Searching for a mind's brain

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ORIGINAL ARTICLE

Searching for a mind's brain: questioning underlying biophilosophical assumptions

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This article assesses the applicability of a number of biological and neurobiological concepts to biophilosophical concepts of life and mind. Life, as instantiated by viable cells and organisms, is considered as a prerequisite of mind. Views such as embodied cognition, external mind or scaffolding theories were ignored. The biological characteristics of life and mind that are in particular relevant in the present context are: reversibility and irreversibility of brain processes, distinction between metabolic and potential brain energy, and the continuous turnover of brain constituents. The (bio) philosophical concepts multiple realizability, teleology, autopoiesis, panpsychism, supervenience and emergentism are shortly introduced and assessed in such a biological context.

The assessments lead to the conclusion that the philosophical concepts are only partially compatible with the biological concepts and need to be adapted to align with current (neuro) biology. The presently discussed options favor the idea that emergence fits best with the (neuro) biological principles, provided that the mind is considered a neurophysiological process, thus with a time-dimension. Bridging theories to couple neural brain processes directly to mental processes have as yet to be developed.

Keywords: multirealizability, teleology, autopoiesis, panpsychism, supervenience, emergence.

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INTRODUCTION

This article researches the scope and explanatory power of a variety of philosophical (i.e. metaphysical or logical) conceptualizations of neurobiological theories of life and mind. The neurobiological and biophilosophical principles chosen can directly be related to each other. I do not discuss points of view such as embodied cognition or scaffolding theories, not because I reject these theories, but rather they assume implicitly a functioning brain. The underlying neurobiology introduced here does only indirectly relate to the latter concepts and are therefore relatively neutral in the present context. The classical discussions of Smart and Place have to be mentioned here: they assume in some way an identity between mental and brain processes (Smart, 2014). As will be discussed, the issue is not whether they are identical (which I assume), but rather which level of complexity of the brain is helpful to understand and describe the precise relation of mental and brain processes.

In subsequent sections each biophilosophical concept is introduced briefly. Discussed are the conceptualizations of multi-realizability of biological functions, autopoiesis, panpsychism, teleology, supervenience and emergence. The essay focuses on both simple biological complexities (the living cell) and on advanced complexities (the functioning brain). My approach differs from other biological analyses of the mind that emphasize the structure of possible underlying neuronal networks (e.g. Edelman et al., 2011). The text is written from a biological evolutionary perspective, meaning that the living cell is considered as a precursor of the brain and mental functions, as the development of organisms from single cells illustrate. In other words, the assumption of some sort of elementary mind or consciousness associated with and/or realized by all matter or energy of the universe (as e.g. assumed in panpsychism) is considered unlikely and ignores Darwinian evolution (Korf, 2015c). I discuss also possible bridging principles enabling the understanding of the (neuro) biological functioning of organisms. The assessments are predominantly focused on mechanistic ontic conceptualizations, thereby ignoring epistemic explanations. I acknowledge the relatively narrow concept of this mechanistic explanation as compared to causality: mechanistic explanations use a more restrictive, interventionist notion, whereas causality also includes non-mechanistic or indirect interactions (e.g. Kistler, 2010a; 2010b). To my knowledge, a critical analysis of the relation of life or mind and biophilosophical concepts has not been published.

The purpose of my essay is to introduce some (neuro) biological and (bio) philosophical concepts and limitations that might help to develop multi and interdisciplinary theories bridging the gap between (neuro) biology and psychological concepts of mind. This essay offers a tentative conceptual framework that might be understood as an attempt to define principles bridging mental and cellular processing. This article is organized as follows. Various biological and philosophical concepts will be introduced and discussed in the subsequent sections. First, some general biological concepts considered relevant to assess the various philosophical stances are introduced. A (neuro) biological theory should have the potential to realize mental configurations. Next, I introduce various biophilosophical approaches and discuss their relevance in a (neuro) biological context. Finally I discuss in some detail whether and how the here presented philosophical concepts have to be adapted to become compatible with accepted (neuro) biological principles. The general conclusion is that philosophical theories on mind (and life) should be scrutinized to align them to current biological concepts.

