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Charles S. Peirce (ed.)

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Charles S. Peirce

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and a Preface by Achim Eschbach

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Charles S. Peirce
(Probably this photograph was taken not later than 1884, not much earlier than 1879, perhaps between those years.)

PEIRCE AS SCIENTIST, MATHEMATICIAN, HISTORIAN, LOGICIAN, AND PHILOSOPHER*

MAX H. FISCH

At a bicentennial international congress devoted to Peirce and held in Europe, we may well begin by remarking that Peirce himself was in Europe in the centennial year 1876. He was then on the second, the longest, and the most productive of his five European sojourns in the service of the Coast and Geodetic Survey, at that time the chief scientific agency of the United States Government. Peirce was in the first place a scientist, and his career was in the service of that agency. The years of Peirce's five European sojourns were: (1) 1870-1871; (2) 1875-1876; (3) 1877; (4) 1880; and (5) 1883.The five sojourns together added up to nearly three of those thirteen years.[1]

I. The Scientist

The occasion for Peirce's first European sojourn, that of 1870-1871, was an eclipse of the sun on December 22, 1870, whose path of totality was to pass through the Mediterranean. The last previous eclipse had been in the United States in the preceding year, and Peirce had been one of the observers there. The observations of the sun's corona and of its protuberances had prompted new theories as to the composition of the sun, but there was some scepticism about these theories among European astronomers. The eclipse of 1870 would provide an opportunity for an early test of them. There would not be another so favorable in the nineteenth century, and Germany, France, Great Britain, Italy, and Spain planned expeditions. The United States Congress appropriated funds for an expedition under the Coast Survey, and Peirce was

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sent over six months in advance to visit possible sites for observation parties and to make recommendations and begin arrangements. From London, shortly after the Vatican Council had declared the conditions of papal infallibility, and just as the Franco-Prussian War began, Peirce journeyed eastward by way of Rotterdam, Berlin, Dresden, Prague, Vienna, Pest, the Danube, and the Black Sea, to Constantinople. Then he began moving westward along the path of totality in search of eligible sites. He recommended sites in Sicily and southern Spain, and became himself a member of one of the Sicilian teams.

On the whole, the American observations and inferences of the preceding year were vindicated. This was Peirce's first experience of large-scale international scientific cooperation. He had already committed himself to the social theory of logic, but this experience and that of his four later European sojourns confirmed him in that commitment.

Between 1871 and 1875, the Coast Survey made Peirce responsible for two fields of research: photometric studies of the stars of a region of our galaxy, with a view to a more accurate determination of the shape of the galaxy; and pendulum-swinging determinations of absolute and relative gravity at stations in Europe and in the United States, with a view to a more accurate determination of the figure of the earth.[2]

By 1875, the greater part of the photometric researches was completed, but he had still to make a more thorough study of earlier star catalogues. During his second sojourn in Europe (1875-1876), he examined medieval and renaissance manuscripts of Ptolemy's star catalogue in several libraries. He also made inquiries as to the methods used in the preparation of the most recent star catalogue, the *Durchmusterung* of Argelander and Schönfeld at the Bonn Observatory. Peirce's book, *Photometric Researches* (1878), included his own edition of Ptolemy's catalogue, as well as a long letter from Schönfeld concerning the methods of the *Durchmusterung*.

The chief purpose of his second sojourn, however, was to accept delivery from Repsold and Sons in Hamburg of a reversible pendulum apparatus suitable for absolute determinations of gravity, and to make such determinations at so-called "initial stations" in Europe; namely, those at Berlin, Geneva, Paris, and Kew. In April 1875 at the new Cavendish laboratory in Cambridge, England, he consulted Maxwell about the theory of the pendulum. At Hamburg in late May and early June, he took possession of the Repsold pendulum and made preliminary tests of it. He then conferred in Berlin with General

Baeyer, founder and president of the Royal Prussian Geodetic Institute, who questioned the stability of the Repsold stand. Peirce went next to Geneva. By arrangement with Professor Plantamour, Director of the Observatory, he swung his new pendulum there, and detected and measured the flexure of the stand that General Baeyer had suspected.

The first international scientific association was geodetic. Its founding conference was at Berlin in 1864. In the French form of its name, it was called international from the beginning. In the German form, it was called at first middle-European, then European, and only in 1886 did it begin to be called international. Conferences were held every third year, but there was a "Permanent Commission" or standing comittee that met annually. There was also a Special Committee on the Pendulum. In September 1875, the Permanent Commission met for ten days in Paris. On one of those days there was also a meeting of the Special Committee on the Pendulum, at which Peirce reported his Geneva findings. The Special Committee reported to the Permanent Commission. Peirce took part in the discussion of its report. He thus became the first invited American participant in the committee meetings of an international scientific assocation.

Later in 1875 and in 1876, Peirce swung his new pendulum for extended periods in Paris, in Berlin, and at Kew; and, after his return to the United States, at Stevens Institute in Hoboken. The Coast Survey's Report for the year 1876 contained 145 pages by Peirce on "Measurements of Gravity at Initial Stations in America and Europe," on the second page of which he said: "The value of gravity-determinations depends upon their being bound together, each with all the others which have been made anywhere upon the earth. ...Geodesy is the one science the successful prosecution of which absolutely depends upon international solidarity."

The next general conference of the International Geodetic Association was held at Stuttgart in late September and early October of 1877. By invitation, Peirce had sent well in advance a memoir in French on the effect of flexure of the Repsold stand on the oscillations of the reversible pendulum. This memoir and others by Plantamour and his colleague Cellérier confirming Peirce's findings were published as appendices to the proceedings of the conference. Peirce attended the conference as accredited representative of the United States Coast and Geodetic Survey. That was the first formal representation of an American scientific agency in the sessions of an international scientific association. During the discussions, Hervé Faye, president of the Bureau of Longitudes in Paris, suggested that swaying of the stand could be prevented by swinging from the same stand two pendulums with equal amplitudes but in opposite phases. Peirce later made an analytic mechanical investigation of Faye's proposal, concluding that it was as sound as it was brilliant. Copies of this investigation were distributed at the 1879 meeting of the Permanent Commission.

