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Chemistry, context and the objects of thought

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Abstract In this paper we wish to raise the following question: which conceptual obstacles need to be overcome to arrive at a scientific and theoretical understanding of the mind? In the course of this examination, we shall encounter methodological and explanatory challenges and discuss them from the point of view of the philosophy of chemistry and quantum mechanics. This will eventually lead us to a discussion of emergence and metaphysics, thereby focusing on the status of objects. The question remains whether this could be interpreted in terms of a re-description or dissolution of seemingly troubling problems in the philosophy of mind, or whether it further emphasizes the problematic: the ubiquitous and irreducible role of mind and consciousness in scientific (and other) activities.

Keywords Mereology · Emergence · Contextuality · Relationalism · Consciousness and cognition

Mind-matter science?

It has recently been argued that some issues in the philosophy of chemistry are relevant to the philosophy of mind (Earley 2008), thus sustaining a general trend in analytic philosophy to look more closely at the philosophy of science and relate it to the study of the mind. Most often (and quite naturally) this has been done with respect to cognitive science (psychology), neurobiology and physics (Block 2009; Churchland 1986; Esfeld 2001). More recently there has been some interest in an ecological perspective on cognition and consciousness (Noë 2004; Silberstein and Chemero 2012), and now philosophers of chemistry too have begun to probe the interface between mind and matter, following

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Joseph Earley's advice to look in detail at the topics of mereology, emergence and process theory as they pertain to the chemical sciences. There has been plenty of work on the topics of emergence and mereology in chemistry; mostly from the angle of philosophy of science (Scerri 2007; Harré and Llored 2011; Restrepo and Harré 2015; Manafu 2015), sometimes with explicit appeal to metaphysical issues or even the mind–body problem itself (Lombardi and Labarca 2005; Llored 2014; Banchetti-Robino and Llored 2016).

The majority of the philosophy of mind, as shall be construed for the scope of this introduction, pertains mainly to philosophical investigations that have the character of asking (or answering) questions of principle, i.e., questions that can be read the following way: "How is it possible that…?", "How could… follow from or be accompanied by…?", or "What is the nature of…?" Such principled questions are exemplified by the puzzle of "mental causation" (Davidson 1970), by "the hard problem of consciousness" (Chalmers 1995), by the theses of "naturalism and the causal closure of the physical" (Papineau 1993), by "making sense of emergence" (Kim 1999), and others. Insights from the philosophy of science bear on the philosophy of mind but do not (dis)solve its problems. Philosophers of science could—to arbitrarily pick out two examples which are relevant in the context of the philosophy of chemistry—argue for the adequacy of one particular notion of emergence or for the "right" mereology of a scientific theory, but by itself this will not tell us how mind might be understood as an emergent feature of the world, or how the mind's structure could be described in terms of mereology.

A different approach tries to come up with actual theories (or models) of cognition, perception and consciousness which are less focused on such questions of principle. Instead, they aim for a scientific investigation of the relation between mental states and material phenomena. Over the last years several such approaches have been proposed, examples being the project of "neurophenomenology" (Petitot et al. 1999; Thompson and Varela 2001) where verbal or written reports and measurements of neuronal activity are viewed as first and third person perspectives on a single phenomenon, the project of finding "neural correlates of consciousness" (NCCs) (Metzinger 2000) where brain states are tried to be systematically correlated with experiences or sophisticated (and non-reductive) models of psycho-physics and perception (Price and Barrell 2012; Hoffman et al. 2015).

Here, philosophical and qualitative insights are inseparable from empirical work. For example, neurophenomenologists argue for taking phenomenology more seriously and try to make it "operational" in the context of empirical science. Also, the discourse about NCCs is inseparable from psychological considerations and could thus hardly be considered as neuroscience only. In other projects, correlations between mental and material phenomena are taken to result in an empirical classification of experiential states (Fach 2014), and discussions pertaining to reality and consciousness are related to empirically-directed research on perception and evolution (Hoffman and Prakash 2014).

This list of examples is neither comprehensive, nor do we overlook the many controversies associated with each individual project. However, we wish to emphasize the increasing interest in empirically directed mind-matter research over the last years.

On a more general level, one might also ask for the structural details of the underlying framework of these or similar projects (Bitbol 2002; Primas 2009; Prentner 2014; Atmanspacher 2014; Silberstein 2014; Sieroka 2015). Usually (but not necessarily), agents with mental capacities are posited at some stage, and the theory tries to explain how they act upon, access or reason about their (living and non-living) environments. Where such agency is furthermore postulated to be constitutive for (or coincide with) consciousness, these approaches are carried out as part of the scientific study of consciousness.