BIOLOGICAL AND NEUROBIOLOGICAL ISSUES

This section introduces a few biological concepts that might help to assess biophilosophical options. Among the issues to be discussed are reversibility versus irreversibility, metabolic versus potential brain and cellular energy, deterministic versus stochastic transitions, intra and extracellular organization of cellular systems and whether properties of complex systems can be multiply instantiated from lower-level components. Dupré (2012) covers a well-documented and updated introduction on biological concepts. Some concepts have been briefly introduced elsewhere (Korf and Gramsbergen, 2007; Korf, 2010; 2012; 2013; 2014; 2015a, b, c). Table 1 summarizes the biological concepts.

A viable cell handles, produces and degrades a vast number of molecules, such as proteins, intermediate metabolites, ions, DNA, RNA and waste products. These biomolecules together with intracellular organelles (including cell nuclei, and mitochondria) are continuously turning over. So each component of a cell is being replaced during life. The function of genes as carriers of information is well recognized, but DNA and RNA informs only in a biological environment with proper ingredients. The intracellular components and their organization provide the natural environment, enabling specific molecular interactions, as opposed to in vitro conditions. The minimum ingredients necessary to create a viable cell are unknown. This may be approached in one of two ways: to deplete a viable cell of the intracellular ingredients and see which are indispensable, or, alternatively, to synthesize a living cell from biomolecules (Van Roekel et al., 2015). Small aberrations or irreversible damage to proteins or nucleic acids do not necessarily affect the cell's viability, because of redundancy of functions and of compensation by other functions. More severely deregulated metabolism of proteins might eventually poison the cell.

Could the cellular energy regulation be indispensable for life? Two sources of energy in the eukaryotic organism can be distinguished: oxidative metabolism and anaerobic glycolysis. The most effective, oxidative metabolism, depends on direct access to oxygen and the distribution of mitochondria inside the cell. Anaerobic glycolysis is effective when oxygen supply is limited and when energy needs to be produced rapidly at locations lacking mitochondria. The production of energy - denoted as energy metabolism - is often conditional, meaning that it ensures high and constant potential energy (Korf, 2010). Potential energy is defined here not only as the realization of steep ion-gradients over the outer or inner membranes, but also as high concentrations

Table 1. Biological and Neurobiological Characteristics

Biological and neurobiological principles	Typical features	Biological examples
Molecular processes	Reversible and irreversible conversions	Maintenance of anatomical structures versus continuous metabolism
Fluctuations around set points (1)	(Nearly) irreversible changes (heterostasis or allostasis)	Learning / memory / aging individual development and acquiring skills
Fluctuations around set points (2)	Maintenance of functions (homeostasis) energy metabolism to maintain potential energy	Temperature and hormones; repair of (cellular) damage
Viable systems	Continuous development and repair; organization of molecules is sufficient to express life	After hypothermia or metabolic arrest ("death") cells; organs and organisms regain viability ("live")
Energy	Potential versus metabolic energy	Standby of membrane potentials, phosphorylated proteins versus oxidation and anaerobic metabolism
Amplification	Small energy packets or molecules affect systems; no other mechanisms	Photons, neurotransmitters or hormones change protein configurations leading to active neurons and other cells
Nature of processes	Random, stochastic versus deterministic processes	Evolution based on random mutations; pre- and postnatal development leads to (almost) similar organisms (random character not clear)
Complex systems	Arranged from entities leading to predictable or essentially new properties	Cells or organisms as complex systems, composed from biomolecules or cells

of hormones or neurotransmitters in vesicles and high concentrations of phosphorylated nucleotides and proteins. The cellular potential energy is (indirectly) transferred from one cell to another (daughter) cell through duplication (or budding). In mammals, the potential energy originates exclusively in the mother.

Current (neuro) psychological research is heavily based on neuroimaging technologies, such as functional magnetic resonance imaging. The following analysis might help to understand what is precisely detected. In both peripheral and central neurons, information is rapidly transferred via transient changes of potential energy, i.e. action potentials. The neuronal action potential is initiated by small perturbations caused by small packages of energy (e.g. a photon in the retina, a conformation change of a protein). Maintenance of potential energy ensures that the cell can initiate and execute a wide variety of functions (mechanisms) essential for synthesis of macromolecules, intra and intercellular communication. The conformation changes of proteins that precede the decrease of potential energy (i.e. the action potential) are not detected by imaging technologies: they visualize fluctuations of metabolic energy, which are a delayed response to previous (at least 20 milliseconds) cellular activity, instead. Accordingly, resonance imaging shows an indirect response to enhanced or decreased activities of neurons and other cells (Korf and Gramsbergen, 2007; Korf, 2010; 2015a, b). Faster imaging techniques, such as electroencephalography or magnetic mapping, have other limitations, in particular spatial resolution.

