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In search of time and memory. A neurobiological approach of Marcel Proust's novel "*In Search of Lost Time*"

Running head: In search of time and memory

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Abstract

Marcel Proust with his Belle Époque French masterpiece "Remembrance of Things Past" ("In Search of Lost Time") gave us significant insights into the workings of the brain and the nature of memory. Here I try to correlate convincingly Proust's findings and ideas with current neurobiological knowledge. In this respect, various issues are discussed: The concept of time and its relation to memory; the strength of "involuntary memories" and the primacy of the senses of smell and taste; the weaknesses and fragility of memory and the discrepancy between reality and "voluntary memories"; the influences of our expectations on the way we perceive the world, and the limitations set by our physiology; the demanding and capricious nature of memory; the blessing of oblivion as an important biological mechanism; the "organic" nature of the mind; bizarre states of the mind such as synaesthesia and "phantom-limbs."

Moreover, I suggest that Proust, having an informal yet strong background in neurology and deep knowledge of the principles that govern memory, constructed his great novel on the very same principles. Indeed, Proust's "Remembrance of Things Past" remains the great novel of autobiographic memory, a canvas that extents to over 3,000 pages and expands over a long period of time. Time was only regained at the last part of the novel when Proust realized that it is through "involuntary memories" that one finds his personal history in time, the essence of his life and discovers his real self; and Proust made this revelation the most prominent characteristic of his work.

Introduction

Memory has legitimately been called the Holly Grail of neuroscience. Although many have been written on the topic, in truth we still know little about it. Some times we can have useful uncanny insights on brain turning to art and literature. Proust and his monumental Belle Époque French masterpiece "Remembrance of Things Past"[1] is such an exceptional example that gave us significant insights into the workings of the brain and the nature of memory (Dinopoulos, 2007). Proust had an informal yet strong background in neurology and today he would be an excellent "neuroscientist." He strongly believed that our memory can be triggered by chance associations -a scrap of music, a place-name, or a smell-, and that what he called "involuntary memories," stored in our sensory experiences, are progressively assimilated into our "autobiographic self," becoming part, actually the "true" part, of who we are. A single taste of a madeleine can open an entire world. This is why he raised memory into a goddess. "But then from the highest heaven the goddess Mnemotechnia bends down and holds out to us in the formula 'the habit of ringing for our coffee' the hope of resurrection." ("The Captive"). Proust called the goddess for memory "Mnemotechnia" either out of a humorous mood, or out of incorrect quotation to Mnemosyne. Mnemosyne was the personification of memory in Greek mythology. This titaness was the daughter of Gaia and Uranus and the mother of the nine Muses by Zeus. The nine Muses personified all human skills. Indeed, all concept formation, all learning, all skill acquisition, and all acquisition of language during development can be considered as the establishment of new mnemonic representations or traces.

There are many structures in the brain that participate in the formation of memories and there are multiple forms of memory. Memories form when new physical and chemical links, called synapses, are created between brain cells, or when old synapses are strengthened. The notion that stimuli produce enduring physical changes in the brain, and that these changes are the basis for memory, has been with us since Plato's etched wax tablets of memory metaphor in *Theaetetus*. We now make a major distinction between short- and long-term memory. For long-term memory the activation of genes and the formation of new synapses are required. Long-term memory is subdivided into explicit and implicit memory.

Explicit (conscious or declarative) memory involves the conscious, intentional recollection of previous experiences, what we tend to think of as memory in everyday lives. Implicit (unconscious or no declarative) memory refers to nonconscious, unintentional influences of past experiences on current behaviour and performance, and, for some investigators, even motor skills (e.g. to drive a bicycle) and habits. Proust calls to mind the different forms of explicit memory, touching on distinctions recognized by modern brain science. What scientists now call semantic memory is knowledge that is not part of everyday experience but knowledge learned. For example, recalling that the Second World War ended in 1945, makes use of semantic memory. Proust calls this sort of memory "voluntary" and shows very little respect to it. In contrast, episodic or autobiographic memory refers to a form of memory that is based on personal, particularly emotional experience. Recalling that you always found Camembert too strong is an example of episodic memory. Indeed, we not only register events but register them as pleasurable or painful. Episodic memory is considered as the most sophisticated faculty of memory and the one most characteristic of humans. It is not only about what, how and where, but also about when; the ability to place unique experienced events on the temporal axis of personal history. Proust believes that a large part of this sort of autobiographical memories is "involuntary" and that these sorts of memories can be optimally triggered by fortuitous stimuli, particularly olfactory and gustatory stimuli. In addition, he suggests that this sort of memory is the most important to us, for a sense of personal history is critical to defining who and what we are.

Hippocampus and much of the surrounding temporal lobe play a critical role for explicit memory [the temporal lobe is located under the temporal bone, so named because the hair of the temples is the first to go gray with the passage of time (*tempus* is Latin for "time")]. Patients with severe damage or removal of these structures cannot remember what they have done in the recent past and they cannot learn new facts. Other parts of the brain (e.g. the frontal lobes) play crucial roles for implicit and "working memory". "Working memory" includes those processes involved in the short-term recall of information, combining attention and planning and decision making until the task is completed. When we look up a telephone number and keep it briefly in our minds before dialling, for example, we use working memory. And, if the concept of working memory is extended, we remember the number of our hotel room as long as we are in Paris, say a week, and then get rid of this information as it

becomes useless. Finally, the corticostriatal system sub serves skill memory. Although we can distinguish all these types of mnemonic experience and the participation of different brain areas in mnemonic processes, this is not to imply that there exists in the brain a separate set of mechanisms for encoding, consolidating, retrieving, and storing the traces, an idea at odds not only with the ideal parsimony but also with any reasonable notion of the evolution of the human brain (Papanicolaou, 2006).

Proust's background in neurology

Proust possessed excellent medical knowledge, particularly in neurology, because he had been, or felt, ill in all his short life (1871-1922). From the age of ten, he experienced recurrent attacks of severe asthma, a condition which, at the time, was considered a subcategory of "neurasthenia" (also called "hypochondria"), affecting his lifestyle more and more with the progression of age (Falliers, 1986). Proust's asthma was accompanied with other symptoms, mainly neurological; at the end, he developed chronic obstructive bronchopneumonopathia with superimposed infections, which led to his death at age 51. In addition, Proust's father, Adrien Proust, was a distinguished physician, member of the Academy of Medicine and founder of the International Office of Hygiene, the predecessor of the World Health Organization. Proust's brother was an urologist. In order to improve his asthma and other symptoms, Proust became the famous patient -also famous for his lack of discipline- of equally famous physicians: Jules Dejerine, Paul Dubois, Edouard Brissaud -the founder of "La Revue Neurologique" in 1893-, Paul Sollier -who had studied memory extensively-, and Joseph Babinski -also known by the reflex baring his name, to name only a few (Bogousslavsky 2007). The Proust expert Jean-Yves Tadié emphasized that "Proust seems to know all the neurologists in Europe" (Tadié, 1996). Proust's father died in 1903 from a cerebral haemorrhage, and his mother of a stroke, with hemiparesis and aphasia, less than two years later. The above show that Proust was immersed in a medical atmosphere, a situation that obviously became a major source of inspiration for his novel. Seemingly, he decided to write a book for doctors long before he had started working his great novel, as he confessed to the poetess Anna de Noailles, in a letter written in 1904/1905 (Bogousslavsky 2007). Apart from that, it is fascinating that Adrien Proust had almost named the title of the famous novel which

his son would start to write over ten years later, when in his book "*The Hygiene of the Neurasthenic*" he concluded that "the evocation of memories is defective because they [the neurasthenics] are unable to sustain the effort of attention necessary for *the search of lost memory*." (My emphasis).

