The Hypothesis of Reality and the Reality of Hypotheses

Alfred Nordmann

We have to believe that everything has a cause,
as the spider spins its web in order to catch flies.
But it does this before it knows
there are such things as flies.

(Georg Christoph Lichtenberg, H 25)

Abstract:

In a long footnote to an 1868-paper Charles Sanders Peirce remarks upon various mean-ings of the word "hypothesis." One among these treats the hypothetical as an epistemic qualification of scientific knowledge: "too weak to be a theory accepted into the body of a science." Another meaning of the word associates it with Peirce's pragmatism: a hypoth-esis is the conclusion of an abduction and, as such, it is a productive anticipation of reality. The conclusion of an abduction creatively posits a reality which might serve to explain why something has occurred. The ensuing process of inquiry articulates and elaborates this posit. It determines the initially vague meaning of the hypothesis and thereby deter-mines also the real itself – since reality is that which corresponds to the true belief that is achieved at the end of inquiry. The most general hypothesis is therefore the hypothesis that there is a mind-independent reality and it is this hypothesis, according to Peirce, that underwrites the scientific method for the fixation of belief. The reconstruction of Peir-ce's conception of hypothesis shows that he does not associate hypotheticity with fallibilism at all – these two notions play very different roles within his realist metaphysics and epis-temology. Accordingly, his views are closer to constructivist and technoscientific accounts of world-making rather than Popperian characterizations of the scientific method.

When Charles Sanders Peirce declared in 1903 that "Pragmatism what-ever it may be is nothing else than the true Logic of Abduction" hy-potheses took center stage in his philosophy (1903a, p. 224, comp. 1903b, p. 235). After all, the conclusion of an abduction is a hy-pothesis, and the very term "abduction" succeeded the earlier designa-tion "(method of) hypothesis" as in his 1878 paper "Deduction, Induc-tion, and Hypothesis." It would therefore appear that Peirce fits nicely into the story-line of hypotheticity, that is, of an increasing emphasis on the hypothetical in 19th and 20th century philosophy of science. This im-pression is bolstered when Peirce is said to anticipate or influence the

Alfred Nordmann

philosophy of Karl Raimund Popper whose *Conjectures and Refutations* may well represent the apotheosis of this development. Accordingly, Peirce's fallibilism corresponds to Popper's falsificationism and both advance an epistemic view of hypotheses and their role in science as a truth-seeking enterprise and unending quest in which everything remains revisable.

A closer look at Peirce and the logic of abduction reveals, however, that he does not associate hypotheticity and fallibility. Hypotheses do not serve as epistemic qualifiers of belief but as productive anticipations of reality. Their articulation coincides with the settlement of opinion and the determination of reality. Peirce's pragmatism thus points beyond Popper to constructivist accounts of world-making. In these accounts, awareness of the merely hypothetical character of theoretical representations recedes in favor of a pragmatic realism that enables the formation of behavioral and technical habits. Accordingly, Peirce's realism corresponds to a constructivist view of hypotheses and their role in technoscience as an enterprise dedicated to the formation of habits of action, including the acquisition and demonstration of basic capabilities of technical intervention in the world.

The following aims mainly to elaborate the difference between these two conceptions of "hypothesis" and thus also of the two ways of reading Peirce's philosophy. After a reconstruction of the role of hypothesis in Peirce's philosophy, it presents the Popperian and constructivist interpretations, and concludes with a consideration of Peirce's fallibilism. From all this emerges a critical qualification of the claim regarding an ever more pronounced awareness of the merely hypothetical character of scientific knowledge. While it may hold for science conceived as a strictly epistemic enterprise and all the scruples that come with that, it does not hold for technoscientific research which is oriented towards experimental intervention and technological transformation. Here, hypotheses do not signify loss of truth, but are instrumental in the production of truth. And instead of advancing further and further, the general awareness of the conjectural character of all scientific knowledge has been eclipsed by a rise to prominence of epistemically unscrupulous technoscience (Nordmann 2004, 2008). Not all of this can be established here, but a beginning can be made by articulating the notion of "hypothesis" in the work of Charles Sanders Peirce which prepares the parting of the ways between science and technoscience.

1. Peirce's Hypotheses

Charles Sanders Peirce articulated the core intuitions of his philosophy early on. The metaphysical view developed in his 1871 review of Fraser's edition of Berkeley are amended but essentially persist in his Harvard and Lowell lectures of 1903.[1] The pragmatic maxim was formulated early on and assumed greater prominence and scope in his later writings.[2] The following reconstruction of the role of hypothesis in Peirce's philosophy therefore does not need to distinguish between various stages of his intellectual development – it always served not as epistemic qualifier of belief but the productive anticipation of reality.

Even as Peirce replaces the term "hypothesis" with "retroduction" and "abduction," he holds fast to the now-familiar scheme that abduction proposes hypotheses, deduction articulates their consequences, and induction evaluates them (1868b, pp. 31−34; 1908, pp. 441 f.). Peirce presents this succession as a continuous process of reasoning where "just as we say that a body is in motion, and not that motion is in a body we ought to say that we are in thought, and not that thoughts are in us" (1868b, p. 42). To be in thought is for these successions to be nested within each other and to run on whether we are aware of them or not. A physical sensation prompts a perceptual hypothesis. Deduction tells us what to expect if this hypothesis were true. Induction from further perceptions evaluates the original perceptual hypothesis, for example, by confirming it. In the meantime, those further perceptions owe to parallel processes, requiring perceptual hypotheses more or less of their own. Since the coincidence of a series of perceptions also wants explanation and gives rise to more general hypotheses, the formulation of perceptual hypotheses may contribute to a process of

---

1   The later notion of a "spreading of reasonableness," for example, cannot be found in the Fraser review – but this later amendment leaves quite intact Peirce's critique of nominalism and conception of reality. Indeed, this notion can be said to solve a problem that arose from the Fraser review, namely how to explain that "human opinion universally tends in the long run to a definite form, which is the truth" (1871, p. 89). If reality as conceived by the nominalists cannot provide guidance and if a Darwinian random sporting of hypotheses is insufficient, might a tendency towards reasonableness properly constrain the development of human opinion (see Fisch 1986)?

2   Initially Peirce conceived as a semantic criterion the notion of the "practical bearing" that gives meaning to the objects of our conceptions. Later, that practical bearing would consist open-endedly of all the consequence of an abduction (see note 12 below).

evaluating such more general hypotheses. Aside from massive parallelism, even the formation of fairly basic perceptual hypotheses may thus participate simultaneously in bottom-up (from sensations) and top-down (from general conceptions) chains of reasoning.[3]

This process found its most general and consequential expression in Peirce's epistemological writings on the fixation of belief. The irritation of doubt corresponds to a sensation or percept that needs to be put to rest by being accounted for. With this irritation of doubt, a thought process is started that begins with a hypothesis and terminates in the fixation of belief. There are two prominent sources for the irritation of doubt, namely a clash between what we expect to happen and what does occur, and the social impulse or the disagreement among people. Were it for the first of these sources alone, any manner of explaining the irritable fact would do: as long as that fact appears to us as a matter of course, we can accommodate it and more or less tenaciously put our minds to rest. Since we also have to contend with the social impulse, however, what we need is a method of fixing belief that can draw consensus. A generalized scientific method allows for that. It posits an "external permanency" that serves as a common referent and involves a self-correcting methodology that converges upon it (1877, pp. 120 f.).