How are these approaches consistent with the well-known "-isms" postulated throughout the history of philosophy? Must they be taken to imply the activity of disembodied minds that "float on top" of material reality, thereby inducing changes in its behavior? Or should we rather think of any activity as, in the end, nothing but the activity of the brain? In other words, don't we just have cases of dualism, materialism or perhaps panpsychism which now come in the guise of "mind-matter theories"?

We wish to stay agnostic here, but observe that none of the metaphysical positions mentioned before resembles a theory or model but rather a philosophical image of the world, which could hardly be studied in isolation from historical and cultural developments. One should then differentiate between two separate but related projects: one that aims to answer questions of principle and thus arrives at a more coherent (philosophical) world view, and one that tries to (scientifically) engage with the relation of mind and matter. However, could this second project be realized at all? If so, what are its conceptual prerequisites?

In the section "On the way to a science of mind" we shall start by making some methodological considerations which are related to issues in philosophy of chemistry, followed by a discussion of what many deem to be the most promising direction in relating mind and matter, namely emergence. This shall be done in the section "Emergence" in which we wish to emphasize the importance of contextuality, and also discuss the problems associated with the supposed emergence of consciousness that follows from this. We will reach an impasse here that leads us to reconsider some of our basic assumptions about object-hood. In the section "The metaphysics of objects" we shall sketch a general metaphysical picture which finally leads us back to the philosophy of chemistry and quantum mechanics.

On the way to a science of mind?

Methodological challenges

The idea of establishing a scientific study of mind and consciousness is faced with particular challenges which go beyond a scientific method of sorting and analyzing experimental data and comparing them to theoretical descriptions and calculations: Not only do we have to account for the way the world is structured, we also need to consider that our minds play an essential role in structuring the world. It is precisely due to this that the established scientific fields and a future science of mind and consciousness differ methodologically.

Given this, one could name (at least) three challenges, which are also deeply related to the methodology of the chemical sciences:

In addition to analysis, there is synthesis. This comes as no surprise to the practitioner of chemistry who has always been concerned with "making things," rather than with explaining things or building theories. However, this often hasn't been considered as fundamental with respect to a scientific method which usually analyzes complex phenomena into parts and tries to derive the dynamics of a system from its components' behavior. That a "reductionist hypothesis does not by any means imply a 'constructionist' one" was put forward by the renowned physicist Anderson (1972, p. 393); this resonates much better with the practices of chemists than it did with the reductionist agenda of fundamental physics.

Relational concepts abound. To some, speaking of relational concepts implies a belief in the necessity for extra-scientific or subjective (in the sense of arbitrary) methods. This is a mistake, as chemistry might easily demonstrate. A lot of important concepts from chemistry are consistent with such a "relational view." Examples include the concepts of affinity, electronegativity and reactivity of substances. Any intuitive understanding of these notions requires us to take a relational standpoint, but at the same time includes the possibility of quantitative evaluation and measurement of relational properties. Hence, chemistry strongly implies that science is not only about "uncovering the intrinsic nature of things" but also about making exact statements pertaining to relational or structural properties.

What counts as system, as environment or merely as system-component is never unambiguously given. Mereology, the theory of part-whole relationships, dates back to the ancient works of Aristotle but, very much like formal logic, was transformed and refined around 1900 in the hands of mathematicians (Lesniewski 1992; Tarski 1956) as well as psychologists and philosophers (Brentano 1973; Husserl 2001). Since then, it has been possible to understand mereology as the *formal* study of the relations between parts and wholes or systems and subsystems.

As work in the philosophy of chemistry has demonstrated, the opinion that the world presents itself according to a well-defined, fundamental part-whole structure is difficult to sustain (Harré and Llored 2011, 2013; Llored 2014). Mereology, contrary to the idea that it formalizes being in terms of a "formal ontology" (Smith and Mulligan 1983), could be interpreted as a description of the (parthood-) structure of material systems relative to certain initial theoretical assumptions, pragmatically justified decisions about the system, experimental methods, and the overall (scientific or other) objectives of the researchers. In particular, if mereology pertained to *discourse* rather than being (Harré and Llored 2011), then mereological analysis would primarily reflect on the ways of reasoning, accessing and dealing with the world. This is clearly opposed to the idea that mereology is about the different senses of "parthood", "order" or "organic union" exemplified by objects existing "out there."

Decompositional mereology

The adiabatic approximation (also known as the Born–Oppenheimer-approximation) in molecular physics is perhaps the most well-known example in the philosophy of chemistry which illustrates the idea that mereology does not reflect the static structure of reality but rather an objectified outcome relative to a process.