Text books emphasize the importance of steady state or homeostatic mechanisms. Well-known examples of homeostasis are the maintenance of blood glucose or body temperature within a relatively narrow range. Here I emphasize irreversibility as a core principle. Irreversibility implies that the characteristic properties and molecular components of the system remain never exactly the same during life (homeostasis versus allostasis or heterostasis; Selye, 1956/1984). A perfect homeostasis implies that the physiological state of the organism is identical as its previous state. This is obviously never the case: a perfect homeostasis is incompatible with growth, development, aging, evolution and memory. These examples show that in addition to homeostatic principles, irreversible processes are indispensable for life.

Life is often regarded as a property of a self-organizing system (autopoiesis, Fernadez et al., 2013); this capacity can be illustrated as following: single cells or small clusters of cells (including human embryos) can be stored deep-frozen almost infinitely. Accordingly, egg and sperm cells and embryos are stored in liquid nitrogen, which is the basis of the clinical practice of artificial (human) fertilization. After careful thawing, these samples are functioning (”living”) as if they had never been frozen, as if “life was spontaneously regained.” Another illustration of the self-organizing capacity concerns transient interruptions of cerebral blood flow. After the interruption many cerebral physiological activities quickly stop, but many or sometimes all brain functions and memories reappear following awakening when, provided that damage is prevented (by cooling, anesthesia and low blood glucose levels) and provided that brain damage is prevented and the period of unconsciousness (coma) is limited. Similarly, when a mammalian (including human) brain is cooled below 32°C consciousness is lost, but the comatose patient may awake with a well-functioning brain and intact memory after careful warming. The potency of recovery after metabolic arrest, together with the notion that the metabolism of organisms is irreversible, leads to the view that life and mind are not states (“stills”), but they rather reflect (are identical to) ongoing physiological processes (“short movies”).

Core neurobiological principles that are used in the following biophilosophical sections are: potential versus metabolic energy, reversibility versus irreversibility or homeostasis versus allostasis, life as self-organizing capacity and, finally, turn-over of all cellular constituents.

BIOPHILOSOPHICAL CONCEPTS

Autopoiesis

Autopoiesis is a system description used to define and explain the nature of living systems (Maturana and Varela, 1980; 1988). Citing Maturana and Varela, McGann (1991/2004) defines an autopoietic system as “a closed topological space that continuously generates and specifies its own organization through its operation as a system of production of its own components, and does this in an endless turnover of components.” Cells, organs and organisms are examples of autopoietic complexities. Autopoietic systems are accumulating information and energy from an ever-changing environment. The autopoietic cell is relatively (but not in an absolute sense) autonomous to maintain complexity. This adaptive capacity points to a rudimentary form of knowledge, cognition and memory that is even present in unicellular organisms (Van Duijn et al., 2006). Autopoiesis was originally introduced to define and explain the nature of living systems, but is now often used as synonymous to self-organization. Autopoiesis is a general and not exclusively a biological principle: applications have been proposed in e.g. sociology, medicine and psychology.

In this article, we consider autopoiesis an emergent property and is equivalent to the term life, thereby referring to the unique organizing capacity of every living organism. Accordingly, the concept of autopoiesis is currently used in a biological context as equivalent to life or the capacity to realize life and mind: any mechanism realizing life or mind instantiates autopoiesis and vice versa. Autopoiesis and autopoietic capacity are not treated in more detail here: they are considered as a property essentially in the same way as life and mind.

Multirealizability

The concept of multirealizability from elementary (“lower level”) components of mind and life refers to the possibility that emerged (or supervened) properties (discussed later) of a system are or can be realized by a variety of components. Two options are discussed here: one based on the idea that only the same or similar (neuro) biological constituents, like cells or biomolecules, determine viable or mental properties of an organism (Walter, 2006), whereas the alternative is that such properties might also be realized by non-biological constituents such as chips or computers (Chalmers, 1996; 2012).

