naïve confidence in the capacities of science.

- Some have accepted the emergent view as compatible with Christianity. For example, readings of the Christian scriptures can seem to support emergence. For example, Adam received the “breath of life”, but Eve received Adam’s rib. This suggests to some that God kickstarted a process that biology has now taken over. This line of thought misses the fact that *all* existence is by participation. Man’s participation in rational life is that principle whereby he exists in the here and now; wholly material substances also enjoy an abiding participation in existence. Man differs from rocks in that his form, his principle of existence, being rational, is therefore substantial in itself. But we don’t need to go there in this discussion.

Appendix 2

A brief introduction to neuroscientific concepts and terminology.

The **nervous system** is structurally comprised of the *central nervous system* (CNS) and the *peripheral nervous system* (PNS). [1796] Our focus is principally on the CNS although sensorimotor and autonomic communication utilises also the PNS. Afferent messaging is from sensory organs and receptors. Efferent information is outgoing from the CNS.

An **anatomic division of the brain**: cerebrum, the limbic system, the diencephalon (thalamus and hypothalamus), cerebellum, brain stem, and reticular activating system.[1797]

A **functional division of the CNS** into seven main parts:

- The spinal cord.
- The medulla oblongata (the area of the brain stem, the coordinating centre for vital autonomic functions such as digestion, breathing, and heart rate immediately at the top of the cord).
- The pons (also in the brain stem and sitting above the medulla oblongata) involved in movement management.
- The cerebellum involved in movement and motor skills.
- The midbrain (third part of the brain stem) which manages many sensory and motor functions.
- The diencephalon (containing thalamus, which links cerebral cortex to the CNS, and the hypothalamus). This area is the regulator for autonomic, endocrine and visceral function.

[1796] A highly readable introductory overview of the nervous system may be found in: Carter, *The Brain Book*. A concise overview for professionals may be found in: Crossman and Neary, Neuroanatomy. An illustrated colour text. For an introduction to the anatomy and physiology of the brain: Swanson, “Basic plan of the nervous system”.

[1797] Anne M. R. Agur and Arthur S. Dalley II, *Grant’s Atlas of Anatomy*, 12th ed. (Philadelphia: Wolters Kluwer, 2009) provides an excellent introduction to anatomy of the head (7.1 – 7.83) and of the brain (7.84-7.96).

- The cerebral hemispheres consists of an outer layer, the cortex, and three deeper structures, namely the *basal ganglia* (BG) which have a key role in motor activity, the hippocampus which is the centre for memory and the amygdaloid nuclei which have a key role in emotional response.[1798]

Neurons are the basic structural and functional units, the cellular building blocks, of the nervous system. The human brain features some 100 billion neurons and an estimated 100 trillion axonal connections between neurons.

Neurons are interconnected, bioelectrically active, highly polarised, communication cells;[1799] they are highly specialised conductors with an extremely high ratio of surface area to volume, most advantageous for receiving and transmitting stimuli.[1800] Typically they have highly developed and active secretory pathways that play a decisive role acting intra and extracellularly at the **synapse**, the zone of connection between pre- and postsynaptic neurons. The **synaptic gap** is the space between the neurons at this point of junction.

Groups of neurons, or their processes, may be grouped together in the PNS into cordlike bundles commonly called **nerves**. Also clumps of neuronal cell bodies, **ganglia,** are found especially around the spinal cord and in the CNS, within the brain.

Neurons have **principal components**:[1801]

- **Cell** body including **nucleus** and various cytoplasmic organelles. The cell cytoskeleton features **microtubules, microfilaments** (short filaments some 100x diameter in length).[1802]

[1798] Marieb and Hoehn, *Human anatomy and physiology*, 8th ed., 431.
[1799] See Hof, et al., “Cellular components of nervous tissue,” Chapter 3.For detail concerning patterns of individual neuronal circuitry.
[1800] Siegal and Sapru, *Essential neuroscience*, Section II, provides a well structured account of the neuron, its characteristics and function.
[1801] For an introduction to cellular neuroscience: Hof, et al., “Cellular components of nervous tissue,” Chapter 3.

- D**endrites.** For each neuron there are multiple dendrites (additional processes from nerve cell body) which receive synaptic contacts from other neurons. These have complex branching, the **dendritic tree**, and sometimes, on the branches, multiple short protrusions, **spines.** These **neurite outgrowths** have the effect of increasing dendritic surface area. Usually excitatory contacts are located on spines when they are present. They have a role in regulation of neurochemical events related to transmission, and are capable of local synthesis of proteins.
- A**xon**. Normally each neuron has one *axon* although that axon may itself develop branches. The axon is the process of the neuron that connects with and facilitates transmission to the dendritic positioned synapses on target neurons. In comparison with the cell body proper, the axon can be of great length. The axon connects to cell body via **axon hillock**, where an **action potential**, or charge, is generated.

Neurons are highly differentiated throughout the various regions of the brain. They are commonly classified by:

- Function.
- Location.
- The type of chemical neurotransmitter that they synthesise and release.
- Their shape. For example, according to a morphological description of the cell itself (chandelier, double bouquet, bipolar), or according to the shape of their dendritic tree.

In addition to neurons, nervous tissue contains **neuroglia**, cells which, outnumbering neurons perhaps ten to one, support, functionally assist, and bind neurons together to other neurons. Neuroglial cells are grouped into microglia and microglia. Macroglia are most commonly **astrocytes** which provide metabolic support and remove excess neurotransmitter secretions, and **oligodendrocytes** (in

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[1802] Jenkins et al., *Anatomy and Physiology*, 2nd ed, 72-73.

CNS), and **Schwann Cells** (in PNS), both of which synthesise myelin and wrap themselves around axons, in a process known as **myelination**.[1803 1804]

Messaging in the nervous system is via specialised nerve impulse conduction from neuron to neuron. **Neural conduction** requires both chemical and electrical messaging.

- **Communication between neural cells** is most commonly by chemical messaging at the synapse. Each synapse consists of the presynaptic element (on the axon), a cleft or physical gap between cells, and the postsynaptic element (on dendrite). The active secretory pathways of the synapse, releasing quanta of neurotransmitter, are a key to the function of the neuron. Synapses and junctions have localised gatherings of tiny organelles, synaptic vesicles, with roles in transmitter storage. Synaptic vesicles are typically refilled with locally produced neurotransmitter (eg small molecules of *acetylcholine* (ACh), amino acids such as glutamate) and reused locally to the synapse.
- Chemical messaging received across the synapse opens **ion channels** into and out of the cell. Typically there are proteins for the takeup, recycling and restorage of previously released transmitter molecules.[1805]
- After initial inflow of Na^+, further voltage gated Na^+ channels are triggered causing a massive influx of Na^+ ions and local depolarisation. For a few thousandths of a second Na^+ enters freely, and if a threshold is reached, an electrochemical pulse is generated known as an **action potential.** Depolarisation activates K^+ channels and gradually the system resets. The electrical impulse carries the length of the cell, and produces a further **synaptic output** via the axon, ie chemical messaging to dendrites of proximate cells. Specifically, it is the rapid increase in Na^+ followed by the slower efflux of K^+ which generates action potentials. Currents of Na^+ are

[1803] Hof, et al., "Cellular components of nervous tissue," Chapter 3.
[1804] Saladin, *Anatomy and Physiology*, 6th ed., 448.
[1805] Tortora and Derrickson, *Principles of Anatomy and Physiology*, 11th ed., 73-76.

pronounced and transient, whereas the K^+ currents are sustained and gradual; this differential in time generates the action potential.[1806] At **Nodes of Ranvier,** which occur at approximately every 1mm on peripheral nerves, there is a high density of Na^+ channels causing **saltatory conduction** whereby the electrical impulses jump from node to node and are effectively generated almost simultaneously along length of neurons.

- Coinciding with an action potential, **Ca^{2+} second messenger mechanisms** may be triggered within the cell, internally messaging to the nucleus and effecting genetic transcription and structural changes at the synapse itself. This is one mechanism by which **use dependent pathways** are established, and helping to explain at the neural level how experience and environment leave a lasting biological footprint.

Neurons may be classified by their **electrophysiological characteristics**. These classes admit to rough groupings. There are regular firing cells, generating successive action potentials one spike at a time. This can be associated with the phenomenon of decreasing frequency over time, known as spike frequency adaptation. Also there are cells that generate rhythmic bursts of action potentials usually through activation of Ca^{2+} currents. There are cells characterised by short duration action potentials (<1ms) discharging at high frequencies (>300Hz), and there are cells that spontaneously generate action potentials at slower frequencies (1-10 Hz). These are especially associated with neurons releasing neuromodulatory transmitters such as ACh, norepinephrine, serotonin, histamine.[1807] It will be seen that some of these variants are associated with effecting structural and functional changes at the synapse.

There are some dozen classical **neurotransmitters** and dozens of neuropeptides that function as transmitters. In addition, there are other unconventional

[1806] This was first documented by Overton in 1902.
[1807] McCormick, "Membrane potential and action potential," Chapter 6.

transmitters, essentially any compound that permits messaging from one neuron to another at the synapse.[1808]

Neurotransmitters may be classified **according to molecular structure**: classical, peptides, dissolved gases, and *endocannabinoids* (ECs) [1809] [1810] **or by function** (excitatory or inhibitory).

Neurotransmitters most commonly classified as **classical** are:

- **ACh** which was the first neurotransmitter to be identified. It is a cholinergic neurotransmitter that is released at all neuromuscular junctions stimulating contraction of skeletal muscles. In addition, it is released at all pre- and post- ganglionic parasympathetic neurons as well as all preganglionic sympathetic neurons. Its action is excitatory if binding to a muscarinic receptor and inhibitory if to a *nicotinic receptor* (nAChR).[1811]
- The **biogenic amines** made up of the three catecholamines:
    - ***norepinephrine*** (NE): NE also known as noradrenaline is an adrenergic hormone acting as a vasoconstrictor. Its main function appears to be linked to transmission through the sympathetic nervous system associated with fight and flight.
    - ***dopamine*** (DA): a precursor of NE. It is found concentrated in the basal nuclei, acting in an inhibitory manner on the extrapyramidal system. Dopaminergic neurons project via the mesolimbic pathway to the limbic structures and the *nucleus accumbens* (NAc) in the BG, and via the mesocortical pathway to the cingulate cortex and especially the *orbitomedial prefrontal cortex* (omPFC). DA is produced primarily in the *substantia nigra* (SN) and diffused in cortex with 80% of the DA concentrated in the corpus striatum

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[1808] For an introduction to neurotransmitters and their action: Ariel Y. Deutch and Robert H. Roth, "Neurotransmitters" in Larry Squire, et al., *Fundamental Neuroscience*, 3rd ed. (Burlington, MA: Elsevier, 2008), Chapter 7.
[1809] Bear, *Neuroscience. Exploring the Brain,* 120-121.
[1810] Deutch, Ariel Y, and Roth, Robert H. "Neurotransmitters" Chapter 7 in Squire, Larry et al. *Fundamental Neuroscience*. 3rd ed. Burlington, MA: Elsevier, 2008.p152.
[1811] P. Harris, et al. ed. *Mosby's Dictionary of Medicine* (Sydney: Elsevier, 2006).

(part of the BG). It plays a major role in mechanisms for emotion, motivation and reward.

    - ***epinephrine*** (Epi): Effects are not unlike NE and act upon the hypothalamus, the thalamus, the spinal cord, and the adrenal medulla.

- ***Serotonin*** (5-hydroxytryptamine, or 5-HT): 5-HT can act as a potent vasoconstrictor. In the CNS it acts as a neurotransmitter.
- **Histamine:** A vasodilator. Release is from basophils of the blood, and mast cells of connective tissue.
- Amino acid transmitters such as *γ-Aminobutyric Acid* (**GABA**): GABA is the major inhibitory transmitter in the body, present in 20%- 30% of all CNS synapses.
- **Glutamate** and **aspartate:** These are the major excitatory neurotransmitter in the CNS and responsible for most of the fast synaptic transmission in the mammalian brain;
- **Glycine:** It is the most common inhibitory neurotransmitter in the spinal cord. It is present in inhibitory neurons of the CNS and in retina.
- The **purines**: *adenosine triphosphate* (**ATP**) and adenosine. ATP is the major energy transfer molecule. [1812]

Neurotransmitter speed of action is also relevant. **'Fast' neurotransmitters** are excitatory amino acids (such as glutamate or aspartate) or inhibitory amino acids (such as GABA or glycine), whereas slower acting neurotransmitters (such as DA, NE, and 5-HT) produce longer lasting changes in excitability activating metabolic processes within the post synaptic cells. These longer lasting changes are of relevance to this study. DA, it will be seen, mediates permanent synaptic changes.

In addition to neurotransmitters, there are **neuromodulators,** not necessarily released at the synapse, but affecting the strength of the synaptic transmission,

[1812] Siegal and Sapru, *Essential neuroscience*, Chapter 8, provides a well structured account of neurotransmitters, their characteristics and function.

acting either presynaptically on mechanisms of release, degradation and reuptake of neurotransmitter molecules, or postsynaptically affecting uptake.

Neurotransmitter **receptors** at the synapse are of two types: **ionotropic receptors** containing an ion channel within their own structure; and **metabolic** or **metabotropic**.

Ionotropic receptors are ligand gated (they open or close on receipt of the chemical message of the neurotransmitter molecule, the ligand) and mediate direct opening of the ion channel. Consequently these ion channels carry out very fast transmission of signals, passing from an activated to deactivated state in only 10ms, and have been called “the underlying ‘hard wiring’ of the nervous system.”[1813] This class of receptors includes:[1814]

- the excitatory (depolarising) receptors
    - **nAChR**, the nicotinic ACh receptor for ACh.
    - the receptors for **glutamate**, including the *α-amino-3-hydroxyl-5-methyl-4-isoxazole-propionate* **(AMPA)**, *N-methyl-D-aspartate* (**NMDA)** and kainite receptors.
    - for aspartate.
    - for ATP.
- the inhibitory (hyperpolarising) receptors
    - $GABA_{A,}$ a receptor for **GABA.**
    - the receptor for glycine.
    - the 5HT3 receptor for serotonin.

Metabotropic receptors are neurotransmitter binding sites but not containing an ion channel within their own structure. [1815] In contrast to the activation of ionotropic receptors these receptors allow slower onset, longer duration responses (from a fraction of a second to hours) with a series of enzymatic steps

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[1813] Schulman and Roberts, “Intracellular signaling,” 205.
[1814] Dale Purves, et al., *Neuroscience,* 4th ed. (Sinauer Associates, 2008), 128–33.
[1815] Bear, *Neuroscience. Exploring the Brain,* 157.

involved. Signalling also modulates transcription of genes. Essentially these receptors alter the concentration of intracellular metabolites thereby indirectly gating ion channels. They are of two types:

- *G-protein-coupled-receptors* (**GPCRs**) which include the muscarinic ACh receptor, and receptors that bind the biogenic amines and neuropeptides.
- receptor tyrosine kinases that modulate the activity of ion channels through the activation of **protein phosphorylation** (adding of a phosphate group to the compound) reactions and are responsive to growth and trophic factors affecting development and differentiation of neurons. We will see that trophic factors promote structural changes in the neuronal pathways.

Information processing takes place within the neuron itself.[1816] The neuron has been described as a "complex information processing system".[1817] A neuron may receive multiple excitatory and inhibitory dendritic inputs of modulated intensity. These inputs are altered in time and in intensity to form coded electrical outputs via the single axon. This electrical output is then normally converted at the synapse to chemical messaging pathways, both of an internal second messenger nature, and via the release of neurotransmitters and modulators. The response of the cell includes what could be called *pathways for plasticity*. These include genetically driven anatomical changes at the synapse that profoundly influence subsequent messaging downstream.

[1816] Saladin provides a useful introduction to this topic. Saladin, *Anatomy and Physiology*, 5th ed., 468-9. For more detail: Gordon M. Shepherd, "Electrotonic properties of axons and dendrites" in Larry Squire, et al. *Fundamental Neuroscience*, 3rd ed. (Burlington, MA: Elsevier, 2008), 88.
[1817] Shepherd, "Electrotonic properties of axons and dendrites," 88

Appendix 3

Neuroimaging Technologies

Of great assistance to this current study have been the developments in imaging over recent decades. Better imaging has led to a growing appreciation of:

- The potential for widespread plastic change in the *central nervous system* (CNS), both during development and in maturity.[1818] Much research also has been undertaken into addiction, habits, a more refined understanding of the role of specific pathways and centres in the brain, as well as the genetic, biochemical and electrochemical bases processes.
- The workings of living *sub*cortical elements of the brain. The improved imaging has greatly enriched our understanding not only of the roles of subcortical elements such as the amygdala, the hippocampus, the thalamus, the hypothalamus and the BG, but of their vital contribution to "higher cortical activity".
- The fact that brain processes often utilize numerous regions of the brain simultaneously.
- The intricate interconnectivity of virtually all areas within the brain for complex processing. Sophisticated tracer technologies allow the highly complex neural pathways of the brain to be mapped.
- The great complexity of both subtle and striking effects wrought by chemical and hormonal neuromodulation of brain activity.
- The importance of timing patterns of electrical neural activity.
- Reward, attentional, and emotion regulatory systems of the brain are understood with greater clarity.

[1818] Two popular books standout for the quality of their synthesis and analysis: neuropsychiatrist Jeffrey Schwartz documented his insights into cognitive treatments for patients with obsessive compulsive disorder in his *The Brain and the Mind;* and Norman Doidge, in *The Brain that Changes Itself*, focused almost exclusively on plasticity. His narrative distills amd popularises the insights of current research. Schwartz and Begley, *The Mind and the Brain*. Norman Doidge, *The brain that changes itself* (Melbourne: Scribe, 2008), 95.

Neuroimaging Technologies

Sources: Geake (2009)[1819]; Magristretti (2008)[1820]; Nitsche et al. (2008)[1821]; Sweeney (2009)[1822]; Ziemann et al. (2008)[1823].

Name	Abbreviation	Process	Strengths and applications as a research tool	Limitations	Comments
Computerised axial tomography	CT or CAT scan	Computerised analysis of multiple x-rays.	Great improvement over conventional x-ray imaging.	Safety protocols required in use of x-rays. Shortcomings derive from limitations to resolution and opacity differentials inherent to x ray imaging. Capital costs.	
Positron emission tomography	PET	Measurement of emissions from radioactive trace in blood.	A more direct insight into neural activity with many medical applications.	Short radiation half life restricts design of experiments. Scans do not allow instantaneous study of brain response.	Widely used from late 1970s onwards. Radioactive glucose crosses blood-brain barrier. On metabolisation emits positrons, which produce gamma rays on interaction with electrons.
Magnetic resonance imaging	MRI	Use of strong magnetic field delineates contrasting brain tissue by collection and processing of echoes from	High resolution 3D image. Non invasive. Provides precise structural imagery of the	Unable to demonstrate short term brain activity. Capital costs (a factor in MRI applications in	Originally known as NMR. Rabi awarded Nobel Prize in 1944 for discovery.