In the Born–Oppenheimer-approximation, the total molecular wavefunction is expressed as a product of nuclear and electronic wavefunctions, $\Psi = \varphi_{\mathrm{n}} \cdot \varphi_{\mathrm{e}}$. These are calculated using a reduced electronic or nuclear Hamiltonian. These nuclear and electronic "parts" can in turn be expressed as symmetrized products of single "*part*icle" wavefunctions.[1]

[1] The conceptual implications of the Born–Oppenheimer approximation have duly been discussed in the literature, usually in the context of the reduction of molecular structure and its quasi-classical behavior (Wooley and Sutcliffe 1977; Primas 1983, 1998) Note however, that with respect to mereology, the main point isn't whether the adiabatic approximation results in (semi-) classical behavior or not. The product-Ansatz above is still consistent with a nuclear wavefunction that is not classical in the sense of assigning well-localized positions to each nuclei, as could for example be seen in solutions which are describing "tunneling motions" (Albert et al. 2013).

As such, the mereological structure of molecules seems straightforward. However, it in fact depends on whether we have to account for configuration interaction, non-Born–Oppenheimer dynamics and other forms of entanglement during the calculation: this would quickly change the simple "part-product" outlook given above. In addition, mereology is also contingent upon the meaning we give to the parthood relation itself. It has been suggested above that being "part of" a molecule should be understood as being a factor of its wavefunction. However, other readings of parthood are also possible: For example, if $H_{12} = H_1 \otimes H_2$ denotes the total Hilbert space of a composite system, then the subspaces H_i might be interpreted as "parts." This would also account for cases of bi-partite entanglement, and it has been shown recently that this mereological structure even follows the axioms of "closure extensional mereology" (Calosi and Tarozzi 2014).

Together, this makes for a host of internal and external constraints which are placed on the mereological structure of systems. Even speaking of isolated molecular systems is, by itself, already a high abstraction (Primas 1983, Chap. 4). A certain class of objects—be they microscopic, such as molecular structures, or macroscopic, such as biochemically active substances and cells—are not readily "given", but are in part determined by our cognitive (and experimental) access. So, whereas sciences like chemistry might give answers to questions pertaining to the way these structured objects behave, there is always the complementary question of how these structures were recognized. This might be trivial in the case of simple systems but becomes more important as the systems become more complex.

To answer the question how system boundaries are chosen within a theory of cognition, one must be able to address it more formally. For the case of part-whole (system-environment) structures this could be done, for example, by means of a "decompositional approach" to mereology which is based on an algebra of projectors that model the parthood relation an operation: The proposition that "some *x is* part of some *y*" is translated into the proposition that "*x results* from a projection $\hat{P}$ on *y*". In a next step, one could try to arrive at ("object-free") statements which no longer describe parts (or wholes) explicitly, but rather only the projective relations between them. Importantly, this will have consequences concerning the status of some contested types of axioms of classical formulations of mereology (see Simons 1987), such as transitivity (which translates to transitivity being the case iff any two parthood operations could be represented as commutative operators) or the weak supplementation principle (which conveniently translates to a requirement concerning possible decompositions). This is sketched in Table 1 and could serve as starting point for a more in-depth analysis. Roughly speaking, decompositional mereology does not express what is or is not the case with respect to particular objects, but rather how decomposition is possible.

Table 1 Classical versus decompositional mereology

Classical mereology	Decompositional mereology
Parthood $x < y$	$x = \hat{P}y$
Basic axioms of reflexivity and transitivity	$\hat{P}^n = \hat{P}; \quad \exists\hat{P}_{jk}\ (\hat{P}_{jk} = \hat{P}_j\hat{P}_k) \Leftrightarrow [\hat{P}_j, \hat{P}_k] = 0$
Supplementation	$\exists\hat{P} \rightarrow \exists\hat{P}'\forall\hat{P}_j\hat{P}_k(\hat{P}_j\hat{P} \neq \hat{P}_k\hat{P}')$
Closure axioms, summation	..?

Statements on the left are usually encountered in classical treatments of mereology. The corresponding expressions in decompositional mereology are written on the right. Note that decompositional mereology makes ("object-free") statements about the possibility of an operation, not about a pre-existing structure

Emergence

Explanatory challenges

In addition to the methodological challenges we discussed in the previous section, we shall now address a prominent concept that is often encountered when thinking about the mind as *explanandum* of a scientific theory.

In the course of the last century, science had to deal with various situations which defied traditional explanatory schemes. Common to these examples is the fact that they challenge our established mechanistic approach to derive observed behavior from (the interplay of) the parts' behavior as it could be prepared and studied in isolation. Here we provide a selection of examples:

1. Non-separability and entanglement were conjectured in the early days of quantum mechanics, but only received increased attention after theoretical progress in the 1960s and breakthrough experiments in the 1980s. Such experiments form the backbone of the exciting new field of quantum information (Jaeger 2007).
2. Seemingly teleological behavior at the level of systems (Varela et al. 1974) makes the search for mechanistic explanations at the level of material components futile in the sense that causal explanations—though fully compatible with this behavior—are not able to give us answers to questions concerning the directivity of living systems (Ayala 1970; Thompson 2007).
3. Instances of self-organization might be readily found in various fields, such as physics (Anderson 1972; Laughlin and Pines 2000), chemistry (Luisi 2002) and biology (Kauffman 1993).
4. Our intention is not to argue that these examples are fundamentally related or "somehow" express similar structures (this would be simply mistaken or at least a gross oversimplification), but rather to emphasize that their acknowledgement does not in any sense preclude a scientific investigation. And, as the example of quantum information technologies shows, they might even open up new possibilities of (applied and basic) research.