On this account, hypotheses do not designate a particular stage in a thought process such that a hypothesis might be proposed to explain definite perceptual facts and such that it eventually ceases to be merely hypothetical but assumes the status of a true theory. Instead, thinking begins with abduction and the prompting of a hypothesis by an irritation of doubt, and thinking ceases with the fixation of belief and the coincidence of opinions and facts. Rather than designate a problematic stage, hypothetical reasoning is coextensive with mind and thought as such. At the one end of process, it is only through error and the irritation of doubt that self and self-consciousness appear (1868a, p. 20; 1868b, p. 55). At the other end, mind becomes crystallized when upon the fixation of belief thinking hardens by taking on the form of habit (1878, p. 129; 1891, pp. 293 and 297).

---

3 This view underwrites Peirce's rejection of philosophical foundationalism or any human faculty of having immediate knowledge of objects or of oneself: the continuous process of reasoning cannot be traced to an absolute beginning (an intuition) or end, see Peirce 1868a.

Even more importantly, perhaps, the scientific method of fixing belief is initiated by a most general kind of hypothesis.[4] It posits an external permanency as a common referent of all inquiry and all inquirers.

> Such is the method of science. Its fundamental hypothesis, restated in more familiar language, is this: There are real things, whose characters are entirely independent of our opinions about them: those realities affect our senses according to regular laws, and, though our sensations are as different as our relations to the objects, yet, by taking advantage of the laws of perception, we can ascertain by reasoning how things really are, and any man, if he have sufficient experience and reason enough about it, will be led to the one true conclusion. (1877, p. 120)

The fundamental hypothesis thus posits a reality that is prior to and explanatory of our sensations. It directs the formulation of all special hypotheses – starting with the perceptual hypotheses – toward causes of our sensations that are independent of and external to our mind, causes that operate with perfect generality such that anyone in the same position would have experienced the same sensation. The fundamental hypothesis thus directs inquiry to a future time and a reality-to-be (Esposito 1980, p. 220), namely to a discovery of "how things really are." It anticipates reality in a general way by positing an indefinite future time when reality will be known as that which corresponds to the one true conclusion of an unbounded process of inquiry:

> [A]s what anything really is, is what it may finally come to be known to be in the ideal state of complete information, so that reality depends on the ultimate decision of the community; so thought is what it is, only by virtue of its addressing a future thought which is in its value as thought identical with it, though more developed. In this way, the existence of thought now, depends on what is to be hereafter; so that it has only a potential existence, dependent on the future thought of the community. (1868b, pp. 54–55)

On the one hand, the hypothesis of reality posits a mind-independent reality as the cause of our sensations, and on the other hand this reality is to depend on the "decision of the community." What is posited is therefore something that can draw the ultimately unanimous decision of the community. And the community decides on what can be said to be really the case, that is, it decides upon what is independently of and prior to any such decision. This seemingly precarious metaphysical

---

4   Adopting the term from Stephen Pepper, Andrew Reck suggests that one might consider it a "world hypothesis" (1994, p. 130).

construction is supported by the logic of abduction and thus by the conception of hypotheses as anticipations of reality that are productive in that they inaugurate a self-correcting process of convergence on a limit.[5] The following four propositions are at the heart of this logic of abduction and contextualize the hypothesis of reality as an instrument of discovery:

i)   What the hypothesis of reality states is a metaphysically flawed conception of reality, namely, a philosophical nominalism that regards reality as the incognizable cause of mental action.

ii) What Peirce endorses instead is a philosophical realism that regards reality as the normal product of mental action, that is, as a product of hypothetical reasoning.

iii) The scientific method of fixing belief adopts the nominalist hypothesis of reality. This hypothesis posits real things or events as the causes of mental action. These presumed causes are only established as such in the course of reasoning and therefore appear as the product of mental action. The scientific method thus proceeds from a productive "as if": If and to the extent that there is a fixed reality (laws, definite values of variables, limits of series of measurements or experiences), then a self-correcting method that wagers on its existence will reliably establish this reality.

iv) Since that self-correcting method involves multiple chains of hypothetical reasoning (abductive-deductive-inductive), particular hypotheses posit real entities and processes that are then gradually established in the course of inquiry. All the while, the fundamental hypothesis also becomes articulated and the assumption of the real realized.

Peirce develops these four points nowhere more forcefully and cogently than in his 1871 review of an edition of the works of George Berkeley. It contrasts the nominalist and realist philosophical conceptions of reality and begins with the more familiar one:

---

5   This self-correcting process cannot be fully reconstructed here. It found its most succinct formulation in Reichenbach 1961 where the hypothesis of reality appears as a "posit": There is no guarantee that a series of inductions will point towards some truth, that is, that it will converge upon a limit of that series. However, if there is a limit, the method of induction will discover it in the long run as relative frequency approximates objective probability. Thus, if we want to gain truth at all, we have to posit a knowable reality as a limit to the series and hope that this posit proves to be self-fulfilling.

> Where is the real, the thing independent of how we think of it, to be found? There must be such a thing, for we find our opinions constrained; there is something, therefore, which influences our thoughts, and is not created by them. We have, it is true, nothing immediately present to us but thoughts. Those thoughts, however, have been caused by sensations, and those sensations are constrained by something out of the mind. The thing out of the mind, which directly influences sensation, and through sensation thought, because it *is* out of the mind, is independent of how we think it, and is, in short, the real. (1871, p. 88)

What is stated here corresponds to the hypothesis of reality and generally agrees also with positions that are currently known as "scientific realism." Peirce rejects this view, however, as the *nominalist* conception of reality. His reasons for this are at least threefold: i) the nominalist view posits the real as something unknown, perhaps unknowable – it is the we-know-not-what that must be causing our sensations; ii) it assumes that the real is real in virtue of being outside the mind, whereas "the immediate object of thought in a true judgment *is* the reality" and thus in the mind, though not therefore exclusively in the mind (1871, p. 91); iii) nominalism denies the reality or objectivity of universals and holds instead that general conceptions serve only to organize sensations but do not enter into judgment and the process of realizing the real.[6] Another, less familiar conception of reality does not suffer from these three defects:

> All human thought and opinion contains an arbitrary, accidental element, dependent on limitations in circumstances, power, and bent of the individual; an element of error, in short. But human opinion universally tends in the long run to a definite form, which is the truth. Let any human being have enough information and exert enough thought upon any question, and the result will be that he will arrive at a certain definite conclusion, which is the same that any other mind will reach under sufficiently favorable circumstances … The individual may not live to reach the truth; there is a residuum of error in every individual's opinion. No matter; it remains that there is a definite opinion to which the mind of man is, on the whole and in the long run, tending. On many questions the final agreement is already reached, on all it will be reached if time enough is given … This final

---

6   It is due to this third feature, of course, that Peirce chooses the label "nominalist" for this conception of reality: "from this point of view it is clear that the nominalistic answer must be given to the question concerning universals … the one mental term or thought-sign 'man' stands indifferently for either of the sensible objects caused by the two external realities [i. e., two real men]; so that not even the two sensations have in themselves anything in common, and far less is it to be inferred that the external realities have" (1871, p. 88).

> opinion, then, is independent, not indeed of thought in general, but of all
> that is arbitrary and individual in thought; is quite independent of how
> you, or I, or any number of men think. Everything, therefore, which
> will be thought to exist in the final opinion, is real, and nothing else.
> (1871, p. 89)

Peirce attributes the passage from the nominalistic to the realistic view
of reality to Kant's Copernican turn (1871, pp. 90–91; compare Nord-
mann 2006b).

> It was the essence of his philosophy to regard the real object as determined
> by the mind. That was nothing else than to consider every conception and
> intuition which enters necessarily into the experience of an object, and
> which is not transitory and accidental, as having objective validity. In
> short, it was to regard the reality as the normal product of mental action,
> and not as the incognizable cause of it … The realist will, therefore, believe
> in the objectivity of all necessary conceptions, space, time, relation, cause,
> and the like. (1871, p. 91)[7]

Towards the end of his discussion Peirce briefly reflects the tension that
results from the fact that his realist metaphysics and epistemology is fu-
eled by a flawed nominalist conception of reality.