[1819] Geake, *The Brain at School*, Chapter 2, “Neuroimaging technologies”: a useful discussion of the features and limitations of current technologies. Geake is both educator and neuroscientist by training.
[1820] Pierre J. Magistretti,“Brain energy metabolism” in Larry Squire, et al. *Fundamental Neuroscience*, 3rd ed. (Burlington, MA: Elsevier, 2008), Chapter 13.
[1821] Nitsche, et al., “Transcranial direct current stimulation: State of the art 2008,” 206-23.
[1822] Michael S. Sweeney, *Brain*. *The Complete Mind* (Washington: NG, 2009).
[1823] Ziemann, et al., “Consensus: Motor cortex plasticity protocols,” 164-182.

		hydrogen atoms in water molecules in the brain.	brain.	general).	
Functional magnetic resonance imaging	fMRI	Obtains a *blood oxygen level dependent* (BOLD) response through measurement of the paramagnetic qualities of deoxygenated haemoglobin.	Allows mapping of brain activity and performance, and insights into function of specific brain areas. Current resolution $1mm^3$. Non invasive.	Owing to sluggish vasculature changes (3-9 seconds typically) scans do not allow instantaneous study of brain response. Capital costs.	Widely used from 1990s onwards.
Voxel based morpho-metry	VBM	Highly processed MRI data.	Allows refined studies of tissue density.	Capital costs.	
Diffusion tensor imaging	DT-MRI	Specialised MRI analysis of neural pathways.	Allows imaging of connectivity maps in the brain.	Capital costs as for other MRI technologies.	Also known as diffusion weighted MRI.
Magnetic resonance spectros-copy	MRS	MRI used to identify neuro-chemicals present.	Aids in studies of both neurotransmitters and hormones. MRS has confirmed the role of DA in decision making.	Not all neuro-chemicals register. Only applicable to whole brain imaging. Capital costs.	Developed by Ernst (Nobel Prize 1991)
Electro-encephal-ography	EEG	Electrodes on scalp record electrical activity of cortex.	Excellent temporal discrimination and non invasive.	Signals can suffer from distortion.	Used in conjunction with spatial data of fMRI and PET. Used for study of *event related potentials* (ERPs).
Magneto-electro-encephalography	MEG	Magnetic sensors placed on skull reveal currents created by neural discharges.	Excellent temporal discrimination to 1/1000 second. Allows greater clarity of reception than EEG, and allows analysis		Used in conjunction with spatial data of fMRI and PET. MEG has been used to analyse cortical

			of cortical activity when there is no net signal increase.		regions implicated in the first half second of visual word recognition. Used in location of tumors.
Near optical infra red	NOIR	Detects oxygenation and bloodvolume changes on region specific basis during functional studies.	Apparatus easy to handle and portable. Allows functional metabolic investigation.	Optical field dependent.	Under development.
Nuclear magnetic resonance mobile universal surface explorer	NMR-MOUSE	A unilateral NMR non invasive sensor.	Non destructive; permitting 2D and 3D imaging. Portability and relatively low cost are strengths.	Confined to near surface studies. Level of resolution is a deficiency.	Under development.
Transcranial magnetic stimulation	TMS	Localised magnetic field temporarily knocks out effective neuronal activity in localised brain areas.	Used in testing implication of various brain areas in particular tasks. rTMS is shown to be useful in treatment of depression.	rTMS has provoked epileptic seizure in individuals with prior history.	Introduced in the 1980s. Used in conjunction with MRI. rTMS shown to induce plasticity in certain conditions.
Transcranial direct current stimulation	tDCS	Application of highly localised electrical current to cortex.	Will not provoke action potentials and so is less invasive than TMS and rTMS.		Used in conjunction with MRI. Induces long term synaptic change by protein synthesis. Similarities to neuro-modulation.

Tables

Table 1.1
An hylomorphic critique of 20th century currents in philosophy of mind

Four categories are adopted from Kirk Ludwig "The Mind-Body Problem: An Overview" in Stephen P Stich and Ted A Warfield (eds.) *The Blackwell Guide to Philosophy of Mind* (Cambridge MA: Blackwell, 2003).

*Note that hylomorphic responses in one subcategory may be applicable in other subcategories. I have noted the more obvious of these. Responses within broad categorisations are in many cases applicable across subcategories within the same broad category. Responses are my own unless alternate source is cited.

Broad category	**Definitions and subcategories**	**Advocates[1824] and antecedents**	**Tenets**	**Hylomorphic responses***
1. Irrealism[1825]				
Eliminative materialism	Eliminativism is the denial of the existence of mental properties: "the view that beliefs, desires, and other mental states do not exist, and that explanations in terms of such states will be replaced by neurobiological explanations."[1826]	P. Feyerabend (1963)[1827] R. Rorty (1965)[1828] Paul Churchland (1981)[1829] S.Stich (1983)[1830] Patricia Churchland (1986)[1831] Antecedents of eliminativism are found in Feyerabend, Quine, and Nietzschean nihilism.[1832]	"… a strategy which removes the (ontological) obstacles that higher level phenomena pose to naturalism… by denying their existence."[1833] Outspoken opposition to the mental categories of folk psychology, arguing that they fail to capture physical	Eliminativism is a radical departure from realist epistemology. Truth is found not in being but in a relativist *a priori* denial of mental phenomena. Critique of physicalism: that it is based on an impoverished metaphysical conception of reality. [1835]

[1824] As an introduction to the thought of the various figures mentioned in this table, I cite representative texts presenting the views of each. Texts not explored in detail are omitted from bioliography.
[1825] Essentially the material eliminativist view, as proposed by Richard Rorty, that minds are not real.
[1826] Moran, ed., *The Routledge Companion to Twentieth Century Philosophy*, 973.
[1827] P. Feyerabend,"Mental events and the brain," *Journal of Philosophy* 60, (1963): 295-6.
[1828] R. Rorty, "Mind body identity, privacy and cateogories," *Review of Metaphysics* 19, (1965): 24-54.
[1829] P. M. Churchland, "Eliminative materialism and propositional attitudes," *Journal of Philosophy* 78, (1981): 67-90.
[1830] S. Stich, *From Folk Psychology to Cognitive Science* (Cambridge, MA: MIT Press, 1983).
[1831] P. S. Churchland, *Neurophilosophy: Toward a Unified Science of the Mind/Brain* (Cambridge, MA: MIT Press, 1986).
[1832] Sarah Patterson, "Philosophy of Mind" in *The Routledge Companion to Twentieth Century Philosophy*, Dermot Moran ed. (Abingdon: Routledge, 2008), 555 Chapter 12. Feyerabend argued that should mental phenomena and brain processes be identified, then the brain processes would have the same obscurity as the phenomena.
[1833] Moran, ed., *The Routledge Companion to Twentieth Century Philosophy*, 973.

	Eliminativist neuro-philosophy.		reality.[1834]	"Ultimately unintelligible"[1836]: a reductive denial of substance.
Connectionism Connectionism is also known as neural networks or parallel distributed processing.	Connectionism is a model of cognitive processing taking into account neural structures.	Paul Churchland (1988)[1837] Kim Sterelny (1990)[1838] Andy Clark (1989, 1993, 2001)[1839]	A synthesis of eliminativist and functionalist approaches.	Reductionist functional approaches focus on outputs defined according to material criteria, and disregard ontological questions. Reality may not be reduced to actions or relationships. An effective understanding of outputs requires a prior understanding of nature.
The search for the neural correlates of consciousness.	"Self representation accounts of consciousness"[1840]	D. Armstrong (1981)[1841] W. Lycan (1987)[1842]	Consciousness defined as "when the brain perceives, or otherwise represents,	Consciousness and subjective perception are not ontologically prior to being.

[1835] N. Chomsky, *New horizons in the study of language and mind* (Cambridge, MA; MIT Press, 2000). Chomsky's critique of physicalism: it is a misapplication of methodologies of the experimental sciences to metaphysical questions and, as such, is a methodological error.

[1834] Folk psychology argues that the everyday practice of explaining behaviour in terms of beliefs, desires and other mental states, the attribution of "propositional attitudes" to others, allows us to predict how they will behave. In short the theory that this is how we predict others' states and intentions.

[1836] Hylomorphism advocates that knowledge starts in being. As a consequence of their materialist stance, eliminative materialists also deny freedom in human action, even a freedom that is limited. John Haldane, "Incarnational Anthropology," in ed. David Cockburn (ed.), *Human Beings* (Cambridge: Cambridge University Press, 1991), 75-93.

[1837] Paul M. Churchland, *Matter and Consciousness* (Cambridge MA: MIT, 1988) ; Paul M. Churchland, *The Engine of the Reason, the Seat of the Soul* (Cambridge MA: MIT, 1995)

[1838] Kim Sterelny, *Thought in a Hostile World: The evolution of human cognition* (Malden MA: Blackwell, 2003).

[1839] Andy Clarke, *Microcognition: Philosophy, Cognitive Science and Parallel Distributed Processing* (Cambridge MA: MIT, 1989); Andy Clarke, *Mindware: An Introduction to the Philosophy of Cognitive Science* (Cambridge MA: MIT, 2001).

[1840] Terminology proposed by Paul M Churchland in "Consciousness" in Richard L Gregory (ed), *Oxford Companion to the Mind.* (2nd ed) (Oxford: OUP, 2004

[1841] Armstrong, D. (1981) *The Nature of Mind.*

[1842] W. Lycan, *Consciousness* (Cambridge, MA: MIT Press, 1987).

			some of its own cognitive states and activities. Consciousness is thus a form of metacognition." [1843]	Objective being cannot be verified through subjective experience. Consciousness itself may not be reduced to self awareness. [1844]
	Self control accounts of consciousness [1845]	P. Churchland (1995)[1846] J.G.Taylor (2001)[1847]	Consciousness characterises an agent that is "modulating, manipulating, and steering its own cognitive activities… partly autonomous in generating not just its own behaviour, but its own cognition as well." [1848]	False premises: consciousness may not be reduced to self control; nor may self modulation require consciousness. [1849] Being is ontologically prior to activity. Reductive physicalism cannot account for rationality and freedom.
	Special architecture and dynamics account.	G. Edelman (1993)[1850] P. Churchland (1995) [1851] R. Llinas (2001)[1852]	Higher function derives from the complexity of neural pathways and reverbatory circuits.	Neural complexity cannot explain or accommodate choice, freedom, judgement of conscience, and the capacity to abstract to universal principles.

[1843] Paul M. Churchland, "Consciousness" in *Oxford Companion to the Mind,* 2nd ed. Richard L. Gregory ed. (Oxford: OUP, 2004).
[1844] Churchland, "Consciousness".
[1845] Terminology proposed by Churchland, "Consciousness".
[1846] Churchland, *The Engine of Reason, The Seat of the Soul: A Philosophical Journey into the Brain*.
[1847] J.G. Taylor, "The central representation: the where, what and how of consciousness" in *The Emergence of Mind: Proceedings of the international symposium*, S. Colona ed. (Montedison, 2001).
[1848] Churchland, "Consciousness".
[1849] Churchland, "Consciousness".
[1850] G. Edelman, "Neural Darwinism: selection and re-entrant signalling in higher brain function," *Neuron* 10, (1993).
[1851] Churchland, *The Engine of Reason, The Seat of the Soul: A Philosophical Journey into the Brain*.
[1852] R. Llinas, *I of the Vortex: From Neurons to Self* (Cambridge MA: MIT, 2001).

				Reductive physicalism cannot account for rationality and freedom. Output may not only be defined in material terms.
Fictionalism.[1853]	"Fictionalism is the claim that, whilst mental states don't, strictly speaking, exist, it is nevertheless useful to pretend that they do." [1854] Fictionalism is associated with projectivism.	Daniel Dennett (1991)[1855] [1856] W. Lycan (1987)[1857] Ryle's logical behaviourism is a precursor to Dennett's position. Associated with folk psychology, regarding it as indispensable. [1858]	Fictionalism is an example of property dualism combined with "substance monism of a physicalist type".[1859] Functional explanation of consciousness: "necessarily, anything that has physical behavioural dispositions of a certain kind and complexity has a mental life."[1860] Belief and desire "are real inner-causal states of people".[1861] [1862]	A form of total conceptual relativism: humans are given characteristics they do not in fact have.[1863] The view seems aligned with relativist views that meaning is determined by the receiver not the subject.[1864] Critique of eliminativist roots as above. The functionalism evident in Dennett's work circumvents

[1853] Also known as "Instrumentalism".
[1854] Ian Ravenscroft, *Philosophy of Mind. A beginner's guide* (Oxford: OUP, 2005), 193.
[1855] Dennett, *Consciousness Explained* .
[1856] Haldane, "Incarnational anthropology," 76. Haldane suggests that Dennett holds to projectivism with respect to some classes of phenomena, and to realism in relation to others.
[1857] W. G. Lycan, *Consciousness* Cambridge, (Cambridge, MA: MIT Press, 1987).
[1858] Dennett's view.
[1859] Haldane, "A return to form in the philosophy of mind," 58.
[1860] Samuel Guttenplan, ed., *A Companion to the Philosophy of Mind* (Cambridge MA: Blackwell, 1994), 136. A "behaviour-as-sufficient" view.
[1861] William G. Lycan, "The Mind-Body Problem" in *The Blackwell Guide to Philosophy of Mind*, ed. Stephen P. Stich and Ted A. Warfield (Cambridge MA: Blackwell, 2003), 60**.** Dennett proposed this view in common with with identity theorists, functionalists and token physicalists.
[1862] Ravenscroft, *Philosophy of Mind. A beginner's guide,* 72. Ravenscroft classifies Dennett within eliminativism and argues that although Dennett is on record suggesting he is not a fictionalist, his writings suggest that he holds this position. He presents his thought in the section of his book dedicated to eliminativism. Lycan, on the other hand argues that Dennett regards mental ascriptions as real inner causal states.
[1863] Haldane, "Incarnational anthropology," 76.

				deeper ontological questions. (See above.)
2. Conceptual reductionism[1865]				
Neutral Monism	Neutral Monism holds that "...the mental (and the physical) are reducible to something more basic."[1866] It is "the view that mind and matter are complex constructions out of more basic elements which are neutral, neither mental nor material." [1867]	Ernst Mach 1886)[1868] William James(1904)[1869] Bertrand Russell (1921)[1870]	A non dualist, non physicalist, approach. We are "constructed" by experience. [1871] [1872] James argued that pure experience, not the subject of pure experience, should be the focus of study. Russell argued that matter is a "logical fiction (giving) us a convenient way of stating causal laws". [1873] "Mind is … exemplified in number and complexity of habits… mind and matter alike are seen to be constructed out	Neutral monism reverses the fundamental tenet of hylomorphism, that activities of an organism follow upon its nature - do follows be. This leads to a consequent loss of the sense of substance. A failure to address richness of substance, and a substitution of idealism or phenomenalism. [1875] Neutral monism is incapable of making meaningful statements about the real nature of things because, as an *a*

[1864] Haldane, "Incarnational anthropology," 77. Dennett proposes a world in which "an event may be wholly determined in its causes (but) conceived of in a fashion which allows it to be a free action". The view seems aligned to Hume's relativistic argumentation.

[1865] The view that whatever can be said about the whole can also be expressed in concepts pertaining to the parts. In philosophy of mind, this presents as two strands: that man and his mental life are reducible to the material, or to idealism.

[1866] Ludwig, "The Mind-Body Problem: An Overview," 21.

[1867] Moran (ed.), *The Routledge Companion to Twentieth Century Philosophy*, 985.

[1868] E. Mach, *Die Analyse der Empfindungen und das Verhältnis des Physischen zum Psychischen* (1886), available in translation as *The Analysis of Sensations and the Relation of Physical to the Psychical* (New York: Dover, 1959).

[1869] William James, "A World of Pure Experience," *Journal of Philosophy, Psychology and Scientific Methods* 1, 20-21 (1904).

[1870] Bertrand Russell, *The Analysis of Mind* (1921), 308.

[1871] Ludwig, "The Mind-Body Problem: An Overview," 21. The view of Mach and Russell.

[1872] C.D. Broad, *The Mind and its Place in Nature* (London: Routledge and Kegan Paul, 1925). Charles Broad classified Russell's position as "mentalistic neutralism".

[1873] Bertrand Russell, *The Analysis of Mind*, 308. Russell advocates a monist metaphysics.

			of neutral stuff.” [1874]	*priori* position, it holds that it is experience that creates reality.
Logical Behaviourism	Behaviourism sees behaviour as intelligible and rational. Having a mind “is constituted by nothing more than the engaging in especially sophisticated types of overt behaviour, or of being disposed to engage in such behaviour in suitable circumstances”. [1876]	R. Carnap (1931) G. Ryle (1949)[1877] J.L. Austin. Their followers: Peter Geach, Anthony Kenny, Normal Malcolm, AI Melden, and Peter Winch.[1878] The early articulation of behaviourism was by logical positivists, Carnap, Hempel, and Ayer. It developed from the verificationism of logical positivists prior to WWII, and was also influenced by British Empiricism. Wittgenstein and Russell used aspects of behaviourism. [1879]	Logical behaviourism stands in contrast to physicalism and in profound opposition to Cartesian dualism. “The behaviourist takes minds to be (at least to a significant extent) constituted by (evident) outer effects.”[1880] The link between mental states and behaviour is logical not causal. [1881]	Logical behaviourism fails to propose an ontological framework, [1882] nor to consider the “non dualist, dual aspect, ontological anti-reductionist” [1883] view. The meaning of terms such as *mind* requires clarification by reference to Aristotelian terms such as intellect and rational nature.[1884] Where appropriate, an hylomorphic critique addresses behaviourist affinities to physicalism. (See above).

[1875] Leopold Stubenberg, "Neutral Monism" in *The Stanford Encyclopedia of Philosophy (Spring 2010 Edition)*, Edward N. Zalta ed., http://plato.stanford.edu/archives/spr2010/entries/neutral-monism/.

[1874] Bertrand Russell, *The Analysis of Mind*, 308. Russell advocates a monist metaphysics.

[1876] Armstrong, “Mind body problem: philosophical theory”. This “peripheralist” view stands in contrast to the “centralist” position admitting the possibility of “‘inner’ mental processes which interact causally with the rest of the body.”

[1877] G. Ryle, *The Concept of Mind* (New York: Barnes and Noble, 1949).

[1878] Adherents of logical behaviourism may or may not subscribe to a reductive materialism. Their approach however is arguably reductive in its behaviourist focus.

[1879] Guttenplan, ed., *A Companion to the Philosophy of Mind*, 132.

[1880] Minds are not “inner psychic mechanisms merely contingently connected with their outer behavioural effects.” Guttenplan, ed., *A Companion to the Philosophy of Mind*, 132. Logical behaviourism manifests little interest in the ontological questions, or in the inner world for that matter. There is a phenomenal approach to behaviour, with the assumption of a logical link between the mental and behaviour which follows. Logical behaviourism exhibits non engagement with the issue of mental causality.