Peirce was active in still other fields that called for international cooperation. One of these was metrology. Until the establishment of the National Bureau of Standards in 1901, the United States Office of Weights and Measures was a department of the Coast Survey. The American Metrological Society had been founded in 1873, and two years later, Peirce had become a member of its Committee on Units of Force and Energy. When he was elected to the National Academy of Sciences in April 1877, he was immediately made a member of the Academy's Committee on Weights, Measures, and Coinage.

There were close connections between gravitational and metrological researches. Accurate determinations of gravity depended on accurate measurements of the lengths of pendulums. Peirce swung yard and meter pendulums for a fresh determination of the relation between the yard and the meter. At a meeting of the Permanent Commission during the Stuttgart Conference of 1877 he proposed the use of a wavelength of light to measure the standard yards and meters and to detect and measure changes in their length. This project, which involved the use of diffraction gratings, came to be called that of "the spectrum meter." Peirce made rapid progress on it during the next three years. He returned to Europe early in May 1880, authorized to remain through December if necessary. He was expected to attend the sixth general Conference of the Association at Munich in September, and to report there both on his latest gravity researches and on "the spectrum meter"; but he was called home in July by his father's final illness. He did, however, address the French Academy of Sciences on 14 June on the value of gravity at Paris, correcting an error in the then accepted value. The discussion of his paper was resumed a week later, with Peirce again present.

Peirce's fifth and last European sojourn was from May to September 1883. One of his many tasks was to obtain from Breguet's in Paris an instrument for determining the flexure of the pendulum stand. Another was to obtain from Gautier's in Paris two pendulums designed by Peirce himself to eliminate a cause of flexure inherent in the structure of previous pendulums. Still another was to compare the Coast Survey's Standard Yard No. 57 with the Imperial Yard No. 1, and also with the Iron Yard No. 58, at the British Standards Office in London.

More than a month after Peirce had returned from this final sojourn, the Seventh Conference of the International Geodetic Association was held at Rome in mid-October 1883. At that Conference, Professor von Oppolzer of the Austrian Survey made a comprehensive and critical report on different forms of apparatus for the determination of gravity. He reviewed the problem of flexure of the Repsold stand and stated that the solution proposed by Faye and shown by Peirce to be theoretically sound — namely, to swing two pendulums from the same stand with equal amplitudes but in opposite phases — was a solution in the right direction, but was not practicable.

Impracticable it was generally taken to be, for reasons chiefly of economy, for the next thirty years. But during the gravity survey of Holland in the years 1913-1921, because the mobility of the soil rendered the pendulum supports more unstable there than elsewhere, Vening Meinesz finally adopted the Faye-Peirce method and found that it solved the problem. Meeting as we are in Holland, it is fitting that we should take note of the fact that this first of several posthumous vindications of Peirce's scientific work took place here.

Meanwhile the United States Coast and Geodetic Survey had entered a long decline, mainly because of pressure from Congress to make drastic cuts in expenditures for instruments, for field work, and for travel. Shorter and more easily portable pendulums were adopted, but Peirce was unwilling to use them because the results would no longer be comparable in precision with those of the best European researches. His last trip to Europe had been in 1883; his last field work at home was in 1886. On 25 November 1889, Annibale Ferrero of the Italian Survey, who had coached Peirce in Italian, wrote him from Florence that, under such discouraging circumstances, the best place for him would be in the central office of the International Geodetic Association in Berlin. But Ferrero's efforts to that end were fruitless; Peirce's Survey appointment was terminated at the end of 1891, after thirty-one and a half years of service. In the remaining twenty-three years of his life he had no regular salaried employment.

Peirce now set up in private practice as a chemical engineer, thereby returning to the profession to which he had committed himself before he entered the service of the Coast Survey, and from which his career in the Survey had been a diversion. This brings me to the question how Peirce came to be a scientist, and more particularly a chemist, and how his diversion from chemistry to astronomy and geodesy, and thence to metrology and other sciences, came about.

He grew up in the scientific circle in Cambridge, Massachusetts, in the 1840's and 1850's. His father, Benjamin Peirce, was professor of astronomy and mathematics in Harvard College, and was one of the moving spirits behind the establishment there of the Lawrence Scientific School in 1847. Eben Norton Horsford had then recently returned from two years at Giessen studying chemistry under Liebig, who combined laboratory instruction with demonstration experiments during lectures. To Liebig more than to anybody else it was due that the experimental method of teaching was more highly developed in chemistry than in any other science, so that the study of chemistry offered at that time the best entry into experimental science in general. Horsford was now made professor of chemistry in the Lawrence Scientific School, where he developed, on the Liebig model, the first laboratory in America for analytical chemistry. Peirce's uncle, Charles Henry Peirce, until then a practising physician in Salem, became Horsford's assistant. Horsford encouraged him to translate Stöckhardt's *Principles of Chemistry, Illustrated by Simple Experiments* for textbook use. Peirce's aunt, Charlotte Elizabeth Peirce, whose German was excellent, did most of the actual work of translation. During the years in which the chemical laboratory was being established and the translation was in progress, Peirce's uncle and aunt helped him set up a private laboratory at home and work his way through Liebig's hundred bottles of qualitative analysis (*MS* 619.6). In 1850, when the translation appeared, Peirce, then eleven, wrote "A History of Chemistry" (*MS* 1634.5). In that year, his uncle became federal inspector of drugs for the port of Boston. Two years later, in 1852, he published *Examinations of Drugs, Medicines, Chemicals, &c., as to their Purity and Adulterations*, giving some of the results of his official labors. Not long before Peirce entered Harvard College in 1855, his uncle died, and Peirce inherited his chemical and medical library. His college teacher of chemistry was Josiah P. Cooke, who had founded the undergraduate departments of chemistry and mineralogy just five years earlier. The textbook used in chemistry was Stöckhardt's, as translated by Peirce's aunt and uncle.

