CHARLES S. PEIRCE NINETEENTH CENTURY MAN OF SCIENCE*

By CAROLYN EISELE

THOSE interested in American scientific vistas of the late nineteenth century will find them sharply focussed when viewed with the aid of Cattell's *American Men of Science* (1906). For this compilation of biographical sketches is a rich tapestry from the loom of the scientific workshop; and when one comes across a mind like that of C. S. Peirce (1839–1914), one finds that a thread of gold has been woven into the pattern in such a way that all the areas are brought into a brilliantly illuminated unity. An effort will be made in this paper to retrace the design woven by the scientific thought of Peirce, and to do so in the light of biographical detail, for the most part hitherto unpublished.

Since these *Men of Science* sketches were presumably prepared for Cattell by the scientists themselves, it is possible to learn directly from Peirce what he considered his principal subjects of research to be. They are "Logic, especially logic of relations, probabilities, theory of inductive and abductive validity; epistemology; metrology; history of science; multiple algebra; doctrine of multitudes; gravity; wavelengths; phonetics of Elizabethan English; great men; ethics; phaneroscopy; cosmology; experimental psychology; physical geometry.—Foundations of mathematics; classification of science; code of terminology; topical geometry."[1]

[1] P. 248. Cattell explains that the dash separates the subjects accomplished from those in progress.

* This study is dedicated to the memory of Jekuthiel Ginsburg. His constant encouragement added greatly to the joy of the writer's research on Peirce's many activities. In the last interview regarding the development of this paper just a few short months before his passing, Professor Ginsburg spoke once again of the informal talks on Peirce which he had had with the late Cassius J. Keyser. He intended to share one day with the writer his knowledge of Peirce biographical detail which cannot now appear in the records, but the strong sense of indebtedness will always remain.

Received by the editor, May 19, 1958.

Peirce also listed a few of the institutions with which he had had scientific connections. Consequently the evidence establishing him as a man of science may be found in a study of his association with the personnel of these and other organizations known from other sources. As a result, a most unusual picture of him emerges and those who have hitherto regarded him as a retiring, unworldly philosopher may be surprised to find him viewing the philosopher's ivory tower as a good vantage point for the observation of a double star.

The greatest personal force in Peirce's life was that of another man whose devotion and approbation were the mainspring of Peirce's existence, a man for whom he felt to the end of his days the deepest gratitude and devotion in turn. That man was his father, the renowned mathematician, physicist, and astronomer, Benjamin Peirce.

In 1839, when Charles was born, Benjamin already was Professor of Mathematics and Natural Philosophy at Harvard University. He undertook personally to cultivate the boy's obvious talents, keeping him at games of mental concentration until dawn, and imbuing him so thoroughly with the analytical outlook of the mathematician and scientist that Charles often spoke of himself as having been brought up in a laboratory. Later, they together tackled many of the philosophical and logical intangibles that happened to plague either or both at the moment. By guiding Charles in the intensive study of Kant when the lad was still in his teens,[2] his father shaped the beginnings of the boy's formal thought in logic and philosophy.

More powerful still as a formative influence was the position which his father enjoyed as one of America's top-flight scientists. For Benjamin was a respected and honored scientific leader who walked in the company of the greatest scientific talent of his time in America. Private individuals and government officials alike turned to him for scientific counsel. Witness the fact that the important office of the Nautical Almanac was established in 1849 in Cambridge in order that the personnel might conveniently avail themselves of Benjamin's advice as needed. Because a galaxy of scientific talent gravitated to Peirce in his household during Charles' impressionable youth, the boy quite naturally adopted the way of life and the idiom of thought of a scientific community. The extent of that home influence is exemplified by Charles' now famous maxim: "Consider what effects, that might conceivably have practical bearings, we conceive the object of our conception to have. Then, our conception of these effects is the whole of our conception of the object."[3] This *leitmotiv* of Peirce's pragmatism subsequently affected every phase of his intellectual life. It is but a restatement of valid laboratory procedure as a means of arriving at new truths.

[2] *Collected Papers of Charles Sanders Peirce*, edited by Charles Hartshorne and Paul Weiss, 1.560, 1.563.

[3] *Ibid.*, 5.18.