> The realistic philosophy of the last century has now lost all its popularity,
> except with the most conservative minds. And science as well as philosophy
> is nominalistic … On the other hand, it is allowable to suppose that science
> has no essential affinity with the philosophical views with which it seems to
> be every year more associated. History cannot be held to exclude this sup-
> position; and science as it exists is certainly much less nominalistic than the
> nominalists think it should be. (1871, p. 104)

By proposing a somewhat casual ad hoc explanation for the nominalism
of science, Peirce clearly does not fully appreciate as of yet that accord-
ing to his own realism, scientists have to start from the nominalist hy-
pothesis of reality. Instead of providing a realist justification for the
only apparent but necessary nominalism of science, that nominalism
of science still seems in this passage to be something of an embarrass-

---

7   Peirce goes on to state that "[n]o realist or nominalist ever expressed so definite-
    ly, perhaps, as is here done, his conception of reality." Peirce's own definite ex-
    pression claims Kant for his own "common-sense position" and thereby rejects
    Kant's notion of an incognizable thing in itself (but see Peirce 1931–35, 5:525
    and 1905b, 353–354). And in this, too, Peirce might actually be going beyond
    or even against Kant. Peirce refers to his own view of reality as inevitably real-
    istic, "because general conceptions enter into all judgments, and therefore into
    true opinions. Consequently a thing in the general is as real as in the concrete"
    (1871, pp. 91, 90).

ment to him. According to Andrew Reck, the resolution of this tension required gradual adjustments to his conception of the relation of science and philosophy: "The tension between scientific method, as an empirical method involving hypothesis and experimental observation, and the goal of science, in a systematic formulation of truth such as the philosopher seeks, is somewhat resolved when Peirce defines philosophy as a science of discovery" (Reck 1994, p. 130 [sic]).

The fundamental hypothesis of a foregoing reality sets us on a track towards the discovery of truth. And reality *will be* what corresponds to the eventually established truth. Science thus vindicates the "bad metaphysics" of nominalism in that it gradually realizes a conception of a unified reality as the cause rather than the product of our sensations and their attendant mental actions.[8] The course of science cannot establish the uniqueness of reality, however. "[I]f two groups of inquirers could never compare notes, there could be conflicting sets of perfect knowledge" or conflicting ways in which general conceptions enter into experiences and judgement.[9]

To complicate things even further, the "bad metaphysics" comes with a mechanism of validation – once a nominalist conception of reality is introduced as a hypothesis, the logic of inquiry will articulate it and determine the real accordingly. In contrast, there is no hypothesis of realism. Indeed, Peirce's assertion that "human opinion universally tends in the long run to a definite form, which is the truth" has no clear status. It is partly (historical) observation, partly normative insistence against arguments from tenacity, authority and a prioricity, and partly a consequence of the self-corrective method ("if there is truth or a limit to a series of observations, the method of abduction–deduction–induction is sufficient to discover it in the long run"). Peirce was keenly aware

---

8   In Nordmann 2006a I describe this as the interplay between metaphysics (that posits a substantial underlying reality) and metachemistry (that deals with the realization of the real). More in line with Peirce's debt to Schelling, this could also be viewed as a dialectic of *natura naturans* and *natura naturata*.

9   Quoted here is Sandra Rosenthal's paraphrase of unpublished ms. 409.112 (Rosenthal 1994, p. 138). To be sure, the social impulse guarantees that this case cannot be sustained in the long run and that we will arrive at perfect knowledge and a corresponding determination of reality on some track, and there will then be no question whether or not there might have been a possibly preferable alternative track: "Wherever universal agreement prevails, the realist will not be the one to disturb the general belief by idle and fictitious doubts" (1871, p. 91).

that the truth of the assertion required constraints on abduction or hypothesis-formation. Rather than being entirely random, the hypotheses that account for our sensations and experimental findings have to continue us on some adopted track towards the truth.[10] Aside from being controlled by the hypothesis of reality, they ought to be consistent with the best of our prior knowledge. Peirce referred to these controls on abduction as reasonableness on the one hand (1903b, p. 235; 1903c), instinct on the other (1913, pp. 464–465).[11]

A final aspect of Peirce's conception of hypothesis emerges when one considers why consistency with background knowledge or previously adopted hypotheses is not enough for a sufficiently powerful logic of abduction that explains how human opinion always tends to the truth. This aspect is closely linked with the pragmatic maxim and thus with the establishment of meaning: Hypotheses are anticipations of reality not in the sense that they specify how things would be if they were true (Rosenthal 1994, p. 135). Instead, they anticipate reality vaguely. By discovering instances that can serve to verify the hypotheses, the process of inquiry simultaneously articulates their meaning. When the pragmatic maxim enjoins us to consider what effects the objects of our conceptions might conceivably have, we are asked to engage in an experimental investigation. The full meaning of our conceptions emerges at the end of inquiry and the determination of reality coincides with the clarification of ideas (1878, 1903a).[12] The concept of "reality" and the concept, for example, of "electricity" therefore have in common that both are first introduced by abduction in a hypothesis and then accrue meaning as they grow from vagueness to determinacy, that is, the power to determine how things really are. Accordingly,

---

10 "If hypotheses are to be tried haphazard, or simply because they will suit certain phenomena, it will take the mathematical physicists of the world say half a century on the average to bring each theory to the test …" (1891, p. 288). To solve this problem, Peirce's earlier and metaphysically sparser account needed to be amended (see note 1 above).

11 "We call that opinion reasonable whose only support is instinct" (1903a, p. 218).

12 In his Harvard Lectures Peirce revisits the pragmatic maxim. Rejecting a purely linguistic reading of the maxim (whereby we introspectively group conceptions of effects under conceptions of objects), he emphasizes that the meaning of a term is the "entire general intended interpretant" or the sum of consequences of a perceptual nature (1903a, pp. 220, 225, see also 1903b).

the following passage can be read as an account of the history of the term "reality" (as the general account or symbol of the real):

> [T]he universe is intelligible; and therefore it is possible to give a general account of it and its origin. This general account is a symbol; and from the nature of the symbol it must begin with the formal assertion that there was an indeterminate nothing of the nature of a symbol. This would be false if it conveyed any information. But it is the correct and logical manner of beginning an account of the universe. As a symbol it produced its infinite series of interpretants, which in the beginning were absolutely vague like itself … But every endless series must logically have a limit. (1904, p. 323)

Here, Peirce introduces again the scientific method of fixing belief. It begins with an abduction, the merit of which is not in any information that it conveys but in that it posits a hypothesis or a symbol that sets in motion an unbounded process of inquiry. The endless series converges on a limit and that limit is reality.[13] A hypothesis or a symbol is therefore "essentially a purpose, that is to say, a representation that seeks to make itself definite" (1904, p. 323) – in other words, an anticipation of reality.[14]

2. Interlude: The Popperian Interpretation

Hypotheses or conjectures also take center stage in Karl Popper's philosophy of science. It has therefore been suggested that there is a philosophical kinship between Popper's and Peirce's approaches. And indeed, Popper can be said to provide an interpretation or further development

---

13 "Reality, therefore, can only be regarded as the limit of the endless series of symbols" (1904, p. 323).