In his freshman year at college, Peirce began intensive private study of philosophy with Schiller's *Aesthetic Letters* (*MS* 1634.6). From that he moved on to Kant's *Critic of the Pure Reason*. In his later college years, while continuing with Kant, he added modern British philosophy. But all the while, as he later said, he "retained...a decided preference for chemistry" (*MS* 1606.11), and it was well understood in the family that he was headed for a career in chemistry. He suffered so from ill health during his senior year, however, that an interval of outdoor employment seemed desirable before he proceeded further. His father was Consulting Geometer to the Coast Survey and a personal friend of its Superintendent, Alexander Dallas Bache. Bache offered Peirce a place in his own field party in Maine in the fall of 1859, and in another field party around the delta of the Mississippi in the winter and spring of 1860. In early August 1859, before joining Bache's party, Peirce spent a week at Springfield reporting sessions of the American Association for the Advancement of Science for six issues of the Boston *Daily Evening Traveler*.

During Peirce's absence in Maine and Louisiana, Darwin's *Origin of Species* appeared (*CP* 5.64; *NEM* 3:155), and also a separate edition of Agassiz's *Essay on Classification*. Chemistry was an experimental, but also a classificatory science. Biology was the chief other classificatory science. The differences between these two sciences were being brought into focus by the controversy between supporters of Darwin and supporters of Agassiz. In the latter half of 1860, while serving as proctor and tutor at Harvard College, Peirce was for six months a private student of Agassiz's, to learn his method of classification (*MS* 1634.6; *SS* 114; *NEM* 4:64).[3]

In the spring term of 1861, Peirce at last entered the Lawrence Scientific School. Two and one half years later he became its first summa cum laude Bachelor of Science in Chemistry. But during his first term the Civil War had begun, and his father had lost, by resignation, the computing aide who assisted him in his chief service to the Coast Survey, that of determining the longitudes of American in relation to European stations from occultations of the Pleiades by the moon. Peirce asked his father to obtain that appointment for him. His father wrote Superintendent Bache that he had at first urged his son to "keep to his profession and wait till he could get money by his chemistry — to which he replied that he wants to get the means to buy books and apparatus and devote himself longer to the study of his profession."[4] Bache authorized Peirce's appointment as aide beginning 1 July 1861, and he was launched on the career that occupied his next thirty and one-half years and took him from chemistry into astronomy, geodesy, metrology, spectroscopy, and other sciences. To the indications already given of his eminence in some of them, I may add that his father proposed him for the chair of physics at The Johns Hopkins University to which Henry Augustus Rowland was appointed, and that he was the first modern experimental psychologist on the American continent.

Throughout those thirty and one-half years and on beyond them, however, when he had occasion to state his profession, or even his occupation, he continued to call himself a chemist. His first professional publication in 1863 at the age of 23, was on "The Chemical Theory of Interpenetration." In later years, he found in Mendeleev's work on the periodic law and table of the elements the completest illustration of the methods of inductive science (*MS* 315.24). And he took satisfaction in having, in June 1869, when he was not yet thirty, published a table of the elements that went far in Mendeleev's direction, before Mendeleev's announcement of the law, a little earlier in that same year, became known in western Europe and America (*MS* 1042.1). At that year's meeting of the American Association for the Advancement of Science it was remarked that Peirce "had greatly added to the illustration of the fact of pairing by representing in a diagram the elements in positions determined by ordinates representing the atomic numbers."[5]

I now conclude this brief sketch of Peirce as scientist by remarking that the words "scientist" and "physicist" — two of the ugliest in English — were both coined by William Whewell and were put forward together, in the year after Peirce's birth, in *The Philosophy of the Inductive Sciences*. Peirce later came to admire that work, but he was never quite comfortable with "physicist," and was far less so with "scientist." "Physicist" was at least all Greek, but "scientist" was an ill conceived Latin-Greek hybrid. He much preferred the older phrases "scientific man" and "man of science." It must have pleased him that in 1906 his friend and former student, the psychologist James McKeen Cattell, gave the title *American Men of Science* to the biographical directory in which Peirce was starred and the full range of his work was most succinctly and accurately stated. But we ourselves, living in a time when male chauvinism is under continual attack, and in which recent editions of that directory bear the title *American Men and Women of Science*, may find a virtue in Whewell's coinage which he did not claim for it.

II. The Mathematician

All the time that Peirce was a scientist, he was also a mathematician. Only an expert mathematical physicist could have had the scientific career we have been sketching. We knew from the *Collected Papers* that at the very least he published original contributions of some importance to linear algebra and matrix theory. But now the four-volumes-in-five of *The New Elements of Mathematics by Charles S. Peirce*, edited by Carolyn Eisele and published here in Holland in this bicentennial year, bring us well over two thousand pages of previously unpublished writings that show technical competence, originality of comprehesion, and pedagogical skill, in the whole range of pure mathematics.

His father, Benjamin Peirce, was Professor of Astronomy and Mathematics at Harvard University, and was the leading American mathematician of his day. Charles's older brother, James Mills Peirce, succeeded to their father's chair but not to his leadership. Charles was so well trained in mathematics that as early as 1869, at the age of thirty, before his major undertakings for the Coast Survey began, he was willing to be considered, and thought himself qualified, for the chair of mathematics and astronomy at Washington University in St. Louis, which William Chauvenet had resigned because of failing health. And when, early in 1892, just after his career in the Survey had ended, it was rumored that a chair of mathematics was about to be vacated at Columbia University, he wished to be considered for that.