Idealism[1885]	Idealism is the view that reality is composed of minds and collections of ideas.[1886]	G. Berkeley (1710)[1887] R. Carnap (1928)[1888] In more recent forms see, for example, A.C. Grayling (1985)[1889]	Idealism began as a refutation of dualism. Idealism gave rise to to phenomenalism.[1890] [1891]	Idealism, as a denial of the material, is a reductive and unsatisfying understanding of the complexity of substance.[1892] [1893]
Identity theory[1894]	The identification of sensations with brain processes is a type physicalist theory. David Lewis' psychophysical	U. T. Place (1956)[1895] H. Feigl (1958)[1896] J. J. C. Smart (1959)[1897] David Lewis (1966)[1898]	Mental states are identified with brain states.[1899] Identity theory bestows causal relevance on mental properties.[1900]	The type-type causality attributed to mental properties by identity theory is unable to account for the non predictability of

[1881] Brian McLaughlin, "Philosophy of Mind" in *The Cambridge Dictionary of Philosophy*, ed. Robert Audi (Cambridge: CUP, 1995). The position of Ryle and Wittgenstein.
[1882] Patterson "Philosophy of Mind," Chapter 12. It has been pointed out that Ryle tends to argue as though dualism and behaviourism exhaust the philosophical alternatives.
[1883] A classification suggested by Haldane, "A return to form in the philosophy of mind".
[1884] This approach is a response to the origin of behaviourism in semantics. Thus, the subjective meaning of mind in behaviourism could be displaced by one founded on essential properties of being.
[1885] Also known as universal pure mental particle theory.
[1886] Ludwig, "The Mind-Body Problem: An Overview," 16.
[1887] G. Berkeley, *Treatise concerning the Principles of Human Knowledge,* (1710).
[1888] Rudolf Carnap, *Der logische Aufbau der Welt* (Berlin: Bernary, 1928) trans. R.A. George: *The Logical Structure of the World* (Berkeley: University of California Press, 1967).
[1889] A. C. Grayling, *The Refutation of Scepticism* (London: Duckworth, 1985).
[1890] Ludwig, "The Mind-Body Problem: An Overview," 16
[1891] McLaughlin, "Philosophy of Mind," 597. Phenomenalism (as, for example, advocated by Ayer) is a version of neutral monism or idealism: "all empirical statements are synonymous with statements solely about phenomenal appearances"
[1892] Haldane avoids offering opinions on questions of qualia and consciousness, preferring to anchor his discussion on the primacy of existence.
[1893] An hylomorphic metaphysics accounting for real existence and for substances having physical and rational properties overcomes the difficulties posed by idealism.Without such an hylomorphic response, the challenges raised by idealism with reference to consciousness are virtually insurmountable.
[1894] Identity theory known also as psychophysical (or mind-brain) identity theory. R. W. Sperry, "Consciousness and Causality" in *Oxford Companion to the Mind,* 2nd ed., ed. Richard L Gregory (Oxford: OUP, 2004).
[1895] U.T. Place, "Is consciousness a brain process?" *British Journal of Psychology* 47, (1956): 44-50.
[1896] H. Feigl, "The 'Mental' and the 'Physical'" in *Minnesota Studies in the Philosophy of Science* 2, H. Feigl, et al. ed. (Minneapolis: U Minnesota Press, 1958), 370-497.
[1897] J. J. C. Smart, "Sensations and brain processes," *Philosophical Review* 68, (1959): 141-56.
[1898] D. Lewis, "An argument for identity theory," *Journal of Philosophy* 63, (1966): 17-25.
[1899] McLaughlin, "Philosophy of Mind," 597.
[1900] The view of Feigl. This is an understanding of causality limited to efficient material causality assuming , on an *a priori* basis, the identity of mental and physical.

	theory.		Mind and brain appear different things "because we have used different languages and perspectives".[1901] Lewis makes use of "functionalist descriptions of states extracted from a 'folk theory' of psychology to identify mental states with physical states".[1902]	correspondence between the mental and the physical, and is ultimately a consequence of human freedom. Instead, however, of opening the way for hylomorphic solutions that uphold human freedom, the token physicalist, non-reductive solutions of anomalous monism (see below) inherited the middle ground.
Central state materialism.	Central state materialism is a type physicalist theory, a further development of identity theory and a form of functionalism.[1903]	David Armstrong (1968)[1904]	"All mental states are contingently identical with states of the brain or CNS that are apt to produce a certain range of behaviour…. Mental states are actual internal states with causal effects".[1905] "We can give a complete account of man in purely physico-chemical terms… (by a) purely electrochemical	Armstrong presented a reductionist view of the human being as "nothing but a physic-chemical mechanism".[1907] Yet, since mental events and brain processes have different intrinsic properties, they cannot *be* identical. Functionalist stance is unable to avoid ontological issues because of its association with the

[1901] Sperry, "Consciousness and Causality".
[1902] Lewis, "An argument for identity theory," 17-25.
[1903] McLaughlin, "Philosophy of Mind," 597.
[1904] David Armstrong, *A Materialist theory of the mind* (London: Routledge and Kegan Paul, 1968).
[1905] McLaughlin, "Philosophy of Mind," 597. Some believed the mind is the brain, others subscribed to Ryle's view that the mind is capacities and dispositions, a view that has gained widespread traction.

			account of the workings of the brain."[1906]	physicalist conception of reality and a mechanistic view of human behaviour.[1908]
Epiphenom-enalism	Mental phenomena are the result of physical processes in the brain, or else both enjoy a common cause. A form of interactive parallelism. [1909]	F. Jackson (1982)[1910] David Chalmers (1996)[1911 1912] Epiphenom-enalism, began as a reaction to dualism, asserting a form of scientific behaviourism. Type epiphenom-enalism: "that no state can cause anything in virtue of falling under a mental type"; mental states cannot be causes. Token epiphenomenalism: "that no mental state can cause anything".[1913]	Essentially the mind is a spectator. Conscious experience is a side effect of brain activity.[1914] A denial that human beings can be intentional agents. "Mental states do not cause anything."[1915 1916] Chalmers writes, "the hard problem of consciousness is that of explaining how it is that physical processes in a brain are associated with subjective experiences…. A science of consciousness needs to admit both first-	Hylomorphic response would address the inconsistencies in marrying a reductionist,[1918] emergent approach to the Cartesian notion of a mind independent of matter.[1919] See response to dualism below. Jackson (and Van Cleve), by arguing that consciousness is irreducible and emergent, fall into the deterministic camp. [1920] Their position is fundamentally materialistic. See refutation of reductive materialism above. Chalmers lacks

[1907] Patterson, "Philosophy of Mind," 547.
[1906] David Armstrong quotation. Sperry, "Consciousness and Causality".
[1908] Overt materialism can be answered by an hylomorphic defence of non material properties in certain substances.
[1909] Richard L. Gregory ed., "Epiphenomena" in *Oxford Companion to the Mind,* 2nd ed. (Oxford: OUP, 2004). Epiphenomenalism admits only one way psychophysical action.
[1910] F. Jackson, "Epiphenomenal qualia," *Philosophical Quarterly* 32, (1982): 127-36.
[1911] Chalmers, *The Conscious Mind*.
[1912] Paul M Churchland classifies Chalmers as an ephphenomenalist. Churchland, "Consciousness".
[1913] McLaughlin, "Philosophy of Mind," 597.
[1914] A. Delbridge et al., *Macquarie Dictionary*, 3rd ed. (Macquarie University: Macquarie Press, 2001). "Conscious processes, though distinct from physical processes, have no distinct causal properties."
[1915] McLaughlin, "Philosophy of Mind," 597.
[1916] Haldane, "Incarnational anthropology," 78.

			person data and third person data as real and mutually irreducible."[1917]	both an adequate rational psychology and notion of formal causality.[1921]
3. Conceptual anti reductionism[1922]				
Emergentism Emergent theories may be classified as type-type (Category 2 above) or as supervenient non type-type.	"Emergent materialists hold that there are only material things, but that some complex material things... have mental properties and that those mental properties are not conceptually reducible to any of the physical complexes of the complexes that have them" [1923]	C.D.Broad(1925) [1924] Emergentism began as a materialist rejection of dualism, idealism, and of reductive materialism as empirically implausible. [1925] It is associated with the nineteenth century rise of science and theory of evolution.[1926] [1927]	C.D. Broad following J.S.Mill distinguishes mechanism and emergentism. [1928] Emergentism is non reductive, [1929] [1930] and essentially materialistic.[1931] [1932]	Hylomorphism teaches that properties follow upon the essence: the nature of something limits its behaviour and activities. The emergence of rationality, a new class of property, does not correspond to an empirical understanding of the world.[1933]

[1918] Haldane, "A return to form in the philosophy of mind," 58.
[1919] With some characteristics of a dualistic theory, epiphenomenalism asserts an unbridgeable gap between two orders of being.This must lead either to a deterministic universe, or to an incomprehensible universe unable to account for human freedom and causality.
[1920] McLaughlin, "Philosophy of Mind," 597.
[1917] David Chalmers, "Consciousness" in *Oxford Companion to the Mind,* 2nd ed., Richard L Gregory ed. (Oxford: OUP, 2004). Chalmers seeks to explain the connection of physical processes to conscious experience. He advocates the development of "simple, basic and universal" principles connecting physical processes and consciousness by means of correlating first-person data (subjective description) and third person data (neuroscience and psychology).
[1921] Without these, Chalmers' goal of developing "principles connecting physical processes and consciousness" appears impossible. His principles would simply reflect behavioural phenomena.
[1922] That the mental activity of the human being and their minds, cannot be reduced constituent parts.
[1923] Ludwig, "The Mind-Body Problem: An Overview," 18.
[1924] C.D. Broad, *The Mind and its Place in Nature* (London: Routledge and Kegan Paul, 1925).
[1925] McLaughlin, "Philosophy of Mind," 597.
[1926] Ludwig, "The Mind-Body Problem: An Overview," 9.
[1927] In recent decades emergentism has resurfaced in numerous forms. It is currently the broad materialist category into which many philosophers and neuroscientist classify themselves.
[1928] He argues they are typified variously by mechanical and chemical combination... one the sum of its individual effects, the other only known "inductively".
[1929] Patterson, "Philosophy of Mind," 525. "Mind (is) beyond belief of reductive explanation".
[1930] Moran, ed., *The Routledge Companion to Twentieth Century Philosophy*, 973. It is "the view that wholes exhibit novel features which are emergent, or not explicable in terms of the properties of the parts of the whole".

Anomalous monism.	"A metaphysical view... according to which all mental events are physical events, but there are no strict laws linking mental and physical predicates." [1934] A form of dual aspect theory whereby events can have autonomous mental and physical aspects. A token physicalism.[1935]	Donald Davidson (1963)[1936] Anomalous monism built upon the work of Kripke[1937] who argued that statements of strict identity between sensation and physical state are not possible.[1938]	A form of emergentism; [1939] a non reductive materialism. Davidson introduced notion of supervenience. [1940] [1941] Mental events can be causally related to physical events but mental events are physical events. Anomalous monism established the paradigm for non-reductive	Anomalous monism circumvents ontological questions and relies on positivist principles.[1943] Foundation on a physicalism and causalism seeing the mind as the efficient cause of behavioural outputs. [1944] Non reductive materialist, emergent, and functionalist understandings (without an explicit enriched

[1931] Broad's emergent materialism held that every substance is wholly made up of the physical**.** Later advocates of emergentism tend to adopt an *a priori* materialist position. Drawing on an evolutionary paradigm, emergentists assert that higher properties evolve according to mysterious inner processes as yet unknown.
[1932] Broad, "Mind and its Place in Nature," 647. Mentality is "an emergent characteristic of certain kinds of material complex". Broad regards behaviourism as reductive materialism and opposes this to emergent materialism.
[1933] Hylomorphism argues that there is a lack of scientific foundation for the fundamental emergentist presupposition, that higher properties (rationality) evolve. The more distinctive the qualities that are recognised in human nature, the more difficult for the emergent position to gain any traction. See **Appendix 1** for detailed refutation of emergent rationality.
[1934] Moran, ed., *The Routledge Companion to Twentieth Century Philosophy*, 967.
[1935] McLaughlin, "Philosophy of Mind," 597. "Every particular is physical... yet physical tokens can fall under non physical types. Not all token physicalism is type physicalism."
[1936] D. Davidson, "Actions, reasons and causes," *Journal of Philosophy* 60, (1963): 685-700. "Interacting mental and physical events instantiate physical laws and hence are both physical". He upheld the anomality of the mental but offered no concession to dualism.
[1937] S. Kripke, *Naming and Necessity* (Cambridge MA: Harvard University Press, 1972).
[1938] McLaughlin, "Philosophy of Mind," 597.
[1939] Ludwig, "The Mind-Body Problem: An Overview," 9.
[1940] McLaughlin, "Philosophy of Mind," 597. Supervenience: "An asymmetric relationship of determination between sets of properties or facts. If mental properties supervene on physical properties, then there is no variation in mental properties without a variation in physical properties. There is a special kind of dependence between "higher level" properties and "lower level properties that does not allow conceptual reductions".... Davidson submits that the mental supervenes on the physical, such that no mental change can occur without a physical change. See Moran, ed., *The Routledge Companion to Twentieth Century Philosophy*, 993.
[1941] Davidson, "Actions, reasons and causes," 214."Mental characteristics are in some sense dependent, or supervenient, on physical characteristics."

			physicalism that has predominated in latter 20th century.[1942]	ontology) must ultimately be physicalist and unable to account for human freedom.
Biological naturalism	Biological naturalism is the belief that mental and physical categories are mistaken. Searle argues that higher level features of the human organism are caused by lower level elements.[1945]	John Searle (1984)[1946] M. Gazzaniga (2011)[1947] Biological naturalism is a rejection of functionalist and Computational Theory of Mind understandings. Searle moved from this position to "quantum indeterminism" (see below) to explain freedom through physical quantum processes.	A subtle form of emergentism. Biological naturalism questions the distinctions between the mental and physical suggesting there is no basis in reality for the distinction. Searle argues consciousness is a result of neurobiological processes, an evolved brain process.[1948 1949]	Hylomorphism mental and physical properties exist in reality.[1950] If mind is accorded executive status (in a dualist paradigm of substance) it will necessarily lead to a dualist, an epiphenom-enalist position or a physicalist position.[1951]
Competition for executive control accounts[1952]	A further form of emergentism - this account proposes that	B.J.Baars (1988)[1953] F.Crick and C. Koch (1990)[1954]	These are essentially emergent positions:	The material determinism of these accounts lacks adequate

[1943] Hylomorphism also holds to the fundamental intelligibility of reality. Anomalous monism, and the non reductive physicalisms in general, propose anomalous mental and physical properties on a physical foundation. Essentially this must be either self contradictory or at the very least paradoxical.

[1944] Haldane, "A return to form in the philosophy of mind," 45.

[1942] Patterson, "Philosophy of Mind," 552. Davidson rejected psychophysical laws and focused on intention rather than sensation. He argued that what is mental are "attitudes such as believings, desirings, intendings, identified by their content: what is believed, desired, intended."

[1945] Searle outlines his position in Guttenplan. Guttenplan, ed., *A Companion to the Philosophy of Mind*, 544-557.

[1946] John Searle, *Minds, Brains and Science*, (Cambridge, MA: Harvard University Press, 1984).

[1947] Gazzaniga, *Who's in charge. Free will and the science of the brain.*

[1948] Patterson, "Philosophy of Mind," 569.

[1949] Julian Baggini and Jeremy Stangroom, *What Philosophers Think* (London: Continuum, 2003), 185. "One of the things we know... is that all of our mental processes are caused by processes in the brain. That's the kind of starting point I can take when I work in the philosophy of mind."

[1950] This is so even if the distinction between mental and physical substances is misplaced at times.

[1951] It is possible that a clarification of terminology is required: *mental* can be used synonymously with *mind* understood as the very source of human consciousness and autonomy.

[1952] Terminology proposed by Churchland, "Consciousness".

[1953] B.J. Baars, *A Cognitive Theory of Consciousness* (Cambridge: Cambridge University Press, 1993).

	neural complexity leads to consciousness and executive control.	D.A.Leopold and N.K.Logothetis (1999)[1955] W.Singer (2000)[1956] S.Greenfield (2008)[1957]	consciousness arises from neuroscientific complexity Rationality and autonomous personhood arise from brain complexity. Accounts of mechanisms for executive control: the “global workspace account”, the “shifting coalitions” account, and the “synchrony” account .[1958] ‘Compatibilism’ accounts for apparent freedom.[1959]	understanding of the person endowed with both spiritual and material faculties. Haldane urges, “No epistemology without ontology”.[1960] Hylomorphism rejects the position that substances are either material or immaterial. Instead it posits the possibility of psycho-physical substances, with a nature capable of both physical and mental activity.[1961]
Non reductive physiological accounts.	These accounts take advantage of powerful recent imaging	A.Damasio (1994) [1962] (1999)[1963] (2003)[1964]	Supported by quantities of neuroscientific research,	Damasio’s attempts demonstrate the difficulty,

[1954] F. Crick and C. Koch, “Towards a neurobiological theory of consciousness,” *Seminars in the Neurosciences* 2, (1990).

[1955] D. A. Leopold and N. K. Logothetis, “Multistable phenomena: changing views in perception,” *Trends in Cognitive Science* 3, (1999).

[1956] W. Singer, “Phenomenal awareness and consciousness from a neurobiological perspective,” in *Neural Correlates of Consciousness*, T. Metzinger ed. (Cambridge MA: MIT Press, 2000).

[1957] Susan Greenfield, *I.D. The Quest for identity in the 21st Century.*

[1958] The global workspace account posits a seat of consciousness in the brain. The shifting coalitions (Baars, 1988) suggests temporary networks underpinning consciousness. The synchrony account (Crick and Koch, 1990) which suggests synchronous firing of neurons is the key. This account lends itself to utilising brain imagery to localise higher function. For example, Crick in *The Astonishing Hypothesis* locates free will in the anterior cingulate region of the brain.

[1959] This is the view, first proposed by Koch and Dennett, that free will and determinism are compatible, essentially free will is reduced to freedom to act.

[1960] Haldane, “A return to form in the philosophy of mind,” 57. This principle underpins the hylomorphic refutation of attempts to discuss executive control, qualia or consciousness without addressing the ontology of the substance.

[1961] Haldane argues that an hylomorphic understanding of the person allows a richer model of human behaviour than the various alternative contemporary approaches to the philosophy of mind that are physicalist, or epiphenomenalist. He argues that these alternatives are both reductionist. He insists that form contributes order, that forms received play a decisive role in perception, and that intentional forms play a decisive role in action.

[1962] Damasio, *Descartes’ Error*.