First I focus the discussion on the formal analysis of multi-realizability by biological systems (Walter, 2006), stating that "a property F is multiply realizable if there are distinct properties G1 ….., Gm (m>1) such that each Gk can realize F at some time t in some object (or subject)". The identity-theory (e.g. Smart 2014) maintains that each mental property is identical to some physical property or configuration: hence, for every mental property M, there exists a physical property P of some creature such that M = P at some time t. Applying this analysis to the mind-body case, we can say that a mental property M is multiply realizable if M has as its realization base a set of distinct physical properties P1 ….., Pn (n>1) such that each P can realize M. This concept can, mutatis mutandis, be applied to life. How does Walter's analysis work in the living brain or organism? I have argued that life and mind are instantiated by the continuous turnover of species-characteristic elements and molecules. Walter's criteria imply that the thus realized life or mind contain different molecules at later times, unless one acknowledge that biomolecules are a wrong criterion. But does this criterion work with larger aggregates, as for instance cells or perhaps brains? For instance life and mind are realized by anatomically relatively stable components; in both cases still a time-criterion has to be included. Hence I conclude that from a biological perspective that multiple realizability has to be defined more accurately because of the continuous turnover brain constituents and compensatory capacities of organisms.

The alternative concept of multi-realizability, is whether a mind can be instantiated by non-biological vehicles, such as computers. Chalmers (1996; 2012) argues that consciousness (and mind) remains intact when a substantial number of (or all) brain neurons are gradually replaced by electronic (micro)devices with the same properties as the original neurons. Arguably, the mind is "evoked" by many media. The issue is whether and when they affect consciousness. My answer is that the analysis depends on the alleged role or functioning of neurons (e.g. Lewis in Weatherson, 2014). Chalmer's hypothesis seems reasonable when applied to information processing, executive and cognitive processes, but difficult to accept when personal memories, inborn or acquired capacities and previous experiences are included. I have criticized Chalmers' suggestion (Korf, 2014; 2015b,c), because electronic devices have no history similar to neurons, whereas the mind and life are shaped by a nervous or cellular systems modified by past experiences.

In conclusion, in nature life and mind are the capacities of a complexity that is both characterized by the continuously changing of biomolecules and cells and by relatively stable structures, such as organs and organisms. In silico at least some properties of the mind, and presumably of life, can be mimicked; but similarity does not mean sameness. The challenge remains to describe and understand life and mind as (neuro) biological processes.

Panpsychism

Related to the concept of multi-realizability is substance dualism and panpsychism: the idea that the mind is an extension of all matter (or energy), but made of an entirely different "substance" than the brain or any other material in the universe. Substance dualism as alluding to the non-biological nature of mental capabilities and it is beyond the present scope. Panpsychism assumes that all matter and some of its configuration is associated with (a precursor of) mind and has to be precisely specified in (neuro) biological terms (Edelman et al., 2011). Thus formulated, panpsychism might imply that consciousness (mind and mental functioning) can be realized with non-biological aggregations of matter (robots), as well. This point of view has been discussed earlier, and is, unless adapted, rejected. The issue is whether and how a mind developped through panpsychistic processes or interactions become effective in a biological system, like the brain. If the mind is developed through a fusion of panpsychistic elements, it must in some way affect brain physiology. If not than substance dualism and panpsychism have no place in neurobiology. Alternatively, if a panpsychistic mind affects brain physiology it might be identified as some form of energy and is -at least in principle- experimentally detectable. The latter idea of panpsychism requires the integration of the presumed elements and implies therefore some kind of supervenience or emergentism (see later sections).

Teleology

The central idea of teleology is that complex systems are modeled according to a sort of preexisting or finalized end configuration, thereby assuming that subsequent steps and intermediate transitions during the realization are predetermined (at least to some extent). Teleology as used here should not be regarded in a theological context. Teleological terms in biology refer to the idea that the development of individuals or the evolution of species is directed towards an ultimate and well-established end-product. Teleological principles might assume to work in biology. An example. Mammals are formed out of a single cell. The pattern of (embryonic) development is highly predictable. Biologists generally prefer bottom-up mechanisms leading to the final outcome. From the outsider's view, the course of development is compatible with a (more or less) teleologically anchored process, as the "final" product is obvious. But one may also propose that the end-configuration of an organism is hidden in the fertilized egg, and that this configuration needs a particular environment to become discernible over time. I am not advocating here that some kind of teleology determines individual development, but suggest that teleological hypotheses might be helpful to conceptualize and understand patterns of individual development and eventually of the mind. This way of reasoning is rather similar to that of David Bohm (2000) proposing an implicit world, as complementary to the observable or explicit world, as a guiding principle in the universe. I suggest that teleological principles might be useful in biology to understand aspects of ontological and evolutionary processes.