It is interesting to note here that theoretical efforts have also been made to accommodate these new explanatory or descriptive approaches, for example the theories of "Synergetics" (Haken 1983) or, more recently in the context of neurobiology, the "free-energy principle" (Friston 2010). These developments are very promising and are consistent with the aforementioned decompositional approach towards mereology.

Contextual emergence and the mind-matter gap

A way to *philosophically* respond to the above-mentioned instances of non-separability and self-organization consists of conjecturing a mechanism of the *emergence* of phenomena. One particular approach which drew many of its examples from chemistry and related fields was initially proposed by Hans Primas (1998) and was later developed into the theory of "contextual emergence" (Bishop and Atmanspacher 2006; Atmanspacher and Bishop 2007). This approach is sometimes understood to be mainly interested in the details of how scientists apply asymptotic expansions to relate different theories like quantum physics and ab initio quantum chemistry (Llored 2014). However, on this view the main lesson might get overlooked, namely that emergence should be understood as *contextual* relation between descriptions.

In the theory of contextual emergence this is expressed as the requirement to construct a so-called "context", which is dependent on insights external to the fundamental theory. This could be understood, e.g., as a form of pattern recognition by a cognitive agent (possibly within the setting of a measurement). In addition, an objectivizing criterion that renders the chosen context "stable" is necessary to distinguish cognitive artefacts from real insights into the relation of descriptions, thereby transforming initial contingencies into regularities.

An example which is often discussed is the emergence of thermodynamics from the underlying theory of (quantum) statistical mechanics. The latter supplies us with necessary (but not sufficient) conditions, whereas a sufficient (but not necessary) condition has to be provided by appeal to phenomenological considerations of thermal equilibrium. Expressed more formally, the latter amounts to a transitivity relation that holds between macroscopic bodies, which could be described by a single parameter, i.e., by the bodies' temperature T, and is implemented in the so-called KMS-construction (Sewell 2002). (The corresponding equilibrium relation between thermal systems is sometimes known as the "zeroth law of thermodynamics."). Only then can the well-known relation between the mean kinetic energy of an ensemble of microscopic states and the macroscopic observable of temperature, $3/2kT = m/2\langle v^2\rangle$, be *understood* (rather than just heuristically posited) as a relation of identity between levels of description,[2] as opposed to many discussions of property reduction found in the philosophy of science.

Importantly, this whole scheme neither denies the lawful character of the regularities found in thermodynamics, nor does it propose that thermodynamics is in any way independent from the underlying physics. Still, it is proposed that the *relation* between the description of material systems in terms of thermodynamics, on the one hand, and statistical mechanics, on the other, is *contextual.*

In the account outlined above, emergence is about the relationship between *descriptions* of systems, however, it knows of ontic and epistemic states of systems. Put simply, ontic states refer to an individual description which we take to be about (the properties of) the described entity itself, whereas epistemic states refer to our knowledge expressed in terms of statistical descriptions of such entities. Note that both ontic and epistemic states are types of descriptions and as such subject to epistemology, i.e. the ontic descriptions need not mirror or imply any (supposed) ontology. It is essential to emphasize, however, that whatever counts as ontic description is relative to some "ontological commitment:" Whereas for the classical physicist an ontic state amounts to the description of an entity in terms of its position and momentum, the chemist might think of substances as being the ontological primitives, and the engineer might take levers and cogwheels to be the things which inhabit the world. Different senses of "matter" are never given a-contextually but already presuppose some ontological commitment which is usually expressed in terms of intuitions, convictions or outside knowledge.

How should this be regarded with respect to the emergence of mind and consciousness? At first sight, contextual emergence seems to be able to circumvent a dilemma: if emergence is taken in a strong ("ontological") sense, this will (by definition) "bridge" any

[2] Of course, a relation like the above can be introduced for all different kinds of ensembles, and it is quite common to define such a "temperature" in diverse contexts (e.g., in NMR-spectroscopy a negative "spin-temperature" is sometimes defined for inversely populated levels of quantum states). However, the macroscopic property expressed by the 0th law of thermodynamics need not necessarily follow from this.

metaphysical gap between mental and material states. However, this will also render it hardly intelligible to contemporary naturalists, since the familiar cases of emergence in the sciences have nothing to say about metaphysics but only about types of descriptions. If emergence is taken in a weak ("epistemological") sense, this makes it compatible with the examples of emergent behavior discussed in the section "Explanatory challenges", but then it seems that emergence is too weak to actually bridge an ontological gap like the one which is presupposed to exist between mind and matter.