The study of mathematics had made Charles question the security of his reasoning, and he soon turned his attention to the study of methods of investigation. He characterized his appointment as aid in the Coast Survey, immediately after graduation from Harvard College in 1859, as an opportunity to learn his lesson in methods of investigation in one science. A little later he also made arrangements to study the problem of classification with Louis Agassiz, who was then lecturing at the Lawrence Scientific School. He had added other studies to this program and, with a specialization in chemistry, was graduated in 1863 a Bachelor of Science *summa cum laude*, the first to receive the honor from the School. By this time he was already aware of his unusual gift for logical analysis.

Peirce's exemption from Civil War military obligations during this period may be ascribed to the Coast Survey assignment. The first letter from Peirce in the Coast Survey files of the National Archives[4] is addressed to Superintendent Bache and is dated August 11, 1862. He queries, "Does my appointment in the C. S. service exempt me from draft or not? I have not had any letter of appointment so I am in doubt." He is assured by Bache of his exemption because of his appointment in an executive department of the government.[5]

Charles' activities were varied during the next few years, but Benjamin's guiding hand can still be sensed behind many of them. In the spring of 1865 he lectured at Harvard on the "Logic of Science" and during the season 1866–1867 he gave twelve lectures at the Lowell Institute on the "Logic of Science and Induction." By 1867 he was watching "the stars dancing"[6] at the Harvard Observatory and was entering amusing and characteristic astronomical notations in the official records. After nights of futile vigil he wrote: "Observer thinks something must be the matter with his eye tonight"[7]; ". . . Sky completely overclouded. I don't think I shall be taken in again this way! N. B. Clerk of weather drunk"[8]; ". . . Very poor indeed, all

[4] The writer wishes to express her indebtedness to the personnel at the National Archives in Washington for their assistance in making the Peirce records available to her. Quotations not otherwise identified in this paper are from the National Archives files. This research was incidental to the larger project of gathering material for a book on Charles S. Peirce as a historian of science under a grant from the American Philosophical Society.

[5] The Coast Survey was under the supervision of the Treasury Department at that time.

[6] *Harvard College Observatory Record*, October 31, 1867. The writer is indebted to the Harvard College Observatory staff, and, in particular, to Dr. Dorrit Hoffleit, for making these records available to her.

[7] *Ibid.*, November 18, 1867.

[8] *Ibid.*, December 29, 1867.

guesswork. This branch of astronomy cannot be advanced here tonight."[9] During the years 1868 and 1869 Peirce served as an assistant at the Harvard Observatory under Director Winlock.

William James wrote regretfully of this appointment to his brother Henry and remarked, after hearing one of Peirce's nine lectures on "British Logicians" at Harvard, ". . . But I wish he could get a professorship of philosophy somewhere. That is his forte, and therein he is certainly *très fort.* I never saw a man go into things so intensely and thoroughly."[11] William had written to Henry a year earlier in the same vein, bewailing the certainty that Charles would go into the Observatory for good, since there seemed to be no professorial prospects in logic or metaphysics.[10] However, the *Historical Register of Harvard University* lists Peirce as a Lecturer on Philosophy in the period 1869–1870 and on Logic during 1870–1871.

Benjamin's appointment as Superintendent of the Coast Survey in 1867 opened to Charles further opportunities to learn about scientific method at first hand. Charles and his wife both became members of the 1870 Coast Survey expedition to the Mediterranean basin to observe the solar eclipse,[12] with Benjamin personally directing the over-all program. Charles seems to have been temporarily in charge of the Coast Survey Office for several months during 1872. At the end of that year, on November 30, Charles was officially notified by his father that he was "hereby directed to take charge of the Pendulum Experiments of the Coast Survey and to direct and inspect all parties engaged in such experiments—and as often as circumstances will permit,. . . to take to the field with a party, organized by himself, with the estimates made in the usual manner and approved by the Superintendent. . . . " Also, in combination with the pendulum experiments, Charles was to "investigate the law of deviations of the plumb line and of the azimuth from the spheroidal theory of the earth's figure." Moreover, although he had become an Assistant in the service by this time,[13] he was to continue under Winlock the work to which he had been assigned earlier at the Harvard Observatory. Charles carried out this part of the assignment with notable success until 1875. His astronomical investigations during those years became in 1878 the subject of his celebrated report entitled *Photometric Researches.*

[9] *Ibid.*, January 5, 1868.

[10] *The Thought and Character of William James*, Ralph Barton Perry, I, p. 320; December 29, 1869.

[11] *Ibid.*, I, p. 292; January 24-25, 1869.