Supervenience

Supervenience is a quality of a system that is realized through processes of the constituent physical elements of that system. Supervenience has been discussed in particular in connection with the issue of how the brain realizes or instantiates mental processes. Quoting Kim (2005, p.34):

> "a mental (supervening) property is instantiated by an organism at a time because, or in virtue of the fact that, one of its physical "base" properties is instantiated by the organism at that time."

In other words: if a property supervenes on an object, there is no change in the property without change in the object, but the reverse is not the case. That is particularly relevant when discussing the concept of mind

Supervenience assumes that mental properties are not reducible to and are not identical with physical properties (Kim, 2005). Brain processes are physical processes and in every state of the brain (in Kim's notation P1) at time t , a (mental) property (or quality) M1 occurs. Transition from P1 to P2, another state of the brain, is concomitant with a synchronic transition of quality M1 to quality M2. This concept implies that the reverse, M determines P, is impossible. What kind of property (of type M1 or M2) might be supervening to cell processes or biological states of the brain (of type P1 or P2)?

First, I present two of Kim's illustrative examples of supervening properties. Kim uses bronze sculptures having timeless properties of the microstructure. Macro-level properties that are rather stable over time ("vertical" determination); they refer to such properties as the size, weight or shape of the bronze. The macro-properties are vertical as by its synchronous micro-structure, realized according to the (increasing) complexity of the material. Horizontal causation is ordered as a line (from past to future) depicting the diachronic causal relations. The appearance of the bronze statue might change rapidly; for instance, when the sun starts to shine, it changes its color gray into yellow. Why is it yellow at later time? There are two presumptive answers: 1) because its surface has a microstructure property M at t1; and 2) because it was yellow at t+Δt. The "vertical" qualities suggest that the microstructures remain stable at least for a moment and, moreover, these "vertical" states are causally unrelated. In contrast, subsequent "horizontal" causation (the sun shining) connects P-states: the past determines the future and the future depends on the past (Kim, 2005, p. 36-37). The second – biological - example: the pattern of spots on a panther's skin. This pattern can be modeled mathematically as a biological although chaotic processes in living skin cells (the "vertical" component; "P-state"). These spots are useful for the panther only in a natural environment and in the presence of light (causing the "M-state"). Then, the skin pattern becomes detectable and because of that it favors survival and helps finding a partner for mating (the "horizontal" aspect).

In both examples, supervenience refers to quality, rather than to a property, realized by complex structures. Kim's idea is that the quality yellow or spots (first and second example) does not affect the microstructure of the sculpture; but this is not necessarily true, verified by physical examination. The "quality" mind influences an organism anyway, not necessarily because of introspection, but rather as non-conscious biological processes. For instance, "qualities" such as forms and colours of objects evoke personal (mental) images through brain processes. In the case of mental supervenience, the reasoning is analogous: a supervening mind is scientifically relevant only for a person if it influencs the brain's physiology. Kim argues that mental properties have causal efficacy: that is, their instantiations cause other properties, both mental and physical (Kim, 2005, p. 35). The concept of supervenience is exclusively discussed in the context of the mind-body issues. The question could be raised what supervenes on a functioning cell? Life might be the answer or, perhaps, there is no term or concept to denote the supervening quality.

The concept of supervenience has been challenged by both philosophical argumentations and Kim's illustrative examples. Philosophical arguments against the possibility of physical downward causation of a supervening quality have been raised (examples in Van Gulick, 2001; Kistler, 2010a, 2010b; Eronen and Brooks, 2014). My major problem with supervenience is that it is conceptualized in terms of qualities without causative power on brain physiology.

Emergence: the concept

Emergence as defined here is applicable from elementary components of physics and chemistry up to complex systems, including living cells, organisms and brains. My analysis of emergence is based largely on the work of Archim Stephan (1999), in which he distinguishes the following characteristics of emergentism: naturalism, systemic properties, novelty, and hierarchy of levels of existence, diachronic and synchronic determinism, irreducibility, unpredictability, and downward causation. Biologists and neurobiologists tend to consider emergence as a framework to explain the behavior of organisms assuming that complex systems provide the causal description of behavior. In other words, emergent properties have a direct power over underlying constituents (top-down causality). Life or mental states are properties emerging from the constituting elements and the thus emerged organization determines or affects at least part of the underlying physiological activity. The organization and mutual interactions of constituting elements characterize the complexity of the system and the presumed emergent properties. Table 2 summarizes various options discussed in this section.