Why is a contextual approach to emergence promising in this situation? Precisely because it makes intelligible how epistemology bears on our ontological assessments: whatever we identify as the object in need of explanation is never simply given, but is already the product of a process which includes selection of theories, models or methods. Epistemology, the way we acquire knowledge of things, is always intertwined with ontology, the way things (supposedly) are.

Still, there is a particular difficulty that is encountered when the *explanandum* is chosen to be consciousness itself: if the above process is found to be relative to a conscious mental entity which selects or pre-defines a context, then does this mean that consciousness is relative to a process which involves the presence of consciousness? It might seem tempting for some physicalists to render consciousness as (epistemologically) relative. However, any such move commits them to presupposing the existence of mental entities. This difficulty is not unique to the theory of contextual emergence, but seems to trouble all explicitly epistemological readings of emergence (Seager 2012, p. 184f).

Hence, appealing to emergence, even in its most sophisticated versions, does not provide us with a tool to naturalize consciousness in the sense of identifying it as an object or property of an object "out there." If we do wish to take consciousness seriously, then we will need to reconsider some of our basic assumptions.

The metaphysics of objects

The previous discussion of ontological relativity and ways to connect different modes of description of phenomena leads to a much more general question: To what does the notion of "phenomenon" refer and how does this relate to the objects of the sciences? Or more concretely, with respect to the philosophy of chemistry: how do phenomena (in a very general sense) relate to what chemists call "substances" (in a very concrete sense)?

To answer these questions, we wish to sketch a *relationalist view* of objects. This would be justified if there were, instead or in addition to "objects out there", any relations which could not be expressed or reduced to functions of (parts of) given objects.[3] According to the relationalist view, any such object should be understood as a fixed point in a relational network (see Fig. 1): "To be is to be a node in a network of processes."

One particular interpretation which acknowledges the existence of relational properties does not only distinguish micro- from macro-descriptions or lower from higher levels of analysis but also "extra-representational real" from (representational) "real patterns" (Ladyman and Ross 2007, p. 298), the first of which usually correspond to the microscopic

[3] In philosophical parlance, the reduction of relations to intrinsic properties of things is dependent on the supervenience of relations on intrinsic properties. If supervenience wouldn't hold, then one could have changes in relational structure without accompanying changes in "intrinsic nature", and this leaves open the possibility of having two intrinsically identical bodies which differ relationally. The issue of relationalism and supervenience would need more discussion, which, however, lies outside of the scope of this article.

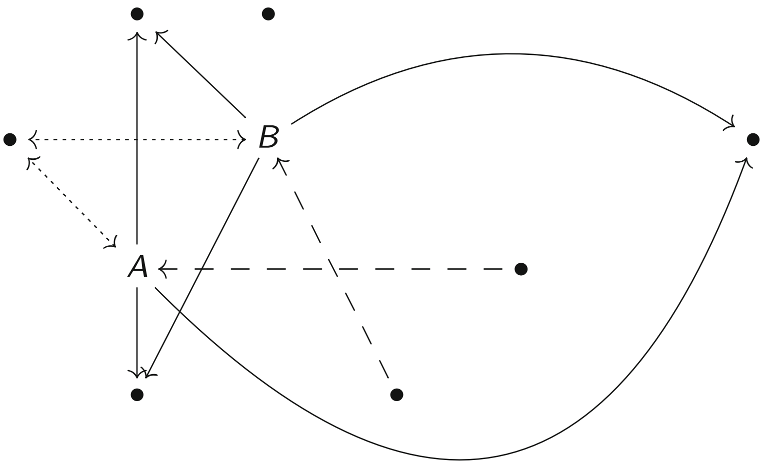

Fig. 1 A relational view of objects. Any object is determined by its (stable) position in a relational network

(quantum) structures and the latter to meso- and macroscopic objects dealt with in the various "special sciences" (Fodor 1974), for example, in psychology or chemical engineering.

True, so the proposal goes, the ultimate structure of reality is relational, but this applies primarily to what we conceive of as the objects of fundamental physics (or of whatever else one conceives as the most basic science). Observers, understood as macroscopic (biological or artificial) systems, are not subject to fundamental physical analysis. It is therefore appropriate to distinguish between fundamental physical objects (= relations) and special science objects (= things) such as chemical substances, organisms and perhaps minds. In other words, we should adopt relationalism, but restrict it to a limited domain.