14 Inversely, Peirce speaks of the "Universe being precisely an argument" that is "working out its conclusions in living realities" (1903a, 193–194; compare 1891, 293, 297): "Was ist Wirklichkeit? Vielleicht gibt es so etwas gar nicht. Wie ich wiederholt hervorgehoben habe, ist sie nur eine Retroduktion, eine Arbeitshypothese, die wir ausprobieren, unsere einzige, verzweifelte Hoffnung, etwas zu erkennen … Aber wenn es irgendeine Wirklichkeit gibt, dann besteht sie, insofern es eine Wirklichkeit gibt, in folgendem: daß es etwas im Sein der Dinge gibt, das dem Prozeß des Schlußfolgerns, daß die Welt *lebt* und *sich bewegt* und *ihr Sein hat*, in der Logik der Ereignisse entspricht. Wir alle stellen uns die Natur syllogistisch vorgehend vor, selbst der mechanistische Philosoph tut das, der so nominalistisch ist, wie es ein Naturwissenschaftler nur sein kann" (this passage from manuscript 439 has only been published in a German translation so far, Peirce 1991, p. 396).

Alfred Nordmann

of Peirce's philosophy of science.[15] This interpretation, however, makes three mistakes: It solidifies Peirce's fluid continuity of abduction–deduction–induction, it unwittingly transforms Peirce's realism into nominalism, and it construes hypotheses not as vague anticipations of reality that seek to make themselves definite but takes them to be perfectly meaningful.

In *The Logic of Scientific Discovery* and his later works Popper distinguishes contexts of discovery and justification. He leaves the context of discovery unconstrained and, indeed, allows for guesswork, for general or metaphysical conceptions to enter into the process of hypothesis-formation. Indeed, his stance towards discovery, invention, and creativity is so liberal or respectful that he leaves the domain of abduction entirely unregulated, saying hardly anything about it. What matters for the purposes of science is only that the context of justification is sharply set off from the context of discovery. It is the domain of logic and ruled by the principle of non-contradiction. Here, testable predictions are derived from the hypotheses and subsequently evaluated by way of experiment and controlled observation. This corresponds to Peirce's stages of deduction and induction with the notion of "induction" wide enough to accommodate Popper's anti-inductivism: The evaluation of hypotheses through induction is introduced by Peirce as a "self-correcting" process which is always attended by normal observational error and that can at best corroborate and will often falsify or modify the hypothesis. Indeed, Peirce's fallibilism – "there is a residuum of error in every individual's opinions" (1871, p. 89) – appears to constitute the strongest link to Popper:

> [N]o matter how far science goes, those inferences which are uppermost in the mind of the investigator are very uncertain. They are on probation. They must have a fair trial and not be condemned till proved false beyond all reasonable doubt; and the moment that proof is reached, the investigator must be ready to abandon them without the slightest tenderness towards them. Thus, the scientific investigator has to be ready at a moment to aban-

---

15 Popper called Peirce "one of the greatest philosophers of all time" (1972, p. 212). The most significant intellectual kinship between Popper and Peirce concerns the propensity interpretation of probability and the notion of indeterminacy in physics (which lie beyond the scope of this paper). Larger claims of kinship owe to lax interpretations that find it comparatively easy to understand Peirce as a proto-Popperian. Popper himself fostered this by distinguishing the clear and easy-to-understand Peirce – a good Popperian, of course – from the obscure and speculative Peirce.

don summarily all the theories to the study of which he has been devoting perhaps many years. (Peirce 1895, p. 25)

As long as we are thinking and have not settled on a final opinion, we are working with hypotheses, Peirce is saying. Popper appears to agree by adding that our best available knowledge is therefore only hypothetical and always on probation. Upon closer scrutiny, however, this agreement proves illusory. It conflates Peirce's conception of hypotheses as anticipations of reality with Popper's notion of the hypothetical as an epistemic qualification of our best available knowledge. After identifying the philosophical differences between Popper and Peirce and suggesting Peirce's affinity to constructivist accounts, Peirce's fallibilism will be revisited and shown to be unrelated to his conception of hypothesis.

The philosophical difference between Popper and Peirce emerges from Popper's motto at the opening of *Logic of Discovery*. Popper quotes Novalis: "Theories are nets: Only he who casts will catch" (1968, p. 11). Novalis, of course, was an idealist poet-philosopher whose views are close to Schelling's (and thus closer to Peirce than Popper), but the one isolated sentence as appropriated by Popper suggests not only a philosophical nominalism but also a nominalist reading of Kant: Reality is out there as the cause of all our sensations but it is shrouded in an inaccessible darkness; we can bring it to light only partially by formulating scientific hypotheses, hoping that they will capture something. What we capture, however, remains tentative because we do not see the things as they are in themselves but only as we brought them to the light of reason. The ways in which we frame our hypotheses structures our scientific experience but hypotheses are not otherwise productive and do not inaugurate a process of clarification of ideas alongside the fixation of belief and the determination of the real. Reality is in no way thought of as "the normal product of mental action" and the real is not what corresponds to a true judgement and not something that is in the mind as much as it is outside it.

This difference becomes more pronounced when one considers the meaning of a hypothesis. According to Peirce, the hypothesis seeks to become definite and requires deduction and induction not as a test of its truth or falsity but – in line with the pragmatic maxim – for the exploration and discovery of the sensible effects that belong to its conceptions. Any hypothesis thus retains a residuum of vagueness (and the criterion of non-contradiction or consistency is therefore insufficient to

326   Alfred Nordmann

guide the formation of further hypotheses). In contrast, the virtue of Popper's hypotheses is that they have definite truth-conditions: To understand a hypothesis is to know under which conditions it would be false. Moreover, good hypotheses are very general and therefore could be falsified by a wide range of experimental findings.

Popper's hypotheses are semantically determinate and experimental inquiry does not serve "to make our ideas clear." On the contrary, an experiment can test a hypothesis only to the extent that it is clear already. This is also why Popper views as a static logical sequence rather than as a fluid continuity the succession of abduction, deduction, and induction: Abduction ends when it issues in a hypothesis; deduction and experimental evaluation refer to that hypothesis with the aim of falsifying or else corroborating it. As many of his critics have pointed out, Popper's idealization of this process neglects the formation of auxiliary hypotheses, perceptual judgments and other aspects of discovery, creativity, or abduction in the context of justification.

Popper's idealization is meant to remind us of limits of knowledge and to establish epistemic norms for intellectual honesty. Popper does not "believe in belief" because what distinguishes Einstein from an amoeba is that Einstein can learn from his mistakes and does so by maintaining a healthy distrust of all claims to knowledge (1972, pp. 24 f.).

Like Popper, Peirce views hypotheses as inhabitants of a "third world" of ideas (Popper 1956, p. 156–161). The scientific method of fixing belief requires the possibility of a disagreement between expectation and experience but also of disagreement among inquirers. By being detached from their inventors, hypotheses have a life of their own and become part of a communal process of inquiry, and in this process the attitude of personal belief or disbelief drops out as insignificant – the only opinion that matters is the final opinion that is reached by all inquirers as questioning ceases and knowledge becomes sedimented as a habit of action. But as opposed to Popper, Peirce's understanding of this process gives him something other than criteria for the evaluation of a discontinuous series of theories, where each theory is primarily a linguistic artifact that offers a nominalistic conception of an otherwise incognizable foregoing reality. Instead, an understanding of the process of inquiry provides Peirce with an explanation of reality and a view of the evolution of mind and world (Pape 1991). Even if no individual ever knows the final truth, the hypotheses that are advanced by this individual are productive in that they contribute to the determination of

reality as the product of an indefinitely long process of collective mental action.[16]

3. The Constructivist Interpretation

Karl Popper associates the hypothetical with the tentative and always fallible character of scientific representations or descriptions of the world. As such he remains firmly within the confines of a nominalist epistemology, that is, an epistemology that must remain nominalist because the world "out there" is unknowable except indirectly through evidences gathered from observation and experiment. In contrast, Peirce associates the hypothetical with productive anticipations of reality. Abduction and hypothesis are central to his scholastic realism that includes Kantian idealism,[17] and thus central to a view according to which general conceptions enter into true judgements, thereby determining the real as that which corresponds to true judgements.

