Reasoning in Action: Charles S. Peirce's Philosophy of the History of Science

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"Each chief step in science has been a lesson in logic"
- C.S. Peirce[1] -

1. Introduction

The writings and thought of Charles S. Peirce have often received an ambiguous treatment by philosophers and historians of science. Acclaimed as "one of the most original minds of the later nineteenth century, and certainly the greatest American thinker ever" by Bertrand Russell (Russell 1959, 276) and as "a towering giant among American philosophers" by Hilary Putnam (Putnam 1990, 252), Peirce has been simultaneously neglected (or at best misinterpreted) by the very community who enthusiastically praised his intellectual contributions to philosophy. Residues of this ambivalent attitude toward Peirce are still visible in the instrumental and fragmented ways in which contemporary philosophers of science tend to engage with his thought and works.[2]

The reasons for such a fragmented approach have been examined quite extensively by Peirce scholars.[3] For instance, in a 1981 paper that still offers a range of plausible explanations for Peirce's poor reception in contemporary philosophy of science, Kenneth Laine Ketner argues that philosophers usually approach Peirce as an "interesting failure" in the history of philosophy (Ketner 1981, 55ff). While Peirce's thought tends to attract considerable interest, Ketner explains, the anecdotes about his notoriously temperamental character have been used to support *ad hominem* arguments suggesting that his philosophy would be equally eclectic. Another reason

[1] Peirce, EP1:111.
[2] It is always quite amusing to see what philosophers make of Peirce. Depending on who discusses his work, he is described as a forerunner or supporter of convergent realism, conventionalism, instrumentalism, foundationalism, coherentism, and the list might continue!
[3] For many years, the main difficulty in engaging with Peirce's philosophy has been locating his voluminous corpus of writings. For an account of the vicissitudes of Peirce's writings, and how this affected Peircean scholarship, see especially Burch 2010.

Ketner provides to explain philosophers' ambiguous attitude toward Peirce's writings is their supposedly unsystematic nature. This misleading and still widespread idea is rooted in an exclusive reliance on Peirce's poorly edited *Collected Papers*, which have been for a long time the only source available to philosophers.

Since Ketner's article, over thirty years of Peircean scholarship made full amend for both these criticisms. A major biography of Peirce by Joseph Brent (1998) advances the hypothesis that his notoriously temperamental character might have been the result of a serious condition, facial neuralgia, which caused him days of confinement in excruciating pain, mood swings, and eventually induced him to become dependent on morphine. As to the unsystematic nature of his writings, the poorly edited *Collected Papers* have now long been superseded by the *Writings of Charles Sanders Peirce*, a chronological edition now in eight volumes[4] that has occupied the Peirce Edition Project for the past three decades.

Deeper reasons for Peirce's poor reception, especially in the philosophy of science, are probably to be found in the very nature of his philosophy. Peirce wrote at a time in which the distinction between descriptive and normative accounts in philosophy of science was not a primary concern for philosophers. Even more importantly, in Peirce's time philosophers still accepted that the process of discovering new hypotheses was co-extensive with their justification. Indeed, Peirce's emphasis on what we would now call – following Reichenbach (1938) – the "context of discovery" is probably what compelled philosophers of science to dismiss his thought and writings in the first place.[5]

On the other hand, and perhaps as a result of the painstaking work of the Peirce Edition Project, some aspects of Peirce's philosophy of science are eventually gaining an increased academic visibility. The current revival of interest in Pragmatism in philosophy of science, for instance, is giving great visibility to some of Peirce's most influential papers, such as "The Fixation of Belief" (1877) and "How to make our Ideas Clear" (1878). Other aspects of Peirce's philosophy have occasionally

[4] At present, volume seven of the *Writings* is still in preparation, whereas volume eight appeared in 2010.
[5] Here a note to Laudan's article on why the context of discovery was abandoned by philosophers.

begun appearing in a range of philosophical publications, with various elaborations on his approach to realism and his theory of abduction being some of the topics that philosophers of science seem to find particularly congenial. Strangely enough, however, philosophers of science still seem to refuse to engage with Peirce's philosophy of scientific discovery, which remains the domain of a few specialised Peirce scholars.[6] These, in turn, seem to have paid poor attention to another crucial aspect of Peirce's thought: his history of science.

The aim of this paper is to reconnect these two strands of Peirce's thought – history and philosophy of science – under the heading of a Peircean philosophy of the history of science. I claim that Peirce construed the history of science as *reasoning in action*, and that this view revolves around his fascination (and fixation) with the philosophy of discovery, the logic of science, and with the process of formulating hypotheses. My approach brings together some historically relevant aspects of Peirce's philosophy: abduction, diagrammatic (and more generally "iconic") reasoning, and his pragmati(ci)st account of representations. By placing them at the centre of Peirce's philosophy of the history of science, I hope to advance a new methodological perspective on this neglected aspect of his thought. My account builds on the existing (and now flourishing) Peircean scholarship and is meant to be faithful to Peirce's thought, but at the same time it also aims to place Peirce at the centre of a much broader discussion around the desirability of integrating history and philosophy of science, as well as discovery and justification, into a unified enterprise.