Upon what do we base this? One important argument is the finding that meso- and macroscopic bodies are good candidates for individuals in the following (deflationary) sense: Individuals are distinct objects taking up well-defined regions in spacetime that behave (more or less) classically. Another one is the commitment to scientific realism, i.e., the belief that scientific theories ultimately map onto a mind-independent reality.

Following this realist proposal, we should conceive of a basic level of reality which is populated by objects which do not resemble individual things but rather instead *modal structures* (relations) which are nevertheless thought of as real, existing "out there", in contrast to equally real but less fundamental *patterns* of such entities which form the objects of the special sciences. Minds too, broadly speaking, are nothing more than real patterns with special capacities, namely the ability to detect (or "track") what is there, instead of playing an irreducible role in co-creating it.

The belief that mind and consciousness are just the objective patterns which are investigated by the special sciences of psychology and neurobiology might suggest such a realist reading. However, as we have seen in the sections which pertained to emergence and mereology, neither mereology nor emergence supply us with standpoint-free perspectives on a supposedly given world which includes mind as one of its patterns.

An alternative interpretation of the importance of relations for ontology might be called a "processual relationalist" stance. It dispenses with the mind-independent/dependent and the fundamental/special science distinction altogether.

Where does it place consciousness and cognition? Interestingly, issues that were discussed in the philosophy of chemistry might be of importance here: By arguing that the ontology of substances (the objects of chemistry) is dependent on the relations we experience—that is, the way they enter into the "manifest image" (van Brakel 2000, Chap. 3)—and at the same time arguing that realism about them is enforced not by the success of our theories but by the activities of substance transformation (Hoffmann 2007), philosophers of chemistry shift the discussion towards practical and instrumental considerations which are thoroughly relational; one could hold on to relationalism and still acknowledge the grounding role of our experience. Realism: yes—about relations, not about things; about processes, not about (modal) structure. On this view the idea that the mind is "just" an objective pattern, identical to the regularities of brain activity, seems foreign.

Finally, an appeal to contemporary quantum physics alone is not sufficient to decide between a realist and a relationalist view, since quantum mechanics is open to diverse philosophical positions ranging from "ontic structural realism" (Esfeld and Lam 2010) to non-interpretative Quantum-Bayesianism (Fuchs and Peres 2000; Fuchs and Schack 2013) which do or do not include an irreducible role of mental agents (observers). Some speculative proposals even conjecture that spacetime, the "background" for the objects of quantum physics and chemistry, is itself emergent (e.g., Hamma et al. 2010) and thus fundamentally relational. It is then a challenge for the future to accommodate quantum mechanics and other physical theories within such a relationalist framework. This surely is difficult, however, it is not impossible as some might be prone to argue.

Conclusions

Whether mind and consciousness can be studied in an empirical fashion is a central question which occupies many contemporary philosophers. At the same time, there are approaches which already attempt to relate mind and matter in a non-metaphysical, scientific way. These, however, are severely challenged—both methodologically as well as conceptually –, and issues in the philosophy of chemistry could be used to illustrate some of these challenges.

We suggested, for example, to reply to the questions of emergence and the status of scientific objects with a highly contextualist and relationalist answer. Whatever counts as "object" is relative to the context and to the relations in which it appears. One consequence of this is the rejection of the idea that philosophy of mind is best understood as philosophy *of* something: Such a view, according to a broadly Kantian epistemology, would first need to posit a conceptual scheme which enables us to identify (and experience) any particular object or property. But where to start? When we believe in a detached mind which engages conceptually with the world, the connection of epistemological emergence with a materialist metaphysics might seem promising. However, such a view quickly turns into a question-begging account of mind once we think mind is yet another property "out there" that is ready to be explained (away).

The alternative is to suggest a productive principle behind the seemingly static objects which belong to any single conceptual scheme. Productivity, on this view, should not be regarded as the result of (or as "emergent from") some complex configuration of otherwise "inert" entities, but rather as a condition for their very existence. Or, as Joseph Earley put it recently: "Higher-level coherences result from closure of relationships among *dynamic* components." (Earley 2016, p. 223).

A philosophical reflection of chemistry—and perhaps its pre-modern predecessor alchemy too—seems to suggest such an image. This is at the same time attractive and dangerous. It is attractive because it promises a more integrated worldview, a dissolution of the mind–body problem and, finally, a reconciliation of the manifest and scientific image of man. It is dangerous because a reification of “nature” or “productivity” is tempting which would, however, contradict any pluralist or non-substantialist commitment.

The conscious mind does not resemble a thing which exists out there in the world, waiting to be discovered like the Americas waited to be discovered by European sailors in the fifteenth century. Rather, to stay with the metaphor, consciousness is to be found in a particular moment[4] or mode of the act of discovery. That there is such activity might, at least for now, be accepted as brute fact, but that doesn’t prevent us from asking how this activity is shaped by culture, how it differentiates among species or even how it is correlated with physical effects which we could observe in our laboratories.