[12] *Report of Coast Survey Expedition (1870).* Peirce was married to Melusina Fay by this time. Melusina wrote for this report a delightful account of her assignment as a sketcher of the solar spectacle.

[13] Peirce erroneously states in *Men of Science*, "Asst, U.S. Coast and Geod. Surv., 73–93." The terminal date is also in error.

Indeed, it was in his several associations with this great government agency, the Coast Survey, that Charles was to find the opportunity to develop his scientific talents, to reap the tangible rewards of a dependable livelihood, and to achieve international recognition for his scientific ingenuity. Many outstanding nineteenth-century scientists were associated with the Coast Survey in one capacity or another, but few earned distinction for themselves, as well as their young country, primarily through their Coast Survey service as Peirce did.

The first evidence that Charles was making a scientific reputation for himself is found in an official Coast Survey letter written by Benjamin, now retired as Superintendent but still active as the Consulting Geometer. It is addressed to Patterson, his successor as Superintendent, and is dated June 15, 1875, five days after Winlock's sudden death.[14] It reads: "I want you to write to President Eliot, and commend Charlie S. Peirce as a fit person for the directorship of the observatory. I wish you would especially speak of the efficiency with which he administered the office during the absence of Hilgard—i.e. if you can truthfully do so." Four months later Benjamin writes in a different vein, for he now says, "Your kind interest in Charlie and earnest appreciation of his ability and of the value of his recent researches have been a great comfort to me and especially now when Charlie is so fixed *not* to be a candidate for the observatory here."[15] His hope for Charles' appointment failing, in another six months Benjamin was encouraging Simon Newcomb, in vain, to accept the observatory post. By September 28, 1876, Charles, back in America again, was writing to Patterson: "I saw Eliot the other day. . . He says no solution of the question of a director of the observatory has been approached to."[16]

On what grounds did Benjamin dare to recommend Charles for such a responsible position in the first place? Paternal solicitude unquestionably played a part, but an examination of Charles' contributions to astronomical research in the performance of his duties during the three years which had elapsed since he had been given the observatory

[14] Charles was abroad on official business at this time, from April, 1875 until August, 1876.

[15] The letter continues, "I have no exact knowledge of his pecuniary arrangements—but suspect that the embarrassment arises altogether from his having had two different bankers at the same time. This very fact may have confused Mr. Hein. I am quite in the dark about it and beg you to relieve my anxiety as soon as you can. The two words 'all right' telegraphed to me will return me at once to a relieved state of mind."

A U. S. Coast Survey Office note to Benjamin (October 21, 1875) reads, "All right. Received letter from and telegraphed Charley yesterday."

Charles had run into a financial difficulty which was finally straightened out with the aid of his father. This episode cannot be treated adequately in a short paper and properly belongs in a full biography. It is possible that this incident affected his candidacy for the position at this time.

[16] Pickering was finally chosen to head the observatory. He served from 1876 until 1919.

assignment, shows that work to have been particularly meritorious. For in a letter to Patterson from Paris, written on January 7, 1876, Charles referred to a "photometry book"[17] which Patterson had suggested that he write, an honor that Charles greatly appreciated. He mentioned Winlock's death and he claimed that Eliot was trying to give Winlock some of the credit due himself. For the first time in an official letter he wrote of his friends urging him for a Professorship of Logic in the Johns Hopkins University[18] and continued: "I think logic is my best power, but I am not going to do anything which will involve abandoning the Coast Survey after all the money which has been spent in teaching me to swing pendulums."

The "photometry book" discloses the high calibre of Charles' researches. But the general reader will be better able to estimate their value from a description of them given much later by Dr. Solon I. Bailey, Director of the Observatory during 1920, in his *History and Work of the Harvard College Observatory* (1931). His remarks run as follows: "In attempting to reform the existing scales of magnitudes by the aid of instrumental photometry, Peirce decided that they should be so adjusted that equal numerical differences in magnitude would be represented by equal ratios in light. . . Peirce attempted to reduce all the discordant scales of magnitudes of the various observers to one, and to render his magnitudes accordant with it. . . . .It is obvious that the work of Peirce during the years 1871 to 1875 was of a pioneer nature. . ." (p. 124). Dr. Bailey continues later in the book: "The first attempt of the Harvard Observatory to determine the form of the Milky Way, or the galactic system, was made by Charles S. Peirce. In connection with his photometric work undertaken during the administration of Joseph Winlock, in the years 1871 to 1875, Peirce made a study called 'Form of the Galactic Cluster.' He states that 'The chief end of observations of the magnitudes of the stars is to determine the form of the cluster in which our sun is situ-