Midway between those fruitless episodes, he was part-time Lecturer in Logic for five years (1879-1884) at The Johns Hopkins University, while continuing his work for the Survey.[6] Before receiving the appointment in logic, Peirce had been proposed for the chair of physics to which Henry Augustus Rowland was appointed. The Johns Hopkins, which opened in our centennial year, 1876, was the first real university in the United States, and Peirce's courses in logic were our first graduate offerings in that field. Most of the philosophy students, including John Dewey, scarcely knew what to make of them. Peirce's best students came to him from mathematics. The head of the mathematics department was James Joseph Sylvester from England, a friend of Peirce's father. He founded the *American Journal of Mathematics*, and Charles had contributed to the first number in 1878 a review of his Italian friend Ferrero's treatise on the method of least squares. To the next three volumes he contributed four articles of his own and a new edition of his father's *Linear Associative Algebra*, with notes by himself throughout and with two addenda.

Peirce was a member both of the Mathematical Society and of the Scientific Association at The Johns Hopkins. He presented papers at both, and took part in the discussion of papers by others. Abstracts of some of his papers were published in *The Johns Hopkins University Circulars*. On 28 March 1881, Sylvester wrote to President Gilman: "We now form a corps of no less than eight working mathematicians — actual producers and investigators — real working men: Story, Craig, Sylvester, Franklin, Mitchell, Ladd, Rowland, Peirce; which I think all the world must admit to be a strong team." Of these, Franklin, Mitchell and Ladd had already studied with Peirce, and Story did so later.

Sylvester's leadership had already given an international character to the department, and this was strengthened when Arthur Cayley spent the first half of 1882 there. At the earliest meeting of the Mathematical Society after his arrival, that of 18 January 1882, papers were presented by Cayley, Sylvester, and Peirce. Peirce's was "On the Relative Forms of Quaternions."

Peirce had been elected a member of the London Mathematical Society in March 1880. In November 1891, he was elected a member of the New York Mathematical Society, which became the American Mathematical Society in 1894. He presented mathematical papers to the National Academy of Sciences, reviewed mathematical books for *The Nation*, and had extensive correspondence with mathematicians. He wrote the definitions of mathematical terms for the *Century Dictionary* (1889-1891), as well as those in logic, metaphysics, mechanics, astronomy, weights and measures, names of colors, many psychological terms, and all terms relating to universities. In the *Dictionary*'s concluding "List of Writers Quoted and Authorities Cited," Peirce appeared (after his grandfather and father) as "American mathematician and logician."

Thomas Fiske was soliciting contributions by Peirce to the *Bulletin of the New York Mathematical Society* in 1894 (*NEM* 1: xviii-xix). H. B. Fine and E. H. Moore in 1901 were urging him to write up his demonstration of abnumeral multitudes and his critique of Cantor for the *Bulletin* or the *Transactions* of the American Mathematical Society or for the *American Journal of Mathematics* (*NEM* 3:xviii-xix). On 19 October 1902, Frank Morley, editor of the *American Journal*, sent Peirce a copy of the issue containing Whitehead's "On Cardinal Numbers," in the hope that that memoir would call forth one by Peirce on his own theory of multitude (*MS* L 302).

But until this bicentennial year most of his mathematical writings remained unpublished and so difficult of access that only one of the books on Peirce, that by Murray Murphey, has made any serious attempt to deal with them. With *The New Elements of Mathematics* now in our hands, we can proceed to try out answers to numerous such questions as the five following.

1. What were Peirce's contributions to pure mathematics, particularly in the way of demonstrations?

2. What were his contributions to the logic, the pedagogy, and the philosophy of mathematics?

3. From boyhood on, against views then prevalent, he argued that we can reason mathematically about infinity, and therefore about continuity. In later years, he labored at a mathematical theory of what he called true con-

tinuity, as contrasted with the pseudo-continuity of the calculus. Did he succeed in constructing a mathematical theory of "true continuity," and, if so, what was his best formulation of it?

4. Was he a foundationist in mathematics? Surely not in the sense of founding mathematics on logic. As early as 1869 he argued strenuously with his father against the view later embraced by Dedekind (*NEM* 3:526). He had no sympathy with the lines taken in Russell's *Principles of Mathematics* or in the *Principia Mathematica* of Whitehead and Russell. Yet he began a memoir on "Foundations of Mathematics," and in 1906 he placed "Foundations" first among the fields of his ongoing research. What foundations, then, did he contemplate?

5. What Peirce called topology, topical geometry, or topics, was something very different from what topology became. Is there reason for returning to the parting of the ways and trying with Peirce the road not taken, as nonstandard analysis has returned from the doctrine of limits to that of infinitesimals?

These are but a few of the many questions for answers to which, in the decades ahead, we shall be searching *The New Elements of Mathematics* and the still unpublished mathematical manuscripts.

III. The Historian

All the time that Peirce was a scientist and a mathematician, he was also a historian. In his classification of the sciences of discovery, mathematics and philosophy were followed by the special sciences in two branches, the physical and the psychical. The psychical sciences he cultivated most continuously and intensively were history and linguistics. Among the others were experimental psychology and mathematical economics. That he meant from the beginning to do original work in both the physical and the psychical sciences appears from the fact that his first professional publication, in 1863, was on the chemical theory of interpenetration; his second, in 1864, on the pronunciation of Shakespearian English.

He was a lifelong student of comparative and historical linguistics. He valued his first European sojourn, in 1870-1871, not only for the experience it gave him of field work and international cooperation in astronomy, but also for the opportunity to study the languages spoken in the countries he visited. On 16 November 1870, five weeks before the eclipse, he wrote home that he had heard eighteen distinct languages spoken, seventeen of them (including

Basque) in places where they were the languages of everyday speech (*MS* L 341). In Constantinople and later in Cambridge, England, he studied Arabic with Edward H. Palmer.