[1963] Damasio, *The Feeling of What Happens. Body and Emotion in the Making of Consciousness.*

	techniques revealing the mechanisms of emotion and cognitive processing.	J. LeDoux (1998)[1965]	Damasio and LeDoux have developed arguments supporting the notion of a profound unity in the organism on materialistic assumptions.	perhaps impossibility, of defending specific metaphysio-logical conclusions about human nature in the absence of a concept of person. They demonstrate the need that mind-body speculation must be supported by a metaphysically rich anthropology. [1966]
Functionalism.	Functionalism It is "the view that mental states can be analysed in terms of their relationships to sensory inputs, behavioural inputs, and other mental states. Thus pain is not identical with a particular neuro-physiological state, but with any state which is caused by injury and manifests itself in pain behaviour." [1967] Functionalism is more a family of	Hilary Putnam (1968)[1970] J.Fodor (1968)[1971] N.Block (1978)[1972] Ryle seems to be a forerunner of functionalism which may be seen as a successor to behaviourism. Functionalism built on the insights of folk psychology. Functionalism is the orthodox view in contemporary philosophy of mind (going	Functionalism allows mental states to be causes of behaviour.[1974] [1975] Functionalism is a reassertion of the language of psychology. Mental states, while physically based, are not conceptually identified with the physical. The mental, while supervening on the physical, is not conceptually reducible to the physical.[1976]	Critique of the functionalist approach observes that the focus is on the phenomenon of consciousness rather than on an articulation of its causes. Functionalism finds its origins in behaviourism. [1978] (See above.) The focus is on black box inputs and outputs. Functionalism has much in common with hylomorphism. [1979] It grants

[1964] Damasio, *Looking for Spinoza*.
[1965] LeDoux, *The Emotional Brain*.
[1966] See **5.2.1.1** and **5.2.1.2**.
[1967] Moran, ed., *The Routledge Companion to Twentieth Century Philosophy*, 977.
[1970] H. Putnam, "Brains and Behaviour" in *Analytical Philosophy II*, R.J.Butler ed. (Oxford: Blackwell, 1968), 1-19.
[1971] J. Fodor, *Psychological Explanation* (New York: Random House, 1968).
[1972] Not all those who describe their approach as "functional" are necessarily materialist.

	empirical models concerned with sensory inputs and behavioural outputs, rather than an understanding of mental activity.[1968] [1969]	back to Putnam and Fodor).[1973]	Functionalism comes in many forms. It developed primarily as a token physicalist theory.[1977]	the real existence of things, avoids treating mind as a substance and discusses causality in apparently non-material terms.[1980]
Computational functionalism.[1981]	"According to this theory, mental states are complex symbols, and mental processes are computational processes. In short: the mind is a computer."[1982]	R.W. Sperry (1966)[1987] J. Fodor (1990) N. Block (1986 and 1995)[1988] H.Putnam(1992)[1989] Computational Theory of Mind was the predominant	This non reductive physicalist form of functionalism emphasises the reality of mental phenomena, consciousness and mental causation.[1991] [1992] An account that is	An hylomorphic critique notes the lack of scientific foundation for emergentist presupposition. The hylomorphic responses to functionalism, above, also

[1974] Putnam (1968) and Chihara and Fodor (1965). McLaughlin, "Philosophy of Mind," 597. Their position "appeals to the simplicity, plausibility, and predictive accuracy of an explanatory system as a whole".[1974]

[1975] Ned Block, "Consciousness" in *Oxford Companion to the Mind,* 2nd ed., Richard L. Gregory ed. (Oxford: OUP, 2004). Yet the adoption of an *a priori* materialist position by some functionalists, and a disregard for metaphysical considerations, lead to a deterministic reading of human action. In contrast with others of behaviourist lineage but on the basis of real world observations, functionalists do acknowledge the causal role that mental states play. Functionalism, in contrast to behaviourism, allows that mental states should be causes and effects.

[1976] Ludwig, "The Mind-Body Problem: An Overview," 9.

[1978] Block, "Consciousness".

[1979] "It is often said that Aristotle is the founder of functionalism because of his view that the function of an entity determines its form." Cf Moran, ed., *The Routledge Companion to Twentieth Century Philosophy*, 977. Of course this is in the order of knowledge. Metaphysically, the reverse is true: the form of an entity determines its function.

[1968] For example, functionalism seems unable to grapple with the notion of 1st person experience.

[1969] Functionalism shows little interest in the ontological questions. Cf Hilary Putnam in Guttenplan, ed., *A Companion to the Philosophy of Mind*, 513. It is telling that Putnam, after his repudiation of functionalism, has written that the "key elements of functionalism operate... within a seventeenth century perception of the mind".

[1973] Moran, ed., *The Routledge Companion to Twentieth Century Philosophy*, 977.

[1977] Patterson, "Philosophy of Mind". In an early variant, the Australian Functionalists (Armstrong, Lewis and Smart) "used functionalist analyses to argue for the type identity theory. They regarded mental states as functionally specified physical states."

[1980] Nussbaum and Putnam, "*Changing Aristotle's mind,"* 27-56. See Chapter 4. Prominent Aristotelian philosopher, Martha Nussbaum, and Putnam have jointly issued publications discussing what they describe as the functionalist aspect of hylomorphism.

[1981] Roger Penrose, "Consciousness" in *Oxford Companion to the Mind,* 2nd ed., Richard L. Gregory ed. (Oxford: OUP, 2004). Roger Penrose classifies the search for the neural correlates of consciousness (see above "Competition for executive control accounts") under this category.

[1982] Ravenscroft, *Philosophy of Mind. A beginner's guide,* 192.

[1987] R.W. Sperry, "Mind, brain and humanist values," *Bulletin of Atomic Science* 22, (1966).

	"Brain physiology determines the mental effects" in this "interactionist" model "in which mental phenomena are described as …supervening, rather than intervening in the physiological process". Consciousness is an "autonomous phenomena".[1983] The mentalist view corresponds to the ascendency of cognitivism over materialist behaviourism in psychology in the 70s.[1984][1985][1986]	theory of mind from the mid 70s to mid 80s.[1990]	"emergentist, functionalist, interactionist and monistic."[1993] Proponents contrast their position with both behaviourist materialism and dualism. In more recent years it has been influenced by computer development.[1994] Fodor and Block have investigated the challenge of qualia for functionalism.	apply. References to neurobiology are characterised by *non sequitur* conclusions typically attributing consciousness to the complexities of neurobiology.[1995][1996] Computational functionalism is bereft of a metaphysical basis upon which to demonstrate freewill and causality. Ultimately, it appears open to reduction to determinism or dualism.

[1988] Ned Block, "On a confusion about the function of consciousness," *Behavioural and Brain Science* 18, (1995): 227-47.
[1989] Nussbaum and Putnam, "*Changing Aristotle's mind,"* 27-56. See Chapter 4.
[1991] Patterson,"Philosophy of Mind," Chapter 12. Again, this is a most broad category. Not all those included would consider themselves materialist.
[1992] Block, "Functionalism". Putnam and Fodor "saw mental states in terms of an empirical computational theory of the mind"
[1983] Sperry, "Consciousness and Causality".
[1984] Moran, ed., *The Routledge Companion to Twentieth Century Philosophy*, 982. Mentalist understandings of consciousness are founded on neurobiological explanations. "Mentalism treats meaning and concepts as psychic phenomena in the mind of individuals."
[1985] Armstrong, "Mind body problem: philosophical theory". Mentalist theories emphasise the immediacy and certainty of the mind knowing itself in contrast with material things.
[1986] Hilary Putnam in Guttenplan, ed., *A Companion to the Philosophy of Mind*, 513. Fodor's work contributed to "The rehabilitation of mentalism, the conception of mental phenomena as inner causes, involved its detachment from the 'Cartesian' conception of mental phenomena as immaterial causes which were 'inner' in the sense of being private, of being subjective phenomena uniquely accessible to a single consciousness." Non reductive functionalism may include teleological approaches.
[1990] Jerry Fodor *The Language of Thought*. New York: Thomas Crowell, 1975.
[1993] Sperry, "Consciousness and Causality".
[1994] Ned Block, "Functionalism" in Guttenplan, ed., *A Companion to the Philosophy of Mind*, 323.325. through Putnam (1967) who suggested mind to be analogous to software, and through

	Quantum indeterminism. This is an attempt to marry the physics of quantum theory to neural science in order to account for free will.	H.P Stapp (1993)[1997] Roger Penrose (1994)[1998] J.Schwartz (2002)[1999] G.Vitiello (2002)[2000] J.Searle (2007)[2001] M.Gazzaniga (2011)[2002]	Penrose proposes "Quantum gravitation coherence".[2003] Other advocates adopt detailed analysis of neural structures to argue for laws of quantum mechanics and therefore of physical indeterminacy. Recently Penrose and Hameroff publicized their "quantum soul theory".[2004]	This position appears to be characterised by a misapplication of the principles of quantum physics to account for phenomena not reducible to the physical. The theory is based on imagination and assertion rather than weight of evidence. Physicalist emergent approaches must fail to demonstrate any physical and therefore determined basis for human freedom, the ability to know

Block's (1978) psychofunctionalism: "that the scientific nature of the mental consists not in anything biological, but in something organizational, analogous to computational structure."

1995 Sperry, "Consciousness and Causality". As for note above, this need not imply a position of determinism. For example "Thus the critical, multinested space time pattern properties of the neuronal infrastructure, as well as the mass-energy elements, must also be included in the causal account."

1996 "A representation is conscious if it is broadcast on a global neuronal workspace." Block, "Consciousness". This position does not necessarily suggest physical determination but the exact meaning requires clarification. Note also: the underpinning emergent view is primarily based on an evolutionary development of the mind. Essentially it is materialist view, asserting that matter possesses undescribed mechanisms that account for the phenomena of consciousness.

1997 H.P. Stapp, "A quantum theory of the mind-brain interface," in *Mind, Matter, and Quantum Mechanics*, (Berlin: Springer, 1993), 145–172.

1998 Roger Penrose, *Shadows of the Mind* (Oxford: OUP, 1994).

1999 Schwartz and Begley, *The Mind and the Brain*.

2000 G. Vitiello, "Dissipative quantum brain dynamics," in *No Matter, Never Mind*, ed. K. Yasue, et al. (Amsterdam: Benjamins, 2002), 43–61.

2001 J. Searle, *Freedom and neurobiology. Reflections on free will, language and political power* (NY: Columbia University Press, 2007).

2002 Gazzaniga, *Who's in charge. Free will and the science of the brain.*

2003 Churchland, "Consciousness". "'Quantum gravitation coherence' occurs within the microtubules of the brain's axonal fibres as the hallmark or essence of consciousness, on grounds that blocking such coherence may explain how anaesthetics work, while the achievement of such quantum-level coherences may explain the existence of sound but non algorithmic mathematical knowledge."

2004 The hypothesis that quantum effects within neuronal microtubules constitute the soul.

				reality and universals, and to form love-choices. The notion of participation in being remains an insuperable obstacle for materialist indeterminacy.
	New mysterian account The term harks back to the "old mysterians", supposedly the Cartesians, who proposed nonnatural solutions without adequate explanation.	Colin McGinn (1989)[2005]	"New mysterianism is a postmodern position designed to drive a railroad spike through the heart of scientism" [2006] The position argues that the hard problem of consciousness cannot be resolved because we can never know another's subjective experiences.[2007]	As the New mysterian account is essentially an emergent view of consciousness, the hylomorphic responses to emergentism are applicable. Ultimately qualia, in a physicalist account, cannot escape the determinism of their origins. Haldane insists that preoccupation with the study of qualia must not take priority over the ontological questions. See above.
Panpsychism	"The view that the basic physical constituents of the universe have mental properties."[2008]	William James (1900s) Thomas Nagel (1974)[2009] Panpsychism has ignited interest in	A form of property dualism following four premises: materialism; non reductionism;	Nagel's concern has been to provide an effective refutation of physicalism. [2012] Hylomorphic

[2005] C. McGinn, *Mental Content* (Oxford: Blackwell, 1989).
[2006] O.J. Flanagan, *Consciousness Reconsidered* (Cambridge MA: MIT Press, 1992), 10,131.
[2007] Nevertheless, as there is no possibility of studying consciousness from outside the system, there is a certain common sense in these insights.
[2008] Thomas Nagel, *Mortal Questions* (Cambridge: Cambridge University Press, 1979), 181.
[2009] T. Nagel, "What is it like to be a bat?" *Philosophical Review* 83, (1974): 435-50.

		consciousness and qualia. It was to some extent a reaction to the materialist identity theories that were dismissive of the significance of subjective experience.	realism; and non emergence.[2010] It is a universal mental particle theory. Nagel postulated non-mental, non-physical properties, “proto mental properties” in response to the difficulty of understanding subjective experience [2011]	critique would question the possibility of discussion of rationality, as a prerequisite to certain mental experience, within a functionalist and essentially materialist paradigm.[2013] As a non reductive materialist position responses above apply.
4. Ontological anti reductionism[2014]				
Dualism	Dualism is “the philosophical theory that supposes that the mind is essentially independent of the brain, though mental events run parallel with physical brain events”.[2015]	K.Popper and J.Eccles (1977)[2016] J.Foster (1996)[2017] Following Descartes other figures modified the theory. Malebranche developed “occasionalism”	Descartes proposed separate spiritual and material substances. “Mind and body interact and ideas represent material things without resembling them”; “God	“The error of the Cartesian is to suppose that non-physical attributes imply an exclusively incorporeal substance as bearer.”[2021] [2022] Cartesian dualism represents an

[2012] Cf Nagel, “What is it like to be a bat?” 437. Nagel argued “If physicalism is to be defended, the phenomenological features (of experience) must themselves be given a physical account. But when we examine their subjective character it seems that such a result is impossible” His approach respects the hylomorphic principle that only like properties may be compared.

[2010] The view of Thomas Nagel.

[2011] McLaughlin, “Philosophy of Mind,” 597.

[2013] Nagel is preoccupied with demonstrating the reality of experience rather than the reality of being itself. He chooses not to discuss key metaphysical questions. Strawson’s argument that person is more fundamental than a person’s mind or body is relevant here.

[2014] “Ontological antireductionism holds… that certain higher-order phenomena cannot even in principle be fully explained by physics, but require additional principles that are not entailed by the laws governing the basic constituents. With respect to biology, the question is whether the existence and operation of highly complex functionally organized systems, and the appearance of self-replicating systems in the universe, can be accounted for in terms of particle physics alone, or whether they require independent principles of order.” T Nagel, “Reductionism and Antireductionism” *Novartis Foundation Symposium* 213, (1998):3-10.

[2015] “Dualism” in *Oxford Companion to the Mind,* 2nd ed., Richard L. Gregory ed. (Oxford: OUP, 2004), 271.

[2016] K. Popper and J.Eccles, *The Self and its Brain* (Springer, New York, 1977).

[2017] J. Foster, “A defence of dualism” in *The Case for Dualism*, J. Smythies and J. Beloff ed.(Charlottesville: University of Virginia Press, 1989).

		[2018]; Leibnitz developed a theory of harmony among non interacting monads; Spinoza within a one substance view proposed a paradigm of property. [2019]	makes these things happen".[2020] Cartesian dualism has difficulty in accounting for sensation, knowledge and causality.	essentially anti-Aristotelian view of the material world.[2023] Descartes' view of the mind as a substance, an object, was a category mistake.[2024] "There is no *a priori* reason to think that the mind is intimately related to the brain and Aristotle did not associate them." [2025] [2026]
Attribute Dualism	Essentially attribute dualism proposes we comprehend the same reality whether under mental or	Spinoza (1677)[2028] Strawson (1959)[2029] Thomas Nagel (1986)[2030] David Chalmers (1996)[2031]	The higher region of the brain is a physical substance "with some non physical properties".[2032]	The "neo dualist" approach may cite the "body or some part of it, ie the brain, as being that with which this

[2021] Haldane, "A return to form in the philosophy of mind," 58 Haldane argues that "a proper understanding of substantiality should lead one to reject the idea that a wholly physical particular could be the bearer of intrinsic attributes that are non-physical.`

[2022] Anscombe insisted philosophy must once and for all discard Cartesian ways of thinking about matter. "The divide between matter and mind was drawn differently by the ancients and medievals from the way it is drawn in modern times. So far as I know, the source of the new way of drawing the line is Descartes…." She nominated the very passage where Descartes made the mistake of identifying brain and mind in his *Second Meditation*. G. E. M. Anscombe, *Collected papers of GEM Anscombe*, Vol 2, *Metaphysics and the Philosophy of Mind*. Republished as *Human Life, Action and Ethics* (Oxford: Basil Blackwell, 1981), Chapter 1.

[2018] Occasionalism: in which the mind and body do not interact but God makes them appear to.

[2019] Richard A. Watson, "Dualism" in *The Cambridge Dictionary of Philosophy*, Robert Audi ed. (Cambridge: CUP, 1995).

[2020] McLaughlin, "Philosophy of Mind," 597. Descartes held that extension is the essence of the physical and so minds are not physical. He held that two way causation without any physical basis connects our minds to our brains.

[2023] Armstrong, "Mind body problem: philosophical theory". This involves rejection of teleological considerations, with bodies operating as machines according to physical principles. Ironically Descartes opens the door to a materialist account of the mind.

[2024] Ryle and Anscombe both argued this. Furthermore an hylomorphic critique points out the mistake of attributing efficient causality to representations in the intellect and guards against a materialisation of the process.

[2025] McLaughlin, "Philosophy of Mind," 597.

[2026] McLaughlin, "Philosophy of Mind," 597.Ryle argued that mind, while a noun, is not an object, and so Descartes was confusing discourse about body with that of mind, which is to have capacities and dispositions.

	physical attributes. There are many forms of dual aspect theory. Double aspect theory is in fact a family of theories: universal or restricted, mixed mental particle theories.[2027]	Attribute dualism traces back to Spinoza who proposed a single eternal substance with attributes including extension and thought; ordinary things are modes of this substance. Spinoza's theory may also be seen as a form of panpsychism.	Attribute dualism adopts a "special particle theory" that incorporates a restricted mixed mental particle theory: "that some basic constituents of things, which are at least spatially located, have mental properties, but not all".[2033] [2034]	subject is associated" thus permitting "a psychophysical subject of thought and action".[2035] In contemporary philosophy of mind, the attribute dualist appears to underestimate the notion of participation and so struggles to offer a plausible explanation for rationality.[2036]
Non dualist, dual aspect, social being	A non reductive account holding that human beings are truly free and that they operate in a social context.	Gillett (2001)[2037]	There are aspects of an analytic approach that avoids the metaphysical. Gillett holds that the explanation	Malo's critique of this position centres on free action as not to be conceived as external. It is not a "freedom from without", but rather "from

[2028] B. Spinoza, *Ethics* (1677).
[2029] P. Strawson, *Individuals. An Essay in Descriptive Metaphysics* (London: Methuen, 1959).
[2030] T. Nagel, *The View from Nowhere* (Oxford: Oxford University Press, 1986).
[2031] Chalmers, *The Conscious Mind. In Search of a Fundamental Theory*.
[2032] Haldane, "A return to form in the philosophy of mind," 58.
[2027] Leopold Stubenberg, "Neutral Monism". "Its relationship to neutral monism is therefore difficult to discern. All versions of the theory appear to be committed to the view that there are certain substances—god or nature (Spinoza), persons (Strawson), body or brain (Thomas Nagel), information (a view explored by David Chalmers)—that are intrinsically neither material nor mental."
[2033] Ludwig, "The Mind-Body Problem: An Overview," 17.
[2034] Ludwig, "The Mind-Body Problem: An Overview," 17. While this position is not among the traditional responses to mind body problem it appears to hold currency in certain neuroscientific circles
[2035] Haldane, "Incarnational anthropology," 78.
[2036] This challenge was unanswered also by Spinoza whose one substance view was ultimately an unsatisfying understanding of rationality. Cf David Papineau, "Consciousness" in *Oxford Companion to the Mind,* 2nd ed., Richard L. Gregory ed. (Oxford: OUP, 2004), who notes that attribute dualism requires us to make a false choice of either denying dualism or identifying conscious experiences with the neural causes of behaviour.
[2037] G. R. Gillett, "Free will and events in the brain," *Journal of Mind and Behaviour* 22, 3 (2001): 287-310. (Available at www.btinternet.com/~Negativecharisma/freewill/gillet1.pdf.) Gillett's approach is to link freedom with the ability to accord one's behaviour with socal rules: in a sense this is another perspective on freedom shown in one's capacity to carry out the will of another, or the beloved.

			of human action lies in the the person's mental acts. He argues that there are two kinds of reality: physical and psychic. Psychic is constituted not by mental processes but by the form of the human action in a social context.	within", depending "ontologically on the person".[2038]
Non dualist, dual aspect, hylomorphism.	A non reductive account holding that, in the person, the material is animated by a non-material principle, and that operations and activity, both mental and physical, are carried out by this ensouled body.	Aristotelian-Thomistic philosophers of mind. In recent years, Haldane and Nussbaum among others.	See extended discussion in **1.5**.	Hylomorphism provides a "third way", a most attractive solution that allows for a non dualist, dual aspect, alternative, while allowing for the non-material dimension of human nature.