Stephan (1999, pp.49-50) distinguishes weak, synchronic and diachronic emergentism. "Synchronic emergentism is a timeless relationship between a system's property and its microstructure, i.e. the arrangement and properties of the parts determined the property of the complexity. A property of that system is taken to be emergent, if it is irreducible, i.e. if it is not deducible to the arrangement and properties of the system's parts." Accordingly, life and mind classify as emergent. Diachronic emergentism is mainly focused on the predictability of novel properties. According to diachronic determinism, it is not possible to realize different structures out of the same initial conditions and assuming the same laws of nature. Properties are considered emergent if they could not be predicted in principle before their first instantiation. Irreducibility and unpredictability might be connected when they imply that irreducible properties are in principle also unpredictable before their appearance. However, it is possible that a property is reducible yet unpredictable: the latter situation is in a sense more complex than irreducibility. One problem with irreducibility depends on the behavioral un-analyzability of a property, i.e. it cannot be analyzed in terms of the behavior (in the widest possible sense) of the related structures. Hence, mind would then be beyond neurobiological analyses. Stephan combined both criteria. "A systemic property is irreducible, if (i) it is not behaviorally analyzable, or (ii) if the specific behavior of the system components, over which the systemic property supervenes, does not follow from the behavior

Table 2. Characteristics of emergentism

The table is largely based on the work of Archim Stephan (1999)

Characteristic	**Explanation**	**(Neuro) biological equivalent**	**(Neuro) biological implications**
Naturalism	Issue of natural science, materialism	Treated here as biological issue	Brain function = mind
Systemic properties	Properties deviate from those of constituting components	Special properties of living cell or brain; realized by varying components	Conglomerates of cells, properties of organs, living organisms
Novelty	Complexities have new unforeseen properties considering their components	Information DNA is expressed only in a "biological" environment; properties of organisms not deducible from cells	Life, biomolecules, memory, personal feelings
Hierarchy of existence levels	Complexities exert causal powers over less complex systems	Systemic levels are often artificial; better to define functional levels	Replace concept levels by complexity (e.g. cell, brain, organ)
Diachronic determinism	Predictability of novel properties	Microstructures relatively independent	Nerve cells' activity relative to that of a functioning brain
Synchronic determinism	Timeless relation between system's properties and its microstructure	Microstructures fixed in system / agglomerate	Cell arrangement in an organ; static, nonfunctional
Unpredictability	System's property not conceived before instantiation	When does a cellular aggregate have a mind?	Development of an organism from fertilized egg cell
Irreducibility	System's property not recognized in microstructure or components	Individual cells not representative for organism; random modification cells during aging	Relation between brain cell and brain function
Downward causation	System influences or determines behavior of components	Overt behavior causes activities of muscle and nerve	Extracorporeal information is (cognitively) recognized before initiating behavior

of these components in isolation or in simpler systems" (Stephan, 1999, pp.53-54). Other reasons could be that the property of the system is by itself irreducible (for instance a human being, the mind, a living cell) or that the universe is fundamentally non-deterministic. Arguably, a panther's skin patterns might be explained with chaotic models; hence, the question is whether chaotic processes are predictable "in principle".

In contrast to supervenience, emergentism assumes downward causation. Stephan (1999, p.65) emphasizes the dilemmas: "(1) if the emergentist wants to grant emergent properties a causal role, he (she) must accept a form of downward causation and thereby deny the closure of the physical realm [but only if the emergent properties are considered non-physical; Korf, 2015b]; (2) if the emergentist denies downward causation, he must accept that emergent properties have no causal role, so that they are epiphenomenal." An indirect argument for downward causation is this: if the behavior of the components of a system cannot be deduced from their behavior in other systems, there must be an additional causal influence (Eronen, 2015). Such additional causal influences might be extracorporeal (e.g. light, food or heat): but even then they interact with the physiology of the system. A challenging exception could be when the system's behavior is determined by probabilistic events. Recently quantum-related models have been developed to describe mental processes (Buzemeijer and Bruza, 2012). According to Stephan (1999, p.58), downward causation can be interpreted in two ways: (1) the system that has emergent properties causally influences the behavior of its components; or (2) the emergent properties themselves influence the behavior of the components of the system. This, of course, depends on whether we assume that properties as such can have causal powers or only the systems that realize them. Considering life, it seems that both interpretations apply: an organism recruits molecules or organs to enable food collection and eating, whereas feeling hungry or low blood glucose activates the search for food.

