Chapter 6
Pragmatism and the Philosophy of Chemistry

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6.1 Introduction

"How is it possible in a universe consisting entirely of physical particles in fields of force that there can be such things as consciousness, intentionality, free will, language, society, ethics, aesthetics, and political obligations?" John R. Searle suggests that this is the single overriding question in contemporary philosophy—but also notes that "many, perhaps most, contemporary philosophers do not address it directly" (Searle 2010, 3). Joseph Margolis (2012, 129 ff.) agrees with Searle's assessment of the importance of that question—but he rejects the response to it that Searle proposes. Instead, Margolis claims that the philosophical approach called "Pragmatism" is well on its way to resolving the problem that Searle identifies.

Charles S. Peirce (1839–1914) (the family name is pronounced '*purse*') is generally regarded as the founder of philosophical Pragmatism. Arguably, this characteristically American approach is the only non-religious philosophical school that originated outside Europe—but it may now be cultivated elsewhere more than it is in the United States. Peirce did his graduate studies in chemistry, and he identified himself as a chemist throughout his career. Peirce worked for many years in The United States Coast Survey, mainly carrying out precise geophysical measurements: his voluminous philosophical publications deal more with logic and semiotic[1] (the theory of signs) than with chemistry. It is now clear that the

[1] Peirce considered 'semiotic' to be a discipline parallel to 'logic.' He continued to develop and modify his theory of signs throughout his life, several times rejecting his earlier efforts because of difficulties he had identified. However, Jacques Derrida and others have continued to apply Peirce's early theories of signs under the designation 'semiotics' (Short 2007, 45). Peirce's theory of signs (semiotic) is discussed later in this paper.

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nineteenth-century investigations by which chemists solved the problems of stereochemistry were pragmatic[2] rather than theoretical (Ramberg 2001). Clevis Headley (2013) convincingly argued that features that distinguish philosophical Pragmatism from other approaches derive directly from Peirce's deep experience in chemical-laboratory practice.

Peirce is now recognized as one of the most original and significant thinkers that America has produced (Moore and Robin 1994, ix). Philosopher and educational leader John Dewey (1860–1952) was a prominent exponent of philosophical Pragmatism during the 1920s and 1930s, but that mode of thought became less fashionable during the ascendancy of analytical philosophy in the 1950s and 1960s. Richard Rorty (1931–2007) and Hilary Putnam (b. 1926) sparked a revival of interest in Pragmatism in the last quarter of the twentieth century. This chapter aims to show that Pragmatism is relevant to current problems in philosophy of chemistry. After introducing some main themes of Pragmatism and aspects of current philosophy of chemistry we will return to Searle's question.

6.2 Philosophy as Un-modern

Peirce did not produce a comprehensive summary of his thought, but in the early 1940s John Dewey drafted a book that reviewed some main points of Pragmatism. Unfortunately, Dewey misplaced his nearly-completed manuscript. That work was recently found, edited, and published (Dewey 2012). In it, Dewey vigorously criticized other types of mid-twentieth-century philosophy claiming that obsolete concepts, distinctions, and problems remain imbedded in contemporary thought—even though results and practices both of science and of philosophy clearly require otherwise. Following Peirce, Dewey stressed the important fact that, necessarily, human activities are *socially* located—therefore all philosophical doctrines are influenced by the cultures in which they originate. Dewey called much of mid-twentieth-century philosophy "*un-modern*" since it had failed to recognize that basic concepts of the Western philosophical tradition had been formulated under assumptions that we now know to have been wrong. When established cultural patterns are challenged by technological change or external influence, new philosophical approaches may emerge—as they did in Classical Greece, Medieval France, and Renaissance Europe. However, even such major conceptual innovations are generally framed, considered, and discussed in terms of categories originally developed for other purposes. Such conservatism often leads to misunderstanding—and to distortions which are difficult to identify and to remedy.

The dichotomies that abound in philosophy—subject/object, individual/property, contemplation/action, mind/body, essential/accidental, fixed/changeable, theory/practice—generally identify mere sections of some continuous variation—parts

[2] This word (un-capitalized) refers to a practical attitude rather than to Peirce's philosophical approach (capitalized here).

selected under the influence of a local culture. Societies in which a small and leisured elite dominated the majority—such as slave-based ancient societies and patronage-driven early-modern ones—accorded higher dignity to theory over practice. Dualities of this sort tend to persist long after the disappearance of factors that had brought about their adoption. Failure to revise simplifying assumptions is a related problem. Results obtained *synchronously*—at a single instant, as in a photograph—are generally quite different from results that would have been obtained by *diachronic* investigation—considering time-variation.