2. Peirce's 29 Lessons from the History of Science

Charles Sanders Peirce is not particularly remembered nowadays for his history of science. While his posthumous fame and legacy as a philosopher, logician and the founder of semiotics attracted the attention of a community of scholars short after his death in 1914, a thorough investigation of Peirce's history of science began

[6] A forerunner of this tradition is Ilkka Niiniluoto, who paved the way to a reception of Peirce – and his approach to discovery – in philosophy of science. See for example Niiniluoto (1999). More recently, Sami Paavola (2006) has presented an account of Peirce's theory abduction that does full justice to the importance of incorporating the context of discovery in philosophical accounts. I will return to Paavola's work later on.

only in the 1950s,[7] and has surprisingly remained a marginal area of inquiry even among Peirce scholars. This is rather unusual, especially considering that in his time Peirce was primarily a practicing scientist and a historian of science, and this is how he was best known among his contemporaries (Fisch 1974, 147).

Almost immediately after graduating in chemistry at Harvard, Peirce joined the U.S. Coast and Geodetic Survey, where he worked from 1859 to 1891. During this time, he was involved in theoretical and practical work on gravimetrics, a branch of geodesy concerned with the measurement of the earth's gravitational field. Part of Peirce's work consisted in carrying out measurements through pendulum swings, an area in which he became progressively more specialised and to which he offered substantial theoretical contributions. Along with his work on geodesy, Peirce pursued also a research interest in astronomy.[8] Drawing on observations he had carried out at the Harvard Observatory, as well as upon existing star catalogues such as Ptolemy's and Tycho Brahe's, Peirce advanced a novel way of using the relative brightness of stars to determine the structure and composition of the solar galaxy (HP, 3; Brent 1998, 105-6). This became the subject of his only book, the *Photometric Researches*, which was published in 1878.

In parallel with his practice as a scientist, Peirce turned to the history of science. In 1892, just after his resignation from the Geodetic Coast Survey, he was invited in Boston to deliver a series of lectures at the Lowell Institute. Peirce entitled them "Lessons from the History of Science".[9] Six years later, in 1898, a prospective publication authored by Peirce on "The History of Science" was announced by the

[7] This was mainly a result of Carolyn Eisele's lifelong dedication to Peirce's mathematics, cartography and his history of science. Along with authoring several articles, books and anthologies, Eisele edited Peirce's *New Elements of Mathematics* (1976), consisting of a four volume edition of Peirce's mathematical writings, and a two-part edition of Peirce's writings on the history of science entitled *Historical Perspectives on Peirce's Logic of Science: a History of Science* (1985).

[8] Peirce's father, Benjamin Peirce, was one of the most renowned mathematicians and astronomers of his time, and one of the founders of the US Coast and Geodetic survey. It is no surprise, therefore, that astronomy played an important role in Peirce's scientific training well before he joined the US Coast and Geodetic survey.

[9] Part of the lectures has been reprinted in CP 1.43 – 1.125 [c1896]. Eisele's 1985 edited collection (here referred to as HP) contains a more structured and systematic edition of Peirce's writings on the history of science based on Peirce's own manuscripts. This material is classified in Richard Robin's (1967) *Annotated Catalogue of the Writings of Charles S. Peirce* (here referred to as RC, or Robin Catalogue). Whenever possible, I will refer to Eisele's HP in the course of this paper.

publishers G.P. Putnam and Sons. Alas, Peirce's History of Science, a 125,000 words volume of which we have an outline and some drafts, was never completed.

It is to Peirce's History of Science that I want to turn my attention. The manuscripts for the lectures and the prospective book show that Peirce looked at the history of science as an invaluable repository of examples of scientific reasoning, which could disclose the process of how hypotheses arise. Through a patchwork of case studies ranging from Egyptian and Babylonian science to Chaldean and Greek astronomy, from Pythagoras and Archimedes to Petrus Peregrinus, Copernicus, Galileo and Kepler, the lectures bring together several strands of Peirce's philosophical thought.[10] His primary concern is to explore the logic of science – logic being understood as "the anatomy of reasoning" (HP1, 143). In this, Peirce's approach seems to contrast sharply with the historical and historiographical attitude of his American contemporaries, which construed the history of science as biographies, eulogies and celebrations, or stories of human interest (Dauben, 1995, 187). At the same time, Peirce's choice to proceed by case studies (at least at the stage in which the lectures and plan were drafted) is far from resembling a philosopher's quest for *ad hoc* episodes in support of a normative argument. History was for Peirce part and parcel of his pragmatic clarification of the process of reasoning that constitutes scientific inquiry. It is in this sense that his history of science can be construed as *logic in action*.

It is no coincidence that Peirce refers to his Lowell Lectures as "Lessons from the History of Science". A comparison of the notes for the lectures with the plan for the book shows that Peirce gradually construed the structure of his prospective publication in a way that would reveal what can be learned from each episode he planned to discuss. Each lesson from history, in turn, seems to correspond to a particular aspect of the complex architecture of Peirce's philosophical thought, history providing the connections between its components.

[10] Peirce's lectures conclude with a biographical note on Kepler, however his drafts of the table of content for the book shows that his plan was to expand his narrative until the late 1890s.