Time and memory

"For a long time I used to go to bed early." In this first phrase of "Remembrance of Things Past," the main novel of Marcel Proust, the great novelist makes the first of over 1,200 allusions to time and memory (in volume 6 -"The Sweet Cheat Gone"-, memory is quoted more than once per page) (Bogousslavsky and Walusinski, 2009). And Proust continues. "I would ask myself what o'clock it could be; I could hear the whistling of trains, which, now nearer and now farther off, punctuating the distance like the note of a bird in a forest, shewed me in perspective the deserted countryside through which a traveller would be hurrying towards the nearest station: the path that he followed being fixed for ever in his memory by the general excitement due to being in a strange place, to doing unusual things, to the last words of conversation, to farewells exchanged beneath an unfamiliar lamp which echoed still in his ears amid the silence of the night; and to the delightful prospect of being once again at home." ("Swann's Way"). Proust shows an intense interest for the nature of time, and this is reflected in the title of his novel. This is why the novel extends to over 3,000 pages and expands in such a long period of time; for the reader should feel the fiction as well as the actual time pass, the reader should form memories. It is Proust's belief that only through episodic memories we develop a feeling of time. Psychologist Endel Tulving dubbed this ability "chronaesthesia" [from the Greek χρόνος (chronos), "time" and αίσθησις (aisthēsis), "sensation"] (Tulving, 2002). Chronaesthesia is the human ability to mentally travel in time, to reconstruct oneself in the past as well as in the future.

But how does the brain manage time? Neuroscientists who work on the problem of time -they call it "time perception"- have discovered that our brain is one of the least accurate time measurement devices we will ever use. At the very least, we have got two internal clocks running. One is the clock that tracks our circadian rhythms, telling us when to go to sleep, wake up, and eat. This is the most

fundamental and important of all our internal clocks, and it has been found to be running in the majority of organisms, even the simpler ones. The other clock is the one that tells us how long a particular activity is going to take. This other clock is like a digital watch in some ways. It measures time in pulses. Those pulses are accumulated, and stored in our memory as a time interval. The problem is that this biological clock can be sped up or slowed down by anything from drugs to the way one pays attention. Thus human beings measure relatively short periods of time with this highly subjective biological clock, not to speak for periods of the magnitude of a life span. It is only the memories, particularly autobiographic (episodic) memories, that give us the ability to bring together "what," "where," and "when" into a single recollection and to "write" our personal history in time and space. In this respect, newly generated cells in the hippocampus may play a role forming temporal associations among memories. Because the population of newborn cells is constantly changing, events that occur around the same time period may be encoded into the hippocampal circuitry by the same, or at least an overlapping, group of newborn cells, with presumably overlapping patterns of synaptic connections for memories laid down around the same time (Eriksson et al., 1998). This hypothesis provides a plausible mechanism for the long-recognized observation that remote memories are often roughly linked according to the time at which they were encoded into our brains.

"Involuntary memory" and emotions

Proust's allusions to memory give specific emphasis on "involuntary memory", and were, according to scholars, largely inspired by Sollier's theories (Bogousslavsky and Walusinski, 2009). "Involuntary memory" is deeply associated with emotions. Famous is the quotation of "petites madeleines," a kind of small French cake, said to have unleashed many recollections of Proust's stay at Combray as a child. "Many years had elapsed during which nothing of Combray, save what was comprised in the theatre and the drama of my going to bed there, had any existence for me, when one day in winter, as I came home, my mother, seeing that I was cold, offered me some tea, a thing I did not ordinarily take. I declined at first, and then, for no particular reason, changed my mind. She sent out for one of those short, plump little cakes called "petites madeleines,"

which look as though they had been moulded in the fluted scallop of a pilgrim's shell. And soon, mechanically, weary after a dull day with the prospect of a depressing morrow, I raised to my lips a spoonful of the tea in which I had soaked a morsel of the cake. No sooner had the warm liquid, and the crumbs with it, touched my palate than a shudder ran through my whole body, and I stopped, intent upon the extraordinary changes that were taking place. An exquisite pleasure had invaded my senses, but individual, detached, with no suggestion of its origin. And at once the vicissitudes of life had become indifferent to me, its disasters innocuous, its brevity illusory — this new sensation having had on me the effect which love has of filling me with a precious essence; or rather this essence was not in me, it was myself. I had ceased now to feel mediocre, accidental, mortal. Whence could it have come to me, this all-powerful joy? I was conscious that it was connected with the taste of tea and cake, but that it infinitely transcended those savours, could not, indeed, be of the same nature as theirs. Whence did it come? What did it signify? How could I seize upon and define it? ("Swann's Way").

In this passage, Proust emphasized the "shock" provoked by the surge of a previously forgotten, almost "fossilised," memory, which may lead to an intense feeling of happiness and beatitude due to the affective overlap between the past and the present. This phenomenon leads to a synthesis of past and present persons in the subject, with a feeling of untemporality. It is, however, only at the last part of his novel, in "Time regained," that he actually realizes this consciously.

The human brain takes in enormous amounts of information every second and must decide which parts are worth remembering. Generally, information that gets stored as long-term memory is coupled with an emotional experience. The stronger the emotional signal, the easier the memory is to retrieve. Indeed, emotional events or details regarding an emotional situation tend to be remembered better than neutral details (Adolphs et al. 2001; Cahill et al. 2003). Memory is enhanced by hormones that are released when we experience stress. Epinephrine (also called adrenaline) and cortisol are released from the adrenal glands and play a powerful role in regulating the strength of memory by regulating the release of norepinephrine (also called noradrenaline) in the amygdala as well in the hippocampus and neocortex. This explains why emotional arousal has such a powerful influence on how well we remember things, and why emotional things are more memorable than trivial ones.

Amygdala, an almond-shaped structure situated deep in the temporal lobes, provides the emotional intensity that digs important events into the brain as memories, but it is not the site of long-term storage of memories. It was believed that amygdala plays a role in unpleasant emotions such as fear, but imaging studies in humans have shown that amygdala is involved in pleasant emotions as well. Therefore, the amygdala acts as a gatekeeper and a governor of both emotion and memory. A research team at Stanford discovered that a "higher" part of the brain, the orbitofrontal cortex, plays also a critical role, suggesting that emotions may be more "intelligent" than we thought (Anderson et al., 2003). The greater the involvement of the brain's cortical regions, it appears, the greater the risk that a fear-creating event and memory, like Kennedy's assassination in 1963 and Sept. 11, will result in potential long-term physical consequences.

The primacy of smell and taste in memory formation

Most environmental information reaches the human brain through the visual system. There are more than thirty visual areas, occupying a large part of the cortex, in the cerebral hemispheres specific for the parallel processing of the various attributes of the visual world -form, color, luminance, motion, depth-, which eventually bind together to give us an integrated and comprehensive image. However, Proust prefers, instead of such a developed and "rational" system, a system more primitive and, for this reason, more authentic and strong. After all, when organisms first swam in the primordial soup, the ability to smell (or taste) chemicals is what kept them alive. According to Proust "involuntary memory" is strongly associated with the undervalued senses, the "orphans" so to speak, of smell and taste. "But when from a long-distant past nothing subsists, after the people are dead, after the things are broken and scattered, still, alone, more fragile, but with more vitality, more unsubstantial, more persistent, more faithful, the smell and taste of things remain poised a long time, like souls, ready to remind us, waiting and hoping for their moment, amid the ruins of all the rest; **and bear unfaltering, in the tiny and almost impalpable drop of their essence, the vast structure of recollection**." (My emphasis) ("Swann's Way").