Modern experimental psychology was founded in Germany, in Peirce's youth, by men like Weber, Fechner, Wundt, and Helmholtz. The works that most impressed him at the time were Fechner's *Elemente der Psychophysik* (1860) and Wundt's *Vorlesungen über die Menschen- und Thierseele* (1863). One thing that struck him in the latter was its "showing that every train of thought is essentially inferential in its character, and is, therefore, regulated by the principles of inference" (*N* 1:37). That was akin to, and may have been one of the sources of, the doctrine that "all thought is in signs" which Peirce developed in three articles in the *Journal of Speculative Philosophy* in 1868-1869. He sent Wundt copies of those articles in 1869 and obtained Wundt's permission to prepare and publish a translation of the *Vorlesungen* (*MS* L 478). Peirce did not carry out that plan, but he soon became himself the first modern experimental psychologist in the Americas.[7]

Thanks to the labors of Carolyn Eisele, Peirce is now recognized as one of the precursors in mathematical economics, and we shall be hearing from Nicholas Rescher of Peirce's work on "the economy of research." Passing over his contributions to those fields, I come now to the psychical science at which he worked longest, most continuously, and most intensively. This was history, and more particularly the history of science.

Peirce tells us that in 1850, at the age of eleven, he wrote "A History of Chemistry" (*MS* 1634.5) and later, in his twenties, a history of scientific methods (*MS* 958.48); but neither of these has so far been found.

On 12 November 1863, at the age of twenty-four, at a reunion of the Cambridge High School Association, he delivered an oration on "The Place of Our Age in the History of Civilization," and extensive extracts from it were published nine days later. By "our age" he meant the seventeenth, eighteenth, and nineteenth centuries.

Six years after that, in 1869-1870, he gave a series of fifteen Harvard University Lectures on the history of logic in the British Isles from the earliest times to his own day. The opening lecture was on "Early Nominalism and Realism" (*MS* 584; *CP* 1.28-34).

In the first half-year of his Lectureship in Logic at The Johns Hopkins University, he gave a course in Medieval Logic. The only Ph.D. thesis known to have been written under his direction was by Allan Marquand on "The Logic of the Epicureans," an introduction to and translation of the Herculaneum papyrus of Philodemus on inductive signs and inferences.

The planning of *The Century Dictionary* began in 1882. As I have already remarked, Peirce was made responsible for logic and metaphysics, mathematics, mechanics, astronomy, weights and measures, names of colors, many psychological terms, and all terms relating to universities. His chief qualification was that he had not only current but also historical competence in all these fields. As further preparation, in his last year at The Johns Hopkins (1883-84), he added two new courses, one in comparative biography called "The Psychology of Great Men," the other in "Philosophical Terminology." In the latter, his chief resource, and that of his students Dewey and Jastrow, was the Berlin Academy edition of Aristotle, with its Greek texts, Latin translations, and Bonitz's monumental index.

I have already spoken of his historical researches during his second and longest European sojourn. During his fifth and last, in 1883, he transcribed the manuscript of Petrus Peregrinus in the Bibliothèque Nationale, and a decade later, he circulated a handsomely printed prospectus of an edition that was to contain the Latin text and an English version with notes, preceded by an "Introductory History of Experimental Science in the Middle Ages." The Prospectus began:

> The brief treatise on the lodestone by Petrus Peregrinus, dated 1269, occupies a unique position in the history of the human mind, being without exception the earliest work of experimental science that has come down to us. Nor can we learn that anything of this sort had been written earlier.

But the subscribers were too few, the book was never printed, and no complete manuscript for it has so far been found.

Soon thereafter he was inviting subscriptions to a twelve-volume work called *The Principles of Philosophy: or, Logic, Physics, and Psychics, considered as a unity, in the Light of the Nineteenth Century*. The eleventh was to consist of *Studies in Comparative Biography*. But this project also failed because the subscribers were too few.

Meanwhile, in 1892-1893. Peirce had given in Boston a pathbreaking series of twelve Lowell Institute Lectures on "The History of Science."

In 1893, in response to criticisms of his theory of scientific method by the editor of *The Monist*, he wrote: "For the last thirty years, the study which has constantly been before my mind has been upon the nature, strength, *and history* of methods of scientific thought" (*CP* 6.604, my italics).

In 1896, in *The American Historical Review*, he reviewed Andrew Dickson White's *History of the Warfare of Science with Theology in Christendom*.

When Lutoslawski's *Origin and Growth of Plato's Logic* came out in 1897, Peirce worked out his own improvements on Lutoslawski's methods for determining the chronological order of the dialogues, and on that basis he later made a study of the development of Plato's ethics (*MS* 434).

In 1898, he contracted with G. P. Putnam's Sons to write a history of science for their Science Series, edited by James McKeen Cattell. In a draft of a chapter called "The Principal Lessons of the History of Science," he wrote that

> science...does not consist so much in *knowing*, nor even in "organized knowledge," as it does in diligent inquiry into truth for truth's sake, without any sort of axe to grind, nor for the sake of the delight of contemplating it, but from an impulse to penetrate into the reason of things. This is the sense in which this book is entitled a *History of Science*. (*CP* 1.44)

That work too remained unfinished, but, with *The New Elements of Mathematics* now behind her, Carolyn Eisele will return to an earlier project, that of making the nearest approach to the intended book that can be pieced together from Peirce's surviving manuscripts.

At the beginning of the twentieth century there were many reviews of the nineteenth. Perhaps the best of these was that which filled two sections of the New York *Evening Post* on 12 January 1901, and later appeared in book form. In previous advertising, the Post had promised thirty-eight essays by leading authorities in as many fields. The sixteenth was to be by Charles S. Peirce on "The Century's Great Men in Science." But when the essays were in hand, the *Post* moved Peirce's to first place, and leaned heavily upon it in an editorial, deciding that "the chief characteristic and the crowning glory of the century" had been such a "kindling and quickening of the scientific spirit" as to carry with it a change in the very meaning of the word "science." Peirce himself had written:

> The glory of the nineteenth century has been its science. ...It was my inestimable privilege to have felt as a boy the warmth of the steadily burning enthusiasm of the scientific generation of Darwin, most of the leaders of which at home I knew intimately, and some very well in almost every country of Europe. ...The word *science* was one often in those men's mouths, and I am quite sure they did not mean by it "systematized knowledge," as former ages had defined it, nor anything set down in a book, but, on the contrary, a mode of life; not knowledge, but the devoted, well-considered life-pursuit of knowledge; devotion to Truth — not "devotion to truth as one sees it," for that is no devotion to truth at all, but only to party — no, far from that, devotion to the truth that the man is not yet able to see but is striving to obtain. The word

> was thus, from the etymological point of view, already a misnomer. And so it remains with the scientists of today. What they meant, and still mean, by "science" ought, etymologically, to be called *philosophy*.