The earliest draft for the table of contents (HP1, 397) focuses mainly on the distribution of words that Peirce intends to assign to each topic. From the outset[11] it is clear that Peirce reserved considerable space to "Generalizations and Lessons" from the historical material contained in his narrative:

General History of Man and Civilisation	10 000 words
Essential Narrative of History of Science	60 000 words
Generalisations and Lessons of the History	30 000 words ------------------
Total essential parts	30 000 words
Extra matter, picturesque, curious, or otherwise going to make the book readable	15 000 words
Chronological table, Indices, Table of Contents, Preface, Appendices	10 000 words -------------------
Grand Total	125 000 words

(HP1, 397)

The following draft for the book, entitled "Notes toward forming a plan of a History of Science in 100.000 Words" (HP1, 401ff), gives a far more detailed view of the "didactic" material that Peirce plans to include in his lessons. Here he begins to extrapolate 29 "lessons" from the history of science, which eventually become the guiding principle of a third (more detailed, but still provisional) draft for the table of contents of the final publication (HP1, 407ff).

Strangely enough, very few Peirce scholars seem to have paid attention to this series of manuscripts, and even fewer of them attempted to assess the relevance and role of Peirce's "29 lessons" within the broader framework of Peirce's thought. The only discussion I have been able to find on this topic is in a 1971 article by Willard M. Miller, published in the *Transactions of the Charles S. Peirce's Society*. Miller

[11] As the manuscripts are undated, I follow Carolyn Eisele's chronological organisation of Peirce's drafts in HP1. These correspond to MS 1290 and 1291 in RC.

insightfully brings together material from several undated manuscripts, and connects them to relevant passages contained in the *Collected Papers*.[12]

I reproduce Peirce's lessons below (with the corresponding references to the two most developed drafts reproduced in HP1) and add some of the contextual implications that appear in Peirce's own writings. My reconstruction of Peirce's 29 lessons builds on Miller's classification, and slightly expands the historical details and their philosophical implications.[13] Each lesson sketched by Peirce corresponds to a particular milestone in his history of science. It is important to point out that some lessons appear to have more substantial implications than others in my reconstruction; this is due to the fact that not all the lessons have an immediate connection to the historical events that Peirce planned to discuss in his history of science. However, in most cases there seems to be a satisfactory correspondence to Chapter 2 of the first volume of Peirce's *Collected Papers* (CP 1.43 – 1.125, c1896), aptly entitled "Lessons from the History of Science", which is a further reprint of Peirce's notes for his prospective publication.

[note: these require further elaboration!]

> "Lesson 1. Scientific curiosity, which Egyptians lacked, essential" (HP1, 407). "Devote 1000 words to pointing out that science cannot flourish [unless] there is a desire to know from pure scientific curiosity without any ulterior purpose to make use of the knowledge" (HP1, 402).
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> "Lesson 2. The Imagination of the Babylonian a help not a hindrance 1000 words" (HP1, 407).
> "Devote 1000 words to pointing out the necessity of imagination in science and that the magic etc. in Babylon as contrasted with the heavy absence of theory in Egypt, (except such as related to practical religion) only helped to make the Babylonians the real authors and nurses of science as they were" (HP1, 402).
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> "Lesson 3. Academic conservatism in China 500 words" (HP1, 407; MS 1291)

[12] In the 1970s the *Collected Papers* were, of course, the only edited collection of Peirce's writings available to scholars. Moreover, it is important to point out that Miller's article precedes Eisele's HP, which appeared only in 1985.

[13] In what follows, I start from MS 1291 (HP1, 407ff), which would appear closer to Peirce's final formulation of his table of contents, and whenever possible I complete each lesson with notes from the earlier draft in HP1, 401-406.

"Devote 1000 words to the deadly influence of academic conservatism upon science" (HP1, 403).

"Lesson 4. Diagrammatic reasoning 1000 words" (HP, 407).
"Devote 1000 words to showing that the only *a priori* reasoning that amounts to anything is diagrammatic reasoning" (HP, 403).

"Lesson 5. Greek Science ruined by their mixing moral, practical with scientific purposes (HP, 408).
"Morality means behaving according to traditional ideas. Hence, morality is essentially conservative. Conservatism becomes a habit and extends itself to opinions, especially before speculation and practical opinions become clearly distinguished, that is to say, in all but the most cultured intellects. Hence, the whole moral weight of the community will be cast against science; because science implies a desire to learn; and a desire to learn implies dissatisfaction with current opinions. Thus, an early development of good morals, and still more of good manners, is unfavourable to science" (HP2, 1118).[14]

"Lesson 6. The Greeks disinclined to abandon themselves to a method without knowing what it would lead to" (HP1, 408).
"Devote 1000 words to show how science is kept back by a disinclination to abandon oneself to methods whose results cannot be foreseen, which is just what science consists in" (HP1, 403).

"Lesson 7. Medieval conception of truth and influence of universities 500 words (to be rearranged)" (HP1, 408).
"Devote 10 000 words[15] to the examination of the medieval conception of truth and heresy and the influence of universities" (HP1, 403).