Of the five senses, smell and taste are the least studied and least understood. Taste is the sensory modality that guides organisms to identify and consume nutrients

while avoiding toxins and indigestible materials. For humans this means recognising and distinguishing sweet, umami, sour, salty, and bitter –the so-called "basic" tastes. There are likely additional qualities such as fatty, metallic, and others. Proust knew that the senses of smell and taste go together. Indeed, it is the combined sensory experience of olfaction and gestation that exponentially multiplies the flavours we taste. It is the whiff of cinnamon that ricochet us back to our mother's kitchen with the pâté made of wild field mushrooms and Greek olive oil. We now know that the reward system of the brain, a collection of basal forebrain structures responsible for feeling pleasure or even hedonic, is activated by the consumption of food and alcohol and when having sex. The activation of the reward system with such stimuli is an evolutionary strategy to "remember" pleasurable things useful for our survival.

In "The Captive" Proust recollects. "Françoise came in to light the fire, and to make it draw, threw upon it a handful of twigs, the scent of which, forgotten for a year past, traced round the fireplace a magic circle within which, perceiving myself poring over a book, now at Combray, now at Doncières, I was as joyful, while remaining in my bedroom in Paris, as if I had been on the point of starting for a walk along the Méséglise way, or of going to join Saint-Loup and his friends on the training-ground." However, we know today that most people have no difficulty in recalling, in detail, visual and auditory percepts but are unable to reexperience in the same manner and with the same degree of clarity, gustatory, olfactory, and tactile sensations. Similarly difficult, or impossible, is for most people to remember emotions. Instead, people recall or recognize the external circumstances or the thoughts that had occasioned or surrounded these sensations, and, in the case of emotions, people may "reexperience" the state, but the experience does not have that ineffable quality, alluded to before, which allows us to know without doubt whether it is a new, current one or a re-enactment of a past episode. That is, remembering of an emotion is remembering its source and circumstances, which, in turn, results in a current emotional state, analogous to the original one (Papanicolaou, 2006).

Many things are, however, lost due to the degradation of the sense of smell, things reminded to us with an almost unbearably tragic way by Gilbert Chesterton in the song of Quoodle: *They haven't got no noses, / The fallen sons of Eve;…/ [They haven't no noses for]The brilliant smell of water,/ The brave smell of a stone,…/ They haven't got no noses,* / *And goodness only Knowses* / *The Noselessness of Man*. The

mouse brain has about 1,200 different types of odorant receptor genes (about two-thirds of which are functional), whereas the human brain has only about 700 (about half of which are functional). These genes encode an equivalent number of odorant receptor types on the olfactory receptor cells, which occupy a small area of the nasal epithelium (Buck and Axel, 1991; Mombaerts, 2004). A dog's sense of smell is 10,000 more acute than a human's, and dogs are used to detect drugs or bombs (the area of the olfactory epithelium in dogs is some forty times larger than in man).

Humans have lost some of the odorant receptor genes during evolution. However, the remaining receptors form combinations, or patterns, depending on what is detected and in what concentration, to signal the brain. As a result, an average person can detect from 10,000 to much more different chemicals or odours across a wide range of concentrations. In parallel to the main olfactory epithelium, the vomeronasal organ senses non-volatile chemical stimuli, including pheromones (Dulac and Torello, 2003). Consequently, humans maybe have not lost the smell game for ever. After all, 90 percent of taste comes from smell, babies use their sense of smell to bond with their mother, as all mammals' offspring do, the smell of smoke warn us of danger, and women always wear a perfume. Aromas may trigger more memories, especially more emotional memories, than other cues such as sights and sounds. Aromas are today being used to treat everything from mood disorders to sleep problems to emotional difficulties, a new field called aromatotherapy. Indeed, the sense of smell is thought to play a pivotal role in people's physical, emotional and psychological well-being and quality of life. It is perhaps this particular nature of smell and taste that gives them their strength to form memories born purely by senses and not by thoughts, and to reveal the true aspect of life.

Reality-"voluntary memory" discrepancy

"*Footfalls echo in the memory* / *Down the passage which we did not take* / *Towards the door we never opened*" (Eliot, T. S., from Dudai, 2004).

Memory, as Daniel Schacter at Harvard's psychology department puts it, is a "fragile power" because we are subject to forgetting and memory is not always as accurate as we would like to believe. There is a great variety of phenomena that could be regarded as false memory in the contemporary literature; however, the term is

commonly reserved to refer to erroneous memory, particularly episodic memory, in normal subjects. "It seems that events are larger than the moment in which they occur and cannot confine themselves in it. Certainly they overflow into the future through the memory that we retain of them, but they demand a place also in the time that precedes them. One may say that we do not then see them as they are to be, **but in memory are they not modified also**?" (My emphasis) ("The Captive"). In this passage Proust, several decades before scientists, disputes the accuracy of voluntary memory. In the same volume he continues. "Thus it is that jealousy is endless, for even if the beloved object, by dying for instance, can no longer provoke it by her actions, **it so happens that posthumous memories, of later origin than any event, take shape suddenly in our minds as though they were events also**, memories which hitherto we have never properly explored, which had seemed to us unimportant, and to which our own meditation upon them has been sufficient, without any external action, to give a new and terrible meaning." (My emphasis).

Today, we know that memory is not a perfect record of what has occurred. Rather, we construct memories out of an interaction between prior knowledge and current incoming information (Tulving 1983; Schacter et al. 1998). We have learned, for example, that people will "remember" having heard a word before -and be quite certain that it was among a previous list of words they heard- when in fact it is only closely to many of the words on the list (Roediger and McDermott, 1995). In this case, the listener is retaining not a literal recording of the list but what the brain has constructed. PET (Positron Emission Tomography) or fMRI (functional Magnetic Resonance Imaging) images of people during a true-and-false memory task, show that generally the same areas are activated whether the memory is true or false. Moreover, after extensive investigation, scientists have not found anything in the brain that looks like a truth-detecting region. This may be part of the reason why a false memory seems so real. "He is lying as an eyewitness," argues a Russian saying. Inaccurate eyewitness testimony in the courtroom is a common source of wrongful convictions (Wells and Loftus, 1984). Indeed, memory distortion has already had legal implications, resulting particularly from misattribution, i.e. attributing memories to an incorrect source, resulting in false recognition. A concrete example is the story of the psychologist Donald Thomson, a memory researcher from Australia, who a number of

years ago was accused by the victim of a brutal rape as being the perpetrator; the police were led to Thomson on the basis of a detailed and accurate recollection of him provided by the raped woman. Fortunately, Thomson had an airtight alibi. He could not possibly have committed this rape because at the moment it occurred he was giving a live television interview on, of all the things, memory and memory distortion. Ironically, what had happened here was a classic though extreme memory case of memory misattribution. The woman had actually been watching the interview and then had been raped by an intruder, she merged her memory of the ordeal with that of Thomson's face from the television screen (from *Neuroethics: Mapping the field*. The DANA Foundation, 2002). "We have of the universe only formless, fragmentary visions, which we complete by the association of arbitrary ideas, creative of dangerous suggestions." ("The Sweet Cheat Gone").