Kistler (2010a; 2010b) proposes three core elements: 1) the brain (or living cell) might be described as deterministic chaos, meaning that underlying deterministic processes lead to an unpredictable outcome; 2) mental processes (and life) emerge from brain (or cellular) states, either by fusion (strong interaction) of underlying elementary processes or by systemic interaction of parts of the brain (or cell) in a mechanism; and 3) mental (or cellular) states obey to "systems laws" at for instance psychological levels. Such laws impose constraints on the evolution of the system and thus contribute to its determination. The realization of a complex system might well be understood as the result of mutual interactions between the constituting elements. Considering mind, this is not instantaneously realized [as assumed by Searle (1982, pp.87-89) and Vicari 2008, p.54)] but requires at least 150 milliseconds (Korf, 2012.). The core issue is, then, how to relate the proposed "system laws" that are presumably in the physical domain to psychological (or functional) "laws". The latter suggests the existence of a psychological domain.

Emergence: levels of causation

During the last decade a central discussion has been whether distinct levels exist to exert top-down mechanisms in complex biological or neurobiological systems. The issue is particularly relevant when considering life or mind emergent from cellular or cerebral subsystems: they might emerge exclusively from intact organisms, or, alternatively, just from one or several (crucial) sub-structures and how such emerged properties affect the physiology of the system. The question is then: do complex systems use special mechanisms to exert their influence on underlying structures and – ultimately - on the outside world? I discuss some views of the defenders (Craver and Bechtel, 2007) and the opponents (Fazekas and Kertész, 2011; Eronen, 2015). The proponents (Craver and Bechtel, 2007, p.547) assume that "top-down causation" describes a perfectly coherent relationship between the activities of the entities and the behavior of their components, but the relationship is not a causal relationship." Likewise, the phrase "bottom-up causation" does not, properly speaking, refer to a "causal relationship". Mechanisms are entities and activities organized in such a way that they exhibit a phenomenon. Craver and Bechtel claim that causation does not cross levels: what appears to be downward or upward causation should be understood as intra-level causation that has mechanistically mediated effects downwards or upwards in the mechanism (Eronen, 2015, pp.55-56).

Kistler (2010a; 2010b) proposes, first, that levels are related by constitution (belonging to the same level of physiology or anatomy); second, that constitution is not the appropriate concept to account for downward causation; and third, that higher level phenomena constrain phenomena at lower levels. Kirsler used spatial memory (Morris maze experiment) as the top level configuration, directly causing behavior: first at the lower level hippocampus, then at the level of synapses and finally at the level of brain glutamate receptors. I stress here that the trained rat recognizes the condition first before performing its behavior. Hence, additional brain complexities and processes are involved. Apparently, this top-down causality requires several inter-level mechanisms (e.g. learning, memory) resulting in top-down regulated behavior.

The concept of levels was also critically analyzed by Eronen (2015). He argues (p.41) that the main motivations for giving an account of organization levels are: 1) to provide a framework for understanding reduction and reductive (or mechanistic) explanation; 2) to capture and understand significant features of the organization of nature; 3) to clarify and understand the talk of levels in the relevant sciences; and 4) to provide a framework for analyzing top-down or downward causation. Craver and Bechtel (2007) consider only the first of these as particularly relevant for their thesis. Eronen (2015, p.51) concludes that “there does not seem to be a plausible way of defining the same-level relation based on just composition”. He questions the concept level, because it does not help understand functions and mechanisms. All that is needed for arranging things on a scale is some property (such as size) that can be quantitatively measured in those things. The scale might be divided into segments (e.g. atoms, molecules, synapses, neurons, etc.), but “this is merely heuristic, in contrast to levels or compositional hierarchies” (Eronen, 2015, p.52). I suggest replacing scale or size as index levels by levels of complexity . Cellular elements, such as mitochondria and nuclei, might be described as complexities composed of less complex elements (proteins etc.). Cooperating cellular elements instantiate life; a well-organized ensemble of specialized and cooperating cells instantiates mind. Both bottom-up and top-town causality occurs; their recognition depends on the point of view of the researcher . External observers may then ascribe the thus emerging processes not only to neurophysiological properties but rather as a property of the emerged system (Fazekas and Kertész, 2011). The cell might be considered a well-identifiable level and through interaction (and programming) form functioning complexities, such as organs and organisms.