[2038] Antonio Malo, "Three theories about freedom" pre publication manuscript, 145.

Table 2.1
Search Process

Search number	Date	Database	Key words Numerous other searches were conducted in preparation, identifying words that were most effective in the searches.[2039]	Number of studies	Number of relevant results
1	21.8.08	Medline	Learning. Plasticity. Synaptic strengthening.	18	9
2	10.2.09	Scopus	Neuroscience. Plasticity. Habitual behaviour.	20	12
3	10.2.09	Scopus	Neuroplasticity. Learning. Emotion.	23	1
4	10.02.09	Medline	Neuroscience. Neuronal plasticity. Behaviour.	27	3
5	10.02.09	Medline	Neuronal plasticity. Learning. Habits.	11	2
6	22.04.09	Scopus	Neuroplasticity OR Plasticity AND Moral development.	82	12
7	22.04.09	Scopus	Neuroplasticity OR Plasticity AND cognition AND Habit AND Moral	12	3
8	22.04.09	Scopus	Neuroplasticity OR Plasticity AND Cognition AND Habit	188	19
9	22.04.09	Scopus	Plasticity AND Executive Function AND Moral	3	2
10	22.04.09	Scopus	Plasticity AND Personality AND Neuroscience AND Habit	13	4
11	19.10.12	Pubmed	Neuroscience AND Emotion regulation (Recent reviews only)	82	7
12	19.10.12	Pubmed	Basal Ganglia AND Emotion regulation	67	3
13	19.10.12	Pubmed	Experience AND Plasticity	75	5

[2039] Prior to settling on searches of 10.2.09 and 22.04.09 I conducted extensive trial searches with further key words: procedural learning, automatisation, automaticity, goal directed actions, mirror neurons, virtue, emotion, emotion regulation, neuropsychology, attention.

Table 2.2
Systems for sensitive periods of development

Principal sources: Arden and Linford (2009); Coon (1997); Kessels and Malinow (2009); Knudson (2008); Stevens (2008).

Prima facie association with development and exercise of virtue	Principal associated brain areas Discussion proceeds from overview, and thence to higher brain areas, to subcortical structures, the BG and limbic structures.	Principal pathways and mechanisms.
• The term "sensitive periods" denotes a developmental window of opportunity, whereby there is an enhanced capacity for plastic change and learning in response to experience, emotional content, or novelty. • Of particular interest in the field of virtue education are sensitive periods found in relation to affection, early experience, imitation, and adoption of new behaviours during early years. First impressions are lasting impressions. Experiences during upbringing, particularly when the stimuli are associated with emotional significance, can be virtually indelible. • Windows of opportunity in sensitive periods vary: for imprinting the window is open only for a few hours; for language, for years. Responsiveness to maternal affection is largely lost after the earliest years. The security of affection, in turn, facilitates other aspects of learning from parents.	• Sensitive periods of development occur across all neural structures and pathways. • Forms of sensitive period learning relevant to virtue education are closely associated with attentional systems. Learning in critical periods is effortless because the **nucleus basalis** presents as active throughout during these periods. The nucleus basalis, and the attention system in which it plays a critical part have been described as "the modulatory control system of plasticity". (See **Table 2.9 Attentional systems.**) • **The relationship between sensitive periods and cortical development** is much documented. • The **amygdala** is particularly active in mediating early attachment relationships, and reaction to stress and non conscious emotional memories.	• During the early stages of neuronal development, **guidance mechanisms** are particularly active: astrocyte, and associated molecular guidance cues of migrating neurons and production of growth (trophic) factors; • **Various mechanisms are directly involved in sensitive period learning.** Experience tunes both excitatory and inhibitory connections in a largely non reversible manner and according to Hebbian principles. NMDA receptors triggering gene transcription associated with LTP and LTD are integral to the mechanisms of the sensitive periods and developmental learning. Also, BDNF, hypothalamic oxytocin, DA and 5-HT are implicated. • **Systems associated with responsiveness to affection** are implicated in sensitive periods. • **Attentive mothering** leads to gene transcripted cellular changes in the hippocampus reducing basal levels of glucocorticoids and abolishing thereby anxiety and fearfulness. The end of the sensitive period is triggered sensory input

and possibly by myelination.

- **Neurotrophins**
- **Emotional arousal**, for example in the positive affect produced by sound mothering, appears to promote synaptic plasticity in memory promoting learning. Mechanisms include release of NE.
- Attentional mechanisms operate in conjunction with the great range of **mechanisms of plasticity** associated with sensitive periods of development

Table 2.3
Overview of the numerous systems and mechanisms of plasticity operating at the cellular and molecular level.

Principal sources: Butz (2009); Graybiel (2008).

Prima facie association with development and exercise of virtue	Principal associated brain areas Discussion proceeds from overview, and thence to higher brain areas, to subcortical structures, the BG and limbic structures.	Principal pathways and mechanisms.
• The brain's virtually ubiquitous **capacity for plastic change** permits the various forms of learning, including the learning of good habits. • Plastic changes are shown to be **triggered by neural activity** itself. Hence repeated experience lays down consolidated pathways whereby previous behaviours are more easily revisited. • Plastic changes provide a **neural explanation for the phenomenon of habit**. Furthermore, freely chosen behaviours and activities are self-reinforcing. Prior choices are more easily replicated. • Forms of structural plasticity dependent on gene expression bring about permanent neural changes, and potentially new behaviours and a modified personality.	• **Plasticity is evident throughout the cortical and subcortical areas of the human brain**, including areas of the brain associated with emotional regulation and reward systems: most notably areas of the PFC, the limbic system and the BG, areas central to the changes evident in the acquisition of virtue. • See also: **2.4.7**; **2.5.4**; **2.7.3.**	• **Structural plasticity** is ubiquitously present in the mature human brain. (See **Table 2.15 Summary of mechanisms for neuronal structural plasticity as presented throughout Chapter 2.)** • **Developmental plasticities** allow neural development driven by for timely inputs. In the character development of a young child, training in moderation of gratification and endurance of difficulties is more easily learned. • **Activity dependent plasticity** is present across the cortex, in subcortical, limbic, and lower brain areas, and at the neuromuscular synapse.

Table 2.4
Systems for learning

Principal sources: Ito (2001); LeDoux (2001); Manns and Hichenbaum (2008); Pollak (2005); Siegal and Sapru (2006); Waxham (2008); Wickens (2009).

Prima facie association with development and exercise of virtue	Principal associated brain areas Discussion proceeds from overview, and thence to higher brain areas, to subcortical structures, the BG and limbic structures.	Principal pathways and mechanisms.
• Learning denotes **knowledge acquired through experience**, or changed behaviour as a response to experience. Learning may be either conscious or unconscious. • Learning and memory are **key processes by which environment and experience alter behaviour**. • Systems implicated in general learning will also be **implicated in moral learning**. • **Virtue is a form of experiential learning**. Moral learning, moral "education", is central to the development of virtue, and in particular, to the development of conscience, an aspect of the virtue of prudence. • **Growth of intrinsic motivation** over external reward as automaticity is developed accords with view that virtue is carried out for its own sake. • **Development of automaticity is intrinsice to virtue.** That DA release associated with rewarding outcomes facilitates learning, and that reward paradigms convert over time to automaticity in the BG suggest a central role for reward systems in learning of at least some	• **Numerous brain centres are implicated in learning**, including: hippocampus (initially implicated in classical conditioning but now known to play a major role in filing explicit memory); cerebellum (critical for long term retention of the learned response); striatum (procedural and reward learning); amygdala (emotional memories); cortex (long term memories). • The **roles of the cortex and of the BG are most significant** for this study. The ventral striatum is associated with emotional and reward learning; the dorsal striatum lays down memory for motor habits and instructs the PFC in S-R situations. The cortex (most especially areas of PFC, association areas, and the medial temporal lobe) plays a role in many forms of memory. The networks of the major learning systems include cerebral cortex.	• See **2.3 Neural bases for learning and memory.** • Forms of functional and structural neuronal **plasticities underpin mechanisms of learning**. Forms of implicit learning such as fear and operant conditioning, classical conditioning, habituation, and sensitization utilise various mechanisms varying synaptic strength. For example, there may be decreases or increases in synaptic strength following changed transmitter release or presynaptic facilitation, associated changes in the dendritic tree, etc. • **Explicit learning**, tends to utilise forms of LTD mediating longer term changes. Learning associated with LTP and LTD is mediated by NMDA receptors, coexisting with A receptors, activated by L-Glutamate. • **DA is a key mediator** of emotion and reward associated learning throughout the limbic, striatal and cortical regions. Various other neurotransmitters and modulators also effect learning. • **ACh mediates learning** at the neuromuscular synapse as well as vivid

forms of volitional behaviours associated with virtue.		fearful memories in the nucleus basalis. • Forms of procedural learning, involving increased **automaticity may develop from prior goal directed actions**. This appears to be a pattern associated with habit learning: A-O paradigms transform to S-R paradigms with over learning. Automaticity takes over with accompanying changes from external to intrinsic motivation.

Table 2.5
Memory systems

Principal sources: Alvarez et al. (2007); Arden and Linford (2009); Bailey and Chen (1983); Bear (2007); Bechara et al. (2000); Butz et al. (2009); Byrne (2008); Chistiakova and Volgushev (2009); Costa-Mattioli (2008); Da Cunha et al. (2009); Desmurget et al. (2007); Engert and Bonhoeffer (1999); Deutch and Roth (2008); Floyer-Lea and Matthews (2008); Froemke et al. (2007); Lynch (2004); Manns and Hichenbaum (2008); Marieb and Hoehn (2010); McGaugh (2004); Pastalkova et al. (2006); Pasupathy and Miller (2005); Roesch and Schoenbaum (2006); Romero et al. (2008); Squire et al. (2008); Stranahan and Mattson (2008); Tapia and Lichtman, (2008); Tomita et al (1999); Tully et al. (2003); Vaynman and Gomez-Pinilla (2005); Waxham (2008); Wickens (2009); Whitlock (2006); Yasumatsu et al. (2008).

Prima facie association with development and exercise of virtue	Principal associated brain areas Discussion proceeds from overview, and thence to higher brain areas, to subcortical structures, the BG and limbic structures.	Principal pathways and mechanisms.
• **Learning and memory are key processes** by which environment and experience alter behaviour. • Memory is the process of encoding, storage and **retrieval of knowledge acquired through experience**. • **Memory systems are functionally implicit to learning**, to response to reward and emotion, to habit formation, to goal election, and all cognitive function. • **Memory is a functional prerequisite for the exercise of virtue**: memory of past behaviours, of reward, of contextual and emotional resonances, and of principles of right and wrong, all have relevance. • Mechanisms of **non-declarative memory appear to facilitate the ease of practice** and the inherent motivational rewards in virtue, while during the more arduous process of acquisition of virtue, declarative	• Memory is distributed through cortical and lower brain areas. Actual behaviour is supported by **multiple memory systems**. Memory may be non-declarative (implicit and procedural) or declarative or episodic (conscious and recollective); it may be long term, intermediate, short term, or working memory, an even more transient form of short term memory. • **Long term non-declarative procedural memory** is located in BG in association with cerebellum and neocortex. Memory in the striatum instructs the PFC with respect to S-R situations. Long term non-declarative emotional memory is dependent on amygdala which associates rewards and punishments with particular cues. Long term non-declarative motor memory is distributed in conditioned reflexes dependent upon cerebellum.	• See **2.3 Neural bases for learning and memory.** • The numerous mechanisms of plasticity are at the basis of memory. • **LTP and LTD** appear to be mechanisms in the cortex and hippocampus associated with long term memory storage. Feedback loops, and permanent loss of axonal input are further attractive mechanisms for information storage. • Further **mechanisms for consolidation of memories** include: synaptic homeostasis; use-induced plasticities another;and BDNF is implicated in converting short term memories to long term memories. • **Neural stem cells** persisting in regions near ventricular layers including the hippocampus are implicated in mechanisms for memory and learning. • There is remarkably **complex interplay of brain areas in both short**

memory plays a more significant role. • **Memory is enhanced in the presence of emotion** that is not excessively intense. That affection enhances memory establishes an early childhood facilitation.	• **Long term declarative memory** is based in the median temporal lobe and the medial diencephalon, known as the hippocampal memory system. • Memory in the **cortex** is highly plastic. OFC is richly connected to other cortical areas and to the limbic system mediating **emotional memory**. • **Hippocampal memory** is important for both spatial and non-spatial learning, and is rapidly acquired by facilitating novel associations. The hippocampus initially acts as retrieval system for information in widespread areas of neocortex and facilities ongoing cortical plasticity. Hippocampal plasticity is supplanted by cortical plasticity over time, mediated by the striatum. • **Cerebellar memory** is involved in motor reflex learning.	**and long term learning**. Short term memory is possibly mediated by virtually instantaneous spine growth, and mechanisms of rapid spine assembly (typically 20 mins) where modifications can be virtually instantaneous. • **Activation of stored memories** depends on PFC – temporal cortex connection. Working memory in neocortex involves some form of synaptic facilitation possibly based on reverberating circuits. Short term memory in PFC appears to depend on dopaminergic receptors. • **Emotional memory** is laid down by NE mediated plasticity principally in the BLA. Intentional recall is managed by hippocampus, which is subject to cortical direction. • Interconnections between the PFC, the medial temporal lobe, and hippocampus appear implicated in **working memory**, which is linked to problem solving and planning. • The **role of the BG in action selection and storage of non declarative memories** is mediated by convergent projections, synchronised by the timing of ACh release by giant cholinergic aspiny neurons, which are tonically active. • Sleep is shown to create a context for Hebbian and non-Hebbian consolidation of memory.

Table 2.6
Systems for imitation and empathy

Principal sources: Arden and Linford (2009); Byrne (2008); Carr and Jacoboni et al. (2003); Jacoboni et al. (1999); Nitschke et al. (2003); Pollak (2005); Schore (2001); Rizzolatti G et al. (2009).

Prima facie association with development and exercise of virtue	Principal associated brain areas Discussion proceeds from overview, and thence to higher brain areas, to subcortical structures, the BG and limbic structures.	Principal pathways and mechanisms.
• **Imitation is one of the core processes for learning** from the environment and from the example of others. The neural basis for this is now increasingly well described and provides an explanation for the ease of acquisition of virtuous behaviours by children. • **Imitation and empathy are related at the level of neural systems**. Plasticity in the systems for empathetic response appears integral to the development of sensitivity for the rights and needs of others, and an understanding of the consequences of one's actions, which appear to be are at the core of the virtue of justice. • **Effective emotional modulation of deliberation is essential for sound reasoning** particularly in areas requiring empathy with others, understanding of others viewpoints etc, and TOM.	• The imitation mechanisms, **mirror neurons**, are present in the left frontal operculum area (Broca's area) and the right anterior parietal cortex. Empathy and imitation involve activity in fronto-parietal, the superior temporal cortex, the amygdala, and insula. • **OFC**, at the apex of a limbic circuit connecting the VMPFC, AC gyrus, amygdala and temporal pole, plays a major role processing appreciation of moral consequences of behaviour, and assessing interpersonal context. Activation of the OFC produces warm and loving feelings, to the extent that the OFC can overwhelm consciousness with these feelings. • **Left and right OFC** appear to differ in function, the right decodes mental states of others and is associated with empathy with others; the left reasons about mental states. The right orbitofrontal and right anterior insula cortices are components of a pathway that integrates bodily	• Increasingly, the mechanisms of imitation and empathy are being linked to the **activity of mirror neurons**. The rapid development of speech appears to reflect the maturation of the association cortical areas indicating that imitative systems enjoy dense cortical interconnections. • There is now abundant evidence that **developmental realities as well as learned realities** (including moral realities such as how one exercises one's freedom), govern effective consideration of the consequences of actions. Grey matter reaches a maximum at 10-12 years of age in parietal lobe, 11-12 in frontal lobe, and 16-17 in temporal lobe. In contrast to grey matter, white matter maturation continues throughout childhood and adolescence, and into early 20s for males. Myelination tends to progress from lower to higher brain areas. Higher cortical areas are last to develop. All this bears significantly on the capacity to consideration of consequences of one's actions, for example on

	responses with attentional and emotional states. The right limbic system is key to complex attachment dynamics and interpersonal coping. • **BG** are acknowledged to have a key role in control and modulation of social behaviours and may be integral to a progressive evaluation process of behaviours. “Current findings are consistent with a role for incoming afferent input in selectively stabilizing functional synapses and in eliminating or suppressing inactive contacts.” (Byrne, 2008.)	rational consideration of risks, and of the impact of one’s actions on others. This area appears closely associated with the development of empathy towards others.

Table 2.7
Systems for habit formation

Principal sources: Beretta et al. (2008); Byrne (2008); Doyon et al. (2009); Marieb and Hoehn (2010); Martin (2003); Wise and Shadmehr (2002); Yin and Knowlton (2006).