"Lesson 8. Continuity 1000 words" (HP1, 408).
"Devote 1000 words to the conception of continuity and its scientific importance" (HP1, 403).
"It is not necessary to read far in almost any work of philosophy written by a man whose training is that of a theologian, in order to see how helpless such minds are in attempting to deal with continuity" (CP 1.62).[16]

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[14] Peirce advocates a similar argument in one of his 1898 Cambridge Conference lectures, commissioned by William James and entitled "Philosophy and the Conduct of Life" (RLT 105ff; EP2, 27ff). Peirce's claim there is that adopting the theoretical attitude that characterises the genuine and disinterested scientific inquiry would be absolutely disastrous when applied to practical issues – or matters of "vital importance". These require conservative sentimentalism, instinct and tradition as a basis for practical action, whereas genuine theoretical science is supposed to be a form of radical thinking guided by reason. Yet, Peirce does not divorce completely theory and practice in his argument: instead he implies that conservative sentimentalism in the short run ultimately paves the way to radical theories in the long run. This point has been insightfully illustrated by Short (2001) and Bergman (2009). This last twist, incidentally, seems to suggest that Peirce is also implicitly drawing a sharp separation between James' reformulation of Pragmatism and his own original formulation, subsequently re-named "Pragmaticism".

[15] Given Peirce's obsession with Scholastic philosophy, it is not surprising to see that he might have intended to devote 10 000 words to medieval conceptions of truth. If this was not a typo, though, this decision would have affected the final word count for the manuscript – hence the "to be rearranged" in the following table of content!

"Lesson 9. Do not block the path of experimental inquiry" (HP1, 408)
" …To set up a philosophy which barricades the road of further advance toward the truth is the one unpardonable offense in reasoning, as it is also the one to which metaphysicians have in all ages shown themselves the most addicted" (EP2, 48).

"Lesson 10. Great triumphs of the analytical method [in the physical and psychical sciences]" (HP1, 408-409; HP1, 404)

"Lesson 11. Kepler's [abductive] logic, 1000 words" (HP1, 409; HP1 404)
"…The greatest piece of Retroductive reasoning ever performed" (CP 1.73)

"Lesson 12. Influence of academies [in promoting the study of the useless] (HP1, 409)
"True science is distinctively the study of useless things. For the useful things will get studied without the aid of scientific men. To employ these rare minds on such work is like running a steam engine by burning diamonds". (CP 1.75)

"Lesson 13. The Light of Nature 500 words (HP1, 409)
"Galileo appeals to *il lume naturale* at the most critical stages of his reasoning. Kepler, Gilbert and Harvey – not to speak of Copernicus – substantially rely on an inward power, not sufficient to reach the truth by itself, but yet supplying an essential factor to the influences carrying their minds to the truth" (CP 1. 80)

"Lesson 14. Devote 500 words to the reciprocal influence of Art and Science" (HP1, 404).[17]

"Lesson 15. Success of Modern mathematics due to Generalisation and Abstraction" (HP1, 409; CP 1.82-84).

"Lesson 16. Prominence of Nominalism. Its metaphysical character. Ockham's Razor (HP1, 409).

"Lesson 17. Neglect by the 'critics' to observe appropriate probabilities" (HP1, 409)
"Devote 1000 words to the appropriate standard of certainty in each inquiry" (HP1, 404)

"Lesson 18. That science can only investigate ordinary course of nature" (HP1, 410)

[16] Here Peirce seems to be addressing the negative influence that religious and moral reasoning had on the acceptance of continuity, which Peirce considered as "the leading conception in science" CP 1.62. On the connections between Peirce's logical account of continuity and his history of science see Dauben 1995:165-170.
[17] Lesson 14 does not appear in the following draft, and it is also omitted by the draft of the preface published in CP.

Lesson 19. The rule of Predesignation etc. 2000 words (HP1, 409)
(reasoning from samples, CP 1.92-97)

Lesson 20. Residual phenomena (HP1, 410; CP 1.98)

Lesson 21. Existence does not embrace all reality (HP1, 410)

Lesson 22. Means of observation create science (HP1, 410). Appears as lesson 21 in earlier draft (HP1, 404)
"It will be found upon close examination that that which renders the modes of thought of the students of a special branch of science peculiar is that their experience lies in a peculiar region. And the cause of this is that they are trained and equipped to make a peculiar kind of observations. The man who is continually making chemical analyses lives in a different region of nature from other men. The same thing is true of men who are constantly using a microscope (CP 1.100)
"So too, the great landmarks in the history of science are to be placed at the points where new instruments, or other means of observation, are introduced. Astronomy before the telescope and astronomy after the telescope. Prephotographic astronomy and photographic astronomy. Chemistry before the exact analytic balance, and after. (CP 1.102).

Lesson 23. Evolutionary view of the history of science (HP1, 410)
(here cf. Peirce's evolutionary metaphysics)

Lesson 24. Do not trifle with facts (HP1, 410. CP 1.110)

Lesson 25. The littleness of science (HP1, 411)
(and the paucity of scientific knowledge compared to all there is to know, CP. 116-119)

Lesson 26 Logic of retroduction (HP1, 411).
(Il Lume naturale, CP 1.121)

Lesson 27. Economics of Research (HP1, 411; CP 1.122)

Lesson 28. Advantages of extending methods of one science to another (HP1, 411)
Lesson 29. Prospect of decadence of intellect (HP1, 411)

3. The "Logic of Science" in Peirce's Lessons

In his reconstruction of Peirce's 29 lessons from history, Miller (1971) proposes an interpretation of Peirce's history of science almost entirely based on his evolutionary metaphysics. In doing so, he relates the lessons to five articles published by Peirce in *The Monist* between 1891 and 1893. The articles, also known as "The

Monist Metaphysical Series" (EP1, 285-371), represent one of the most systematic accounts of Peirce's metaphysics. From the outset, Peirce poses historical inquiry at the very basis of his attempt to apply a thoroughgoing philosophical evolutionism to metaphysical questions. It is no surprise, therefore, that among Peirce's 29 lessons, the one that gains most visibility in Miller's account is lesson 23, "Evolutionary view of the history of science" (HP1, 410).