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References

Albert, S., Lerch, P., Prentner, R., Quack, M.: Tunneling and tunneling switching dynamics in phenol and its isotopomers from high-resolution FTIR spectroscopy with synchrotron radiation. Angew. Chem. Int. Ed. **52**(1), 346–349 (2013)

Anderson, P.: More is different. Science **177**(4047), 393–396 (1972)

Atmanspacher, H.: Twentieth century varieties of dual-aspect thinking. Mind Matter **12**(2), 245–281 (2014)

Atmanspacher, H., Bishop, R.: Stability conditions in contextual emergence. Chaos Complex. Lett. **2**(2/3), 139–150 (2007)

Ayala, F.: Teleological explanations in evolutionary biology. Philos. Sci. **37**(1), 1–15 (1970)

Banchetti-Robino, M., Llored, J.-P.: Reality without reification. In: Scerri, E., Fisher, G. (eds.) Essays in the Philosophy of Chemistry, pp. 83–110. Oxford University Press, Oxford (2016)

Bishop, R., Atmanspacher, H.: Contextual emergence in the description of properties. Found. Phys. **36**(12), 1753–1777 (2006)

Bitbol, M.: Science as if situation mattered. Phenomenol. Cognit. Sci. **1**, 181–224 (2002)

Block, N.: Comparing the major theories of consciousness. In: Gazzaniga, M. (ed.) The Cognitive Neurosciences IV, pp. 1111–1122. MIT Press, Cambridge (2009)

Brentano, F.: Psychology from an Empirical Standpoint. Routledge, London (1973)

Calosi, C., Tarozzi, G.: Parthood and composition in quantum mechanics. In: Calosi, C., Graziani, P. (eds.) Mereology and the Sciences, pp. 52–84. Springer, Cham (2014)

Chalmers, D.: Facing up to the problem of consciousness. J. Conscious. Stud. **2**(3), 200–219 (1995)

Churchland, P.S.: Neurophilosophy. Toward a Unified Science of the Mind-Brain. MIT Press, Cambridge (1986)

Davidson, D.: Mental events. In: Foster, L., Swanson, J.W. (eds.) Experience and Theory, pp. 79–101. Humanities Press, New York (1970)

Earley, J.: How philosophy of mind needs philosophy of chemistry. Hyle **14**(1), 1–26 (2008)

Earley, J.: How properties hang together in substances. In: Scerri, E., Fisher, G. (eds.) Essays in the Philosophy of Chemistry, pp. 169–234. Oxford University Press, Oxford (2016)

Esfeld, M.: Holism Philosophy of Mind and Philosophy of Physics. Springer, Dordrecht (2001)

Esfeld, M., Lam, V.: Ontic structural realism as a metaphysics of objects. In: Bokulich, A., Bokulich, P. (eds.) Scientific Structuralism, pp. 143–159. Spinger, Dordrecht (2010)

[4] In a broadly Husserlian sense (2001, Chap. 3.1).