Prima facie association with development and exercise of virtue	Principal associated brain areas Discussion proceeds from overview, and thence to higher brain areas, to subcortical structures, the BG and limbic structures.	Principal pathways and mechanisms.
• **Virtues may be understood as freely chosen automatised behaviours**. • Strictly speaking **habit learning refers to the spectrum of automatized behaviours** supported by the BG. • Mechanisms of habit learning also offer an explanation for the phenomenon of **behaviours that appear to remain robust in the absence of immediate rewards**. We have seen immediately above that emotional regulation and reward processing are interdependent. Reward processing and habit formation also are interlinked systems, with reward processing essential in the early stages of laying down habits. This accords with the view that extrinsic motivation assists initially in establishing patterns of good behaviour; in time this is transformed into forms of intrinsic motivation with the development of a degree of automaticity. • The brain **regions and pathways associated with the BG seem to offer a significant key to**	• **Brain regions associated with habit formation** are areas of the BG as well as the posterior parts of the cerebellum, the non primary motor cortex, and the PPC. Via the oculomotor and skeletomotor limbic loop, the BG play an integral role in management of motor responses to cortical direction. • **BG** are now seen as a centre, not only for subconscious facilitation of habits, but also mediating deliberate attention, and limbic modulation of cognition and action. Hence it is an area critical for learning, cognition and behavioural control. It appears to have a key role both in habit formation, and in the pursuit of complex, purposeful, behaviour patterns. It may be argued that individual goal directed behaviours, on repetition become automated and less reward dependent, but nevertheless they remain purposeful, thereby fulfilling requirements for virtuous action. That actions are automatic, should not be taken to mean that they are less conscious. The relevance	• **Procedural memory consolidation** is associated with the reward systems of the brain. DA release from the SN is believed to trigger memory formation in the BG. There is also evidence for emotional facilitation of memory in the BG. • Striatal habit formation is subject to cortical management via the striatal-cortical pathway. The **dorsal pars (dorsal striatum and SN) lays down memory for motor habits**, actions and outcomes, playing a key role in S-R habit learning. It receives afferents from associative (more implicated in A-O learning) and sensorimotor domains. The caudate nucleus receives information from cortical sensory, motor and integrative areas. The caudate is an area of the "associative striatum" and receives inputs from association cortices. The putamen is regarded as an area of the sensorimotor striatum. DA neuromodulation inputs this region from the SNpc. This region is involved in learning and movement initiation.

understanding the neural bases of virtue. Converging research over the past decade links habit formation and volition. In particular, the BG-thalamo-cortical loops with their widespread cognitive-emotional interaction offer insights into processes of planning, goal selection, self regulation, attention and motivation. Furthermore this automatisation lies at the heart of the easy repeatability of behaviours associated with virtue… for example the habit of greeting courteously, of getting up when the alarm goes off, of reacting to difficulties with patient strategies, etc. Mechanisms of habit learning also offer an explanation for the phenomenon of behaviours that appear to remain robust in the absence of immediate rewards.	of this to virtues as conscious, automatic (performed with little overt effort) behaviours, is seen. • **Hippocampal plasticity** and memory are present in the development phase of habits in the striatum.	• The **prefrontal cortex-basal ganglionic pathways** sustain voluntary movement, whereas the **motor cortex-basal ganglionic modules** underlie more automatic movements.

Table 2.8
Systems for emotional management

Principal sources: Arden and Linford (2009); Balbernie (2001); Barbas and Zikopoulos (2006); Beauregard et al (2001); Bennett (2011); Carr and Jacoboni et al. (2003); Davidson (2000);.Depue and Collins (1999); Graybiel (2008); Guyton and Hall (2006); Heatherton and Wagner (2011); Keopp et al. (1998); LeDoux (1998); Lee (2007); Markowitsch et al. (2003); Pare et al. (2004); Posner and Rothbart (2000); Rapp and Bachevalier (2008); Ray and Zald (2012); Salzman and Fusi (2010); Schore (2001); Siegal and Sapru (2006); Squire (2008); Zotev et al. (2011).

Prima facie association with development and exercise of virtue	Principal associated brain areas Discussion proceeds from overview, and thence to higher brain areas, to subcortical structures, the BG and limbic structures.	Principal pathways and mechanisms.
• **Emotion management systems are at the heart of directing our desires** towards appropriate pleasure and towards worthy goals despite difficulty. • The **habitual management of emotion according to what is rational** is the essence of the exercise of virtue. • Appropriate **emotional/aesthetic/ social/moral education** is central to the development of virtue. • **Emotional regulation involves cortical regulation of goals, memories and emotional experience**. The potential for emotion to enhance rationality has been much noted in recent years.	• **Emotion is processed in the brain in various regions** including several parts of the PFC, namely DLPFC, VMPFC, OFC, as well as the amygdala, hippocampus, anterior cingulate, and insular cortex. Subcortical sensory inputs to the amygdala can drive emotional responses that precede cortical awareness. • **Conscious regulation of emotion utilizes OFC, DLPFC and VMPFC,** although evidence suggests that it is reciprocal processing rather than top-down direction that is effective. DLPFC appears to "arbitrate" conflicting emotional situations, and in conjunction with VLPFC and ACC can formulate action plans not tied to emotional input. The VMPFC which appears to play a key role in predicting positive and negative affective consequences. The OFC is regarded as the limbic gateway to the cortex, crucial in emotional control. The OFC, within	• There is **no single emotional system in the brain** and therefore no single system for emotional management. Furthermore there is close interplay between the reward systems, the goal directive and executive systems of the brain, and the systems of emotional management. • **Major emotion associated connections** enter the PFC and especially the OFC and ACC from various brain locations including cortical memory centres, amygdala, hippocampus, thalamus, hypothalamus, VTA, and olfactory system. • **The PFC utilises rich interconnectivity** to the BG, amygdala, hippocampus, anterior cingulate, and insular cortex. Several parts of the PFC, namely DLPFC, VMPFC and OFC are involved in this processing of emotion. The capacity of the PFC to elicit conscious representations of emotion and to assess affective consequences of actions, via neuroplastic remodelling, is at the core

the lateral sulcus is adjacent to both the temporal lobe and the parietal, appears to integrate various sensations, allowing rational processing of raw emotion: viscerosensations, taste, pain, and feelings of disgust. The OFC is activated by tasks where processing of rewarding or emotional information is required.

- **The proximity of these areas of the PFC and limbic centres** facilitates emotional regulation. The DLPFC and ACC are activated in suppression of sexual response and in conscious management of lustful feelings. The ACC appears to play a role in inhibiting impulsive behaviours and in generating goal-directed behaviours. There is evidence that it plays a role in analysing conflicting options.
- There are **brain circuits for specific emotions**, eg hypothalamus associated with the basic drives; anterior insula plays a key role in disgust; amygdala is active in the experience of fear and mediates emotional influences on attention and perception; the BLA in the storage of emotional memories; and the PFC is active in conscious representations of emotion, and in assessing affective consequences of actions.
- **Amygdala** is active in processing of emotion. Via reciprocal pathways reaching virtually all parts of the cortex the amygdala influences not only fear response, but higher order thought of improved affect regulation in the PFC, allowing the OFC to effectively inhibit activation of subcortical areas such as the amygdala.
- The **DMPFC** is also closely associated, linking with inferior parietal cortex, the DLPFC, and the posterior cingulate. It receives limbic inputs and, with its linkages to other PFC areas, integrates the emotional reaction and experience with cognitive processing.
- **BG-thalamo-cortical loops** permit complex cognitive-emotional interaction offer insights into processes of planning, goal selection, self regulation, attention and motivation. The prefrontal-limbic network (including ACC, amygdala and hippocampus), modulated through hypothalamus, BG and midbrain, is central.
- The amygdala plays a central role in fear conditioning, via **the reciprocal cortico-amygdalic pathway in emotional regulation**. The amygdala is now known to receive neuronal signals from all limbic cortical areas, and from the temporal, parietal and occipital cortex (most especially the auditory and visual association areas). Efferent connections return to these cortical areas as well as to the hippocampus, the septum, the thalamus and the hypothalamus. Cortical afferents to the amygdala appear to assist in modifying fear representations in the amygdala. The frontal-

	process, working and long term memories, ongoing perceptions, attention, mental imagery etc. • The **BG** are strategically positioned for regulation of emotional responses as it is positioned within the thalamo-limbic-cortical pathway, the limbic loop of emotional management; dysfunction of basal ganglia-limbic circuitry leads to schizophrenia and severe anxiety. “Increased corticostriatal transmission leads to increased thalamocortical activity, and an increased likelihood of behavioural response expression”(Horvitz, 2009). In the case of tonic, not phasic, DA output, LTD is likely to result in these cells.	amygdala pathway is less effective in mediating frontal regulation of emotion than the frontal-striatal pathway. • The architecture of the brain facilitates the close cooperation of basal structures, OFC, amygdala and hippocampus in cognitive and emotional deliberations. The **ventral striatum** is the target of inputs from the limbic cortex, the hippocampus and the amygdala. • **Neurotransmitters** (most particularly the amines, DA, 5-HT and NE) play a key role in modulating the individual’s emotional responses. DA, which plays a major role in mechanisms for emotion and reward, is widely diffused in cortex with 80% is concentrated in the striatum. 5-HT receptors are found in cells in the raphe nucleus in the brain stem, and also in nerve endings throughout brain. 5-HT is known to inhibit aggression.

Table 2.9
Attentional Systems

Principal sources: Breedlove et al. (2010); Froemke et al. (2007); Kaas and Stepniewska (2002); Knudson (2008); Koch (2008); Lundy Ekman (2007); Markowitsch et al. (2003); Pollak (2005).

Prima facie association with development and exercise of virtue	Principal associated brain areas Discussion proceeds from overview, and thence to higher brain areas, to subcortical structures, the BG and limbic structures.	Principal pathways and mechanisms.
• **Plasticity both enables and is directed by our attention system**. In turn focussed attention permits directed plasticity in the brain: it is regarded as the system controlling aspects of plasticity. In other words, our capacity to direct attention allows us some management of plasticity mediated learning, including the development of habit and virtue. • **Attention allows suppression of goal irrelevant issues** and is a prerequisite for many forms of learning and memory, and for goal election, cognition and executive function, all of which are required for the acquisition of virtue. • The **capacity to attend and will power** appear closely linked. • Normally we attend to stimuli that our senses or imagination present to us. However, the **ability to pay attention to a goal that is neither pressing nor present is central to rationality**.	• **Various cortical and subcortical areas** cooperate in the attentional systems. The parietal lobes, extensively connected with subcortical areas of the thalamus and the nucleus basalis, appear to account for the capacity to direct attention, known as endogenous attention. • The **BG** play an integral role in attention regulation, and in attentional loops. • **ACC** involvement in attentional systems appears necessary for learning, and a prerequisite for goal election and executive command.	• Attention is dependent upon the **fronto-parietal control system**. Structures in the parietal, frontal and cingulated cortices at the top of the visual system hierarchy, neuromodulated by the cholinergic nucleus basalis, generate signals guiding selective attention. • **Attentional mechanisms** are linked to NMDA plasticities. Mechanisms for enhancing attention involve neural signalling amplification. • Various **neurotransmitters** are directly implicated in mediating attention: DA appears to facilitate attention. ACh release into thalamus is critical for consciousness and for selection of objects of attention.

Table 2.10
Instrumental learning in the basal ganglia.

Principal sources: Da Cunha et al. (2008); Graybiel (2008); Horvitz (2009); Robinson and Berridge (2003); Yin and Knowlton (2006).

Learning with respect to rewards may be	**Goal directed**		**Habitual**
Form of instrumental learning present in BG	***stimulus-outcome*** **(S-O) Preceding A-O learning.**	***action-outcome*** **(A-O)**	***stimulus-response*** **(S-R)**
Form of memory		declarative (explicit and conscious)	procedural (unconscious or automatic)
Facilitation	DA mediated in the presence of representations of rewards.	DA mediated in the presence of representations of rewards.	Appropriate schedules of reinforcement, or overtraining of A-O learning leads to habitual learning and movement of active zone of BG towards the dorsal striatum.
Process	Presentation of reward.	Through learning the behavioural response is associated to a particular outcome.	Coincident active inputs for stimuli and outputs for motor responses are strengthened.
Core features	Immediate appetitive response.	A cognitive and explicit recognition of the causal relationship between act and outcome.	A habitual association between specific stimulus and response is established.
Conditions	Process of initial exposures.	The subject must retain in memory the value of the expected outcome. The causal relationship between action and outcome must be demonstrated.	Unaffected by reward devaluation. Highest level of automaticity.
Cortical substrate		DLPFC and motor cortices	Motor cortices
Striatal substrate	NAc.	Ventral striatum. Caudate.	Dorsal striatum.
Pathway	Limbic to NAc.	Association cortex to DMS (caudate in humans) and is modulated by reward expectancy (and by the limbic loop which plays a key role in Pavlovian learning)	Sensorimotor cortex to DLS... the sensorimotor striatum, the putamen, in humans.

Table 2.11
Reward and motivational systems

Principal sources: Arden and Linford (2009); Barbas and Zikopoulos (2006); Beretta et al. (2008); Buitelaar (2012); Da Cunha et al. (2009); Depue and Collins (1999); Di Filippo et al.(2009); Graybiel (2008); Guyton and Hall (2006); Hamann et al. (2002); Heatherton and Wagner (2011); Koch (2008); Manns and Hichenbaum (2008); Miller and Cohen (2001); Horvitz (2009); O'Doherty and Dolan (2006); Petersen (2007); Price (2006); Roesch and Schoenbaum (2006); Roberts and Parkinson (2006); Shiflett and Balleine (2011); Somerville and Casey (2010); Wagner and Silber (2004); Schultz and Tremblay (2006); Wickens (2009); Yin and Knowlton (2006).

Prima facie association with development and exercise of virtue	Principal associated brain areas. Discussion proceeds from overview, and thence to higher brain areas, to subcortical structures, the BG and limbic structures.	Principal pathways and mechanisms.
• **Reward systems are implicated at most levels of volitional and sub-volitional activity**. Through their interaction with the emotional systems they provide incentive for action, including virtuous action. • **To find pleasure in appropriate activities is the mark of virtue**, and hence the link between reward expectations, emotional responses, conscious goal election, and virtue. • **Intrinsically motivated activity is pleasurable in itself** and is an essential characteristic of virtuous activity. • A **habit of appropriate reward expectation** is directly linked to the development of the virtue of temperance.	• Areas of the amygdala, BG, and OFC are interconnected **major reward centres of the brain.** • The **OFC** is activated in processing rewarding or emotional information, of both an affective and attentional type; it is associated with goal-directed conscious choices of action, and in integrating information about rewards and punishments and their predictors to select goals for action. Medial OFC may be implicated in reward and lateral OFC in punishment. OFC allows association information to access representational memory promoting “voluntary, cognitive, and goal directed (not stimulus driven) behaviour and facilitating new learning.” Spindle cells link the OFC and the ACC. They are now believed to play a key role in goal directed behaviour and self control, and possibly also in mechanisms of attention.	• There are two **major reward systems**: the exciting DA driven, and the blissful endorphin driven. **DA release** is the principal mechanism of reward activation. **5-HT and oxytocin also mediate rewards**. • There are **two major DA systems** in the brain: o from the SNpc to caudate and putamen and in a minor way to the NAc- this appears linked to laying down of procedural memory, and possibly to higher order personality traits; o the mesocorticolimbic DA system (mesolimbic dopamine system) originating in the VTA and innervating the NAc, the amygdala and the various parts of the cortex, particularly the PFC- central to the brain’s reward circuit, and critical in facilitation of incentive motivation. • **Emotion and reward processing are interdependent**. The

- **BG** are a central component in both of the principal DA reward systems. The role of the BG, and of the cortico-striatal pathways, in conscious goal election is increasingly well understood. Ventrally based limbic reward transforms to dorsally based pathways associated with habit formation and also addiction.
- **Goal directed behaviours modified by the BG** are based less on reward representations in the ventral striatum and more on cortical based rewards. A-O mechanisms give way to S-R mechanisms also mediated by the striatum. These are not opposed to actions carried out with intention, expectancy and internal representation: such neural activity should not be assumed to be solely a function of antecedent stimuli. In turn, the BG exert a major modulatory effect on glutamatergic cortical outputs via striatal-cortical reciprocal pathways.
- **The BG and OFC are closely associated** in reward processing. BG and OFC are activated in association with movement for an expected reward; cells of the striatum become active in anticipation of reward, mirroring reward coding in the OFC. BG are a central component in both of the principal DA reward systems. Ventrally based limbic reward transforms to dorsally based pathways associated with habit formation and also ventral pars (NAc and the VTA) is a key component of mesolimbic pathway which is active in reward situations playing a major role in motivation. DA afferents to BG effect modulatory output back on the cortex via the cortical-BG-cortical pathways. Appetitive and aversive systems share aspects of common neurobiology. Phasic DA and μ-opioid messaging are mutually interdependent.
- The **OFC** has reciprocal connections to the limbic system and to the striatum (including via the cortico-striato-pallido-thalamic loop) similar to a loop associated with the medial PFC. The OFC (particularly area MOC13), with rich connection to the amygdala, plays a complex processing role.
- **DA** release, triggered by the novelty of reward stimuli, is central to the creation and reinforcement of associations, is the condition for synaptic plasticity in the BG synapses between corticostriatal neurons and MSNs, possibly involving reverberation in the cortico-striatal loop. this study proposes that triggerings by deliberate and conscious cortical pathways offer the satisfaction of greater self management and are thus attuned to the integrated flourishing of the entire organism.
- Cognitive control of goal election depends on **interplay of a PFC areas, reward system** (moderated by NAc), and

	addiction. • **NAc, pallidum** and **amygdala**, as well as areas of the OFC are active in reward and also in pain processing. • Cue-reward learning and synaptic plasticity in **LA** appears to be a decisive mechanism underpinning goal directed behaviour. • The **hippocampus** appears also to play an integral role in the formulation of goal directed motor plans.	harm avoidant system (amygdala). • Closed cortical (lateralPFC, orbitalPFC, and the premotor cortex) - BG loops possibly enable **PFC to link complex anticipated behaviours with rewards** and then cache chunked to achieve desired outcomes in the rapid plasticities of the striatum.

Table 2.12
A summary of the domains of executive function.

Note: Regions of the PFC do not act in isolation in relation to the functions outlined below: other brain regions provide provide input and feedback facilitating executive control.

Principal sources: Arden (2009); Balbernie (2001); Beauregard et al. (2001); Davidson (2000); Koch (2008); Lazar et al. (2005); Lee (2007); Manns and Hichenbaum (2008); Markowitsch et al. (2003); Miller and Wallis (2008); Moghaddam B & Homayoun H (2008); Nelson (2006); Nolte (2009); Posner (2005); Reynolds et al. (2008); Tomita et al. (1999); Zald and Rauch (2006).

Region	Location and linkages	Executive functions in which implicated	Comment
DLPFC	• Top and sides of the forward lobes. • Closely linked to parietal multimodal cortex, and somatosensory, visual and parietal association areas	• Key regulator of cognitive processes. • Manipulates sources of information. • Involvement in cognitive strategies, planning and formulation of goals. • Appears to be seat of working memory; (evidence that OFC also implicated)	• Damage leads to poor contextual modification of plans. • DLPFC appears to juggle the various cognitive cortical inputs of memories, anticipations, self evaluation, long and short term planning. It appears to play a role in measuring personal conduct against norms. • DLPFC and ACC have been shown to be directly related in conscious management of lustful feelings.
VLPFC	• In interacting with DLPFC and ACC, the VLPFC is active in choosing not to follow familiar behaviour or in choosing a novel behaviour.	• VLPFC appears contributory to self control and emotional inhibition. • VLPFC activated by tasks requiring information in working memory.	• VLPFC appears implicated in reward circuitry in monkey studies.
VMPFC	• Includes anterior cingulate and orbitofrontal areas	• Key role in inhibition of inappropriate behaviours. • Mediation of emotional processing and social decision making. • Prediction of positive and negative affective consequences. • Role in analysis of conflicting options. • Possible role in	• Damage leads to impulsivity, socially inappropriate behaviours and inappropriate emotional responses.

		working memory.	
OFC	• Adjacent to frontal areas of the striatum and provides gateway for thalamo-striatal and limbic connection with higher cortical regulation. • Linkages to all PFC areas, ACC and insula. • Modulatory inputs from VTA.	• Central role in regulation of motivated responses. • Implicated in risk taking and decision making. • Implication in executive processing of reward incentive. OFC codes for the reward value of stimuli, responding to anticipation of future events and so are shown to have access to representations of the external world. • Olfactory processing • Co-implication in working memory in the DLPFC.	• Inhibition of impulsive behaviour may be localised to the right lateral and medial OFC. • Right hemisphere appears to play a greater role in response inhibition. • NB: effective regulation also requires election of appropriate choices. • Possibility that mOFC is implicated in reward and the lateral OFC in punishment. • Right OFC decodes mental states of others, and is associated with empathy with others; left OFC reasons about mental states. • Activation of OFC can flood consciousness with warm positive feelings.
ACC	• Extensive links to limbic system via the hippocampus, the shell region of the NAc and the amygdala. • Extensive links to all cortical areas.	• Involvement in direction of attention, inhibition of impulsive behaviours, and in generation of goal-directed behaviours • Facilitation of information transfer between areas of the PFC	• Parietal, frontal and cingulated cortices at the top of the visual system hierarchy, appear to generate signals guiding selective attention. • Maintenance of attention appears to involve the ACC with the cooperation of the right anterior insula.
DMPFC	• Links with inferior parietal cortex, the DLPFC, and the posterior cingulate. It receives limbic inputs and, with its linkages to other PFC areas, integrates the emotional reaction and experience with cognitive processing.	• Adjusts behaviour according to emotional cues, and assists in regulation of emotional response.	• Active in perspective taking and TOM.
Parietal cortex	• Fronto-parietal network implicated in	• Involvement in response inhibition	• Parietal, frontal and cingulated cortices at

	visuo-spatial processing and working memory.	and attentional systems.	the top of the visual system hierarchy, appear to generate signals guiding selective attention.
Temporal cortex	• Closely interconnected to all parts of the the cortex, and especially PFC.	• Implication in memory, processing sensory input, use of language, and aspects of emotional processing.	• Hippocampus is below the cortex of the medial temporal lobe.