This conception of the realization of the real is not, of course, a social constructivism but rather more closely akin to Bruno Latour's notion of the world as a construction jointly of human and non-human agents (Nordmann 2006a). Indeed, Latour echoes Peirce's critique of nominalism in his critiques of the purely social or mental constructivism that he attributes to Immanuel Kant and William James. Inverting Peirce's reading of Kant, Latour attributes to him an "extravagant form of constructivism" according to which "everything was ruled by the mind itself and reality came in simply to say that it was there, indeed, and not imaginary":

> Kant invented this science-fiction nightmare: the outside world now turns around the mind-in-the-vat, which dictates most of that world's laws, laws

---

16   This again might be seen as close to Popper: He praises the demolition of hypotheses as clearing the way for the generation of new and presumably better ones. In this sense, too, the failure of the individual is productive for the whole. To the extent that this is Popper's view, it becomes interesting how little he makes of this. Since each hypothesis is logically distinct from previous and subsequent hypotheses (even if it were to be a mere modification of them), Popper cannot and does not attempt to envision the continuity of the productive process.

17   Peirce designated his own "realism" also as "objective idealism" and "critical common-sensism" (Nordmann 2006b). With reference to Peirce, Ian Hacking contrasts nominalism somewhat misleadingly with "dynamic nominalism" (2002, pp. 48 f.).

it has extracted from itself without help from anything else (Latour 1999, 5 f.).

Latour's reading differs from that of Peirce because he assumes that Kant's inaccessible things-in-themselves are the "real reality." While Latour takes Kant to be an unreformed nominalist, we saw that Peirce is more generous and views him as the first realist. According to Peirce, Kant does not "think of the mind as a receptacle, which if a thing is in, it ceases to be out of" (1871, p. 91). Peirce maintains that the Kantian "things in themselves" become dispensable once one recognizes that there is no question of a reality beyond the world of experience and that this experience or reality is a product of the joint actions of mind and nature (1931–1935, 5.525, 1905b, 353 f.).

Though a nominalist like Peirce, Latour credits not Kant or Peirce but only William James with debunking the notion that reality is that which lurks behind our experiences, that we can only gather highly mediated evidences about this reality which nevertheless serves to ground and validate our knowledge:

> When a rationalist insists that behind the facts is the ground of facts, the possibility of the facts, the tougher empiricists accuse him of taking the mere name and nature of a fact and clapping it behind the fact as a duplicate entity to make it possible. (James 1907, p. 263, quoted in Latour 1990, p. 64)[18]

But James's critique does not go far enough for Latour, nor would a Peircean realism if all it did was assert that general conceptions enter into true judgements, thereby determining the real as that which corre-

---

18 That the "rationalist" here holds the same position as Peirce's "nominalist" becomes apparent when Latour quotes James another time: "On the pragmatist side we have only one edition of the universe, unfinished, growing in all sorts of places where thinking beings are at work. On the rationalist side we have a universe in many editions, one real one, the infinite folio, or *edition de luxe*, eternally complete; and then the various finite editions, full of false readings, distorted and mutilated each in its own ways" (James 1907, p. 259, quoted in Latour 1990, pp. 78 f.). Here, the *edition de luxe* stands for the incomprehensible reality as it is in truth – and knowing subjects are condemned to write books of their own that always fall short of the original. The pragmatist or nominalist, in contrast, engages with all subjects to write the single book that in the course of time determines reality as the normal product of mental action. Reality is that which would correspond not to the original but only to the very final edition which represents the consensus of all and has quieted the social impulse and all other irritations of doubt.

sponds to true judgements. Narrowly construed, such a realism would still amount to merely a social or mental constructivism. And on such a narrow reading, the notion of hypotheses as productive anticipations of reality would reduce to the claim that reality is shaped or constructed by our hypotheses, and that reality is fitted to the requirements of the mind. Insisting that "there is a history of things, not only of science" Latour therefore formulates his critique of James's pragmatism:

> The limit of pragmatism is to be concentrated on man (individual at that). But if essence is existence and existence is action, this pragmatism is to be extended to the things in themselves now endowed with a history. James was ready to "add to reality." He transforms the metaphor of the book one reads to a book one *writes* … But, he was prepared to do it as you add shape to a shapeless and plastic matter, not as you meet other non-human actors who have also their history. This shift away from human overcomes the other limit of pragmatists. They have no way slowly to withdraw existence out of essence. This withdrawal occurs by shifting the task of maintaining the consensus to non-humans and moving from in-teractions, talks and controversial practices to a world *in which* we live (1990, p. 66 and 78 f.).

This, to be sure, is a rather cryptic passage. As a critique of James it ech-oes Peirce's critique of James's all too narrowly conceived pragmatism – leading Peirce to adopt "pragmaticism" to designate his more compre-hensive constructivism that goes beyond epistemology to semiotics, phi-losophy of nature, and a metaphysics of non-human agency (Pape 1991, Reynold 2002). In particular, Peirce's doubt-belief dynamic offers what Latour finds lacking in James, namely an account of the gradual with-drawal of "existence out of essence": In the process of fixing belief and of determining reality, how does one arrive at an essential nature of things that is no longer dependent on what some knowing subjects experience as a currently existing fact? In other words: if science begins with sensations and perceptions, perceptual hypotheses and the like, how does it attribute those finally to a more or less immutable and eter-nal reality which causes the sensations as signs of something other and prior to these sensations? Where Latour speaks of withdrawing exis-tence out of essence such that the essence remains after everything ac-cidental has been removed, Peirce uses the metaphor of settlement or sedimentation. He refers to the fixation of belief also as a settlement of opinion and thereby captures that this settlement cannot be compared to an explicit human consensus on a hypothesis or on a political issue. Instead, the settlement of opinion is a withering away of discourse

and thought as a habit is being formed that becomes a subterranean stratum or a robust way of living in the world.

Latour studied the withdrawal of existence from essence and thus the construction of a robust objective reality through the cooperation of human and non-human actors in the course of his laboratory studies (e.g., Latour 1990). A "laboratory man" himself,[19] Peirce tells a similar story of experimental practice. It begins by bringing together various existences and establishes something that no longer depends on existence but fixes a certain relation that can be invoked at any time:

> What are the essential ingredients of an experiment? First, of course, an experimenter of flesh and blood. Secondly, a verifiable hypothesis … The third indispensable ingredient is a sincere doubt in the experimenter's mind as to the truth of that hypothesis. Passing over several ingredients … we come to the act of choice by which the experimenter singles out certain identifiable objects to be operated upon. The next is the external (or quasi-external) ACT by which he modifies those objects. Next, comes the subsequent *reaction* of the world upon the experimenter in a perception …

Out of all these diverse ingredients that are all more or less arbitrary existences (human bodies, sentences, mental states, chosen objects, actions and reactions) the successful experiment generates an experimental phenomenon that is independent of any particular event:

> When an experimentalist speaks of a *phenomenon*, such as "Hall's phenomenon," "Zeeman's phenomenon" and its modification, "Michelson's phenomenon," or "the chessboard phenomenon," he does not mean any particular event that did happen to somebody in the dead past, but what *surely will* happen to everybody in the living future who shall fulfill certain conditions. The phenomenon consists in the fact that when an experimentalist shall come to *act* according to a certain scheme that he has in mind, then will something else happen, and shatter the doubts of sceptics, like the celestial fire upon the altar of Elijah (1905a, pp. 339 f.).