Memories are not stored in a single place, but reassembled from bits and pieces scattered across the neural network. They never come back (neuroscientists call this process "retrieval") exactly the way they went in because new experiences have reshaped the brain in the interim. But who says that accuracy is always a positive selective pressure in evolution? There are no doubt situations in which accurate recollection of episodes is but a burden. There is a possibility that evolution "selects" against accuracy of details, because excessive accuracy may hamper generalization and categorization. As Dudai puts it, the Rashomon phenomenon may hence be a price we pay for the cognitive success of our species. The term is after the classic film *Rashomon*, by Akira Kurosawa, in which four conflicting versions of the same traumatic event are offered by four narrators. "Permanent memories", therefore, are not only vulnerable to change, but become vulnerable every time they are called to mind, a process called by the experts reconsolidation. In essence, "your memory is only as good as your last memory" as said by Joseph LeDoux, or, as said by Proust, "Our memory is like a shop in the window of which is exposed now one, now another photograph of the same person. And as a rule the most recent exhibit remains for some time the only one to be seen." ("Within a Budding Grove"). It is not yet established, however, whether the entire reactivated memory trace could become sensitive to interference in this process of reconsolidation, or, alternatively, whether a core memory has privileged stability (Dudai, 2002).

Moreover, Proust believes that sometimes our brain forms memories of things that never happened. "But she had thought that the son looked down upon her, had sought for something that would embarrass him, put him to shame, had invented a long story of evidence which she imagined herself called upon to give in court, and, by dint of repeating the details to herself, was perhaps no longer aware that they were not true." ("The Captive"). Mythomania (from the Greek μύθος (mythos), "myth" and μανία (mania), "mania", also called pseudologia fantastica or pathological lying) is a known extreme situation of the creation of false memories (creation of false stories) and habitual or compulsive lying (Dike et all, 2005). The defining characteristic of mythomania is that the stories are not entirely improbable and often have some element of truth. Mythomania is often associated with thalamic lesions that result in reduced activity of the frontal lobes.

The above do not imply that memory is useless. Memory is powerful because most of the time it serves us well, forming the foundation of our knowledge of the world and of ourselves. Memories are commonly oriented toward the present or the immediate future, i.e. application of knowledge for ongoing needs. In a way, memory projects images from the past as if they are promises for the future.

The problem of perception

"The evidence of the senses is also an operation of the mind in which conviction creates the evidence." ("The Captive"). A neuroscientist would say "If the top is convinced, the bottom level of data will be overruled". Let us examine for example - all sensory systems would do- visual perception.

When humans see light and colors, they actually "see" just a small part of a huge continuous spectrum of electromagnetic radiation, the visible light (approximately 380-780 nanometers). Light and colors (different wavelengths appear to us as different colors) do not really exist; they are constructed by our brains. And we construct colors because this proved very useful for the survival of our species. Light and colors need life in order to be seen; otherwise they just do not exist. It is a great paradox, a dissonance between reality and perception, and it is not the only one. The whole world is to a large extent a construct of our senses and brains. Vision creates a three-dimensional perception of the world that is different from the two-

dimensional images projected onto the retina. Visual perception is, therefore, an active and creative process, involving more than just the intake of sensory information. This is so because visual perception largely depends on two general properties of neurons and the brain, particularly the cerebral cortex: abstraction (or specificity) and stability. A given brain cell or a given brain area only responds to a particular category of stimulus. At the end, much of the sensory information received by the peripheral receptors in our body must eventually be filtered out and eliminated within the brain, much as we disregard the ground of an image when we focus on the figure (see below). As a result of these properties a house maintains its identity regardless of whether one views it from the front or the side, from near or from far. When people come toward us, we perceive them as coming closer; we do not perceive them as growing larger, even though the image on the retina does enlarge. A green leaf remains green whether viewed at dawn, at dusk, or at noon of a cloudy or sunny day. If one were to measure the amount of red, green and blue light reflected from the leaf in these different conditions, one would find considerable variations. Yet the brain is somehow able to discount these variations and assign a constant color to the leaf surface (color stability) (Zeki, 1999). The world is determined equally by the inherited operations of the brain and by the physical reality.

"The facts of life do not penetrate to the sphere in which our beliefs are cherished; as it was not they that engendered those beliefs, so they are powerless to destroy them; they can aim at them continual blows of contradiction and disproof without weakening them." ("Swann's Way"). And Proust expressing his very little respect for the accuracy of perception, and after 3,000 pages and several years of fiction time, insists. "There had not been an hour of my life which might not have thus served to teach me, as I have said, that only crudely erroneous perception places everything in the object; while, to the contrary, everything is in the mind." ("Time Regained"). The idea that perceptions can be manipulated by the hardwiring of the brain and our expectations is fundamental to the study of cognition. There are 10 times as many nerve fibers carrying information down as there are carrying it up. Let us give one example. The lateral geniculate nucleus is a station that relays visual information from the retina to the visual cortex (area V1). However, only 10-20% of synapses in this nucleus are formed between retinal fibers and geniculate neurons. The majority of synapses are from fibers originating in the brain stem reticular formation –a tangle of neurons in

the brain stem that project widely to vast regions of the brain- and in the cerebral cortex. It is believed that these afferents control the information flow from the retina to the visual cortex. These extensive feedback circuits mean that consciousness, what people see, hear, feel and believe, is largely based on what neuroscientists call "top down processing". What you see is not always what you get, because what you see depends on a framework built by experience that stands ready to interpret the raw information. However, most of the time bottom-up information matches top-down expectation. These massive feed forward and feedback projections enable us to have the closest possibly approximation to the real world. That is why we are still here and pass our genes to the following generations.

"That reality has no existence for us, so long as it has not been created anew by our mind." ("Cities of Plain"). Many scientists now believe that the brain basically works by simulating reality. The sights, sounds and touches that flow into the brain are put in the framework of what the brain expects on the basis of previous experience and memory. "How many letters are actually read into a word by a careless person who knows what to expect, who sets out with the idea that the message is from a certain person, how many words into the sentence?" ("The Sweet Cheat Gone"). It took several decades after Proust for a research group at Cambridge University to give us the following text:

The phenomenal power of the human mind

I cdnuolt blveiee taht I cluod aulaclty uesdnatnrd waht I was rdanieg The phaonmneal pweor of the hmuan mnid! Aoccdrnig to a rscheearch at Cmabrigde Uinervtisy, it deosn't mttaer inwaht oredr the ltteers in a wrod are, the olny iprmoatnt tihng is taht the frist and lsat ltteer be in the rghit pclae. The rset can be a taotl mses and you can sitll raed it wouthit a porbelm. Tihs is bcuseae the huamn mnid deos not raed ervey lteter by istlef, but the wrod as a wlohe. Amzanig huh? Yaeh, and I awlyas thought slpeling was ipmorantt.

The first and last letter in each word suffices to read easily the whole text. Look at figure 1, first illustrated by the psychologist Edgar Rubin. The image can be seen as two black profiles against a white background or as a white vase against a black background, but it is almost impossible to see both images simultaneously. This figure–ground dichotomy illustrates one principal of visual perception: only part of the image is selected as the focus of attention, while the rest becomes submerged into the background. The winner takes it all.