The quest for *true and certain* knowledge ('the epistemology problem') has been a usual feature of ancient, medieval, and modern conceptual systems (Dewey 2012, 130 ff). Both René Descartes and John Locke sought to ground their systems on bedrock. Immanuel Kant's *transcendental a priori* aimed to provide a firm basis for timeless truth. George Hegel substituted diachronic notions for synchronic ones, but retained 'the absolute.' Following Peirce, pragmatists deny that any conceivable description of the world could possibly be complete and accurate enough to be adequate for *any and all* purposes. There is no '*God's-Eye View*.' On that basis, pragmatists reject Kant's notion of 'the-thing-in-itself' and the related notions of ontological and epistemological descriptions (how things are versus how things appear to be). Certainly, accounts could consider underlying mechanisms or not, and could be more or less adequate with respect to a specific goal of inquiry—but there is no *fully-adequate* ('ontological') description.

6.3 Inquiry as Evolutionary Adaptation

Human knowledge is connected with effective action. Some understandings foster successful action, others lead to failure. *The Pragmatic Maxim* connects many aspects of Pragmatism.

> Consider what effects, that might conceivably have practical bearings, we conceive the object of our conception to have. Then our conception of these effects is the whole of our conception of the object (CP 5.402).[3]

Pragmatists point out that we learn about the world we inhabit—and also about our own capabilities and limitations—by interacting with and exploiting our surroundings, including members of our own species. Other animals sometimes modify 'found' objects to increase their usefulness: humans have developed such abilities to high levels (e.g., pharmaceutical chemistry, nano-electronics, behavioral conditioning). We flourish through cooperation—and also through competition. *Language* fosters cooperative action by persuasion, blandishment, or threat—and thereby facilitates success in inter-group competition. Successful actions and strategies become habitual. Each human grouping has a complex *culture* made up of shared habits—including language, tool-use, and communal ritual.

[3] This reference is to paragraph 402 in volume 5 of *The Collected Papers of Charles Sanders Pierce*. Cambridge, MA: Harvard University Press (1931–1935, 1958), also published electronically.

All biological organisms have adaptations that enable them to search for, and perhaps to acquire, what they need to live, reproduce, and prosper. Primates communicated using vocal signals for long eons before the emergence of *Homo sapiens* about 200,000 years ago (McBrearty and Brooks 2000). The anatomies of the larynxes of fossil hominids (Lieberman et al. 2002) demonstrate that as early as 700,000 years ago strong selection-pressure favored those individuals or groups that were adept at the use of proto-language (McBrearty 2007, 142). Significant *mutual* influence of genetic and cultural factors has been characteristic of the evolution of the ancestors of *Homo sapiens* (Richerson et al. 2010). Explicit knowledge depends on speech—and language is essentially social. Voiceless language-use enables *imagination* of situations that never occurred. When we imagine better ways to act, or when formerly-successful habits no longer work, we sometimes resort to *inquiry*—detailed investigation of specific issues. In favorable cases, inquiry may realize imagined improvements or resolve perceived difficulties, but every such achievement destabilizes other aspects of culture. Human behavior-patterns must continually adjust to cultural change. (The Red Queen[4] rules.)

Transmission of habits between generations and within and among communities depends on narrative, and is never error-free. Results of any inquiry can be extended and modified by findings of subsequent related inquiries. Outcomes of inquiry are never complete or certain. We do not know the entire and indubitable truth about any topic: all human knowledge is, at best, correct as far as it goes, or adequate for this or that purpose (da Costa and French 2003).

Peirce considered that: "The real is that which is not whatever we happen to think it, but is unaffected by whatever we may think of it" (CP 5.430). He held that the results of inquiry tend to converge on progressively better approximations of the real, but final convergence would require indefinitely wide and long inquiry. We may expect that well-established science has arrived at fairly-adequate notions of reality—but this cannot be guaranteed.

We deal with problems by actions—described by verbs (we *attack*). Adverbs specify aspects of actions (they react *rapidly*): adjectives describe qualities of objects (their runners are *fast*). Eventually, we *reify*—postulate objects from aspects of action (their *swiftness* did us in). Dewey (2012, 203 ff.) advised philosophers to be wary of pitfalls connected with progression from verb to adverb to adjective to noun. Descartes illustrated the error Dewey warns against when he postulated a *res cogitans*—a substantial *mind*—to account for successful human action. The fact that we can "Mind the Gap" does not mean that such an entity as 'mind' actually exists.