Without playing down the importance of Peirce's evolutionist philosophy, I would like to offer a different interpretative angle for Peirce's philosophy of the history of science. What does not seem to figure at all in Miller's account is in fact Peirce's concern for the logic of science and the philosophy of scientific discovery. I would like to suggest that Peirce's philosophy of the history of science is at least as much related to these two key aspects of his thought as it is to his evolutionist metaphysics.

In its narrower sense, Peirce's "logic of science" concerns the connections between three types of inference – induction, deduction and abduction – and their role in scientific reasoning. But "logic" has a much broader meaning for Peirce. In a fragment dated 1897, almost simultaneous to his writings on the history of science, Peirce identifies logic with *semiotics*, which he describes as follows:

> "Logic, in its general sense, is…the quasi-necessary, or formal, doctrine of signs. By describing the doctrine as "quasi-necessary" or formal, I mean that we observe characters of such signs as we know, and from such an observation, by a process which I will not object to naming Abstraction, we are led to statements, eminently fallible, and therefore by no means necessary, as to what *must be* the characters of all signs used by a "scientific" intelligence, that is to say, by an intelligence capable of learning by experience".
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> (CP 2.227 [1897])

Peirce included logic among the "normative sciences".[18] However, it is clear from the passage above that he did not identify "normative" with "prescriptive", nor did he characterize it as a plain description of reasoning patterns. His definition of logic aims at reconciling the observational and the theoretical, thus providing a practice-based description of the norms that make reasoning perspicuous and reliable.

[18] See for example his classification of the sciences in EP2, chapters 14 and 18.

The identification of logic with semiotics is important for my claim that Peirce construed the history of science as *reasoning in action*. Peirce thought that it is from the practice of reasoning, and its unfolding through history, that we derive any normative lessons on what makes scientific inquiry valid, economic and fertile. This point becomes particularly evident if one looks at the ways in which Peirce derived his historical lessons from the practices of reasoning of the actors of his historical case studies.

An evident aspect of Peirce's lessons is that most of them hinge on concrete examples of scientific reasoning. This is evident from the outset of his historical narrative. For example, in discussing Egyptian science, Peirce plunges into a detailed analysis of the Rhind Papyrus, criticising the Egyptians' exclusive reliance on unit fractions (HP1, 331ff) and dismissing the value that they assigned to π (approximately 3.16) as "the worst evaluation of π known to the history of mathematics" (HP1, 346). For Peirce these were first and foremost indications of the limitations of the eminently "practical" reasoning of the Egyptians, who lacked the necessary theoretical curiosity resulting in genuine inquiry for inquiry's sake (as Peirce explains in his lessons 1 and 2).

At the same time, Peirce's analysis of Egyptian science is also a meta-evaluation of the methods and modes of reasoning that characterise the field of Egyptology. Thus, he sets to review a number of studies of the Great Pyramid, on which, he claims "more learned foolishness has been written…than upon all other subjects" (HP1, 152). The only works that pass Peirce's critical evaluation are Howard Vyse's (1837) *Operations at the Great Pyramid*, Charles Piazzi Smyth's (1867) *Life and Work at the Great Pyramid from Jan. to April 1865,* and W. M. Flinders Petrie's (1883) *The Pyramids and temples of Gizeh*. The target of Peirce's criticism is the explanation (which saw the astronomer John Herschel among its supporters) that the slope in the entrance gallery of the pyramid was cut at the centre of the pyramid on the northern side, in alignment with the polar star (HP1, 155). With his usual wit, Peirce recalculates the angle of the slope, revealing that the "practical reasoning" of the Egyptians would have compelled them to neglect completely the polar star and its astronomical implications, and build the entrance simply in a way

that would facilitate the operation of carrying a heavy sarcophagus through the narrow passage (HP1, 332).

Egyptian science is not the only case in which Peirce indulges in elaborate methodological considerations on the practice of history. With reference to Greek mathematics, for instance, Peirce presents a long digression on the conflicting evidence surrounding the existence of Pythagoras (HP1 209ff), and the credibility of the documents reporting that he had a golden thigh. Behind the peculiar connotations of his case study, Peirce explicitly states that his interest in Pythagoras is of a logical nature:

> "One thing that interests me particularly in regard to Pythagoras is that we are in possession of a great mass of testimony concerning him, which is extremely conflicting and all of it decidedly of an untrustworthy description, and it becomes a nice question for the scientific logician, what can be concluded from this evidence" (HP1, 209-10).

For Peirce, it is at this stage that logic can fruitfully come to the rescue of the historian. These preliminary considerations on the nature and reliability of historical hypotheses eventually converged in a monograph that Peirce wrote in 1901, entitled *On the Logic of Drawing History from Ancient Documents, especially from Testimonies* (EP2, 75-114; HP2, 705-800). In the monograph, Peirce advocates the use of the method of experimental science as a method for the selection of historical hypotheses. His argument is that historians need an alternative to the unreliable practice of basing their hypotheses exclusively on subjective likelihoods. That would amount to using pre-conceived ideas to block the way of inquiry (which clearly conflicts with his lesson 9). Conversely, the acceptance of certain historical hypotheses demands a method whose logic would admit the choice of a fallible explanatory hypothesis, at the same time leaving the door of inquiry open.