However, attention is a neurobiologically loaded word, and we do not know much about it. As William Games puts it (1890, *Principles of Psychology*): "Millions of items … are presented to my senses which never properly enter my experience. Why? Because they have no *interest* for me. *My experience is what I agree to attend to*…." We would like to know how a normal person is able to attend selectively to a single sensory input, to listen to a single voice calling his/her name amid the background din of voices at a cocktail party (the *cocktail party phenomenon*). Why do we have this vivid sense of having an internal searchlight, one that we can direct at different objects and events around us? We now know that attention requires the participation of many areas of the brain. The reticular activating system activates the entire cerebral cortex, leading to arousal and wakefulness, or -when needed- a small portion of the cortex leading to selective attention (the posterior parietal cortex is particularly important for some types of focused attention). Other subcortical structures such as the pulvinar, the claustrum, and the superior colliculus may play a critical role. It is likely that the dopamine released in the basal ganglia system communicates with the brain areas in the prefrontal cortex to allow people to pay attention to critical tasks, ignore distracting information, and update only the most relevant task information in working memory during problem-solving tasks. Large bodies of evidence now suggest that form, motion, and color are processed in three parallel interacting pathways that extend from the retina to the lateral geniculate nucleus and from there to the visual cortex. Visual attention plays a crucial role bringing these parallel transformations together into a single conscious image. We must also consider, however, the possibility that there is no central control for attention but that attention is a property of the interactions between many areas.

Proust, speaking for his grand mom, provides more insightful comments for perception in parallel with an elegiac description of death. "We never see the people who are dear to us save in the animated system, the perpetual motion of our incessant love for them, which before allowing the images that their faces present to reach us catches them in its vortex, flings them back upon the idea that we have always had of them, makes them adhere to it, coincide with it. … So is it when some casual sport of chance prevents our intelligent and pious affection from coming forward in time to hide from our eyes what they ought never to behold, when it is forestalled by our eyes, and they, arising first in the field and having it to themselves, set to work mechanically,

like films, and shew us, in place of the loved friend who has long ago ceased to exist but whose death our affection has always hitherto kept concealed from us, the new person whom a hundred times daily that affection has clothed with a dear and cheating likeness." ("The Guermantes Way"). Proust, and now days neuroscientists, suggests that what we call perception is really the end result of a dynamic interplay between sensory signals, which we often ignore, and high-level stored information about visual images from the past. Experimental subjects are shown a white man to polish the shoes of a black man. When asked, the majority claims that they show "a black man to polish the shoes of a white man." In this case, the perception of what we have been expecting to see prevails to what we have actually seen.

Illusions, which are "misreadings" of visual information by the brain, also help us to understand how the brain applies certain assumptions about the visual world to the sensory information it receives (Figure 2) or how the brain fills in the objects (Figure 3). "Even the simple act which we describe as "seeing some one we know" is, to some extent, an intellectual process. We pack the physical outline of the creature we see with all the ideas we have already formed about him, and in the complete picture of him which we compose in our minds those ideas have certainly the principal place. In the end they come to fill out so completely the curve of his cheeks, to follow so exactly the line of his nose, they blend so harmoniously in the sound of his voice that these seem to be no more than a transparent envelope, so that each time we see the face or hear the voice it is our own ideas of him which we recognise and to which we listen." ("Swann's Way").

"These words of Jupien set up at once before my eyes, in new and strange colors, a print of the picture of my relations with Françoise so different from that on which I used to like letting my eyes rest, and in which, without the least possibility of doubt, Françoise adored me and lost no opportunity of singing my praises, that I realised that it is not only the material world that is different from the aspect in which we see it; that all reality is perhaps equally dissimilar from what we think ourselves to be directly perceiving; that the trees, the sun and the sky would not be the same as what we see if they were apprehended by creatures having eyes differently constituted from ours, or, better still, endowed for that purpose with organs other than eyes which would

furnish trees and sky and sun with equivalents, though not visual." ("The Guermantes Way"). Humans cannot see ultraviolet light, whereas bees can do. It is so simple for the bees' because it is in their nature. We have indeed only a fragmentary perception of the world, which is strictly restricted by our physiology.

To form memories is a demanding process

"And yet when, later on, this sonata had been played over to me two or three times I found that I knew it quite well. And so it is not wrong to speak of hearing a thing for the first time. If one had indeed, as one supposes, received no impression from the first hearing, the second, the third would be equally 'first hearings' and there would be no reason why one should understand it any better after the tenth. Probably what is wanting, the first time, is not comprehension but memory. For our memory, compared to the complexity of the impressions which it has to face while we are listening, is infinitesimal, as brief as the memory of a man who in his sleep thinks of a thousand things and at once forgets them, or as that of a man in his second childhood who cannot recall, a minute afterwards, what one has just been saying to him. Of these multiple impressions our memory is not capable of furnishing us with an immediate picture. But that picture gradually takes shape, and, with regard to works which we have heard more than once, we are like the schoolboy who has read several times over before going to sleep a lesson which he supposed himself not to know, and finds that he can repeat it by heart next morning." ("Within a Budding Grove"). It took the Muses, daughters of Mnemosyne, a single encounter with Hesiod on Mount Helicon to breathe into the poet's divine voice and knowledge. Yet for most of us who are not granted the privilege to mingle with the immortals, learning is often a much lengthier, complicated and frustrating process. As we show, even if we do devote to training sufficient effort, memory may still betray us. And as if the burden of confusion and forgetfulness stemming from the continuing passage of time is not enough, the period immediately after learning also contributes its share to the fragility of our memories. It has long been recognized that fresh memories need time to stabilize. This brittle phase in the life of a memory is assumed to reflect the process of consolidation. Consolidation, however, is not

necessarily completed within a short time after learning; in some instances it may continue for weeks, months, even years (Bontempi et al. 1999; Haist et al. 2001). After running a maze, rats would replay their route during idle moments, as if consolidate the memory, although the replay, surprisingly, was in reverse order of travel. These fast rewinds lasted a small fraction of the actual time spent on the journey. Wilson and colleagues detected the same replays occurring in the neocortex as well as in the hippocampus as the rats slept. The rewinds appeared as components of repeated cycles of neural activity, each of which lasted just under a second. Because the cycles in the hippocampus and neocortex were synchronized, they seemed to be part of a dialogue for recent events between the two regions (Ji and Wilson, 2006). In this dialogue, the neocortex is trying to make sense of what is going on in the hippocampus and to build models of the world, to understand how and why things happen. These models are able to generate expectations about the world and plausibly fill in blanks in memory. As Larry Squire said, this replay system in the neocortex would certainly provide one clue that part of the function of sleep is to let us process and stabilize the experiences we have during the day. The same might be true for an afternoon nap. It is a shame that we stop encouraging naps once the preschool years are over. After all, there is a growing body of scientific evidence that the afternoon siesta is an important mental tool, which enhances productivity, learning and memory.

One could envisage a situation in which newly formed memories stabilize instantaneously, but as we all know this rarely happens. An appealing explanation is that instant acquisition of every event is bound to waste brain's capacity to store memories. In addition, the time window needed for consolidation, during which the new information is particularly malleable and associates easily with other inputs, could assist the encoding and registration of selected, meaningful mental narratives (Dudai and Morris, 2000). Similarly, it has been suggested that consolidation promotes better categorization and hence a more coherent, effective, and parsimonious construe of the world (McClelland et al., 1995).