What Peirce only hints at has been the subject of laboratory studies by Latour and many others: The production of objectivity requires that one controls for experimental artifacts, that the contingencies of the laboratory are reduced, and that the phenomenon can exist outside the laboratory in which it was first demonstrated.

---

19 His own experience as an experimentalist was to have disposed him towards Kant and the view "that a *conception*, that is, the rational purport of a word or other expression, lies exclusively in its conceivable bearing upon the conduct of life" (1905a, p. 331–3).

More generally, of course, the "withdrawal of existence from essence" refers to the interplay of a realist metaphysics with the nominalist hypothesis of reality. According to realism, we begin with sensations, irritations of doubt, and hypothetical conceptions and find ourselves quite in the realm of existence. That there might be natures or essences "behind" these sensations and existences is suggested only by the hypothesis of reality. To the extent that the process of inquiry adduces evidence (further existences) to this hypothesis – that it confirms or vindicates it – the hypothesized reality or realm of natures emerges as the endpoint and final product of inquiry. At the end of inquiry, there is therefore no longer any reference to particular existence. The work of abduction, deduction, and evaluation has hardened or crystallized into fixed material relations – paraphrasing Latour, the discourses have been weighted down by habits and things (1996a).

These material relations or habits obtain equally between "causes" and "effects" and between "human expectation" and "action in the world."[20] Thus, Peirce (like Latour) treats material things in the world symmetrically along with human thought and action. Both are accounted for semiotically as signs that grow through the articulation of their meaning (that is, their practical effects or bearing on conduct), and both derive from a primordial "law of mind" (1891, p. 292):

> [A]ll mind is directly or indirectly connected with all matter, and acts in a more or less regular way; so that all mind more or less partakes of the nature of matter. Hence, it would be a mistake to conceive of the psychical and the physical aspects of matter as two aspects absolutely distinct. Viewing a thing from the outside, considering its relations of action and reaction with other things, it appears as matter. Viewing it from inside, looking at its immediate character as feeling, it appears as consciousness. (1892, p. 349)

It is common-place within Kantianism to apply these two standpoints to human beings who face the special predicament that they must conceive of themselves simultaneously as determined by nature and as free moral agents. Peirce extends this notion by applying it to all material things (including humans) and concludes that "if habit be a primary property

---

20 Where Peirce speaks of the hardening of habits, Latour refers to trajectories of action that become more predictable as motions are weighted down. For example, in his essay about the heavy key-rings in hotels, he remarks that the behavior of guests (their readiness to leave their keys at the desk) could be regulated by standardizing the guests (for example, through extensive indoctrination) or by making the key so heavy that no one wants to carry it around (Latour 1996a, p. 54).

of mind, it must be equally so of matter, as a kind of mind" (1892, p. 350).[21]

Latour's constructivism boasts that its conception of reality is more robust than that of William James because it complements the social or mental construction of existence with an account of how we can institute an unchanging, eternal, mind-independent nature through the gradual withdrawal of existence from essence. Like Peirce he must therefore account for the peculiar constitution of the modern world and its paradoxical "constitutional guarantee" that "even though we construct Nature, Nature is as if we did not construct it" (1993, 32). He confronts this difficulty in the most direct and philosophically sustained manner in a chapter on the historicity of things: "Where Were Microbes before Pasteur?" (1999, 145–173). In typical Latourian fashion, he first heightens the sense of paradox by suggesting a kind of backward causation: Only our present actions bring into being the world that preceded and enabled these actions. The appearance of backward causation can be dissolved, however, when one considers instead a process of "sedimentation." With new experimental capabilities, people and things assume articulated competencies. In the laboratory, chemical substances can do things that they could not do before, but of this capability it is said that it always existed latently but so far without the chance to manifest itself. As the laboratory experiment is reproduced and varied, the still fairly new behavior of the chemical substance appears more and more to be a property of the substance that does not require specific laboratory conditions for its manifestation. And thus, a newly acquired competence gradually settles into history to reconfigure the past: Its existence in the lab becomes an expression of an immutable essence that precedes existence.

Latour thus shows that not only scientists like Pasteur but also Pasteur's microbes need the laboratory to show what they are capable of. Simultaneously, the new experimental capabilities produce a new past: Controversies about fermentation and spontaneous generation in 1865 produce a year 1864 in which vague, haphazard, and invisible

---

21 In particular, Peirce applies the two standpoints to the atoms and molecules of protoplasm, and goes on to entertain as a consequence of his theory that collectives (of atoms or of people) can act together, acquiring depersonalized habits of thought and action of their own (Peirce 1892). To be sure, Peirce lacked Latour's sociological background or imagination and never considered the world in which we live as a networked collective of human and non-human actors.

processes appear to be in need of interpretation and experimental investigation. Pasteur's persuasive experimental demonstration in 1867 produced a year 1864 in which vague, haphazard, and invisible processes result from the action of microbes. The present in the year 2009 produces a year 1864 in which, as in most of the past, people had limited knowledge of a reality that is theirs as much as ours: We withdraw existence from essence by declaring contingent states of knowledge as accidental existents in the past – opposing these states of knowledge to a nominalistically conceived, essentially given reality. While Peirce could have explained this production of a new past by saying that Pasteur worked with and articulated the hypothesis of reality, Latour's more paradoxical explanation amounts to the same – in Pasteur's laboratory the microbes were constructed as something that has always existed: "After 1864 airborne germs were there all along" (1999, 168–173).

This complementarity of accounts suggests that Peirce and Latour are engaging in a similar project, albeit with different backgrounds and vocabularies. When present articulations of reality sediment and permeate the past, and when they construct now what has always been, this amounts to the realization of a hypothesis of reality that is assumed to hold already. Pasteur's microbes, in other words, were constructed according to the hypothesis that they existed before their construction and that they are certainly not Pasteur's. The construction thus consists in the withdrawal of temporally bound existence so as to leave behind a purified fixed reality which corresponds to our eternally true beliefs. In this process, human and non-human actors work together to co-construct reality. Where Latour speaks of a complete, rather than merely social constructivism (1990, p. 71), Peirce presents hypotheses as self-fulfilling *and* guided by instinct. According to the pragmatic maxim, the meaning of hypotheses becomes articulated through experimental inquiry, and the clarification of ideas coincides with the determination of reality that owes to matter and mind doing their "collective work in the middle" (Latour 1990, p. 68).

But what is the significance of this complementarity, and what is the significance for the history of hypothesis and hypotheticity of the fact that Peirce's conception has greater affinity to Latour's constructivism than to Popper's critical rationalism? The answer to this question is suggested by a succinct statement that was suggested at the outset but cannot be fully elaborated here: Popper is a theorist of science, Latour of technoscience. Popper's science is an epistemic enterprise that aims to produce theoretical representations of the phenomena. As such it is

challenged by the problem of underdetermination and bound up with skeptical questions regarding the relation between representations and their objects. As it deals with these questions, this theoretical enterprise experiences a loss of certain truth (Schiemann 1997); it becomes incapable of marking a threshold between mere hypothesis and true theory – a trajectory that culminates in Popper's philosophy of science. In contrast, technoscience is not an epistemic enterprise (Nordmann 2004, 2008), but constructively pursues hypotheses as productive anticipations of reality. For Peirce and Latour, and for technoscientific research as characterized, for example, by Peter Galison (2006), it amounts to the same whether this reality is conceived of as the one which corresponds to our settled opinions at the end of inquiry or whether this reality is shaped to conform to our technologies and habits of action. The settlement of opinion coincides with formation of habit as we assimilate ourselves to reality and reality to us.