Inquiry gave rise to philosophy and eventually resulted in science. On this basis, language, intentionality, and human inquiry are all analogous to the elaborate behavioral adaptations that other organisms use to survive, reproduce, and flourish. Philosophy and science should be regarded as closely-related and highly-evolved human cultural adaptations.

[4] 'A slow sort of country!' said the Queen. 'Now, HERE, you see, it takes all the running YOU can do, to keep in the same place. If you want to get somewhere else, you must run at least twice as fast as that!' (Carroll 1872, Chapter 2).

6.4 Peirce's Logic of Relations

Athletes in team-sports often refer to '*good chemistry*'—a cooperative spirit that contributes to winning tight games. Chemical properties involve *relations* among substances. Both as a science and as a practical art, chemistry characteristically deals with relationships—arguably, focus on relationships is a *defining* feature of chemistry. As a student of chemistry, and also as the son of one of America's leading mathematicians (Harvard Professor Benjamin Peirce), Charles Peirce had a lively interest in the *logic of relations*: his pioneering work in this field made the development of modern symbolic logic possible.

Each relation involves a number (n) of relata—it has an '*adicity*.' Monadic (n = 1) relations are 'properties' (or 'qualities' or 'attributes'). Ordinary relations are diadic (n = 2) or triadic (n = 3). Relations with four or more relata are properly considered as combinations of relations of lower adicity.[5] Peirce in 1885 and Gottlieb Frege in 1879 independently introduced two innovations (quantification and use of variables) that distinguish modern logic from its Aristotelian ancestor: $\exists\, x = for\ some\ x; \forall\, y = for\ all\ y$ (and $Rxy = x\ bears\ relation\ R\ to\ y$). Peirce's innovations were recognized by leading logicians before 1890, but Frege's work was overlooked until Bertrand Russell called attention to it in 1910.

Some relations are symmetric so that $Rxy = Ryx$. But, if John loves Mary, Mary may or may not love John. Relation Rxy sometimes is reducible (so that $Rxy = Px + Qy$) but diadic relationships are not generally reducible to (decomposable into) combinations of monadic properties ($Rxy \neq Px + Qy$). The same is true for triadic relationships. Peirce cited an analogy between chemical valence and the logic of relatives: "A chemical atom is quite like a relative in having a definite number of loose ends or 'unsaturated bonds,' corresponding to the blanks of the relative" (CP: 3.469). He developed a Method of graphically representing logical relationships including the logic of relatives. This 'Method of Existential Graphs' was not well-received by contemporary logicians but later had important applications in digital computation.[6]

[5] Peirce wrote as if he had a rigorous proof of this, but never published such a proof. Presently-known proofs are not straight-forward.

[6] Peirce developed an approach to experience that explicitly avoided mechanistic explanation: he called this 'Phaneroscopy.' This method was analogous to Phenomenology, developed independently by Edmund Husserl at roughly the same time. Peirce distinguished three modes of being—the three Phaneroscopic Categories. "Firstness is the mode of being of that which is such as it is, positively and without reference to anything else. Secondness is the mode of being of that which is such as it is, with respect to a second [item] but regardless of any third [item]. Thirdness is the mode of being of that which is such as it is in bringing a second [item] and a third [item] in relation to one another" (CP 8.328). A certain color, say fire-engine-red, would be a First. Firsts are potentials—many things might or might not be red. Any bipolar interaction, say some percipient detecting red, illustrates secondness. Struggle and resistance are usual features of Seconds. Seconds correspond to actuality—entities are Seconds. A percipient interpreting red as a stop-signal would constitute a Third. Thirdness corresponds to generality—laws, purposes, and intentions are Thirds (Short 2007, 60–90).

6.5 Determinants of Irreversible (*Finious*) Change

Aristotle counted any adequate response to a why-question as a cause (*aitiā*) (*Physics* 194b, 18–20)—but he also made a clear distinction between *efficient* causes (change-initiating agents) and *formal* causes (arrangements necessary for events to occur). Robert Pasnau (2004) carefully described how, during the rapid development and subsequent slow decline of medieval Scholastic Philosophy, the understanding of the Aristotelian concept of *substantial form* gradually changed away from its original (purely formal) Aristotelian meaning and increasingly acquired overtones of efficient agency. He concluded that further modifications in the usual philosophical understanding of cause that subsequently occurred should be interpreted as continuations of that earlier trend. With the success of Newtonian physics interactions similar to events on billiard tables (where precisely-determined impacts yield exactly-predictable results) came to be considered prime exemplars of causal processes. *Efficient* causality took over the designation of cause. Most philosophers relegated any other factors that might be involved in answers to why questions to subordinate status or to oblivion. Alicia Juarrero (1999) persuasively argued that the restricted notion of causality that was adopted with the rise of modern science is an impoverished one—quite inadequate for analysis of complex questions of properly philosophic interest, such as those that concern human action. Billiard-ball causality, she observes, is not much use in "telling the difference between a wink and a blink."