«Επανάληψη μήτηρ πάσης μαθήσεως» ("repetition is the mother of all knowledge") is a famous ancient Greek saying. "… because Morel's name keeps cropping up all the time and is finally engraved in the memory like a lesson that one has read over a dozen times." ("The Captive"). There is no easy road, but no matter how many trials it takes, repetition of episodes eventually results in the

emergence of facts and the formation of memories. With a lot of repetition, they may acquire automaticity, thus requiring less and less conscious effort in being summoned and used. And, under some circumstances, they may even acquire that feature of habits that enables them to materialize, in the present, without entering at all the field of our consciousness (the memories of the type "Columbus discovered America" or, for Proust, Morel's name, and even the multiplication tables and prayers, and other overused items that sometimes we use being only half-aware of their meaning while using them correctly). The degree of automaticity of memories varies proportionally with the number of repeated episodes in which they have appeared, and the more automated and more effortlessly remembered, the more unconscious but also the more resistant to extinction they become (Papanicolaou, 2006).

Long-term memories require the activation of genes, the synthesis of new proteins and the establishment of new synaptic connections. Eric Kandel had described a memory-forming cascade set in motion by CREB (cAMP Response Element Binding Protein). CREB functions as a molecular switch that turns short-term memory to long-term memory. A learning experience flips that switch, allowing proteins and untranslated messenger RNAs (mRNAs) to be dispatched throughout the cell body. Kandel found, however, that many mRNAs remain dormant until another learning experience acts as an alarm clock, arousing the mRNAs to build the proteins that strengthen just those synapses where long-term memories form. This alarm clock seems unexpectedly to be a prion. The term prion was coined by Stanley Prusiner (Prusiner, 1982). A prion is an infectious agent composed of a protein in a misfolded form. This is in contrast to all other known infectious agents, which must contain nucleic acids (either DNA, RNA, or both). Prions propagate by transmitting the misfolded protein state as a domino wave. The altered structure is extremely stable and accumulates in infected tissue, causing tissue damage and cell death. Prions are responsible for the transmissible spongiform encephalopathies in a variety of mammals, including bovine spongiform encephalopathy ("mad cow disease") in cattle, scrapie in sheep and Creutzfeldt-Jacob disease in humans. Therefore, prions might seem unlikely candidates for safeguarding memories. However, Eric Kandel and colleagues (Si et al. 2003) and other investigators (Shorter and Lindquist, 2005) have found that an isoform of CPEB (Cytoplasmic Polyadenylation Element Binding protein) plays a role in the formation of long-term memory. This isoform of CPEB found in the neurons of the sea slug *Aplysia californica*, as well as in *Drosophila*,

mice, and humans, contains an N-terminall domain not found in other isoforms that show high sequence similarity to prion proteins. CPEB, when in a prion-like state, sustains the perpetual protein synthesis necessary for storing memories. And perhaps that is why certain events -like repeating the times tables and practicing violin- can become so unforgettable. Such events trigger enough CPEB production so that some copies of the proteins convert into prions to perpetuate themselves at the synapses where the long-term memory forms.

But why humans recall both important and trivial events? "Meanwhile Gilberte never came to the Champs-Elysées. And yet it was imperative that I should see her, for I could not so much as remember what she was like. The questing, anxious, exacting way that we have of looking at the person we love, our eagerness for the word which shall give us or take from us the hope of an appointment for the morrow, and, until that word is uttered, our alternative if not simultaneous imaginings of joy and of despair, all these make our observation, in the beloved object's presence, too tremulous to be able to carry away a clear impression of her. Perhaps, also, that activity of all the senses at once which endeavours to learn from the visible aspect alone what lies behind it is over-indulgent to the thousand forms, to the changing fragrance, to the movements of the living person whom as a rule, when we are not in love, we regard as fixed in one permanent position. Whereas the beloved model does not stay still; and our mental photographs of her are always blurred. I did not rightly know how Gilberte's features were composed, save in the heavenly moments when she disclosed them to me; I could remember nothing but her smile. And not being able to see again that beloved face, despite every effort that I might make to recapture it, I would be disgusted to find, outlined in my memory with a maddening precision of detail, the meaningless, emphatic faces of the man with the wooden horses and of the barley-sugar woman; just as those who have lost a dear friend whom they never see even while they are asleep, are exasperated at meeting incessantly in their dreams any number of insupportable creatures whom it is quite enough to have known in the waking world. In their inability to form any image of the object of their grief they are almost led to assert that they feel no grief. And I was not far from believing that, since I could not recall the features of Gilberte, I had forgotten Gilberte herself, and no longer loved her." **(**"Within a

Budding Grove"). James McGaugh, an American neurobiologist working in the field of learning and memory, examined patient AJ, a woman with astonishing ability to remember with remarkable clarity not only major events of emotional power that she could not forget but also trivial events that happened decades ago. Asked what happened on Aug 16, 1977, McGaugh recalls, she knew that Elvis Presley had died, but she also knew that a California tax initiative passed on June 6 of the following year, and a plane crashed in Chicago on May 25 of the next year, and so forth. Most of these events had no personal meaning for her. Moreover, AJ is a fully functioning person, quite different from various types of savants. The ability of AJ is extraordinary, but to a much lesser extent to remember trivial things very vividly and after a lot time happens to all of us from time to time. "Days in the past cover up little by little those that preceded them and are themselves buried beneath those that follow them. But each past day has remained deposited in us, as, in a vast library in which there are older books, a volume which, doubtless, nobody will ever ask to see. And yet should this day from the past, traversing the lucidity of the subsequent epochs, rise to the surface and spread itself over us whom it entirely covers, then for a moment the names resume their former meaning, people their former aspect, we ourselves our state of mind at the time, and we feel, with a vague suffering which however is endurable and will not last for long, the problems which have long ago become insoluble and which caused us such anguish at the time. Our ego is composed of the superimposition of our successive states. But this superimposition is not unalterable like the stratification of a mountain. Incessant upheavals raise to the surface ancient deposits." ("The Sweet Cheat Gone"). As we show memory is not a perfect copy of life, and is very capricious in nature. We never know what we will retain or for ever forget. Prion proteins, and CPEB, reflect this truth, since CPEB's structure is ruled by certain stimuli (e.g. repetitive pulses of serotonin) but also by chance, obeying to the inscrutable laws of protein stereo arrangement, forming or deleting memories. Memory obeys only to itself. The past is at the same time eternal and ephemeral.

The blessing of oblivion

We function so well as human beings because we forget things at a very efficient rate. If we remember everything about every aspect of every day, we would have tremendous difficulty given the fact that our brains have a limited capacity of storing information. If we remember everything we may end up understanding nothing. Oblivion is as important biologically as memory. The brain was "designed" by evolution over the millennia to be able to focus on the essential information than to remember every minor detail. "As there is a geometry in space, so there is a psychology in time, in which the calculations of a plane psychology would no longer be accurate because we should not be taking into account time and one of the forms that it assumes, oblivion; oblivion, the force of which I was beginning to feel and which is so powerful an instrument of adaptation to reality because it gradually destroys in us the surviving past which is a perpetual contradiction of it." ("The Sweet Cheat Gone"). Jorge Luis Borges, the great Argentine writer, in *Funes the Memorious* also recognizes how hard it is having the inability to forget.