It was at least in part because travel, communication, organization and publication had become international if not worldwide, that the scientists of the latter half of the nineteenth century had come to think of science in this way. It was Peirce's European sojourns that had first brought him to this new vision of science. It was his work as historian that enabled him to see how new it was. And one function of our present international Peirce congress is to recognize in him the leading voice of this new conception of science.

IV. The Logician

All the time that Peirce was a scientist, a mathematician, and a historian, he was also a logician; and he was a logician for whom his work as scientist, mathematician, and historian was in some sense subsidiary to his work as logician. What that sense is we may begin to gather from his oft repeated account of his first introduction to logic, within a week or two of his twelfth birthday, in 1851. His older brother Jem (James Mills Peirce) was about to enter upon his junior year at Harvard College and had bought his textbooks for the year. Among them was Whately's *Elements of Logic*. Charles dropped into Jem's room, picked up the Whately, asked what logic was, got a simple answer, stretched himself on the carpet with the book open before him, and, over a period of several days, absorbed its contents. As he often said late in life, it had never since that time been possible for him to think of anything other than logic — including even chemistry — except as an exercise in logic. And, so far as he knew, he was the only man since the middle ages who had completely devoted his life to logic (*MS* 632.2:2).

No comprehensive account or assessment of Peirce's work in logic exists or is likely soon to exist, because every logician approaches him with a conception of logic narrower than his, and ignores or fails to comprehend the relevance of what transcends that narrower conception. I shall attempt here only the briefest sketch of Peirce's development as a logician, under six heads: (1) from logic *within* semeiotic to logic *as* semeiotic, (2) from nominalism to realism, (3) from classification of arguments to stages of inquiry, (4) from analytic through critic to methodeutic, (5) from Boolean algebra to existential graphs, and (6) from logic as non-normative to logic as normative. The most conspicuous constant through all the changes was his "unpsychological view of logic" (*MS* 726).

From logic within *semeiotic to logic* as *semeiotic*

It was from Whately that Peirce first took the premiss that all thought is in signs. If there be, then, a general theory of signs, called semeiotic, the question arises how logic is related to it. In the last chapter of his *Essay*, Locke identified the two. Peirce objected at first that, of the three most general kinds of signs, logic concerns itself only with symbols, and with symbols not in themselves, and not in relation to their interpretants, but only in relation to their objects, and only in respect of their truth or falsity. Logic is therefore at most but a third part of a third part — that is, a ninth part — of semeiotic. He defined it as objective symbolistic, "the science of the relations of symbols in general to their objects"(*MS* 726.14).

But he later came to see that logic cannot do business without icons and indexes, and cannot wait upon Speculative Grammar to define and classify its signs in relation to their nonlogical interpretants. He passed through a stage in which he distinguished a narrow sense of logic in which it was the mid-member of the semeiotic trivium, and a broad sense in which it included the first and third members as well and was thus coextensive with semeiotic. Finally, he abandoned the narrow sense altogether, and the semeiotic trivium became for him the logical trivium: Speculative Grammar, Speculative Critic, and Speculative Rhetoric; or, more simply, Analytic, Critic, and Methodeutic (*NEM* 3:207). I shall use the latter three terms in what follows.

From nominalism to realism

Peirce's gradual progress from the minimal realism of Duns Scotus, which "was separated from nominalism only by the division of a hair" (*CP* 8.11), to the full-fledged realism of his later years, is now a familiar story. Two essential parts of the story, however, are still far from familiar. (i) This progress not only paralleled that from logic-*within*-semeiotic to logic-*as*-semeiotic, but was closely bound up with it in ways still to be shown. (ii) The starting point was apparently not a minimal realism but a nominalism as avowed and explicit as Whately's. During his Harvard University Lectures of 1865, "On the Logic of Science," Peirce projected a book to be entitled *An Unpsychological View of Logic*, drew up lists of chapters, and drafted several of them. The following quotations are from two drafts of Chapter I, "Definition of Logic":

> *Qualities* are fictions; for though it is true that roses are red, yet redness is nothing but a fiction framed for the purpose of philosophizing; yet harmless so long as we remember that the scholastic realism it implies is false. (*MS* 726.9)

> Such words as *blueness*, *hardness*, *loudness*...were framed at a time when all men were realists in the scholastic sense .... To use them, now, then, (and no philosophical doctrine is possible without their use,) is to make use of a fiction, but one which is corrected by a steady avoidance of all realistic inference. (*MS* 726.201)

But these are matters for another occasion.[8]

From classification of arguments to stages of inquiry

The chief focus of Peirce's early work in logic was on classifying arguments and determining the relative strengths of the several kinds. He started from Kant's distinction between two kinds of judgments: those that are analystic or explicative and those that are synthetic or ampliative. He first turned that distinction into one between two kinds of arguments: those called deductive and those commonly called, in a loose sense, inductive. He thus arrived at the then common distinction between the logic of mathematics (that is, of deduction) and the logic of the inductive sciences, or, for short, the logic of science. His first original contribution was to subdivide arguments loosely called inductive into two kinds: inductions more strictly speaking, and what he at first called hypotheses, later abductions, finally retroductions. He thus arrived at three kinds of inference: deduction, induction, and hypothesis.