Mario Bunge, like other philosophers, does "restrict the meaning of the term cause to *efficient cause*, or extrinsic motive agent, or external influence producing change" (Bunge 1959, 33) however he also recognizes that causation "is only one among several types of determination; there are other types of lawful production, other levels of interconnection" (30). He distinguishes between *causes* (effective agents—the *how* of things) and *reasons* (rational explanations—the *why* of things) pointing out that these two notions are often confounded. Bunge notes: "The identity of explanation with the disclosing of causes is even rooted in the Greek language, in which *aition* and *logos* are almost interchangeable since both mean cause and reason. The confusion of cause with reason, and that of effect with consequent, are, moreover, common in our everyday speech" (Bunge 1959, 226–227), but more recently, Bunge observed: "From the point of view of cognitive neuroscience, reasons for acting are efficient causes" (Bunge 2010, 224).

In many (perhaps most) biological examples, causes and reasons cannot be distinguished easily, if at all. "When a trait evolves through intersexual selection, the source of selection is itself an evolving character. The peacock's tail evolves through the mating-preferences in peahens and those preferences coevolve with the male trait" (Laland et al. 2011, 1512). Whenever *reciprocal determination* makes it impossible cleanly to distinguish causes from reasons, restricting causality to *efficient* causes (as philosophers recommend) is not appropriate.

6.6 Determination in Finious Processes

Thomas L. Short (2007, 105–107) observed that the narrowness of the contemporary philosophic understanding of causation (a baleful influence, he says, of David Hume's ghost) has had unfortunate effects—but he also called attention to an alternative understanding of causality that Peirce developed.[7]

The kinds of interaction that classical mechanics deals with have time-reversal symmetry (viewers have no way of deciding whether a video of billiard-ball collisions is running forward or backward). But natural processes often *proceed in one direction only*. Spark-induced explosion of a mixture of H_2 and O_2 loudly and rapidly produces H_2O vapor: the reverse reaction is unobservable. Peirce calls such unidirectional processes *finious*; Short suggests the designation *anisotropic*; chemists call such changes *irreversible*. Pierce held that in irreversible processes an alternate kind of causal process is of central importance—"that mode of bringing facts about according to which a general description of result is made to come about, quite irrespective of any compulsion for it to come about in this or that particular way; although the means may be adapted to the end" (CP 1.211). This corresponds to understanding a cause as reason rather than as agent. Peirce considered that Darwin's account of the origin of biological species exemplifies this alternative mode of result-determination.

Natural selection gradually (and irreversibly) eliminates whichever characteristics of organisms are not suited to the conditions that prevail. Such reduction (culling) of possibilities eventually produces one particular determinate result—which one of the many possible outcomes is actually produced depends on contingencies of culling rather than only (or mainly) on actions of underlying agents.

> . . . there remains little doubt that the Darwinian theory indicates a real cause, which tends to adapt animal and vegetable forms to their environment. A very remarkable feature of it is that it shows how merely fortuitous variations of individuals together with merely fortuitous mishaps to them would, under the action of heredity, result, not in mere irregularity, nor even in a statistical constancy, but in continual and indefinite progress toward a better adaptation of means to ends (CP 7.395).

> Natural selection works in such a way as to produce adaptation of life-forms to their circumstances: this general aim does not determine in what particular way it is to be brought about, but only that the result shall have a certain general character. The general result may be brought about at one time in one way, and at another time in another way (CP 1.211).

Peirce considers that each effective selection-criterion is a *general* rather than a *particular* (a universal rather than a substance). Each such criterion might be

[7] See also Reynolds 2002.

called a *controlling general*—an outcome-determining universal. By this means 'structures'—closures of relationships that have the property of engendering future versions of the same closures—would have result-shaping effects, although they would not be agents. Peirce's interpretation of Darwin's theory featured grounding causality by universals. According to this view, natural selection operates to amplify those features of a system that correspond to stability, under the conditions that prevail. Since organisms that pass the selection test may have many differences that are irrelevant to that test, the condition of persistence that this criterion involves is not a specific individual requirement but a rather more or less vague general condition—a universal.