[17] This is the book already mentioned. It was published as Vol. IX of the *Annals of the Harvard College Observatory.*

In a letter to Peirce dated March 4, 1914 just before Peirce's death, Royce tells of a meeting at which Professor Pickering "spoke with warm appreciation of your early photometric contributions to the Observatory *Annals.*" (Widener Library Archives. Charles S. Peirce Collection. Box VB2a(1). General Correspondence.)

The writer is indebted to the Philosophy Department at Harvard University for permission to use from the Charles S. Peirce Collection in the University Archives the letters and Peirce manuscripts from that source quoted in this paper. She wishes to acknowledge her continued indebtedness to Miss Ruth Allen of that Department for her aid in securing permission for the use of such material in several papers on the activities of Peirce already published, and for her encouragement of the total research.

[18] On December 16, 1875 he wrote to William James from Paris: "I hear from my father that you have written a beautiful letter to the President of the Baltimore University proposing me for the chair of logic and I am asked if I would accept." (*The Thought and Character of William James,* Ralph Barton Perry.)

ated,' meaning the galactic cluster. Without attempting numerical accuracy, he endeavored to show the general form of the surfaces of equal star-density throughout the cluster. . .Peirce also found that for stars from the first to the sixth magnitudes the mean distances as calculated from the proper motions of Mädler were nearly as the square roots of the distances deduced photometrically. . .The investigation was of a pioneer nature, founded on scant data" (p. 198, 199). Benjamin seems to have been justified in his efforts to forward the career of so accomplished an astronomer.

Charles' attempts to carry out the first of the two assignments given him by his father in 1872 met with even greater success than the observatory research just discussed. The Coast Survey reports are filled with his accounts of taking to the field with a party; of setting up pendulum-swinging stations at various places, first in America and then in Europe; of the life of a practical field worker who modifies, and if need be, creates his instruments on the spot; of conferences with his father; of amusing personal incidents; and, finally, of success on the international scene.

The story of his growth into a figure of international repute begins with an undated letter, written by Peirce prior to June 23, 1874, in which he expresses his desire to be sent abroad for at least a year beginning about the first of March, 1875. His purpose was "to learn the use of the new convertible pendulum and to compare it with those of the European Measure of a Degree and the Swiss Survey and to compare" his "invariable pendulums in the manner which has been usual by swinging them in London and Paris."[19]

[19] In a letter dated January 4, 1875, these ideas are expanded into the statement that "The pendulum experiments which our Survey has (like every other great Geodetic Survey) instituted have for their immediate purpose the comparison of the force of gravity in different places. This has to be done with the extremest accuracy. The measure of a force always depends on measuring a length in space and an interval of time. Time is measured by observations of the movement of the stars which can be seen everywhere, but a length can only be compared with a particular rod. Hence, it is an essential and recognized part of all refined measures of length to carry the scale whatever it is to the standards used in different countries. The accurate comparison of two rods is an affair of months.

"In the comparison of pendulums, two methods are in use, both of which it is quite indispensable for us to employ. The first consists in making a regular series of pendulum experiments at certain initial points at which it has been usual to swing all invariable pendulums. These are London and Paris especially. A series of pendulum swings is, as you are aware, a considerable piece of work. It involves time observations the same as are made by a longitude party, a great deal of work with the pendulum apparatus, experiments continued incessantly for at least twenty-four hours at a time, and in my case the training of several assistants for the work at each place where I swing.

"The other method of comparing pendulums is only applicable to convertible pendulums, one of which is being made for us now by Repsold and will be done in April. It is similar to the comparison of yard measures. It must be applied in Hamburg, Berlin, and Switzerland. In the first place only tentatively; in the other two in order to compare with the important convertible pendulums in those places."