He found support for this tripartite classification of arguments from two sources: his own "New List of Categories" and a discovery that he made in the course of examining Kant's essay on "The Mistaken Subtlety of the Four Syllogistic Figures." What he discovered was that

> no syllogism of the second or third figure can be reduced to the first, without taking for granted an inference which can only be expressed syllogistically in that figure from which it has been reduced....Hence, it is proved that every figure involves the principle of the first figure, but the second and third figures contain other principles, besides. (*CP* 2.807; cf. *CP* 2.499)

His logic of relatives soon emancipated him from bondage to the syllogism, and he no longer needed the syllogistic figures as foundation for the distinction of the three main forms of inference. And he became even more assured of the forms of inference than he was of his categories (*MS* 312.43f).

So long as his focus was on the classification of arguments, Peirce set the logic of mathematics (that is, of deduction) over against the logic of science (that is, of hypothesis and induction). But in his later years, his focus shifted from the classification of the forms of inference to the functioning of inferences of the several forms in successive stages of inquiry. The order of the forms then became: hypothesis (abduction or retroduction), deduction, and induction (*CP* 6.468-473; 7.218). From one point of view, the logic of mathematics was thus no longer set over against but *absorbed into* the logic of science. From another, it was *assimilated to* the logic of science, because even the pure mathematician goes through the same three stages of inquiry as the scientist; the difference is that his experiments are performed upon diagrams of his own construction.

Peirce wrote to James McKeen Cattell in 1910 that the system of logic considered as semeiotic on which he was working was to be "a *theory of inquiry*, intended to show the real nature of any inquiry's validity, and the degree thereof, and to consider how to build up a solid structure of science."[9] Twenty-eight years later, when Dewey published his *Logic: The Theory of Inquiry*, he thought of Peirce as his only predecessor in the general view taken.

From Analytic through Critic to Methodeutic

It will be apparent that the shift from classifying arguments, and determining the relative strengths of arguments of the several kinds, to considering how they function in successive stages of inquiry, is at the same time a shift from analytic through critic to methodeutic. For Peirce, critic presupposed analytic, and methodeutic presupposed critic. Analytic was for the sake of critic, and critic for the sake of methodeutic. In a letter of 1911, Peirce wrote that "the greater part" of his life had been devoted to methodeutic, "which shows how to conduct an inquiry," and "of course in order to study methodeutic it is necessary to make researches in as great a variety of sciences as possible" (*NEM* 3:207). In what appears to have been a draft fragment of the same letter, he wrote: "In my own feeling, whatever I did in any other science than logic was only an exercise in methodeutic and as soon as I had the *method* of investigation thoroughly shown, my interest dropped off" (*MS* L 231.81 [= *MS* L 482.75]).

But why was it necessary to be a *historian* of science? Because history is itself one of the sciences, with its own methodology (*CP* 7.162-255); but more particularly because "each chief step in science has been a lesson in logic" (*CP* 5.363), more exactly in Methodeutic, and because "the professional logicians" have slept through the lessons (*CP* 5.390). Peirce wrote to William James in 1909: "I have done a lot of work in Methodeutic that is valuable and very little of it is printed. This will be the most widely useful part of my Big Book" (*NEM* 3:874) — that is, of *A System of Logic, considered as Semeiotic.*

Among Peirce's contributions to Methodeutic that *were* printed, the best known were his "Note on the Theory of the Economy of Research" (*CP* 7.139-157) and his pragmatism. The latter was presented in 1878 as the lesson in logic taught by Darwin's application to biology of the statistical method, which had been used first in political economy and then in thermodynamics (*CP* 5.364). At this bicentennial congress, it is worth remarking that the "Note" appeared in the Coast Survey Report for 1876; that the "Illustrations of the Logic of Science" were invited by the publisher, Appleton, on board the ship that took Peirce to his second European sojourn in 1875; that "How to Make Our Ideas Clear" was written in French on board the ship that took him to Europe for his third sojourn in 1877; and that the "Illustrations" began appearing in November of that year.

As we remarked earlier, Peirce gradually gave up conceiving science as a mode of apprehension by a single knower, or as systematized knowledge, and came to conceive it as a mode of life common to a community of investigators, and to conceive a particular science as a social group pursuing the same or closely related inquiries. Science is what scientists do, and a particular science is what scientists of a particular group do. This too was another form of the movement from analytic through critic to methodeutic.

From Boolean Algebra to Existential Graphs

One of the tasks of methodeutic is the devising and improving of systems of notation. This was a lifelong concern of Peirce's. His first published paper in logic, in 1867, was "On an Improvement in Boole's Calculus of Logic." Three years later, in 1870, came his "Description of a Notation for the Logic of Relatives, Resulting from an Amplification of the Conceptions of Boole's Calculus of Logic." Ten years later, in 1880, came "On the Algebra of Logic," and five years after that, in 1885, "On the Algebra of Logic: A Contribution to the Philosophy of Notation." His *Century Dictionary* article, "*notation* — 2," in 1890, was probably the most extensive, detailed, and thorough ever written on that term for a general dictionary. One of his more interesting unpublished papers, of about 1904, is on "A Proposed Logical Notation" (*MS* 530). There and in a passage of his *Minute Logic* omitted by the editors of the *Collected Papers* (*CP* 4.261), he introduces two notations for the sixteen binary connectives of the two-valued propositional calculus. One of these may be called his box-X, the other his cursive notation.[10]

But at least as early as 1882, Peirce began taking steps toward a more graphical representation of logical relations and operations. In 1896, he invented two graphical systems to which he soon thereafter gave the names of entitative and existential graphs. He continued to work at the latter of these for at least another ten years, and in 1906, he projected "A Comparative and Critical Outline of the Useful Systems of Logical Representation," both algebraic and graphical (*MS* 283.345-361).

Peirce frequently contrasts the mathematical and the logical interest in notations. The mathematician's aim is to facilitate calculation, inference, and demonstration; the logician's, to facilitate the analysis of reasoning into its minimal steps.