In this way, a universal may have efficacy that is 'causal' in a broad sense. In other words, if a certain state-of-affairs results from *selection* on the basis of some criterion then that criterion (a universal) is a determinant (a cause in a general sense) of the state of affairs. To the extent that closure of a network of relationships of components is a prerequisite for the stability of entities, that closure is also a *necessary determinant* of that states of affairs[8] that it engenders. In order for recognizing anisotropic or finious determination, some temporal process must restrict the range of possible future states open to a system, blocking some but not others. If such an *equivalent to selection* accounts for the existence of a structure, then that structure may properly be termed a determinant—a cause in a sense that is more general than philosophers recognize.[9]

Several detailed mechanisms may achieve similar or equivalent results. For each conceivable way of achieving a stable dynamic coherence which works well (under the conditions which prevail) many imaginable variant arrangements would also succeed—but a much larger number of possible variations would not work successfully. Systems complex enough to contain one accessible route to closure typically contain many such ways to achieve dynamic stability (Kauffman 1993, 1995). In addition, if a viable dynamic coherence does exist, it turns out that the same coherence may be reached by several diverse historical routes. Commonly observed biological convergence ('homoplasy')—genetically unrelated species have arrived at similar biological structures through vastly different evolutionary pathways[10]—suggests that long-term viability is rare among possibilities.

[8] Bishop's (2012) account of the philosophic significance of nonlinear dynamics is consistent with this interpretation.

[9] This summary avoids the designation '*final causality*' that Peirce used for this mode of influence—in order to forestall confusion of reason with purpose, and to discourage the erroneous notion that reasons must be purposes of conscious agents.

[10] For instance, the fossil record demonstrates apparently-identical saber-toothed species of both mammals and marsupials (Conway Morris 2003).

6.7 Peirce's Theory of Signs

Peirce published a theory of signs ('semiotic') as early as in 1868–1869 (W2, 193–272).[11] Peirce subsequently recognized serious problems with his early semiotic and made significant revisions in 1885 and again in 1903.[12] At his death in 1914, Peirce left a number of partially-completed manuscripts including further major revisions of the theory of signs. T. L. Short (2007) produced a version of Peirce's theory of signs based on unpublished drafts, especially those written in 1907.

According to Short's reconstruction of Peirce's mature system, a motorist stopping after noticing a red traffic signal would be described as *R interprets X as a sign of O*—where R (the Interpretant) is the action of stopping, X (the Sign) is a particular red, and O (the Object) is a prudential, customary, or legal obligation. Short's version of Peirce's mature semiotic recognizes that semeiosis occurs *in a context*, that context being one of *purposefulness* (Short 2007, 158). According to Short's version of the later Peirce, whenever some feeling, thought, or action (R) interprets a particular X as a *sign* of O (an object, broadly understood) that interpretation must be made in the context of a *purpose*, P. A purpose (or habit) of acting in prudent, customary, or legal ways must exist for stopping at a red light to make sense.

In 1909, Peirce wrote:

> A Sign is a Cognizable that, on the one hand, is determined (i.e., specialized, *bestimmt*) by something *other than itself*, called an Object . . ., while, on the other hand, it determines some actual or potential Mind, the determination whereof I term the Interpretant created by the Sign, that the Interpreting Mind is therein determined mediately by the Object (EP 2:492).[13]

Notice that, in this passage, the Object *determines* the Sign, which, in turn *determines* the Interpretant. These determinations cannot be made by efficient causality. Functioning of signs depends on a purposeful context: the several determinations referred to in this passage must function through the finious causal mode outlined above.

Short does not spell out the means by which the purposes effect the selection on which finious determination depends, but examples can be seen in several types of scientific investigation. In biological systems upper-level coherences (say, the 'lekking' mating-rituals of tropical bower-birds) establish constraints that

[11] 'W2' is Volume 2 of *The Writings of Charles Sanders Peirce, A Chronological Edition*. Peirce Edition Project, eds. Bloomington, Indiana University Press, 1982–2000. In the publication reproduced in W2, 193–272, Peirce vigorously attacked all types of modern philosophy that descend from the work of Descartes, and claimed that we have no valid way of deciding what qualifies as 'an intuition.'

[12] However, as mentioned earlier, Jacques Derrida and others have continued to apply Peirce's early theories of signs under the designation '*semiotics'* (Short 2007, 45).

[13] EP refers to *The Essential Peirce: Selected Philosophical Writings*. Peirce Edition Project, eds. Bloomington: Indiana University Press, 1992 and 1998.

discriminate among lower-level characteristics, fostering some and eliminating others. (Dull-colored or non-displaying male bower-birds have no descendants.) Well-trained drivers ignore lights of many shapes and colors, but actively respond to (interpret) bright red circles. The training and experience of the driver *determine* her response, but as a reason rather than as an agent.