Table 2.13
Systems for cognition, consideration of consequences, planning, goal election and executive direction.

Principal sources: Balbernie (2001); Barbas and Zikopoulos (2006); Beauregard et al (2001); Boller and Grafman (1994); Crossman and Neary (2005); Zald and Rauch (2006); Fuster (1989); Guyton and Hall (2006); Davidson (2000); Lazar et al (2005); Lee (2007); Markowitsch et al. (2003); Miller and Wallis (2008); Moghaddam and Homayoun (2008); Passingham (1993); Posner and Rothbart (2000); Reynolds et al. (2008); Siegal and Sapru (2006); Tomita et al (1999).

Prima facie association with development and exercise of virtue	Principal associated brain areas Discussion proceeds from overview, and thence to higher brain areas, to subcortical structures, the BG and limbic structures.	Principal pathways and mechanisms.
• The **links between cognition, rationality and virtue are closely associated at the psychological level**. Brain systems associated with cognition and goal election interconnect with neural subdivisions implicated in moral behaviour. (See **Table 5.1**.) • **Human cognition normally implies rational capacities**: for conscious goal setting, reasoning, deliberation as to consequences and means, and final election. • The capacity to set specific goals, to direct one's actions to those goals, to reason about consequences and means, appears central to cognition and to rational acts disposed by prudence. **That one chooses goals fitting for one's nature is a mark of rationality**; virtue is essentially the neuronal disposition assisting in the habituation of this capacity. • The **capacity to pay due regard to the impact of**	• **The PFC presents as the most significant region of the brain associated with cognition, deliberation and executive direction.** Areas of the PFC are central to control of behaviour, awareness, memory, and the general interpretive area and the speech centre; they are responsible for limbic regulation and reward, deliberation and assessment of consequences, empathy, motor planning,. The PFC is centrally implicated in higher order cognition, and executive function, involving many aspects of personality, and planning, insight and foresight. This area has the capacity to synthesise cognitive, emotional, contextual and somatic information into goal directed behaviours. • The **interconnection between lateral, orbitofrontal and medial sectors, including the ACC appears to facilitate cognitive and emotional processing, and volitional activity**. (See also above: **Systems of Emotional Management.**)	• The **PFC is richly interconnected** with the other functional sectors in the frontal lobe (for motor and speech), with the other lobes, with subcortical motor systems, with limbic and midbrain emotion and reward circuits. This interconnectivity facilitates cognitive activity. • It is now apparent that **pathways for cognition, executive function,** reward evaluation and motivation, learning and memory, **include the BG** and do not reside solely in the outer cortical layers. The striatum is a key target of excitatory major projections from entire cortex, and is "constantly informed about most aspects of cortical function" (Nolte, 2002). Afferent pathways, input pathways to the BG, are from all regions of the cortex, from the VTA, the ILN and the SNpc. • **Cooperation between cortex and the BG** is necessary for effective cognition and goal

one's actions on others, modifying them accordingly, characterises acts disposed by the virtue of justice.
- The exercise of virtue requires rightness and perfection of reason; **the operations of reason are perfected by the virtues of prudence and justice**.
- **The development of rationality follows a developmental trajectory.** Myelination and development of the PFC continues into the third decade of life. In keeping with the Aristotelian proposal that infants and children, not possessing full rationality, are not capable of perfect virtue, neonates manifest little activity in the cerebral cortex. However the speed of development is striking: in first four years of life, cerebral neuronal activity increases to twice adult levels (reflected in twice adult levels of metabolic rate). There is a decline thereafter to age 15 at which adult levels are achieved. This activity parallels the rise and decline of numbers of synapses.
- **The lateral PFC is activated by cognitive tasks**, the VLPFC by tasks requiring information in working memory, and the DLPFC when information must be manipulated. Anterior areas of PFC may have a role in information transfer between these other areas. Furthermore, the PFC appears implicated in formulation of possible futures. The DLPFC appears to be the key regulator of cognitive processes, richly interconnected to the parietal multimodal cortex as well as to the somatosensory, visual and parietal association areas.
- **The contribution of BG** to intentional behaviour, learning and decision making, is also recognised. BG play an important role in regulation of the function of the cerebral cortexperhaps in overlaying deliberate cognitive agendas onto habituated actions. Check ref.
- Via the cortical association areas-caudate loop, the caudate is implicated in modulation of cognitive cortical function. Interaction between BG-PFC loops adds further dimensions of limbic and cortical modification of outputs.
- This study argues that in the development and exercise of virtue the BG are closely associated with, serves to modulate, and ultimately is second in importance to, the PFC as central protagonist.
- **Learning in the BG** is a dynamic process, directed activity.[2040] **Cognitive control and emotional self regulation are closely interdependent**. Cognition of appropriate rules assists: the PFC (focusing on acquisition of new rules) and the BG (focusing selection of rules appropriate to the situation) play complementary roles in rule learning. Attentional mechanisms play a critical role in achieving such affect regulation and self management.
- **Rich neural loops involving BG and PFC** are also deemed significant in mediating recursive thought. Fast plasticity in the striatum favours learning the "snapshots" of action that capture immediate circumstances, favoured alternatives, and how to get there; slow plasticity of the PFC favours links to other centres and creation of entire models, future scenarios, of action. Neural loops between the BG and other areas provide a basis for the exchange of concrete information inherent in deliberation.
- **Lower brain areas** supply the PFC, along with the other cortical areas, with continuous electrical stimulation; a prerequisite for conscious activity to take place. Excitatory signalling (utilising ACh), and reverbatory excitatory signalling, via the thalamus, to almost all cortical areas, are critical in this process. Mechanisms of control

[2040] Horvitz, "Stimulus-response and response outcome learning mechanisms in the striatum," 131.

	facilitated by highly redundant parallel pathways. The BG contains inhibitory GABAergic neurons, spiny in the striatum and aspiny in the pallidum, requiring strong and coherent excitatory cortical inputs from almost all cortical areas to become active. The BG are a region of great biochemical diversity, exhibiting almost all the neuroactive agents. Basal forebrain projections innervate the hippocampus, amygdala, and neocortex. (See also above: **Systems for habit formation**, for additional contribution of BG in cognition.)	utilize the release of NE from the LC (usually excitatory), DA from the SN (inhibitory in the BG, and possibly excitatory elsewhere in the cortex), 5-HT from the raphe nuclei (inhibitory), and ACh from the gigantocellular neurons of the reticular excitatory area. • **Spindle cells in linkages between ACC, OFC and insula** are associated with quick decision making. These pathways are complemented by neurochemical pathways enabling appreciation of rewards and difficulties.

Table 2.14
Systems for effective execution of motor commands

Principal sources: Bear (2007); Byrne (2008); Doyon et al. (2009); Floyer-Lea and Matthews (2008); Hof et al. (2008); Hoshi et al. (2005); Kaas and Stepniewska (2002); Kalat (2001); Marieb and Hoehn (2010); Pollak (2005); Rapp and Bachevalier (2008); Squire (2008); Wise and Shadmehr (2002).

Prima facie association with development and exercise of virtue	Principal associated brain areas Discussion proceeds from overview, and thence to higher brain areas, to subcortical structures, the BG and limbic structures.	Principal pathways and mechanisms.
• **Virtues empower action in ways tailored to the flourishing of our being.** This includes disposing us to execute movement towards worthy objectives. Therefore the neural bases for virtue require effective connections with motor control, even though not all virtuous activity requires expression in motor activity. • **Efficient and obedient motor control is integral to the practice of some, if not all, of the virtues.** Some virtues, such as generosity, require social interaction for the complete expression of the virtue. [2041] And this is not only the case with social virtues: temperance may manifest in the capacity to redirect one's attention; courage may require expression through words; even justice may necessitate delivering, not just considering, an apology.	• The **PFC** is well connected to motor cortices, primary motor cortex, premotor and supplementary motor areas, allowing effective command pathways. • Long term **storage of explicit motor knowledge** is in the PFC and associated parts of the BG, while storage of intermediate term explicit motor knowledge is in the MTL. The dorsal **striatum** is implicated in the long-term storage of well-learned movement sequences. • The **BG** play a role in anticipating movement and in motor control: putamen neurons are active in *anticipation* of body movements; caudate nucleus neurons are active *prior* to eye movements; the putamen receives input from motor and somatosensory cortical areas. • The **hippocampus** plays an integral role in the formulation of goal directed motor plans. • The **cerebellum** assists in	• The **PFC** is richly endowed with connections for conscious motor management. Anatomical loops between the PFC and the BG, closely associated with motor systems and acting as a site of converging inputs from other cortical and subcortical areas. Also the PFC has direct and indirect connections to the limbic system and endowed with abundant intrinsic connectivity. • Pathways of motor control feature areas of the **BG**: GP and the SN play major roles in motor control selecting patterns of cortical activity and ultimately selecting and reinforcing chosen motor programs; processing of motor commands takes place in the caudate nucleus and in the GP, with output across to thalamus and then back to cortical motor areas. Outputs of the BG directly impact on motor control by affecting activity of motor areas in the cortex.

[2041] And although a person suffering from advanced Parkinson disease, and therefore without the capacity to express emotion on the face, can possess the virtue of cheerfulness in his internal dispositions, he lacks the capacity for the normal manifestation of virtue of cheerfulness, a ready smile.

	movement and motor habits has a likely role in formation of cognitive habits. There is now evidence that the cerebellum and the BG are well interconnected and interactive via a cerebello-thalamo-striatal pathway.	The system operates mainly “to modify cortical motor representations rather than control behaviour through direct motor inputs” (Manns, 2008). • The **BG-thalamo-cortical loop** is associated with motor control and also with habit formation. It provides a direct route for subsequent motor commands. Motor learning involves dynamic interplay between cortico-striatal, cortico-cerebellar, and limbic systems. The dorsal striatum instructs the PFC in S-R situations. • The **mechanisms of efficient motor control at the cellular level** are reasonably well described. The premotor cortex appears to cache memory for motor activities triggered by ACh release from the basal forebrain. ACh is the principal mediating agent (excitatory) at the neuromuscular synapse, opening ion channels, with Epi also playing a role. Glutamate and aspartate are the major excitatory neurotransmitter in the CNS and responsible for most of the fast synaptic transmission in the mammalian brain. NE is distributed to the cerebellum and other areas from noradrenergic nucleus, the locus coeruleus, within the pons. • **Axonal myelination** is required for speed of sensory and motor messaging along the long pathways from the brain, as well as for much connectivity within the brain itself. Mature

myelination of motor systems takes place in the first two years of life, although intracortical connections are myelinating into third decade of life, a fact that seems reflected in the disconnect that can exist between motor activity and cognition. For example a disproportion of serious driving accidents take place with young drivers at the wheel. Cortical myelination is not complete until the third or fourth decade of life.

Table 2.15
Summary of mechanisms for neuronal structural plasticity discussed in Chapter 2.
"Structural plasticity is ubiquitously present in the mature brain." (Butz et al. 2009)

Sources: Alvarez et al.(2007)[2042]; Blakemore (2008)[2043]; Blundon and Zakharenko (2008)[2044]; Butz et al. (2009) [2045]; Chistiakova and Volgushev (2009)[2046]; Conde and Caceres (2009)[2047]; Corlew et al (2008)[2048]; Desmurget et al. (2007) [2049]; Di Filippo et al. (2009)[2050]; Johnston et al. (2009) [2051]; Kessels and Malinow (2009)[2052]; Kim and Hoffman (2008) [2053]; Nelson et al. (2006)[2054]; Nestler (2001)[2055]; Pyne and Shenker (2008)[2056]; Squire et al. (2008)[2057]; Scott and Aperia (2009)[2058]; Stevens (2008)[2059]; Stranahan and Mattson (2008)[2060]; Vaynman and Gomez-Pinilla (2005) [2061];

Category	Mechanism	Features
Developmental plasticity	• Genetic mechanisms, including neural overproduction followed by PCD, and overproduction of synapses and deletion of immature synapses. • Modification of genetic transcription in response	• Mature development of neural structures appropriate to environmental inputs. • Various stages of development manifest periods of elimination of synapses, for example during adolescence.

2042 Alvarez, et al. "Distinct Structural and Ionotropic Roles of NMDA Receptors in Controlling Spine and Synapse Stability," 7365-7376.
2043 *Sarah-Jayne Blakemore (2008) "*The social brain in adolescence" *Nature reviews neuroscience Vol 9 April 2008 267-277*
2044 Blundon and Zakharenko, "Dissecting the components of LTP".
2045 Butz, et al., "Activity dependent structural plasticity," 287-305.
2046 Chistiakova and Volgushev, "Heterosynaptic plasticity in the neocortex (Review)".
2047 Conde and Caceres, "Microtubule assembly, organisation and dynamics in axons and dendrites (Review)," 319-332.
2048 Corlew et al., "Presynaptic NMDA Receptors: Newly appreciated roles in cortical synaptic function and plasticity," 609-625.
2049 Desmurget et al.,"Contrasting acute and slow growing lesions: a new door to brain plasticity (Review)," 898-914.
2050 Di Filippo et al., "Short term and long-term plasticity at corticostriatal synapses: implications for learning and memory," 114.
2051 Johnston et al., "Plasticity and injury in the developing brain," 1-10.
2052 Kessels and Malinow, "Synaptic AMPA Receptor Plasticity and Behaviour".
2053 Jinhyun Kim and Dax A. Hoffman, "Potassium channels: newly found players in synaptic plasticity," *Neuroscientist* 14, (2008): 276-286.
2054 For introduction see Nelson, et al., *Neuroscience of Cognitive Development,* Chapters 1 and 2.
2055 E. Nestler, "Molecular basis of long-term plasticity underlying addiction," *Nature reviews neuroscience* 2, 2 (2001): 119-28.
2056 D. Pyne and N. G. Shenker, "Demystifying acupuncture," *Rheumatology* 47, (2008): 1132-1136.
2057 Squire et al., *Fundamental Neuroscience*. 3rd ed.
2058 Scott and Aperia, "Interaction between N-Methyl-D-Aspartic Acid Receptors and D1 Dopamine receptors: an important mechanism for brain plasticity," 62-68.
2059 Stevens, "Neuron-astrocyte signalling in the development and plasticity of neural circuits," 278-288.
2060 Stranahan and Mattson, "Impact of Energy Intake and Expenditure on Neuronal Plasticity," 209-218.
2061 Vaynman and Gomez-Pinilla, "Licence to run. Exercise impacts functional plasticity in the intact and injured central nervous system by using neurotrophins," 283-95.

	to environmental inputs. • Activity dependent processes that allow for ongoing stabilisation and modification of synapses.	
Neurogenesis	• Genetic mechanisms including BDNF induced transcription. • Modification of genetic transcription in response to environmental inputs, including exercise induced neurogenesis. • Possibility of rapid reaction to environmental cues.	• Present at relatively few sites in the mature human brain: olfactory bulb, dentate gyrus of hippocampus, cingulate gyrus and segments of the parietal cortex. In addition possible presence in amygdala, piriform cortex, and inferior temporal cortex. • Exercise and caloric restriction induces BDNF associated plasticities in hippocampus. • Hippocampal dentate gyrus neurons undergo ongoing replacement.
Dendritic changes	• Genetic mechanisms. • Modification of genetic transcription in response to environmental inputs. • Ca2+influx (fast large amplitude influx leads to LTP; slower, low amplitude to LTD). • NMDAR presence is essential for spine density and regulation of the number of active excitatory synapses.	Changes may include: • Formation of new dendrites, new dendritic spines, new branches in the dendritic tree, and retraction and degeneration of postsynaptic spines. • LTD leads to weakening of synapses and spines. • LTP promotes spine maturation and stabilisation.
Changes at the synapse	• Genetic mechanisms acting on synaptic components and factors. • Modification of genetic transcription in response to environmental inputs. • Calcium influx associated. • Close LTP linkages to synaptogenesis. • Synaptic reorganisation proceeds in stages. • Activity dependent synaptic pruning. Postsynaptic NMDARs trigger classical forms of LTP and LTD. • PreNMDARs mediate tLTD at some synapses with some evidence also of LTP. • Various forms of synaptic strengthening associated with gene expression.	Changes of the synapse may include: • Synaptogenesis and synapse elimination. Changes at the synapse may include: • Changes in post synaptic receptor density, and alterations to thickness of the synapse, increase and decrease in the strength and efficacy of synapses, and physical changes at the synapse leading to pre and post synaptic alterations in membrane potential. • NMDAR plasticities involved at many sites throughout the brain. • Stabilisation of synapses brings plasticity to an end. • Various forms of LTP and LTD can produce long lasting synaptic plasticity. • Intracellular calcium implicated in the various forms of LTP and LTD. • Classical conditioning exhibits forms of LTP. • Synaptogenesis is evident in motorskill learning.