Peirce outlines in another letter, dated February 7, 1875, what he believes his official instructions to be; one being to "inform" himself "thoroughly of all the methods used in

After the leave of absence had been officially granted, Peirce set sail out of Hoboken on April 3, 1875. Once in England, he speedily became acquainted with the British scientists, among whom was Clerk Maxwell. Peirce described him in a letter from London, dated April 30, 1875, as a "pendulum-swinger and a writer upon the mathematical theory of the resistance of the atmosphere and upon other subjects connected with Attraction." He tells of the "immense advantage" to himself of talking with all these people and continues, "For example, in all I ever saw in relation to the effect of the resistance of the atmosphere on pendulums, it has been assumed that the resistance was proportional to the density of the air while the temperature has been left out of account altogether, but from considering the matter in the light of the mechanical theory of heat I was lead to believe that the largest term of the resistance was independent of the density and also of the surface of resistance and was proportional to the absolute temperature. I was happy to find that Professor Maxwell who is one of the greatest authorities on the viscosity of air, and the best experimenter upon it, entirely agreed with me in this view."[20]

After the cordial reception in England—Peirce writes of meeting Lockyer, Clifford, Stokes, and Airy[21]—he went to Berlin where he first conferred with his Excellency Herr General-Lieutenant Dr. Baeyer, the Director of the Prussian Geodetical Institute,[22] and then made arrangements with Professor Förster, President of the German Commission of Weights and Measures, to perform certain experiments. In the same letter Peirce described Baeyer's dissatisfaction with the reversible pendulum and the latter's desire "to adopt the plan of swinging an invariable pendulum *in vacuo*. Baeyer has already brought the matter," according to Peirce, "before the Council of the Europäische Gradmessung and it is to be settled at a meeting in Paris in September." Peirce spoke also of the need to go to Pulkowa to arrange for the construction of a pendulum at a cheaper price than Repsold charged, and expressed the hope of seeing Struve. Although

Europe for the determination of the force of gravity and of local attractions."

[20] The letter continues: "Professor Maxwell was the man whom on the whole I most desired to see. I enjoyed my visit to him exceedingly. The Duke of Devonshire—to whose family I believe the great Cavendish belonged—and who is himself the Chancellor of the University of Cambridge, has given Maxwell a most splendid new physical laboratory which is just finished. The building itself is very roomy and built in the most solid manner. All the partitions are of brick. It is filled with the most admirable contrivances for performing all sorts of physical experiments in the best way and is supplied with magnificent and admirably planned apparatus. I found there very much which interested me most deeply besides what related to my pendulum work."

[21] In a letter dated May 31, Peirce speaks of having called on the Astronomer-Royal whom he "wished to see not only on account of my having made pendulum experiments to determine the density of the earth but also because he had been rather polite to me when I was first in England." This time Peirce was inexplicably snubbed.

[22] Reported in a letter dated June 4, 1875.

he wrote again on June 7 of possibly going to St. Petersburg to order a new transit, Peirce did not reach Russia. But he was able to report at last from Berlin on June 30; "What I desired to do and have now really completed was to compare the two standards of the Prussian Instrument and ours."

The summer of 1875 appears to have been an extraordinarily busy one for Peirce at Geneva and in Paris. A sixteen-page report dated September 23, 1875 summarized his accomplishments during that period as follows: (1) I have swung my new pendulum during 16 days at Geneva. (2) I have made important experiments on the flexure of the stand and have investigated the effect of this flexure on my result. (3) I have designed and ordered made in Geneva a vacuum chamber for the reversible pendulum. (4) I have assisted at the seances of the International Geodetical Association and also of the Permanent Commission, where the subject of pendulums has been minutely discussed. (5) I have nearly completed the calculations of the work at Geneva and before the 1st of January shall send you a detailed report on it. (6) I have continued the calculations of American work but without making much progress as I preferred to rush the Geneva calculations. (7) I have devoted considerable time to studying French."[23]

Item (4) of the report is of the greatest interest, for it was at the general meetings of this Association as well as at meetings of its Standing Committee that Peirce's reputation as an American scientist was established. The meetings at Paris in 1875 were held in the *Palais des affaires étrangères*, and Peirce was invited to attend them. At one point the President of the Association, General Ibãnez, quite unexpectedly called on Peirce for an expression of opinion. Peirce took the opportunity to discuss a purported error the Europeans had been making during the previous ten years. There seems to have been little open opposition to his remarks at the time, but the following year, at the Brussels sessions, a member of an investigating committee reported Peirce's criticism to be erroneous. Peirce, in America, stood his ground, and applied for a leave of absence to attend the meetings in Stuttgart in 1877. On this transatlantic trip he was to find it possible to compose on shipboard the original paper on pragmaticism, com-