6.8 Nominalism Rejected

One of the main themes of Peirce's work was an attack on '*nominalism'*—the erroneous doctrine of fourteenth-century Ockhamists (and present-day analytical philosophers) that only individuals 'really exist'—this is to be contrasted with the *'realist'* opinion that some composite entities are 'real.' Dewey describes a usual, but highly damaging, result of nominalism:

> Ability to regulate, to guide and direct, the ongoing course of life-experience, as well as furtherance or prevention of occurrence of this or that special event, depends on breaking down the actual total event into a number of lesser events. But the history of human beliefs shows that two connected errors have accompanied the performance of this necessary task. . . . [T]he events which are analyzed into more minute events have been assigned a secondary degree of reality, and the actions in virtue of which the lesser ones constitute the original gross event are lost from view, or what is even more harmful, are treated as themselves simple or elementary static entities. It is one of the functions of philosophy to recall us from the results of analyses, which are made for special purposes, to the larger, if coarser and in many respects cruder, events which alone have primary existence.[14] (Dewey 2012, 324)

Peirce maintained that "the nominalist error" has wide significance.

> . . . though the question of realism and nominalism has its roots in the technicalities of logic, its branches reach about our life. The question whether the genus *Homo* has any existence except as individuals, is the question whether there is anything of any more dignity, worth, and importance than individual happiness, individual aspirations, and individual life. Whether men really have anything in common, so that the community is to be considered as an end in itself, and if so, what the relative value of the two factors is, is the most fundamental practical question in regard to every institution the constitution of which we have it in our power to influence (CP 5.38).

Searle's question with which this paper began contains a subordinate clause—"in a universe consisting entirely of physical particles in fields of force." The word 'entirely' in this clause, if taken seriously, would wipe chemistry completely off the map of significance. Chemists have good reason to be wary of nominalism. For Searle, nominalism needs no supporting argument: facts inconsistent with that approach are invisible to him. However, if the world consists *entirely* of particles in fields then John R. Searle does not exist.

[14] At this point Dewey added the footnote: "It is one of the merits of C. S. Peirce that he appreciated so thoroughly this aspect of philosophy. . . ."

6.9 Philosophy of Chemistry

Even though Charles S. Peirce was both a chemist and a significant philosopher, only a few papers in philosophy of chemistry refer to his work. Charles Siebert (2001) pointed out that Peirce's juvenile adventures in a home chemistry laboratory profoundly influenced his future development. Jaap van Brakel (1994) considered Peirce's 'Tychism'—the doctrine that "absolute chance is a factor in the universe" (CP 6.201)—and concluded that Peirce's belief in chance was "limited" since he held that: "Everyone knows that chance has laws and statistical results follow therefrom" (CP 6.606). On this basis, Peirce's Tychism anticipated recent interest in the practical importance of highly-improbable events (Taleb 2010).[15] Also, van Brakel (1998) discussed Peirce's concept of *natural kinds,* and decided that "Pierce's views are consistent with a form of pluralism in which the difference between natural and non-natural classes disappears" (38–39) and that the "ultimate end of inquiry" must be "pluralistic" (41). He also included incidental references to Peirce in his book on philosophy of chemistry (van Brakel 2000).

Chemists switch easily and smoothly among several types of discourse. They are comfortable dealing with materials in microgram quantities and also, on occasion, with barge-loads: they deal conceptually with truly immense macro-molecules and also with submicroscopic diatomic molecules and their much smaller constituents—electrons and nuclei. Chemists determine which entities they will consider depending on the question they are investigating. There is no 'universe of discourse' set up in advance of chemical investigation. Chemists are quite content to postulate existence of some new entity (a complex, an intermediate, an eximer, an excited state, a hybrid orbital, ...) if doing so makes sense of data already in hand, *and also* suggests additional investigations which might confirm or put into question the existence of the postulated entity. There is no preset fundamental level of chemical discourse: the level of discourse is chosen to facilitate achievement of the purpose of the investigation. Such purposes include (but are by no means limited to): devising a new synthesis for a natural product, discovering a drug to foster (or impede) a biological process, determining the accuracy of a theoretical prediction, exploring the range of conditions under which a new process occurs. Chemists shift among levels so effortlessly and (generally) unconsciously that philosophers and other non-chemists may fail to appreciate the consequences of this cultural feature.