Changes at the axon	• Genetic mechanisms acting on axonal structures and guidance cues. • Modification of genetic transcription in response to environmental inputs. • Myelination of axons (perhaps closing off sensitive periods of development) • Processes associated with axonal overdevelopment.	Changes may include: • Formation of new neural structures related to the axon including axonal growth zones, localized axonal sprouting, changes to axonal fibre densities, myelination of axons, changes in the degree of myelination of the axon, sprouting of boutons and other presynaptic sites, interstitial axonal branching, and retraction and degeneration of pre synaptic terminals.
Formation of additional connections.	• Modification of neuronal connectivity in response to genetic and environmental inputs. • Activation of intracortical connections that are dormant.	Changes may include: • Additional connections may be established between same axon and dendrite. • Changes in conjunction with further outgrowth of axons and dendrites. • Synaptic rewiring whereby targets are disengaged and new targets established using same presynaptic or post synaptic element.
Further structural and signalling contributions to plasticity.	Growth factors.	• Intracellular messengers and growth signalling factors are commonly associated with structural plasticity. • BDNF induced transcription. • Implication of astrocytes releasing trophic factors and gliotransmitters. • GABA may also act as a neurotrophic agent.
	Receptors.	• Cellular plasticity in the forms of LTP and LTD can be a result of AMPA receptor trafficking. • preNMDARs mediate tLTD at some synapses with some evidence also of LTP. • NMDARs assist in the stabilisation of glutamatergic synapses. • K+ channels are a postsynaptic mechanism for regulation of synaptic plasticity. • Changes in voltage gated ion channels function lead to plasticity changes the probability of PSP and duration, and mediates metaplasticity, the capacity to induce consequent plasticity at the synapse.
	Neurotransmitters.	• Plasticity as a result of NMDA interaction with DA. • The mesolimbic reward system supports reward seeking and motivational behaviour by regulated release of DA. • AMPAR trafficking evident in fear

		conditioning in hippocampus. • NMDA-LTP develops rapidly, is expressed postsynaptically, and is needed for short term memory retention. • NMDA-independent LTP develops more slowly, is expressed presynaptically, and allows longer term retention. • Release of NE following emotional arousal may promote synaptic plasticity. • Alteration to presynaptic release of neurotransmitter • Enkephalin dependent mechanisms of neuroplasticity.
	Chemical signalling across the synapse.	Ephrin/Eph signalling plays a role in regulating the morphology of spines, possibly in stabilising immature filipodia into mature spines.
	Bioelectrical mechanisms for plasticity.	• STDP can produce calcium-triggered activation of certain protein kinases resulting in: variation in and enhancement of AMPARs, increasing responsiveness to glutamate, synaptic strengthening, and activation of silent synapses. • Patterned tetanic electrical stimulation can bring about NMDAR dependent spine changes. • High frequency firing of the cortical neurons may also lead to LTD at the striatal synapses according to principles of heterosynaptic plasticity (see below). • PSPs trigger NMDA related plasticity as a result of pre and post synaptic interaction. Precise timing of backpropagating PSPs following EPSP leads to a strong depolarisation. This leads to glutamate ejection from NMDA receptors, thus allowing Ca2+ influx, a cascade of intracellular messaging, and release of growth signalling factors associated with structural plasticity and consequent LTP. • Back propagation.
	Internal signalling	Addictive drugs produce the protein DeltaFosB which accumulates to the point of causing a gene transcription leading to plastic change.
	Contribution of microtubules to structural plasticity.	Regulation of growth cone motility managed by microtubule-associated-protein 1B (MAP1B).
Forms of experiential	Hebbian mechanisms	With repeated firing, nerve cells become firmly connected.

plasticity		
	Anti-Hebbian mechanisms	Unwanted noise is filtered out allowing only preferred spiking patterns to emerge.
	Homeostatic plasticity: • Synaptic changes of transmission as a result of the specific induction related to learning.	The capacity for neurons to compensate for network activity by regulating their own excitability.
	Heterosynaptic, or nonassociative, plasticity: • Changes at other synapses on a given neuron that are non-involved in the original induction related to learning.	Occurs when presynaptic and postsynaptic neurons are depolarized at the same time. Repeated activation of cortical synapses induces LTP. Heterosynaptic plasticity: • May result in a neuron as a result of back propagation. • May assist in synaptic homeostasis, the maintenance of the overall synaptic weight of a neuron, and in ensuring that certain memories are given greater permanence. • Reverberation in loops may assist in maintaining conditions for heterosynaptic plasticity in the striatum and cortical neurons.
	Metaplasticity • The capacity to induce consequent plasticity at the synapse.	Changes in voltage gated ion channels function leads to change in the probability of PSP and its duration, and mediates metaplasticity.

Table 5.1
Neural subdivisions implicated in moral behaviour.

Sources: Beauregard et al. (2001); Burnett et al. (2009); Casebeer (2003); D'Argembeau and Salmon (2011); Fuster (1989); Grafman (1994); Green et al.(2001 and 2004); Green and Haidt (2002); Harenski et al. (2008) (2012); Jackson et al. (2006); LeDoux (1998); Leknes and Tracey (2008); Lee et al. (2007); Martin (2003); Moll et al. (2005); Passingham (1993); Ruby et al. (2009); Wood et al (2004).

Neural subdivision	Specific Area	Brodmann's Area[2062]	Role
PFC	Anterior PFC (aPFC) Ventral sectors of PFC Frontopolar cortex	9,10	Active in moral evaluations relying on predicting the long-term outcomes of one's own actions, such as the anticipation of guilt. Active in social–emotional contextual knowledge and learning of learning of moral values. Active in moral judgement.
	VMPFC	9,10,12,32	Active in adherence to well-established social norms and attitudes. Active in reflection on impact on others. Active in moral judgement.
	Anterior rostral medial prefrontal cortex (MPFC)	11,12,25	Active in social emotional responses, especially in adolescents.
	Medial portion of the superior frontal gyrus, orbitofrontal gyrus and rostral anterior cingulate cortex (MPFC)	9,10,11,32	MPFC active in moral judgement. Active in processing various kinds of self-referential information, appraising and coding the self-relatedness or self-relevance of information. Contribution to representations of specific future events and autobiographical memory retrieval. Active in inference of mental states of others, and in empathy for others in pain, with linkages to anterior ACC and anterior IC.
	Posterior PFC areas	6,9,10,46,	Active in overlearned sequences.
	DLPFC Mostly right hemisphere.	46	Active in accepting external guidance. Active in moral judgement. Pain and reward processing.
	Right lateral PFC	44,45,46,47	Active in suppression of sexual arousal. [2063]

[2062] Based on Martin, *Neuroanatomy: Text and Atlas*, 3rd ed., 48-49.
[2063] Beauregard and O'Leary, *The Spiritual Brain. A Neuroscientist's Case for the Existence of the Soul*, 272-3. Beauregard's work noted in the table above refers to studies of subjects dismissing pornography. He has also carried out some fascinating work identifying the neural bases of spiritual and mystical experience. Debunking the fad idea of a "god spot" in the temporal lobe, Beauregard reviewed brain activations during religious, mystical and spiritual experiences: "Our objective and subjective data suggest that RSMEs (religious, spiritual, and or mystical experiences) are complex and multidimensional and mediated by a number of brain regions normally implicated in perception, cognition, emotion, body representation, and self consciousness." He noted significant loci of activation, relative to baseline condition, in the following (underlined indicates significant activation with respect to control condition): right and left inferior parietal lobe, visual

	LPFC	44,45,46,47	Active in suppression of sadness.
OFC	Orbitofrontal cortex (OFC)	11,25	Active in appreciation of moral consequences of behaviour and consideration of impact on others.
	Lateral OFC (LOFC)	47	Active in adapting to social–emotional cues.
	Right OFC	47	Active in suppression of sadness.
Cingulate cortex	Anterior cingulate cortex (ACC)	24	Involvement in moral conflict resolution. Active in consideration of impact on others. Pain and pleasure processing.
	Rostral ACC	(peri-genual BA24/BA33; subcallosal BA32/BA25)	Active in empathy with the pain of others.
	Right ACC	23,24	Active in suppression of sexual arousal.
	Posterior cingulate/retrosplenial cortex	23,26	Contributing region to imagination of specific future events and autobiographical memory retrieval. Active especially in females in responses requiring moral sensitivity to others. Active in adult moral judgement, less so in adolescence.
Temporal lobes	Temporal lobes	20,21,22,35, 36, 38,41,42	Storage of social perceptual representations. Contributing region to imagination of specific future events and autobiographical memory retrieval.
	Superior temporal cortex	22	Active in adult moral judgement.
	Posterior superior temporal sulcus (STS)	22	Active in recognition of socially relevant perceptual features of faces, body posture and movements. Active in moral judgement.
	Posterior temporal lobes	20,36,37	Assists in storage of representations of objects, actions and spatial maps; storage of social semantic knowledge.
	Anterior temporal lobes (aTL)	20,21,38	Storage of knowledge of social concepts and values that are more context independent (eg honour and greed).
Occipital lobe		18,19,37,39, 40	Active in creating representations of objects, actions and spatial maps; storage of social semantic knowledge.
Parietal lobe	Inferior parietal lobe	40	Contributing region to imagination of specific future events and autobiographical memory retrieval. Active especially in males in responses requiring moral sensitivity to others.

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cortex, caudate nucleus, right medial orbitofrontal cortex, right medial prefrontal cortex, right middle temporal cortex, right and left superior parietal lobule, left brain stem, left insula, left and right anterior cingulate cortex, among others.

Beauregard’s insights accord with the view presented in this study that consciousness and decision making involve complex and highly coordinated neural activation (note that three of the four cortical lobes as well as other subcortical areas show heightened activity). To argue that there is a single location for moral thought and responses is opposed both to neuroscientific data, and to the philosophical expectation that higher activity must involve greater biological integration.

	Temporo-parietal junction (proximate to insula and rich in spindle cells)	39,40	Active in adult moral judgement, less so in adolescence.
Limbic and paralimbic areas	Amygdala		Activation in basic emotional and motivational states thereby affecting moral behaviour. Active in exercise of self control, patience, and empathy. Active in moral judgement.
	Hypothalamus especially ventromedial sector		Activation in basic emotional and motivational states thereby affecting moral behaviour. Active in exercise of self control, patience, and empathy.
	Insula		Activation in basic emotional and motivational states thereby affecting moral behaviour. Active in exercise of self control, patience, and empathy. Active in judgements of fairness.
	Anterior insula		Active in empathy with the pain of others. Pleasure and pain processing.
	Posterior insula		Processing of hypothetical reward outcomes.
	Hippocampus		Role in storage of memories according to context.
	Thalamus		Contribution to pain and pleasure in initial processing of sense input.
Basal ganglia (BG)	Ventral striatum		Active in judgements of fairness. Activation in basic emotional and motivational states thereby affecting moral behaviour.
	NAc (in association with Ventral striatum)		Hedonic and aversive processing.
	Caudate nucleus		Active in responding to moral values, attitudes and moral emotions.
	Pallidum		Active in judgements of fairness.
	Vental pallidum		Aspects of pain and pleasure processing.
Septal nuclei			Participation in assessing the reward potential of events.
Cerebellum			Contribution to processing of unexpected reward and pain.
Brainstem	Rostral brainstem tegmentum		Active in thalamic activity and therefore in filtering cortical inputs.

Table 5.2
A summary of the principal brain systems contributing to the development and exercise of virtue.

System	Ref	Contribution to the development and exercise of virtue
The numerous systems and mechanisms of plasticity operating at the cellular and molecular level.[2064]	2.2 Tables 2.3, 2.15.	• The brain's virtually ubiquitous capacity for plastic change permits the various forms of learning, including the learning of good habits. • Plastic changes are shown to be triggered by neural activity itself. Hence repeated experience lays down consolidated pathways whereby previous behaviours are more easily revisited. • Plastic changes provide a neural explanation for the phenomenon of habit. Furthermore, freely chosen behaviours and activities are self-reinforcing. Prior choices are more easily replicated. • Forms of structural plasticity dependent on gene expression bring about permanent neural changes, and potentially new behaviours and a modified personality.
Systems for learning.	2.3 Table 2.4	• Learning denotes knowledge acquired through experience, or changed behaviour as a response to experience. Learning may be either conscious or unconscious. • Moral learning is central to the development of virtue, and in particular, to the development of conscience, an aspect of the virtue of prudence. Moral learning will take advantage of systems implicated in general learning. • Virtue is a form of experiential learning. • Development of automaticity is intrinsice to virtue. That DA release associated with rewarding outcomes facilitates learning, and that reward paradigms convert over time to automaticity in the BG suggest a central role for reward systems in learning of at least some forms of volitional behaviours associated with virtue.
Attentional systems.	2.5.5 Table 2.9	• Plasticity both enables and is directed by our attention system. In turn focussed attention permits directed plasticity in the brain: it is "the modulatory control system of plasticity".[2065] In other words, our capacity to direct attention allows us some management of plasticity mediated learning, including the development of habit and virtue. • Attention allows suppression of goal irrelevant issues and is a prerequisite for many forms of learning and memory, and for goal election, cognition and executive function, all of which are required for the acquisition of virtue. • The capacity to attend appears closely linked to will power. • Normally we attend to stimuli that our senses or imagination present to us. However, the ability to pay attention to a goal that is neither pressing nor present is central to rationality and virtue development.

[2064] Arguably plasticity involves both systems and mechanisms. Systems involve coordination of various brain areas (eg VTA release of DA to striatum effecting cortical regulation) and cellular mechanisms (eg second messenger plasticities).
[2065] Michael Merzenich. cf **2.2.6**; **2.3.4.1**; **2.5.5**; **2.7.3.1**.

Memory systems	2.3 Table 2.5	• Learning and memory are key processes by which environment and experience alter behaviour. Structural neuronal plasticities are a core mechanism underpinning learning. • Memory is the process of encoding, storage and retrieval of knowledge acquired through experience. There is a self evident link to habits reinforced by experience. • Memory systems are functionally implicit to learning, to response to reward and emotion, to habit formation, to goal election, and all cognitive function. • Memory is a functional prerequisite for the exercise of virtue: memory of past behaviours, of reward, of contextual and emotional resonances, and of principles of right and wrong, all have relevance. • Mechanisms of non-declarative memory appear to facilitate the ease of practice and the inherent motivational rewards in virtue, while during the more arduous process of acquisition of virtue, declarative memory plays a more significant role. • Memory is enhanced in the presence of emotion that is not excessively intense. That affection enhances memory establishes an early childhood facilitation.
Systems of emotional management	2.5 Table 2.8	• Emotion management systems are at the heart of directing our desires towards appropriate pleasure and towards towards the endurance of pain, fear and difficulties for the sake of worthy goals. Hence they are the essence of the virtues of fortitude and temperance. • The habitual management of emotion according to what is rational is the essence of the exercise of virtue. • Emotional regulation involves cortical regulation of goals, memories and emotional experience. The potential for emotion to enhance rationality has been much noted in recent years. • Appropriate emotional/aesthetic/social/ moral education is central to the development of virtue.
Reward and motivational systems	2.6 Table 2.11	• Reward systems are implicated at most levels of volitional and sub-volitional activity. In concert with the emotional systems they provide incentive for action, including virtuous action. • To find pleasure in appropriate activities is the mark of virtue, and hence the link between reward expectations, emotional responses, conscious goal election, and virtue. • Intrinsically motivated action, activity is pleasurable in itself, is an essential characteristic of virtuous activity. Growth of intrinsic motivation over external reward as automaticity is developed accords with view that virtue is carried out for its own sake. • A habit of appropriate reward expectation is directly linked to the development of the virtue of temperance.
Systems for habit formation	2.4 Table 2.7	• Virtues may be understood as freely chosen automatised behaviours. • Mechanisms of habit learning also offer an explanation for the phenomenon of behaviours that appear to remain robust in the absence of immediate rewards. Just as emotional regulation and reward processing are interdependent systems, reward processing and habit

		formation also are interlinked systems, with reward processing essential in the early stages of laying down habits. This accords with the view that extrinsic motivation assists initially in establishing patterns of good behaviour; in time this is transformed into forms of intrinsic motivation with the development of a degree of automaticity. • Strictly speaking habit learning refers to the spectrum of automatized behaviours supported most particularly by the BG via the BG-thalamo-cortical pathways. • The brain regions and pathways associated with the BG seem to offer a significant key to understanding the neural bases of virtue. Converging research over the past decade links habit formation and volition. In particular, the BG-thalamo-cortical loops with their widespread cognitive-emotional interaction offer insights into processes of planning, goal selection, self regulation, attention and motivation. Furthermore this automatisation lies at the heart of the easy repeatability of behaviours associated with virtue… for example the habit of greeting courteously, of getting up when the alarm goes off, of reacting to difficulties with patient strategies, etc. Mechanisms of habit learning also offer an explanation for the phenomenon of behaviours that appear to remain robust in the absence of immediate rewards.
Cognition, consideration of consequen-ces, planning, goal election, and executive direction.	2.7 Tables 2.13, 5.1.	• The links between cognition, rationality and virtue are closely associated at the psychological level. Brain systems associated with cognition and goal election interconnect with neural subdivisions implicated in moral behaviour. (See **Table 5.1**.) • Human cognition normally implies rational capacities: for conscious goal setting, reasoning, deliberation as to consequences and means, and final election. • The capacity to set specific goals, to direct one's actions to those goals, to reason about consequences and means, appears central to cognition and to rational acts disposed by prudence. That one chooses goals fitting for one's nature is a mark of rationality; virtue is essentially the neuronal disposition assisting in the habituation of this capacity. • The capacity to pay due regard to the impact of one's actions on others, modifying them accordingly, characterises acts disposed by the virtue of justice. • The exercise of virtue requires rightness and perfection of reason, the operations of which are perfected by the virtues of prudence and justice.
Systems for effective execution of motor commands	2.7.3.1 Table 2.14	• Virtues empower action in ways tailored to the flourishing of our being. This includes disposing us to execute movement towards worthy objectives. Therefore the neural bases for virtue require effective connections with motor control, even though not all virtuous activity requires expression in motor activity. • Some virtues, such as generosity, require social interaction for the complete expression of the virtue. And this is not only the case with social virtues: temperance may manifest in the capacity to redirect one's attention;

		courage may require expression through words; even justice may necessitate delivering, not just considering, an apology. Hence efficient and obedient motor control is integral to the practice of some, if not all, of the virtues.
Systems for imitation and empathy	2.3.6 Table 2.6	• Imitation is one of the core processes for learning from the environment and from the example of others. The neural basis for this is now increasingly well described and provides an explanation for the ease of acquisition of virtuous behaviours by children. • Imitation and empathy are related at the level of neural systems. Plasticity in the systems for empathetic response appears integral to the development of sensitivity for the rights and needs of others, and an understanding of the consequences of one's actions, which appear to be are at the core of the virtue of justice. • Effective emotional modulation of deliberation is essential for sound reasoning particularly in areas requiring empathy with others, understanding of others viewpoints etc, and TOM.
Sensitive periods of development	2.2.4.1 Table 2.2	• The term "sensitive periods" denotes a developmental window of opportunity, whereby there is an enhanced capacity for plastic change and learning in response to experience, emotional content, or novelty. • Of particular interest in the field of virtue education are sensitive periods evident in responsiveness to affection, early experience, ease of imitation, and in development of new behaviours during early years. First impressions are lasting impressions. Experiences during upbringing, particularly when the stimuli are associated with emotional significance, can be virtually indelible. • Windows of opportunity in sensitive periods vary: for imprinting the window is open only for a few hours; for language, for years. Responsiveness to maternal affection is also established in the earliest years, and if an infant is reared in an environment deprived of maternal affection there will be lasting deficits. • The security of affection, in turn, facilitates, at the neurophysiological level, other aspects of learning from parents.

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Abbreviations for much cited texts:		
DA	Aristotle,	*De Anima*
EE	Aristotle,	*Eudemian Ethics*
M	Aristotle,	*Metaphysics*
NE	Aristotle,	*Nicomachean Ethics*
ST	Aquinas,	*Summa Theologiae*

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‘Quando il corpo sta bene, l’anima balla’

When the body is well the soul dances.
Italian proverb.