[23] In a sense this report is supplemented in a letter to Patterson from Richmond on July 6 of the following year. Peirce tells of swinging in the great Salle du Méridien and that he had "made during the year various improvements in the art of swinging pendulums. The most important is my measurement of the flexure of the stand, which introduces a very large correction into all results with the Repsold reversible pendulums. General Baeyer, who is really the head of European geodesy, was extremely pleased with this and brought a large party of scientific men to see my apparatus in operation in Berlin. However, the invention which pleases me the most is a new method of noting the time of vibration which will greatly diminish the expense of computations which is excessive in my present system."

pleting it, in French, before his arrival in Plymouth.[24]

In the meantime Peirce had received an invitation from Professor Plantamour, in the name of the Standing Committee of the Association, to communicate to President Ibañez an account of his study of the pendulum tripod for publication. Peirce's twenty-three page report, entitled "De l'influence de la flexibilité du trépied sur l'oscillation du pendule à reversion," confirming his original criticisms, and establishing the correctness of his point of view, was delivered by M. Plantamour at Geneva on October 27, 1877.

His father undoubtedly watched Charles' progress with great interest. He expressed his great pleasure in a letter to Patterson on October 17. Meanwhile Charles intensified his researches on the flexure problem. A memoir from Professor Plantamour in March 1878 suggested further revision, and by August 30 Charles was able to report: "I have very recently succeeded in reducing the whole problem to the effect of the 'elastische Nachwirkung' of the metal of a pendulum tripod upon the time of oscillation to a complete mathematical analysis. This shows precisely what allowance has to be made for the phenomenon of delayed flexure to which M. Plantamour has called attention."

Although Peirce was not sent abroad during 1878, he urged in a letter to Acting Superintendent Hilgard, dated June 1, 1878, American cooperation with the Europeans in this work. He wrote: "Permit me to ask whether a brief report of the doings of the Coast Survey this year, say two or three pages of quarto, will not be forwarded to the European Geodetical Association in order to keep up our connection with them. It appears to me to concern our interests, in the narrowest conception of them that any congressman could have, that our scientific reputation abroad should be sustained; and to withdraw now from the Association at the moment when steps have been taken to change the organization of it on purpose to admit us, would in my

[24] "The *Comptes Rendus* of the Europäischer Gradmessung show that on Sept. 29 he was absorbed in quite another discussion in Stuttgart" (*Collected Papers*, 5.526).

On September 10 Peirce suggested to Hilgard that he would like to show his quincuncial map at Stuttgart and stated that he would "be extremely glad to execute any commission of any kind" for Hilgard in that part of Germany where he might be, and enclosed his Berlin address. Several months later, in a letter to Hilgard dated June 1, 1878, he speaks of having received an invitation to attend the meetings of the British Association in Dublin beginning August 14 and gives reasons why it might be advantageous for him to accept. The paragraph ends with, "However, I equally recognize that my going abroad two years successively is not a matter likely to receive your approval." Since he listed himself in *Men of Science* as a "Delegate for U.S. Int. Gradmessung Conf, Stuttgart," and does so without giving a date, one must conclude that Peirce went abroad for a short time in 1877. In a memoir read on April 17, 1897 before the National Academy of Sciences, he mentioned the success of the visit to Stuttgart and, incidentally, acknowledged his indebtedness to his father (*American Journal of Science and Arts*, 3rd series, vol. 18–19,p. 112).

opinion produce a very bad effect. The report could be sent even if no delegate attended."

There is no evidence at this point in the files that such a report was sent. By June 21, however, Peirce had designed a new reversible pendulum and by June 26 had received permission to arrange for its construction at Repsold's. It was destined to supersede the Repsold models in the Coast Survey until 1890. This was the first of the Peirce pendulums for which he was given full credit in the *Work of the Coast and Geodetic Survey 1909*, the first full review of the Survey.

The climax of Peirce's success as a "pendulum-swinger" is revealed in a letter from him in Paris to Patterson, dated June 21, 1880. It opens quite simply as follows: "I read on the 14th a paper before the Academy on the value of gravity. It was very well received and the discussion of it was resumed today, when I had the satisfaction of receiving a vote of thanks for the research. The error which I have discovered in the old value excites so much interest that a new determination will at once be undertaken by the French. These gentlemen are anxious that I should also make a new determination with new apparatus, owing to the faults of that I previously used. If I could have an apparatus with a long and short pendulum to be swung *in vacuo*, I should make a better determination than they are going to make with a very light reversible pendulum. I am sure their idea of having it so light is a mistake. But if I were to order such an apparatus, it would not be ready for use until another year.