Lee McIntyre (2007) expressed the widespread opinion that chemical discourse mainly concerns 'epistemological' description of how things appear, and rarely if ever attains to the 'ontological' description that is (presumably) characteristic of more-fundamental sciences. This opinion seems to be characteristic of the

[15] Van Brakel also refers incidentally to Peirce in his volume on philosophy of chemistry (van Brakel 2000).

nominalism that Pierce repeatedly attacked. Some chemists (especially those exposed to philosophy) may formally endorse nominalistic views, but chemists generally guide their professional activities by understandings similar to those of Bishop and Atmanspacher (2006, 1755), who describe *contextual property emergence*—by which upper-level properties derive from the *context of constraints* on a system as well as from properties of less-extensive entities that constitute underlying levels. Upper-level constraints typically remove degeneracies that characterize lower-level situations and thus lead to *stable* states. Such constraints are designated *contextual determinants*.

Olimpia Lombardi and Martin Labarca (2005)[16] maintained that entities at several chemical levels should be taken with full seriousness. In so doing, they retained the ontological/epistemological distinction, used Kantian vocabulary, and, in passing, indicated that "Noumenal Reality" exerts influence (their Figure 1, p. 145). Although these authors expressly rejected the notion of 'The God's-Eye View' they did not draw the inference that all that exists for us to know is *how things behave* under this or that set of circumstances. Dewey might consider use of inherited vocabulary by these authors to exemplify philosophical "un-modernism." However, in this case, this conservatism does not appear to have influenced the authors' argument.

Meanings of important terms often change greatly across the centuries, but chemists and philosophers of chemistry tend to anachronistically use more-recent meanings for important words in interpretation of earlier authors who had quite different understanding of the connotation of the same terms. For instance, the Greek words *hyle*, *aitia*, and *ousia* are now generally translated into English as 'matter,' 'cause,' and 'substance,' respectively—but the contemporary meanings of each of those terms to English-speakers is quite different from the significance the original words had for ancient Greeks (and often also for authors in other historical periods). In particular, the designation "matter-theory" that historians of chymistry routinely use (e.g. Garber 2007) to describe a fundamental outlook on nature seems unfortunate, since this usage employs a quite-modern notion of 'matter' (as a type of independent existent) that would not have been recognized by Medieval and Early-Renaissance workers—for whom 'matter' (*hyle*) would have been a more or less abstract 'principle' (*archē*) rather than an independently-existent substance (*ousia*).

As Dewey (2012, 159 ff.) points out, continued use of obsolete categories may raise philosophic problems difficult to recognize and to repair—but a different but parallel error may be even more harmful. Novel findings that do not fit preexisting categorial schemes may be effectively invisible—remain ignored for some time. Philosophy of chemistry has no immunity from this difficulty.

[16] See also Liwowicz and Lombardi (2013).

6.10 Process Structural Realism[17]

Some philosophic systems (e.g., Aristotle's) consider objects that retain their identity through time ('*substances*')[18] as fundamental, others (e.g., Whitehead's) deny that such coherences are so basic but still consider them important: "The Universe achieves its values by reason of its coordination into societies of societies, and societies of societies of societies" (Whitehead 1967, 206). Recent progress in physical chemistry has identified new modes of dynamic coherence (which occur in far-from equilibrium open systems) that are critically important in many areas of science—and have shown how those integrations exemplify and extend current theory (Kondepudi and Prigogine 1998). This major advance is not yet appreciated by philosophers—in part at least because such coherences do not easily fit into prevailing categorial schemes.

The world consists[19] of individuals that are composed of less-extensive components *and also* are parts of more-extensive[20] coherences. With appropriate technology, any item can be analyzed to yield stable materials—however those stable products of analysis need not have been components of the analyzed individual.[21] Similarly, It is possible to partition molecular electron-density distributions into atomic constituents (Bader 2011), but those hypothetical pieces are not the same as corresponding uncombined atoms would be (if such could be prepared).

Some philosophers hold that objects are nothing but aggregates (mereological sums) of their components. William Wimsatt (2006) carefully considered conditions under which such simple aggregativity may obtain—and found that those conditions are rarely fulfilled. Mereological summation does not apply when the functioning of two or more components either reinforce or oppose each other—but interactions of quarks in hadrons, hadrons in atomic nuclei, and electrons in atoms and molecules are all highly cooperative (as are actions of enzymes in metabolic networks, genes in organismic reproduction, social animals in hives and colonies, primates in their various groupings—including human societies). Classical extensional mereology is of vanishingly small relevance to any such examples of compound individuals. The usual case is that the spatial/temporal persistence of each object corresponds to a *closure of a network of relationships* among components (Earley 2013).