Massive amount of research has been done into how the brain learns, and stores memories, and pharmaceutical companies' race for a pill to save memory. Much less has been done about how we forget things. It is generally believed that forgetting can be a failure of either consolidation or of retrieval (the process of recalling a memory). Consolidation occurs when a memory is moved from a short-term holding room -called working memory that lasts a few seconds or minutes- to long-term storage elsewhere in the neural network, mainly in the network of the cerebral hemispheres. In addition, memories may fade or decay over time, or be wiped out by interference from other memories. Interference results when a pattern of activated neurons no longer can be sustained, perhaps because a flood of new information has overwritten the original memory. At the morphological level, people lose memories because they lose the cells and synapses that "contain" those memories. However, it is difficult to know if a forgotten memory has been for ever lost or is somewhere suppressed. Proust in the "Cities of Plain" wrote: "For with the troubles of memory are closely linked the heart's intermissions. It is, no doubt, the existence of our body, which we may compare to a jar containing our spiritual nature, that leads us to suppose that all our inward wealth, our past joys, all our sorrows, are perpetually in our possession. Perhaps it is equally inexact to suppose that they escape or return. In any case, if they remain

within us, it is, for most of the time, in an unknown region where they are of no service to us, and where even the most ordinary are crowded out by memories of a different kind, which preclude any simultaneous occurrence of them in our consciousness. But if the setting of sensations in which they are preserved be recaptured, they acquire in turn the same power of expelling everything that is incompatible with them, of installing alone in us the self that originally lived them."

Many of the crowded memory traces are finally drowned in the waters of Lethe [in Greek mythology, Lethe, one of the five rivers of Hades, flowed around the cave of Hypnos (sleep) and through the Underworld, where all those who drank from it experienced complete forgetfulness]. However, as Proust points out in the above quotation, practically it is difficult to determine whether a forgotten memory is abolished or only repressed. Nowadays researchers are uncovering new information about the mechanisms that cause us to forget things. David Genoux and colleagues in Switzerland examined how an enzyme, known as protein phosphatase 1 (PP1) acts in the brain to suppress the formation of memories. The research team created mice that do not express PP1 and tested the spatial memory of the mice using a water maze. To get out of the water, the mice must remember where a platform is located within the maze. The control mice forgot the location of the platform two weeks after learning, but the PP1-inhibited mice continued to remember for up to four weeks after learning. The authors suggest that PP1 acts specifically after learning to promote forgetting (Genoux et al., 2002).

Researchers have also found that in "lower" animals, such as rats, crabs, and chicks, long-term memories can be erased if they are recalled and then the proteins needed to lay down a memory are blocked in parts of the brain crucial for memory, such as the hippocampus and the amygdala. The same seems to be true for humans as well. It is not science fiction. Administration of a single dose of cortisol prior to exposure to an emotionally arousing situation enhances long-term retention of emotionally loaded details (Buchanan and Lovallo, 2001), whereas administration of drugs that reduce circulating cortisol levels blocks this effect (Maheu et al., 2004). In addition propanolol, which inhibits β-adrenergic receptors, blocks the memory-enhancing effects of stress but does not affect memory for the neutral details (Cahill et al., 1994; Maheu et al., 2004). Although there is still much work to be done to prove that a β-blocker could remove very unpleasant memories, someone traumatized by a

terrible event caused anxiety, distress, and fear might soon be able to call it up and then, while it is still in a vulnerable or labile state, erase the memory, or at least lessen its emotional charge, using drugs that keep it from being reconsolidated. Forgetting or reducing painful memories -known as "therapeutic forgetting"- can be helpful to people suffering from post-traumatic distress disorder such as soldiers or accident or rape victims. The idea is not at all new. William Shakespeare, in his play "Macbeth", puts the King of Scotland to ask his physician for an antidote to be given to Lady Macbeth who is suffering, in order to forget: "*Canst thou not minister to a mind diseased*, / *Pluck from the memory a rooted sorrow*, / *Raze out the written troubles of the brain, /And with some sweet oblivious antidote* / *Cleanse the stuffed bosom of that perilous stuff* / *Which weighs upon the heart*?" Moreover, Sigmund Freud believed that we can keep unpleasant or unwanted memories out of our awareness, though the mechanism of repression in the brain has proved a mystery. Functional magnetic resonance imaging scans show that repressing memorized words increased activity in distinct areas of the frontal cortex -known to control thought processes- and decreased activity in the hippocampus -known to form and retrieve memories (Anderson et al. 2004).

The adverse effect of certain types of brain injury and mental trauma on memory was recognized long ago. But the systematic analysis of amnesia (the serious loss of memory and / or the ability to learn) started only in the nineteenth century, with Ribot, a French psychologist, and Korsakoff, a Russian neuropsychiatrist. The following passage shows that Proust might be aware of at least Ribot's studies. "For if many memories, which were connected with her, had at the outset helped to keep alive in me my regret for her death, in return that regret had itself fixed those memories. So that the modification of my sentimental state, prepared no doubt obscurely day by day by the constant disintegration of oblivion, but realised abruptly as a whole, gave me the impression which I remember that I felt that day for the first time, of a void, of the suppression in myself of a whole portion of my association of ideas, which a man feels in whose brain an artery, long exhausted, has burst, so that a whole section of his memory is abolished or paralysed." ("The Sweet Cheat Gone"). In this passage Proust describes what is called today organic amnesia, a consequence of damage to the brain inflicted by injury, a tumour, or a stroke. There is also substance-induced amnesia that results from the intake of poisons and drugs of abuse, and functional amnesia that develops

after severe mental stress or trauma. When amnesia has a physical basis, memory loss is usually not complete, but rather covers a part of someone's life. The more recent memories are often lost, while memories of most distant events are preserved (Ribot's law). As Proust points out "A memory without fault is not a very powerful incentive to studying the phenomena of memory." ("Cities of Plain"). Indeed, the investigation of amnesia is still a very powerful approach to the analysis of human memory. Whereas the application of functional neuroimaging could identify correlations between the activity of distinct brain areas and the performance of memory tasks, the study of amnesiacs could potentially identify those brain structures that are obligatory for normal memory.

The "organic matter" of the mind

Proust seems to be fully aware of the greatest paradox of the brain, meaning that the mind (brain) must be the discoverer of its own secrets and workings. Proust closes the "petites madeleines" event with the following thoughts: "I put down my cup and examine my own mind. It is for it to discover the truth. But how? What an abyss of uncertainty whenever the mind feels that some part of it has strayed beyond its own borders; when it, the seeker, is at once the dark region through which it must go seeking, where all its equipment will avail it nothing. Seek? More than that: create. It is face to face with something which does not so far exist, to which it alone can give reality and substance, which it alone can bring into the light of day." ("Swann's Way"). In this quotation, Proust expresses poetically an overused, however still valid, pun in neuroscientists' circles: "If humans were intelligent enough to understand the workings of their own brains, their brains would be too complex for them to understand." How can a piece of "meat" inside our skull percept things, remember, feel, be conscious, and at the same time understand itself? Are mind and psyche separate and independent from the brain (the dualistic approach), or this piece of "meat" does everything; It is indeed for many an overwhelming question. Proust seems to have a straightforward materialistic answer to what has been called the "mind-body" problem. "Upon that, Doctor Cottard, with that delicacy which reveals the man of distinction, returns to the history of the pearls and informs us that catastrophes of that kind produce in

the mind of people distortions similar to those one remarks in **organic matter** and relates in really more philosophical terms than most physicians can command, how the footman of Mme Verdurin herself, through the horror of this fire where he nearly perished, had become a different man, his hand-writing having so changed that on seeing the first letter which his masters, then in Normandy, received from him, announcing the event, they believed it was the invention of a practical joker. And not only was his handwriting different, Cottard asserts that from having been a completely sober man he had become an abominable drunkard whom Mme Verdurin had been obliged to discharge." ("Time Regained"). A traumatic event, as well as less dramatically any event, can permanently change the hardwiring of the brain. Once the hardwiring of the brain is changed, the person will never be the same again. The matter changes, the mind changes.