With the rise and increasing prominence of technoscience the epistemic scruples of science fade away. The robustness of technoscientific knowledge does not owe to "confirmation" or "corroboration" but to opinion settling into habit. Accordingly, the notion of hypotheses as epistemic qualifiers of belief may serve to pick out only one strand of 19th and early 20th century "basic science" – of theoretical physics in particular. While it is tempting to place Peirce in this tradition, he is rather the "laboratory man" who constructs phenomena such that something else will happen, "and shatter the doubts of sceptics, like the celestial fire upon the altar of Elijah" (Kant, interestingly but perhaps not surprisingly, is claimed by both traditions as the one who specifies limits of theoretical knowledge and the one who establishes the constructedness of reality – on the one hand offering epistemic qualifications, on the other hand providing an account of experience and reality that is just as knowable as anything that is humanly constructed.).[22]

---

22 In what is perhaps his most sustained reflection on the word "hypothesis," Peirce distinguishes eight meanings of that term, only the eighth coming close to a Popperian usage: "too weak to be a theory accepted into the body of a science." Peirce himself adopts the seventh sense of "hypothesis": "Most commonly in modern times, for the conclusion of an argument from consequence and consequent to antecedent," that is, what he came to refer to as abduction. He then identifies this use of "hypothesis" in seven authors, including Newton, Mill, Kant, and Herbart (1868b, 34 f.).

4. Coda on Fallibilism

Peirce views hypotheses as productive anticipations of reality and it is therefore that pragmatism is the true logic of abduction. This sets him apart from the Popperian concern that even our very best knowledge is only hypothetical because we cannot with certainty traverse the threshold from hypothesis to certainty of truth. Against this sharp juxtaposition might be objected that Peirce was a fallibilist who insisted that "there is a residuum of error in every individual's opinions" and that "the scientific investigator has to be ready at a moment to abandon summarily all the theories to the study of which he has been devoting perhaps many years" (1871, p. 89, 1895, p. 25). Though not in the name of "hypothesis," one might argue, Peirce's fallibilism expresses some limit of knowledge and marks an unbridgeable gap between mere opinion and certainly true belief. However, a brief consideration of Peirce's metaphysics can show that even his fallibilism does not provide an epistemic qualification upon belief.

In Peirce's categorial scheme, "hypothesis" belongs to Thirdness – it involves the doubt-belief dynamic and thus thought and mind as constructive of reality. In contrast, Peirce's fallibilism belongs to Secondness and thus stands entirely outside the doubt-belief dynamic and all things epistemic.[23] A short elaboration must suffice to make this point.

Thought and mental activity begins with the irritation of doubt; it aims for the fixation of belief and the formation of habit. Indeed, thinking ceases with the formation of habit – Thirdness becomes Secondness. Here, Thirdness refers only to a three-place relation: x is a sign of y for z. The continuous interplay of abduction, deduction, and induction involves such thirdness, if only because percepts and concepts are interpreted and mediated in the course of experimental inquiry. As was pointed out above, mental activity is coextensive with hypothetical rea-

---

23 Helmut Pape has grappled with this issue: How does Peirce's method of hypothesis arrive at individual things and not just representations of them? Inversely, how can the two-place indexical relation between a person and an individual thing become represented? These questions have bearing on Peirce's fallibilism: On the one hand awareness of the fallibility of all knowledge marks the beginning of all inquiry in that the mind steps into action only once a subject experiences the discrepancy of what one expects and what is. On the other hand, this awareness does not represent anything but a general sense that all our expectations might be frustrated in their brute confrontation with reality (compare Pape 1997).

soning, it subjects hypotheses to the pragmatic maxim, simultaneously clarifying ideas and determining reality. There is no state of belief beyond hypotheses because a habit is not a belief; it does not interpret the world. Instead, a habit is a mere two-place relation that coordinates a stimulus and a response. Like instinct, law, and matter, habit is crystallized or hardened mind or Secondness: if x then y.

Peirce's fallibilism owes to the possibility of an "outward clash," that is, a brute confrontation of an expectation and the world: x but not y ("direct consciousness of hitting and getting hit," 1885, 233 f.). No matter where we are on the doubt-belief trajectory – whether we are in the process of formulating and testing hypotheses or firmly in the realm of settled opinion and lawful habit – the world may have a surprise in store for us, frustrate our expectations, or create a novel irritation of doubt.

Quite in agreement with Peirce's dictum not "to doubt in philosophy what we do not doubt in our hearts" (1868b, 29), the mere possibility of this outward clash does not qualify our belief and cannot qualify what has become habitual and routine. Nothing would be gained if we were to attach as a footnote to all our expectations the global proviso that these expectations only hold in the absence of an outward clash. "True belief" (the cessation of thought and the formation of habit) arises as we exit the domain of epistemology. Inversely, the possibility of an outward clash and thus the in-principle fallibility of all consciously held or unconsciously embodied expectations obtains before we enter that domain. In the middle of things, however, and where we engage in mental activity, the hypothesis of reality serves the construction of the reality of hypotheses.[24]

Bibliography

Esposito, Joseph (1980), *Evolutionary Metaphysics: The Development of Peirce's Theory of Categories*. Athens: Ohio University Press.

Fisch, Max (1986), *Peirce, Semeiotic and Pragmatism*. Bloomington: Indiana University Press.

Galison, Peter (2006), "The Pyramid and the Ring", presentation at the conference of the Gesellschaft für analytische Philosophie (GAP). Berlin.

---

24 The final version of this paper benefits from critical commentaries by the editors and referees, but also from Helmut Pape and Andreas Hetzel. Unfortunately, it could not address all their objections or meet all requests for elaboration. In particular, Pape's incisive critique needs to be taken up elsewhere.

Hacking, Ian (1980), "The Theory of Probable Inference: Neyman, Peirce and Braithwaite," in: D. H. Mellor (ed.), *Science, Belief and Behavior: Essays in Honor of R. B. Braithwaite*. Cambridge: Cambridge University Press, 141–160.

—— (2002) *Historical Ontology*. Cambridge: Harvard University Press.

Hoffmann, Michael (2004), "Peirces Philosophie der Wissenschaft, Logik und Erkenntnistheorie," *Philosophische Rundschau* 51: 193–211, 296–313.

Houser, Nathan and Kloesel, Christian (1992), "Introduction," in: Nathan Houser and Christian Kloesel (eds.), *The Essential Peirce*, vol. 1. Bloomington: Indiana University Press, xix–xli.

James, William (1907), *Pragmatism, a new name for some old ways of thinking*. London: Longman, Green.

Kuhn, Friedrich (1996), *Ein anderes Bild des Pragmatismus: Wahrscheinlichkeitstheorie und Begründung der Induktion als maßgebliche Einflußgrößen in den "Illustrations of the Logic of Science" von Charles Sanders Peirce*. Frankfurt: Klostermann.

Latour, Bruno (1990), "The Force and the Reason of Experiment," in: Homer LeGrand (ed.) *Experimental Inquiries*. Dordrecht: Kluwer, 49–80.

—— (1996a), *Der Berliner Schlüssel: Erkundungen eines Liebhabers der Wissenschaften*. Berlin: Akademie Verlag.

—— (1996b), "Do Scientific Objects Have a History? Pasteur and Whitehead in a Bath of Lactic Acid", *Common Knowledge* 5(1): 76–91.

—— (1993), *We Have Never Been Modern*. Cambridge: Harvard University Press.

—— (1999), *Pandora's Hope*. Cambridge: Harvard University Press.

Levi, Isaac (1980), "Induction as Self-Correcting According to Peirce", in: D. H. Mellor (ed.), *Science, Belief and Behavior: Essays in Honor of R. B. Braithwaite*. Cambridge: Cambridge University Press, 127–140.