[17] Each emergent coherence corresponds to the closure of one or more networks of relationships—physical processes that have real consequences (Earley 2014, 2008).

[18] Chemists use the word 'substance' with a meaning different from the one used in philosophy—but usually do not notice that difference.

[19] The word 'entirely' is not appropriately used in the Searle quotation with which this paper begins, but it would be an appropriate modifier for 'consists' in this sentence.

[20] 'Extensive' has both spatial and temporal senses.

[21] Chemical analysis of samples of common salt yields metallic sodium and dichlorine (a noxious green gas)—but those stable materials are not in any sense 'components' of salt.

In order for important chemical and biochemical dynamic coherences to persist through time,[22] high-energy starting materials must enter (repeatedly or continuously) and products must leave (Earley 2006). Such higher-level coherences (called 'dissipative structures') result from *closure networks of relationship*s among dynamic components: those components include *processes* (such as chemical reactions) that destroy some items while producing yet others (Earley 2003, 2014). States of affairs that persist and/or recur are generally based on closure of networks of interactions among components.

Many-component systems are controlled by large (often immense) numbers of environmental variables (including concentrations of all components). If functions of components interact (either positively in catalysis of negatively in inhibition) systems will be unstable in some regions of parameter-space (Mainzer and Chua 2013). Such instability opens the way for the origin of more-extensive coherence through closure of networks of processes. The more complicated the original system is the greater is the probability of self-sustaining closure: if any such closure is possible, then generally myriads of mechanisms lead to self-sustaining closure (Kauffman 1993, 1995). In some well-studied chemical systems, molecular mechanisms of such effects can be elucidated in detail. Similar self-organization of dynamic open-system coherence also occurs in more-complex (e.g., biochemical, ecological, economic and political) situations for which molecular-level clarification is not to be expected.

William H. Sewell, Jr. (2005, 124 ff.) avoids explicit definition but understands *human social structures* as sets of habitual actions that persist or recur through a significant time-period—whether or not the human individuals involved are aware of those patterns or desire them to continue. This is analogous to the notion of dissipative structure in chemistry and evolutionary-stable-structure in evolutionary biology.[23] At least since the prehistoric origin of property ownership along with the beginnings of permanent human settlements (Renfrew 2009, 115 ff.) human social structures necessarily have involved some specialization of effort—differentiation of function—however small. According to Dewey, human individuality *originated* in such differentiation:

> To possess and exercise an *office* is to be representative and the history or development of offices, or representative functions, is the history of transformation of biological traits into traits constituting *persons*. . . . As in so many other cases, theoretical doctrine executes an inversion of actual order. Instead of moral relations existing because human beings are intrinsically persons, they become personal because of the rise and development of offices having at least rudimentary moral qualities. And this change from the biological to the distinctively human takes place not just under social conditions but *because* of influences, pressures, and commendations (approvals) occurring in group and community life. The case is similar to that in which, instead of acts being approved because they are virtuous in and of themselves, they become virtues because of the responses in others they habitually evoke. Just as men are worshipped not because they are gods but become gods because of the reverence and adoration which is accorded them. (Dewey 2012, 189–190)

[22] Such coherences cannot long persist in *closed* systems.

[23] This also has parallels in economics.

Arguably, development of human individuality made subsequent stages in cultural evolution more, rather than less, difficult—since individuals and groups would have sought to avoid the constraints of more-inclusive organizations (such as incipient states) when they could. Development of civilization required effective "caging" (Mann 1986) not just generating surplus resources.

6.11 Conclusion

The quotation of John Searle with which this paper started identifies an important problem for contemporary philosophy—but regrettably that quotation presupposes both stark dualism and 'un-modern' respect for the nominalistic presuppositions of current philosophy. An alternate version avoids the Cartesian bifurcation and suggests that clarifying the status of compound individuals—a main goal of philosophy of chemistry—is crucial to resolving Seale's conundrum. That alternative is: 'How is it possible, in a universe *analyzable into* physical particles and fields, that there *also are* atoms, molecules, dissipative structures, biological organisms, social structures, consciousness, intentionality, language, society, ethics, aesthetics, and political obligations?' Chemists interested in philosophy of chemistry can make crucial contributions to resolving the issue that Searle raises.[24] But, following Peirce at least this far, chemists should prefer intuitions that have been developed in their laboratories to the recommendations of academic philosophers.

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[24] And also the related objections brought up by Searle's critics, such as Thomas Nagel (2012).

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