DISCUSSION

The current analysis revealed that without certain restrictions, multirealizability, autopoiesis, teleology, dualism, supervenience and emergence are insufficient principles to apply to life and mind. As argued, the (neuro) biological principles were chosen because they are approximately at the same level as the current metaphysical concepts of life and mind. Life is considered as a biological (autopoietic) capacity that realizes self-support and progeny. Mind is the result of the autopoietic capacity of the brain, as its reappearing after careful warming of comatose or cooled subjects illustrates. Because of the continuous turn-over of molecules of a living organism, and the inter-species differences of the biochemical composition, multirealizability of life is obvious. Similarly, in a living brain the mind is realized through metabolism, with the ongoing involvement of a multitude of brain molecules. The role of teleology is minimal in current biology, although it might be regarded as an implicit property (as defined by Bohm 1980/2008), that becomes discernible by letting the organism to grow and develop. I questioned aspects of supervenience and emergentism, in particular when mind is considered as a quality, rather than as a physiologically active agent. Therefore the concept of emergence should include a time-dimension, signifying physiological processes.

The current treatise does not well define the mind . My concept is arguably broad: mind refers here to consciousness, to mental or to psychological processes . In addition, the term mind has also been conceptualized as a configuration emerging from the brain, a computational structure or as a product of individual or social development. Considering current (neurobiological) knowledge, mind cannot be defined or understood in such a way that it logically includes or excludes certain options. This view is similar to that of, for instance, the concept of the electron (Lewis in Weatherson, 2014). An electron might be defined as a particle (by the older theories), as a wave (according to newer ideas) or as a probability or possibility (contemporary views), but as yet there is no new term proposed. According to the presently posited concept, the mind is part of the physical world and, therefore, not violating the physical closure paradigm, assuming that interactions are only possible between physical objects, not through non-physical elements. This position assumes that, although physical processes are basic in the realization and functioning of complex systems, their outcome is not directly derivable from laws or properties , than can be described by physical terms. This reasoning is similar to the question whether one should describe biochemical conversions in quantum-physical theories: they are conditional for "emergent" properties, but do not explain them (Korf, 2015a; 2015b).

This essay favors the concept of emergence as most useful in a biological context, thereby acknowledging the brain as a complexity. The question is what really emerges from a cell or a brain. With the current knowledge, it seems questionable whether these emergent properties can directly be derived from properties of the constituting elements. It is principally or nearly impossible to completely capture a cell, an organism or a brain in terms of properties of non-living vehicles or artifacts. Considering the present case, because of the many interactions, properties of cells established in vitro do not or only in a limited way predict properties in vivo (Van Roekel et al., 2015). What seems realistic, is to assess in vitro which observed properties are conditional to enable emerging properties. Organisms experience subject-unique events that might consciously or subconsciously be memorized. Memory should be taken as a broad concept: even organisms without a nervous system may incorporate external influences and "memorize" some previous experiences.

One may approach the issue of what is emerging, by introducing and exploring new concepts and to define inter-level bridging principles. Here are some examples. Causal mechanisms understood as a fixed sequence of stimulus-response (or action-reaction) and its temporal ordering is often less obvious when studying mental processes. Most if not all memories are recollected by association rather than by their temporal sequence of their experience or storage: one recollects experiences by similarities or association of related events instead (summary Korf, 2010; Korf, 2012). Moreover, although it might often be difficult to find early-life memories, one does certainly not reach them by systematic regression starting with recent memories. Also, in daily life there is often no clear temporal order of decision-making. A yes/no decision in, for instance, task-tracking experiments, is already prepared before the execution of an action [Busemeyer and Bruza, 2012; more examples in Scheffer, (2009) and Korf, (2014)]. Mathematical models of such experimental studies assume superposition, which means that before an action becomes explicit, more than one possibility are pre-consciously present (Atmanspacher and Fik, 2010; Kornmeier and Bach, 2012; discussed in Korf, 2014). In a way, it is as if an organism (and brain) creates some sort of individual universe that depends partly on unknown inter- and extracellular processes, and might be conceptualized by assuming both causal and a-causal processes.

The purpose of this essay is to introduce and discuss a variety of (neuro) biological and (bio) philosophical concepts and their limitations that might help to develop multi- and interdisciplinary theories to narrow the inter-disciplinary gap between neurobiology and psychology. A biological theory of mind should consider life as an underlying organizing principle to realize both the potentials and the constraints of mental configurations. My analysis might help to improve neurophilosophical and neuropsychological theories on biological functions in relation to life and mind. This essay suggests a tentative conceptual framework to understand neuronal functioning in a complex nervous system and might be appreciated as an attempt to search for principles bridging the mental and brain-physiological processing.

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