There are several other instances in which Peirce's inquiry into the logic of science informs his 29 lessons from history. Lessons 11 (Kepler), 13 (Galileo and *il lume naturale*) and 26 (logic of Retroduction) are explicitly about the formulation of novel hypotheses. What Peirce is obviously referring to here is his theory of abduction (or retroduction, or hypothesis), which has notoriously been (and continues to be, to a

certain extent) at the centre of philosophical debates over the possibility of a "logic of discovery".[19]

Peirce's early writings on abduction date at least as far back as 1878, when he published the paper "Induction, Deduction and Hypothesis" for the series *Illustrations of the Logic of Science* in *Popular Science Monthly* (EP1, 186-199). The papers "The Fixation of Belief" (1877) and "How to Make our Ideas Clear" (1878), in which Peirce laid the foundations of his pragmatism, were published in the same series (EP1, 109-141). That the question of abduction was complementary to the formulation of pragmatism is testified by the fact that by 1903, concomitantly with the publication of his mature theory of abduction, Peirce does not hesitate to state that pragmatism itself "is nothing else than the question of abduction" (EP2, 234).

In Peirce's mature formulation, abduction is the process of suggesting hypotheses, starting from the observation of "surprising phenomena":

> The surprising fact, C, is observed;
> But if H [an explanatory hypothesis] were true, C would be a matter of course,
> Hence, there is reason to suspect that H is true (EP2, 231).

For Peirce, abduction consists in the observation of an anomalous fact, the formulation of a fallible explanatory hypothesis, and the provisional acceptance of that hypothesis, subject to testing. It is not surprising that Peirce's model of how hypotheses arise has been the target of criticism, especially by philosophers of science. For one thing, abduction seems a particularly weak form of inference – one that does not guarantee any necessary conclusion. Secondly, the events leading to the formulation of a certain hypothesis seem to elude any form of conceptual analysis (Paavola 2006, 96).

In response to these criticisms, Peirce scholars have elaborated various ideas on how to support Peirce's formulation. Sami Paavola (2005, 2006), for instance,

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[19] See for instance Laudan 1980 and Nickles 1980; Kapitan 1992, and for a more recent account of abduction and discovery Paavola 2006. A strenuous defender of the rationality of abduction was Norwood Russell Hanson (1958). Lund 2010 proposes a reinterpretation of Hanson that does full justice to the Peircean roots of his approach to abduction and discovery.

offers a reinterpretation of the processual nature of abduction that accounts for the process of inquiry surrounding it, rather than limiting its interpretation to the relations between the premises and the conclusion. Jaime Nubiola (2005) offers an interpretation of abduction as a "logic of surprise" – surprise being the beginning of any genuine process of inquiry. Surprise and wonder, Nubiola claims, require a change in our habit or belief, thus triggering the "irritation of doubt" (EP1, 114) that according to Peirce sets inquiry into motion (Nubiola 2005, 124).

I propose that the most desirable way to make sense of abduction is by regarding it as a process that has to be investigated through historical means. With this, I am not claiming that abduction should be excluded from the philosopher's agenda. Instead, I claim that any normative lesson on the value of abductive reasoning should be derived from a historical investigation of the concrete circumstances in which that form of reasoning occurs – just as Peirce did in his 29 lessons from history. In this sense, abductive reasoning would have the potential of becoming a further ground for the integration of history and philosophy of science, a prospect that Peirce would have welcomed enthusiastically.

This claim is compatible with the recent literature that regards abduction as a process, rather than a relation between premises and conclusions. More importantly, Peirce's own treatment of abduction hinges strongly on historical inquiry, which he regarded as complementary to his analysis of the logic of science. Thus, investigating abduction through historical means is the first step to assess in which sense Peirce's philosophy of the history of science offers an account of history as *reasoning in action*. This is also an important occasion to reconcile Peirce's historical work with his logical, epistemological and metaphysical writings.

Peirce's discussion of Kepler and Galileo, and his inclusion of their methods of reasoning among his 29 lessons offers good support to my claim. His account of how Kepler arrived at the hypothesis of the elliptical orbits of Mars begins from a historical account of the circumstances surrounding Kepler's discovery. Historical inquiry for Peirce is a way of investigating the practice of reasoning as it concretely

takes place in scientific inquiry. This historical evaluation shows first of all that hypothesis generation is not a capricious matter, but is instead a rational process:

> "Thus, never modifying his theory capriciously, but always with a sound and rational motive for just the modifications he makes, it follows that when he finally reaches a modification – of most striking simplicity and rationality – which exactly satisfies the observations, it stands upon a totally different logical footing from what it would if it had been struck out at random…Kepler shows his keen logical sense in detailing the whole process by which he finally arrived at the true orbit. This is the greatest piece of retroductive reasoning ever performed"
> (CP 1.74 [c1896])

But Peirce's account of Kepler's discovery combines logic and history in another important sense. In (give details of paper, from CP vol. 2), he describes Kepler's reasoning as follows:

> "For example, at a certain stage of Kepler's eternal exemplar of scientific reasoning, he found that the observed longitudes of Mars, which he had long tried in vain to get fitted with an orbit, were (within possible limits of error of the observations), such as they would be if Mars moved in an ellipse".
> CP 2.53 [needs date]

What Peirce is suggesting here is that Kepler directed his reasoning toward the practical consequences that would follow from his embracing the hypothesis of the elliptical orbits of Mars. More generally, in science as well as in history, Peirce points out that the first entertaining of a hypothesis occurs in parallel with a consideration of the practical consequences that the adoption of that hypothesis would have upon future conduct and further inquiry. This is just what lies at the core of Peirce's pragmatism. His pragmatic maxim, originally formulated in the paper "How to Make our Ideas Clear" (1878) states that there is a tight connection between our conceptions and their practical effects upon our conduct:

> "Our idea of anything *is* our idea of its sensible effects…consider what effects, which 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". (EP1, 132)

This is an important sense in which Peirce's account of the history of science qualifies as an account of *reasoning in action* – that is, reasoning that involves experimenting upon the conceivable effects of adopting a certain hypothesis. In the introduction to

Historical Perspectives on Peirce's Logic of Science, Carolyn Eisele shows that the same connection between conceptions and their practical effects theorised by Peirce ultimately regulates the construction of geometric proofs:

> 1. "Construct an icon, the relation of whose parts is determined by the premises;
> 2. Experiment upon the *effects* of modifying this diagram. The probable modification is a construction;
> 3. Observe in this experiment certain relations between parts of the enlarged diagram over and above those which sufficed to determine its construction;
> 4. Satisfy oneself by inductive reasoning that these new relationships would always subsist where those in the premises existed."
>
> (HP1, 11)

It is particularly important to notice that the construction of an "icon" does not apply exclusively to reasoning in geometric proof. Peirce applied this very model to Kepler's reasoning, hinting at a connection (which, as we will see, will remain ambiguous) between abduction and what he calls diagrammatic reasoning:

> "All endowments of Keppler's intellect and heart seem to have been concentrated upon one function, that of reasoning. In his great work on Mars, he has laid bare to us all the operations of his mind during the whole research…His admirable method of thinking consisted in forming in his mind a diagrammatic or outline representation of the entangled state of things before him, omitting all that was accidental, retaining all that was essential, observing suggestive relations between the parts of the diagram, performing diverse experiments upon it, or upon the natural objects, and noting the results"
>
> (HP1, 294)

Kepler's reasoning in this passage seems to hinge on the formation of a mental image – or in Peirce's terms a mental icon – of the structure of the problem he was trying to solve. Starting from that iconic representation, which is mostly a representation of abstract relations, Kepler then proceeds to experiment with its possible consequences. Indeed, this is not the only time in which Peirce uses the notion of iconicity to characterise the process of abduction. Occasionally, he uses iconicity synonymously with a concept of *likeness* to explain the relation of intelligibility between the premises and the provisional conclusion of abductive reasoning. In the case of Kepler's abduction, for instance, he states:

> "The facts were thus, in so far, a *likeness* of motion in an elliptic orbit. Kepler did not conclude from this that the orbit was an ellipse; but it did incline him to that idea so much as to decide him to undertake to ascertain whether virtual predictions about the latitudes and parallaxes based on this hypothesis would be verified or not".
>
> CP 2.96 (date?)

More generally, one of the ways in which Peirce explains abduction from a quasi-logical point of view is by claiming that the iconic relation connecting the premises and the conclusion is what eventually induces us to accept the conclusion and use it as a basis for further inquiry:

> "Abduction is an argument which presents facts in its Premiss which present a similarity with the facts stated in the Conclusion, but which could perfectly well be true without the latter being so, so much more without being recognized; so that we are not led to assert the conclusion positively, but are only inclined toward admitting it as representing a fact of which the facts of the Premiss constitute an *Icon*"
>
> CP 2.96 (date)

Peirce's theory of iconicity (and its connections with resemblance or likeness) requires a separate discussion which is beyond the scope of this paper.[20] What seems crucial in Peirce's discussion is that iconicity seems a key concept to understand how abduction makes phenomena intelligible. A successful attempt at examining the connections between abduction, iconicity and Peirce's characterization of perceptual judgments is in Paavola (forthcoming). Paavola claims that in all three cases "clue-like signs" are used as suggestions toward a unifying connection between previously unconnected phenomena (ibid. p.13). More importantly, Paavola attempts at connecting the iconic nature of abduction with another central aspect of Peirce's thought: his theory of diagrammatic reasoning. Diagrams are the last tile in the complex mosaic of Peirce's view of the logic of science as reasoning in action, and it is to this aspect of his thought that I briefly turn in the next section.

4. "Reasoning in Action" and "Moving Pictures of Thought"

Peirce considered diagrams to be at the heart of all reasoning – so much so that by 1896 he began developing his visual system of Existential Graphs, a heterogeneous system of logic which he claimed should put before us "moving

[20] I have attempted to spell out Peirce's concept of iconicity in Ambrosio 2008, 2010 and forthcoming.

pictures of thought" (CP 4.8, c1905; Pietarinen 2006, 103). Peirce's system of diagrams is divided roughly in three parts. The alpha part corresponds to propositional logic, the beta part to predicate logic and the gamma part (which is incomplete) should include modalities, higher-order notions and meta-reasoning about the graphs themselves (Pietarinen 2006, 111). Peirce seems to have planned a delta part, too, which should have extended beyond assertions, possibly to include aesthetic judgments, but that part of the graphs was never realised (Pietarinen 2006).