Lichtenberg, Georg Christoph (1784–1788), "Selections from Waste-Book H", in: R. J. Hollingdale (ed.), *Georg Christoph Lichtenberg: Aphorisms*. London: Penguin, 1990, 111–116.

Nordmann, Alfred (2004), "Was ist TechnoWissenschaft? – Zum Wandel der Wissenschaftskultur am Beispiel von Nanoforschung und Bionik", in: T. Rossmann and C. Tropea (eds.), *Bionik: Aktuelle Forschungsergebnisse in Natur-, Ingenieur- und Geisteswissenschaften*. Berlin: Springer, 2004, 209–218.

—— (2006a), "From Metaphysics to Metachemistry", in: Davis Baird, Eric Scerri, Lee McIntyre (eds.), *Philosophy of Chemistry: Synthesis of a New Discipline*, in the series *Boston Studies in the Philosophy of Science*. Dordrecht: Springer, 347–362.

—— (2006b), "Critical Realism, Critical Idealism, Critical Common-Sensism: The School and World Philosophies of Riehl, Cohen, and Peirce", in: Michael Friedman and Alfred Nordmann (eds.), *The Kantian Legacy in Nineteenth Century Science*. Cambridge: MIT Press, 249–274.

—— (2008), "Philosophy of Nanotechnoscience", in: G. Schmid, H. Krug, R. Waser, V. Vogel, H. Fuchs, M. Grätzel, K. Kalyanasundaram, L. Chi (eds.), *Nanotechnology,* vol. 1: G. Schmid (ed.), *Principles and Fundamentals*. Weinheim: Wiley, 217–244.

Pape, Helmut (1991), *Charles S. Peirce: Naturordnung und Zeichenprozeß*. Frankfurt: Suhrkamp.

––– (1997), "Abduction and the topology of human Cognition: Review of Ansgar Richter, Der Begriff der Abduktion bei Charles S. Peirce", *Modern Logic* 7(2): 199–221.

Peirce, Charles Sanders (1868a), "Questions Concerning Certain Faculties Claimed for Man", in: Nathan Houser and Christian Kloesel (eds.), *The Essential Peirce*, vol. 1. Bloomington: Indiana University Press, 1992, 11–27, compare *Collected Papers* 5.213–63.

––– (1868b), "Some Consequences of Four Incapacities", in: Nathan Houser and Christian Kloesel (eds.), *The Essential Peirce*, vol. 1. Bloomington: Indiana University Press, 1992, 28–55, compare *Collected Papers* 5: 264–317.

––– (1871), "Fraser's 'The works of George Berkeley'", in: Nathan Houser and Christian Kloesel (eds.), *The Essential Peirce*, vol. 1. Bloomington: Indiana University Press, 1992, 83–105, compare *Collected Papers* 8: 7–38.

––– (1877), "The Fixation of Belief", in: Nathan Houser and Christian Kloesel (eds.), *The Essential Peirce*, vol. 1. Bloomington: Indiana University Press, 1992, 109–123, compare *Collected Papers* 5: 358–387.

––– (1878), "How to Make our Ideas Clear", in: Nathan Houser and Christian Kloesel (eds.), *The Essential Peirce*, vol. 1. Bloomington: Indiana University Press, 1992, 124–141, compare *Collected Papers* 5: 388–410.

––– (1885), "An American Plato", in: Nathan Houser and Christian Kloesel (eds.), *The Essential Peirce*, vol. 1. Bloomington: Indiana University Press, 1992, 229–241, compare *Collected Papers* 8: 39–54).

––– (1891), "The Architecture of Theories", in: Nathan Houser and Christian Kloesel (eds.), *The Essential Peirce*, vol. 1. Bloomington: Indiana University Press, 1992, 285–297, compare *Collected Papers* 6: 7–34.

––– (1892), "Man's Glassy Essence", in: Nathan Houser and Christian Kloesel (eds.), *The Essential Peirce*, vol. 1. Bloomington: Indiana University Press, 1992, 334–351, compare *Collected Papers* 6: 238–271.

––– (1895), "Of Reasoning in General", in: Nathan Houser and Christian Kloesel (eds.), *The Essential Peirce*, vol. 2. Bloomington: Indiana University Press, 1998, 11–26.

––– (1903a), "The Nature of Meaning (Sixth Harvard Lecture)", in: Nathan Houser and Christian Kloesel (eds.), *The Essential Peirce*, vol. 2. Bloomington: Indiana University Press, 1998, 208–225, compare *Collected Papers* 5: 151–179.

––– (1903b), "Pragmatism as the Logic of Abduction (Seventh Harvard Lecture)", in: Nathan Houser and Christian Kloesel (eds.), *The Essential Peirce*, vol. 2. Bloomington: Indiana University Press, 1998, 226–241, compare *Collected Papers* 5: 180–212.

––– (1904), "New Elements", in: Nathan Houser and Christian Kloesel (eds.), *The Essential Peirce*, vol. 2. Bloomington: Indiana University Press, 1998, 300–324.

––– (1905a), "What Pragmatism Is", in: Nathan Houser and Christian Kloesel (eds.), *The Essential Peirce*, vol. 2. Bloomington: Indiana University Press, 1998, 331–345, compare *Collected Papers* 5: 411–437.

—— (1905b), "Issues of Pragmaticism", in: Nathan Houser and Christian Kloesel (eds.), *The Essential Peirce*, vol. 2. Bloomington: Indiana University Press, 1998, 346−359, compare *Collected Papers* 5: 438−463.

—— (1908), "A Neglected Argument for the Reality of God", in: Nathan Houser and Christian Kloesel (eds.), *The Essential Peirce*, vol. 2. Bloomington: Indiana University Press, 1998, 434−450, compare *Collected Papers* 6: 452−491.

—— (1913), "An Essay toward Improving Our Reasoning in Security and in Uberty", in: Nathan Houser and Christian Kloesel (eds.), *The Essential Peirce*, vol. 2. Bloomington: Indiana University Press, 1998, 463−474.

—— (1931−35), *Collected Papers*, Charles Hartshorne and Paul Weiss (eds.), 6 vols. Cambridge: Harvard University Press (cited by volume and paragraph numbers).

—— (1991), "Weitere selbständige Ideen und der Streit zwischen Nominalisten und Realisten", in: Helmut Pape (ed.), *Naturordnung und Zeichenprozeß: Schriften über Semiotik und Naturphilosophie*. Frankfurt: Suhrkamp, 378−399.

Popper, Karl Raimund (1968), *The Logic of Scientific Discovery*. New York: Harper and Row.

—— (1972), *Objective Knowledge*. Oxford: Clarendon.

Reck, Andrew (1994),"Peirce's Conception of Philosophy and Its Place within His Classification of the Sciences", in: Edward Moore and Richard Robin (eds.), *From Time and Chance to Consciousness: Studies in the Metaphysics of Charles Peirce*. Oxford: Berg, 115−131.

Reichenbach, Hans (1961), *Experience and Prediction*. Chicago: University of Chicago Press.

Reynold, Andrew (2002), *Peirce's Scientific Metaphysics*. Nashville: Vanderbilt University Press.

Rosenthal, Sandra (1994),"Charles Peirce: Scientific Method and Worldly Pluralism", in: Edward Moore and Richard Robin (eds.), *From Time and Chance to Consciousness: Studies in the Metaphysics of Charles Peirce*. Oxford: Berg, 133−142.

Schiemann, Gregor (1997), *Wahrheitsgewißheitsverlust*. Darmstadt: Wissenschaftliche Buchgesellschaft.