"Meantime, I will have some invariable pendulums constructed on a new model, which I will swing here and take home with me."

In his next report, on June 29, he not only describes the new model but once more suggests American participation in the affairs of the Association. He writes: "I have received yours approving my suggestion to determine the absolute force of gravity here in a classical manner. . .Your instructions do not authorize me to take a seat in the Geodetical Association as a regular delegate. What am I to say in reference to the entrance of our Survey into the Association?" A postscript, written on July 13 to a letter dated July 8, carries the further news that he had attended "by request a conference of the bureau of longitudes on the subject of the pendulum." He thought they would adopt the course he recommended. Let it be recorded that the Association became in fact international in character in 1886 and that the United States became a formal member in 1889.

Another of Peirce's scientific achievements, this in 1879, deserves mention here. It, too, may be best appreciated by reference to a report in the Coast Survey files, for Benjamin wrote of his son's work

to Patterson on May 24 as follows: "I have examined Assistant C. S. Peirce's conclusions contained in his report of the 23d instant, and also have carefully criticized the various operations from which they were derived. It is a most remarkable achievement to have thus determined the length of the meter, from the wave length of light, which is the shortest length which has ever been measured; and the only sure determination of the meter, by which it would be recovered if it were to be lost to science. It will certainly secure for the Survey the applause of all scientific men.

"When combined with the Peirce's admirable measures of the pendulum, which have justly been regarded by the savans of Europe as adding a new era to this most difficult branch of observation, it places him among the great masters of astronomical and geodetic research . . . . . "[25]

Benjamin died on October 6, 1880, shortly after Charles had hurriedly cut short his trip abroad that year to be with his ailing father.[26] During the next ten years Charles' association with the Coast Survey was to be a far less happy one. Many of the reports describe continued efforts to carry out Benjamin's directives of 1872. Charles, for example, wrote to Superintendent Hilgard on September 11, 1882: ". . .Since our conference in Washington, I have been occupied in studying mathematically the relation between the variation of gravity and the figure of the earth and I have now succeeded in producing a method by which from pendulum observations over a *limited portion of the earth's surface*, the figure of the level surface within that district can

[25] Benjamin hoped that Charles would receive some special recognition for this achievement and it seems that the opinions of several eminent American scientists were solicited to corroborate his judgment. Alfred M. Mayer, Professor of Physics at the Stevens Institute of Technology wrote on May 2, 1879: ". . . I think that the results he has even already reached are of the highest importance to the advancement of science and to the interests of the U. S. Coast Survey. Mr. Peirce's methods are original, and of an accuracy and refinement which are unsurpassed. . . . Mr. Peirce deserves well of his countrymen, for his work has added much to the scientific reputation of the U. S. Coast Survey among European nations."

Ogden Rood, Professor of Physics at Columbia University wrote on May 1, 1879: ". . . In our own country little or no attention was paid to this subject (pendulum experiments) till it was assigned to Mr. Peirce by the Director of the Coast Survey. From what I have seen of Mr. Peirce's work I feel safe in saying that it is probably the most important contribution to the subject that has been made in recent times, especially by his acuteness and unwearied patience, he has succeeded in detecting what might be called fundamental errors in the work of European observers that have passed unchallenged for a series of years."

Finally, Wolcott Gibbs, Rumford Professor at Harvard, wrote on April 21, 1879 in the most laudatory terms of the equipment constructed and employed by Peirce in the determination of "a natural unit of length based upon the measurement of one or more waves of light. . . . I do not hesitate to say that both the spectroscope and spectrometer are the most perfect instruments of the kind in existence, and I have been both delighted and *instructed* by a critical examination of the refinements introduced in their construction."

[26] Peirce originally planned to go abroad during 1879. He could not complete his work in time, however, and went instead in September 1880.

be ascertained. . . .There is no doubt at all that divergencies from a spherical form. . .can at once be detected in the earth's figure by this means. Now, this result puts a new face on the relation of pendulum work to geodesy. . . ."