An open question regarding Peirce's account of diagrammatic reasoning concerns its relations with abductive reasoning (Paavola forthcoming, 7). Peirce claims that diagrams are at the basis of all necessary reasoning, and this would suggest that they have little to do with abduction. Even when one looks at the history of science that Peirce was writing almost in parallel with the development of his new logical system, diagrams seem to have a place which is clearly separated from abduction. His fourth lesson, for instance, states that "the only *a priori* reasoning that amounts to anything is diagrammatic reasoning" (HP1, 403). Most Peirce scholars interpret Peirce's diagrams exclusively from the viewpoint of necessary deductive reasoning (Hintikka 1998; Hoffmann 1999), and only some allow a place for abduction in the process of *constructing* diagrams, clearly relegating its role to the pre-diagrammatic stages of reasoning (Stjernfelt 2000; Paavola forthcoming).

Independently of whether diagrammatic reasoning should include abduction, Peirce's characterization of diagrams proves the uniqueness of his approach to logic as *reasoning in action*. The graphs incorporate Peirce's effort to capture the fact that the norms of logic arise from the very process of reasoning. Construed by Peirce as "moving picture[s] of the action of the mind in thought" (MS 298,1, 1905), diagrams are among the most representatively fertile forms of iconic reasoning. The efficacy of diagrams consists of the process that they trigger in the interpreter's mind – and this seems to suggest that they are indeed connected to the formulation of novel hypotheses. Peirce explained this feature of diagrams in connection with the iconic nature of paintings in an illuminating passage of his 1885 *Algebra of Logic*:

> "A diagram, indeed, so far as it has a general signification, is not a pure Icon; but in the middle part of our reasoning we forget the abstractness in great

> measure, and the diagram is for us the very thing. So, in contemplating a painting, there is a moment when we lose the consciousness that it is not the thing, the distinction of the real and the copy disappears, and it is for the moment a pure dream –not any particular existence and yet not general. At that moment we are contemplating an *Icon*" (EP1, 226).

Perhaps the key to the relationship between diagrams, abduction and the logic of discovery might have come from Peirce's never even attempted system of delta graphs, which promised to address aesthetic judgments in a logical context.

Peirce had explored in detail the potential and implications of his "moving pictures of thought", even though he only did in a purely hypothetical form. In 1911, only three years before his death, he announced that his system could have far greater implications:

> "It was about 1870 – I don't think it could have been as late 1872 – that I invented the word "pragmatism" to mean that way of thinking as consisting not necessarily in talking to oneself because an algebraist like Boole plainly thought in algebraic symbols; and so did I, until, at great pains, I learned to think in diagrams, which is a much superior method. I am convinced that there is a far better one, capable of wonders; but the cost of the apparatus forbids my learning it. It consists in thinking in stereoscopic moving pictures".
>
> (NEM:3,191 [1911])

It would be tempting to apply Peirce's method to this hypothetical state of things and imagine the conceivable consequences of adopting Peirce's method of thinking in stereoscopic moving pictures!

Even without their final stereoscopic evolution, Peirce's existential graphs complete the picture of his approach to logic and its role in the process of discovery. The approach that Peirce pursues in his Graphs, and more generally in his logical writings, seems to suggest that he ultimately reconnected logic to its original formulation as *logos* – "thought" or "reasoning", construed in their broadest possible sense. If this is the case, Peirce's account of how hypotheses arise *does* qualify ultimately as a *logic* of discovery. As a logician, Peirce was inevitably committed to valid and sound forms of reasoning, but this did not prevent him from stretching the boundaries of logic as to capture the dynamic nature of reasoning processes in their

concrete historical development. It is in this sense that is history of science qualifies as a history of *reasoning in action.* The price Peirce scholars pay for this is, of course, an extreme ambiguity when it comes to the forms of inference that diagrammatic reasoning may extend to. But Peirce's own ambiguity over whether diagrammatic reasoning should include abduction appears to be only another instance in which Peirce decided to leave the door of inquiry open to novel theoretical possibilities.

Conclusions

I attempted to reconnect Peirce's history and philosophy of science under the heading of a Peircean philosophy of the history of science. I claimed that Peirce construed the history of science as *reasoning in action*, and that this view brings together various strands of his thought which still pose problems for philosophers of science: his philosophy of discovery, the logic of science, and the process of formulating hypotheses. Peirce investigated the logic of science as it unfolds through the concrete practices of reasoning of its practitioners, and it is in this sense that I claim he construed the history of science as *reasoning in action*. This is particularly obvious in his account of abductive reasoning, and it emerges also in the dynamic account of reasoning presented in his unfinished system of Existential Graphs.

In a Peircean spirit, I construed this paper as the beginning of a process of inquiry into Peirce's history of science, disclosing only a minimal part of the range of case studies contained in his works. I consider this only as a preliminary step – but an important one – to bring to light the invaluable contribution that Peirce has to offer to the history and philosophy of science and to any productive interactions between these two fields.

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