Neither Peirce's notation for the logic of relatives nor his existential graphs has had much success as a calculus, and he never completed the adaptation of the graphs to modal logic; but both systems retain their value as instruments of logical analysis, and the graphs are unsurpassed for the teaching of beginners in logic.[11]

From logic as non-normative to logic as normative

In Peirce's later classifications of the sciences, the principal divisions are Theoretical and Practical, and the Theoretical Sciences are divided into Sciences of Discovery and Sciences of Review. The Sciences of Discovery are divided into Mathematics, Philosophy, and the Special Sciences, Physical and Psychical. In his earlier classifications, Philosophy included only logic and metaphysics. (He did not say whether it also included so much of formal or general semeiotic as lay beyond the narrow scope of logic as he at first conceived it.) Logic was not a normative science, and ethics and aesthetics were down among the Practical Sciences. The question of there being any heuretic normative sciences at all was not yet broached.

Yet Peirce, along with a classmate and close friend, had made an intensive study of Schiller's *Aesthetic Letters* during his freshman year in college, in 1855-1856. In notes for a prospectus of his lectures on logic for 1883-1884 at The John Hopkins University, under Lecture III, on "The Fixation of Belief" and "How To Make Our Ideas Clear," we read: "Close connection between Logic and Ethics" (*MS* 745). By that time, Peirce had begun work for the *Century Dictionary*. His assignment included philosophical as well as mathematical words and a wide range of scientific terms. Under philosophical terms were included those of aesthetics and ethics, as well as those terms themselves. But neither in the first edition of 1889-1891 nor in the Supplementary Volumes of 1909 was there any recognition of aesthetics, ethics, and logic as normative sciences or as constituting a triad of sciences of any kind. In the classification of sciences under the term "science," ethics appears as a branch of sociology, and aesthetics is nowhere.

The need for a basis for the "ethics of terminology" (*CP* 2.219ff) and of notation (*MS* 530) probably had something to do with Peirce's growing interest in ethics. And almost certainly his increasing attention to methodeutic had more; for it is in methodeutic rather than in analytic or critic that the dependence of logic upon ethics becomes most evident.

The decisive event, however, was the appearance in 1897 of Lutoslawski's *The Origin and Growth of Plato's Logic*, with its chronological ordering of the dialogues on stylometric grounds. Peirce applied to Lutoslawski's data "all the refinements of the theory of probabilities" and then applied the results to a study of what, if published, we are tempted to say he might have called *The Origin and Growth of Plato's Ethics*—more exactly, of his views on "the single point of what is ultimately good" (*MS* 434.34).

But by 1902 Peirce was ready to assign that problem to aesthetics, and to recognize three normative sciences — aesthetics, ethics, and logic — with ethics depending "essentially" on aesthetics, and logic on ethics (*NEM* 4.19). Having reached that position, he found an adumbration of it in the last four paragraphs of his 1869 paper on the "Grounds of Validity of the Laws of Logic" (*CP* 5.354ff).

By that time, logic-within-semeiotic had become logic-as-semeiotic, and the latter now became "normative semeiotic" (*CP* 2.111).

The most inspiring and suggestive passage in this sixth phase of Peirce's own development as logician is the following:

> As to Plato, unless we are content to treat the only complete collection of the works of any Greek philosopher that we possess as a mere repertory of gems of thought, as most readers are content to do; but wish to view them as they are so superlatively worthy of being viewed as the record of the entire development of thought of a great thinker, then everything depends upon the chronology of the dialogues. (*MS* 434.33f)

The Philosopher

All the time that Peirce was a scientist, a mathematician, a historian, and a logician, he was also a philosopher in a sense in which philosophy included from the beginning not only logic but at least metaphysics besides, and (presumably) so much of formal or general semeiotic as lay beyond the narrow scope of logic as he at first conceived it.

The relation between logic and metaphysics was always intimate. Metaphysics presupposed logic. The categories of metaphysics were those of logic in another application. Metaphysics was applied logic.

Peirce said his work in the sciences and in mathematics was for the sake of his work in logic. It would be equally true to say that his work in logic was for the sake of mathematics, of metaphysics, and, both directly and through metaphysics, of the special sciences, both physical and psychical. Both statements apply more particularly to methodeutic than to analytic or critic, but neither is limited to methodeutic.

At least from the summer of 1859 onward, one of Peirce's main metaphysical concerns was to establish that, contrary to what some metaphysicians were saying, we *can* reason mathematically and logically about infinity and therefore about continuity. On that assumption, synechism became a regulative principle first of logic and then of metaphysics (*CP* 6.171ff).

Two interrelated aims of Peirce's metaphysics were mathematical exactitude (*NEM* 4:x) and testability (*CP* 7.516).

But his work in metaphysics was far from being as continuous as his work in logic. He had only two periods of intensive writing in metaphysics, one in the early 1860s and the other in the early 1890s; only the latter reached publication, in a series of papers in *The Monist* (1891-1893); and that series remained unfinished. Furthermore, he thought his best work was not in that series, or in metaphysics at all, but in logic (*NEM* 3:872f).

Around the turn of the century he began recognizing philosophical sciences other than logic and metaphysics. In the late 1890's, there are several references to something he calls "high philosophy" (*CP* 7.526f), whose chief function seems to be to supply a list of categories for the guidance first of logic and thereby of metaphysics. When logic became normative semeiotic, and aesthetics and ethics were promoted to being normative philosophical sciences antecedent to logic, "high philosophy" became phenomenology, phaneroscopy, phenoscopy, or "*phanerochémy*, — the chemistry of appearances" (*MS* 1338.22). The philosophical sciences, preceded only by mathematics, then became phanerochemy, the normative sciences (aesthetics, ethics, and logic), and metaphysics.

If we think of social philosophy as an integral philosophic science, it may strike us first that Peirce nowhere so recognizes it, and second that his writings, from early to late, contain numerous and often lengthy incidental passages, rich in insights, which, if assembled and organized, would constitute a major contribution to that science. For some of his students, this is his richest vein.

If now we try briefly to describe and assess Peirce as philosopher, we may