Fach, W.: Complementary aspects of mind-matter correlations in exceptional human experiences. In: Atmanspacher, H., Fuchs, C. (eds.) The Pauli–Jung Conjecture and Its Impact Today, pp. 255–274. Imprint Academic, Exeter (2014)
Fodor, J.: The special sciences (or: the disunity of science as a working hypothesis). Synthese **28**, 97–115 (1974)
Friston, K.: The free-energy principle: a unified brain theory? Nat. Rev. Neurosci. **11**(2), 127–138 (2010)
Fuchs, C., Peres, A.: Quantum theory needs no interpretation. Phys. Today **53**(3), 70–71 (2000)
Fuchs, C., Schack, R.: Quantum-Bayesian coherence. Rev. Mod. Phys. **85**(4), 1693–1715 (2013)
Haken, H.: Synergetics, an Introduction: Nonequilibrium Phase Transitions and Self-Organization in Physics, Chemistry, and Biology, 3 enl edn. Springer, New York (1983)
Hamma, A., Markopoulou, F., Lloyd, S., Caravelli, F., Severini, S., Markstrom, K.: A quantum Bose–Hubbard model with evolving graph as toy model for emergent spacetime. Phys. Rev. D **81**, 104032 (2010)
Harré, R., Llored, J.-P.: Mereology as the grammars of chemical discourses. Found. Chem. **13**(1), 63–76 (2011)
Harré, R., Llored, J.-P.: Molecules and mereology. Found. Chem. **15**, 127–144 (2013)
Hoffman, D., Prakash, C.: Objects of consciousness. Front. Psychol. **5**, 577 (2014). doi:10.3389/fpsyg.2014.00577
Hoffman, D., Prakash, C., Singh, M.: The interface theory of perceptions. Psychon. Bull. Rev. **22**, 1480–1506 (2015)
Hoffmann, R.: What would philosophy of science look like if chemists built it? Synthese **155**(3), 321–326 (2007)
Husserl, E.: Logical Investigations, vol. 2. Routledge, London (2001)
Jaeger, G.: Quantum Information: An Overview. Springer, New York (2007)
Kauffman, S.: The Origins of Order: Self-Organization and Selection in Evolution. Oxford University Press, Oxford (1993)
Kim, J.: Making sense of emergence. Philos. Stud. **95**(1), 3–36 (1999)
Ladyman, J., Ross, D.: Every Thing Must Go. Oxford University Press, Oxford (2007)
Laughlin, R., Pines, D.: The theory of everything. PNAS **97**(1), 28–31 (2000)
Lesniewski, S.: Foundations of the general theory of sets. I. In: Surma, S.J., et al. (eds.) Collected Works, pp. 129–173. Kluwer, Dordrecht (1992)
Llored, J.-P.: Whole-parts strategies in quantum chemistry: some philosophical and mereological lessons. Hyle **20**(1), 141–163 (2014)
Lombardi, O., Labarca, M.: The ontological autonomy of the chemical world. Found. Chem. **7**, 125–148 (2005)
Luisi, P.L.: Emergence in chemistry: chemistry as the embodiment of emergence. Found. Chem. **4**, 183–200 (2002)
Manafu, A.: A novel approach to emergence in chemistry. In: Scerri, E., McIntyre, L. (eds.) Philosophy of Chemistry, pp. 39–55. Springer, Dordrecht (2015)
Metzinger, T. (ed.): Neural Correlates of Consciousness: Empirical and Conceptual Research. MIT Press, Cambridge (2000)
Noë, A.: Action in Perception. MIT Press, Cambridge (2004)
Papineau, D.: Philosophical Naturalism. Blackwell, Oxford (1993)
Petitot, J., Varela, F., Pachoud, B., Roy, J.-M. (eds.): Naturalizing Phenomenology: Issues in Contemporary Phenomenology and Cognitive Science. Stanford University Press, Stanford (1999)
Prentner, R.: A framework for critical materialists. Mind Matter **12**(1), 93–118 (2014)
Price, D., Barrell, J.: Inner Experience and Neuroscience: Merging Both Perspectives. MIT Press, Cambridge (2012)
Primas, H.: Chemistry, Quantum Mechanics and Reductionism. Springer, Berlin (1983)
Primas, H.: Emergence in exact natural sciences. Acta Polytech. Scand. Ma **91**, 83–98 (1998)
Primas, H.: Complementarity of mind and matter. In: Atmanspacher, H., Primas, H. (eds.) Recasting Reality. Wolfgang Pauli's Philosophical Ideas and Contemporary Science, pp. 171–210. Springer, Berlin (2009)
Restrepo, G., Harré, R.: Mereology of quantitative structure-activity relationships models. Hyle **21**(1), 19–38 (2015)
Scerri, E.: The ambiguity of reduction. Hyle **13**, 67–81 (2007)
Seager, W.: Natural Fabrications: Science, Emergence and Consciousness. Springer, Dordrecht (2012)
Sewell, G.: Quantum Mechanics and Its Emergent Macrophysics, pp. 108–126. Princeton University Press, Princeton (2002)
Sieroka, N.: Leibniz, Husserl, and the Brain. Palgrave Macmillan, Basingstoke (2015)

Silberstein, M.: Experience unbound. Neutral monism, contextual emergence and extended cognitive science. Mind Matter **12**(2), 289–318 (2014)

Silberstein, M., Chemero, A.: Complexity and extended phenomenological-cognitive systems. Top. Cognit. Sci. **4**, 35–50 (2012)

Simons, P.: Parts. A Study in Ontology. Clarendon Press, Oxford (1987)

Smith, B., Mulligan, K.: Framework for formal ontology. Topoi **2**, 73–85 (1983)

Tarski, A.: Logic, Semantics, Metamathematics, pp. 24–29. Clarendon Press, Oxford (1956)

Thompson, E.: Mind in life: Biology, Phenomenology, and the Sciences of Mind. Harvard University Press, Cambridge, MA (2007)

Thompson, E., Varela, F.: Radical embodiment: neural dynamics and consciousness. Trends Cognit. Sci. **5**(10), 418–425 (2001)

van Brakel, J.: Philosophy of chemistry: between the manifest and the scientific image. Leuven University Press, Leuven (2000)

Varela, F., Maturana, H., Uribe, R.: Autopoiesis: the organization of living systems, its characterization and a model. BioSystems **5**(4), 187–196 (1974)

Wooley, R., Sutcliffe, B.: Molecular structure and the Born–Oppenheimer approximation. Chem. Phys. Lett. **45**(2), 393–398 (1977)