Proust is aware of other states of the mind as well, such as synaesthesia and "phantom-limbs." "Without pressing this comparison farther, I felt that the clear sounds, the blazing colors which Vinteuil sent to us from the world in which he composed, paraded before my imagination with insistence but too rapidly for me to be able to apprehend it, something which I might compare to the perfumed silkiness of a geranium. Only, whereas, in memory, this vagueness may be, if not explored, at any rate fixed precisely, thanks to a guiding line of circumstances which explain why a certain savour has been able to recall to us luminous sensations, the vague sensations given by Vinteuil coming not from a memory but from an impression (like that of the steeples of Martinville), one would have had to find, for the geranium scent of his music, not a material explanation, but the profound equivalent, the unknown and highly colored festival (of which his works seemed to be the scattered fragments, the scarlet-flashing rifts), the mode in which he 'heard' the universe and projected it far beyond himself." ("The Captive"). And elsewhere, "The time was past when I had timidly begun at Balbec by adding to my visual sensations when I gazed at Albertine sensations of taste, of smell, of touch." ("The sweet cheat gone"). Synaesthesia (from Greek συν (syn), "together," and αίσθησις (aisthēsis), "sensation") is a phenomenon in which sensory stimuli evoke sensations usually associated with different stimuli. For example, if one hears a sound, in addition to hearing he would see splashes of colored light and perhaps have a certain taste in his mouth. In a form

of synaesthesia known as grapheme, letters or numbers are perceived as inherently colored. Many synaesthetes do not perceive their synaesthetic experiences as a handicap. On the contrary, they report their experiences as neutral, or pleasant, or even as a gift -an additional "hidden" sense- something they would not want to miss. It is not known if Proust was a true synaesthet, or made use of synaesthesia as an "intellectual idea".

Although synaesthesia was the topic of intensive scientific investigation in the late nineteenth century and early twentieth century, it was largely abandoned by scientific research in the mid-twentieth century, due to the rise of behaviourism, which made the study of any subjective experience taboo, and has only recently been rediscovered. True neurological synaesthesia is involuntary and runs strongly in families, but the precise mode of inheritance has yet to be ascertained. Psychological research has demonstrated that synaesthetic experiences can have measurable behavioural consequences, while functional neuroimaging studies have identified differences in patterns of brain activation (Hubbard and Ramachandran, 2005). Increased cross-talk between cortical regions specialized for different functions may account for the many types of synaesthesia. For example, the additive experience of seeing color when looking at graphemes might be due to cross-activation of the grapheme-recognition area and the color area V4 (Ramachandran and Hubbard, 2001).

"Since she [Albertine] could do so no longer, I ought not to have been pained by the thought; but, as with amputated cripples, the slightest change in the weather revived my pains in the member that had ceased, now, to belong to me." ("The Sweet Cheat Gone"). A "phantom limb" (and "phantom pain" that is sometimes accompanying it) is the impression of an amputee that his missing limb is still there –an arm or a leg that lingers indefinitely in the minds of patients long after it has been lost in an accident or removed by a surgeon. The phantom limb experience seems to depend on signals from at least two sources. The first is remapping; sensory input from the face and upper arm activates cortical areas that correspond to the "arm". Second, each time the motor command centre sends signals to the missing arm, information about the commands is also sent to the parietal lobe containing our body image. The convergence of information from these two sources results in a dynamic, vibrant image of the phantom arm at any given instant –an image that is continuously updated as the arm "moves" (Ramachandran and Blakeslee, 1999).

Finally, Proust's quotations to romantic love are so numerous and insightful that they could be the subject of a future article.

Conclusions

Certain experts have claimed that memory is not the central concept in the novel, and others that "Remembrance of Things Past" probably remains the great novel of autobiographic memory (Deleuze G. 1983). I agree with the latter yet I think that the main concept of the novel is something more than this. I suggest that Proust, having realized that memories are spatiotemporal activity states of neuronal circuits in the brain, decided that the novel should be built on the same principle that the "experiment" should last. This is why the novel extends to over 3,000 pages (and if Proust had lived longer it would have been even larger) and expands over such a long period of time; this gives us the opportunity to paint our own canvas of the passing time, to form our own memories from the novel. I also believe that Proust's informal yet strong background in neurology and his close links to the Parisian neurological intelligentsia, together with his penetrating way of thinking and inexhaustible memory permitted him to succeed in his goal and to come to several astonishing conclusions about memory and the brain, which can be summarized as follows:

● Memory can be triggered by chance associations -a scrap of music, a place-name, or a smell-, and "involuntary memories", stored in our sensory experiences, are progressively assimilated into our "autobiographic self," becoming part, actually the "true" part, of who we are.

● "Involuntary memories" are deeply associated with emotions. The affective overlap between the past and the present results in a feeling of the continuity in time.

● "Involuntary memories" are strongly associated with the undervalued senses of smell and taste. "[Smell and taste] bear unfaltering, in the tiny and almost impalpable drop of their essence, the vast structure of recollection."

● Memories are unlikely to be stored over time as such; rather, they are probably reactivated or even reconstructed each time anew, out of an interaction between prior knowledge and current incoming information, to regain their meaning.

● Perceptions can be manipulated by our previous experience and memories, in short by our expectations. In Proust's words, "The evidence of the senses is also an operation of the mind in which conviction creates the evidence." And elsewhere, "Reality has no existence for us, so long as it has not been created anew by our mind."

● Humans have a fragmentary perception of the world, which is restricted by our physiology.

● Part of the function of the sleep is to let us process and stabilize the experiences we have during the day. "…, like the schoolboy who has read several times over before going to sleep a lesson which he supposed himself not to know, and finds that he can repeat it by heart next morning."

● Repetition of events eventually results in the formation of memories.

● Memory is very capricious in nature; humans recall both important and trivial events.

● Forgetting is as important biologically as memory. "Oblivion, the force of which I was beginning to feel and which is so powerful an instrument of adaptation to reality because it gradually destroys in us the surviving past which is a perpetual contradiction of it."

● Catastrophic events produce in the mind of people permanent changes similar to those one remarks in organic matter.

Figure legends

Figure 1. In this image we either see a pair of faces, or a vase. By focusing on the vase, we cause the faces to recede to the background, and vice versa.

Figure 2. ab equals cd. (From *The Science of Illusions*, J. Ninio, 2001).

Figure 3. The famous Kanizsa triangle. The contours of the triangles are subjective and do not exist in the drawings.

Notes

1. *À la recherche du temps perdu* (in English, *In Search of Lost Time*; earlier translated as *Remembrance of Things Past*) was published in seven parts from 1913 to 1927. For this article, I have used the seven part translation of Scott Moncrieff *Remembrance of Things Past* (translations between 1922 and 1931) [*Swann's Way (The Way by Swann's), Within a Budding Grove (In the Shadow of Young Girls in Flower), The Guermantes Way, Cities of Plain (Sodom and Gomorrah), The Captive (The Prisoner), The Sweet Cheat Gone (The Fugitive), Time Regained (Finding Time Again, The Past Recaptured)*]. eBooks@Adelaide, The University of Adelaide, Australia. In parentheses are newer renderings of the titles of the seven parts of the novel.

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