Peirce was sent abroad for the last time during the summer of 1883. On this trip he supervised the construction of a new pendulum at Gautier's establishment in Paris and visited Brühl, Prussia, and London. But he seems to have attended no scientific meetings. He expressed the hope in two letters to Hilgard, one from Paris on June 1, the other from Brühl on August 1, that two of his papers would be presented for him by General Catts at Rome. One was a mathematical analysis of the new improvement in pendulum construction; the other concerned the motion of the noddy. Peirce felt that these were the most important papers he had yet produced on the subject of pendulum. On March 1 he submitted an appendix to the earlier spectrum meter report.

The Coast Survey correspondence now begins to take on a strange, new tone for Peirce displays less and less interest in the work assigned to him, seems to become more and more lax regarding the completion of calculations on data already amassed, and to be constantly on the defensive with regard to his failure to submit reports on his actual progress. Peirce's inability to submit to institutional discipline, the characteristic that ruined many a promising venture for him, gradually made him *persona non grata* in the administrative offices of the Survey. Poor personal relations with Superintendent Thorn, appointed in 1885, deteriorated into an impasse after Mendenhall's appointment as Superintendent in 1889. The correspondence between Peirce and Mendenhall is full of acrimonious bickering, and finally, after Mendenhall had designed and installed a new instrument and a new procedure for pendulum work, Peirce was driven to write the last, inevitable letter to him on October 1, 1891. It reads: "Sir: I tender herewith my resignation as an Assistant in the United States Coast and Geodetic Survey, to take effect from and after December 31, 1891. Respectfully yours, C. S. Peirce, Ass't. C. & G. Survey." Eight years later the sense of tragedy is heightened by Peirce's desperate and unsuccessful attempt to return to the Survey ranks in the position of Inspector, Bureau of Weights and Measures.[27]

[27] Peirce was a member of the Standing Committee on Weights and Measures of the National Academy of Sciences. On June 10, 1899, Peirce solicited Simon Newcomb's support of his candidacy for this position in a letter in which he summarized his work with the Coast Survey. The letter has been published in a paper by the writer entitled "The Charles S. Peirce-Simon Newcomb Correspondence," *Proceedings of the American Philosophical Society*, vol. 101, #5. Personal aspects as they affected Peirce's career are being omitted.

Although his best years as a productive scientist were now well behind him, Peirce nevertheless continued to seek opportunities for the exercise of his creative scientific talents. As a result of the loss of his Coast Survey connection he was often on the verge of destitution and found it necessary to turn to a variety of odd jobs. And yet, even in the story of this unhappy period in his life, one catches glimpses of the luminous thread of his scientific genius still weaving its pattern through all of his thought.

For Peirce was still the practical inventor as well as the logician of science. For a time he was a consultant to the civil engineer George S. Morison. A receipt[28] from Morison's office shows that Peirce was paid $1000 on August 13, 1895 "for services in making investigations of theory of stiffened Suspension Bridge including calculations and full general report." Another letter from Morison requests information "on a general expression regarding inflow of water into a lake and discharge over a fixed weir."[29] Also extant are a copy of Peirce's application for a patent on a generator for acetylene and other gases which was filed on April 27, 1896[30] and also a copy of a caveat filed by him for a "new and useful improvement in Map Projections."[31] In a letter to "Cabot"[32] Peirce says: "My ingenuity ought to be rendered serviceable. I cannot make it so without backing. I could make a machine which would write a cipher dispatch, as secure as a combination lock, and as readily as an ordinary typewriter, and a companion machine would translate it as fast as a stock ticker—every dispatch in a different cipher which the machine itself would discover."

This streak of mechanical ingenuity is evident also throughout Peirce's correspondence with Samuel P. Langley, one of his steadiest scientific correspondents for many years. A letter from Peirce to Langley at the Smithsonian Institution[33] touches on a problem related

[28] The Peirce Collection, Box III B, Harvard University Archives, Widener Library, Harvard University. Morison's offices were at 49 Wall St., N. Y.

[29] *Ibid.*, dated July 16, 1901.

[30] *Ibid.*, Box IIIB. Serial #589239. Peirce wrote to his friend Russell in Chicago that he had "succeeded in getting in an application for a patent for an indispensable adjunct to a new machine for domestic lighting by acetylene." He felt certain that the machine would "revolutionize domestic lighting" (April 26, 1896. General Correspondence). Patent rights were apparently blocked.

[31] *Ibid.*, Box IB1D, undated.

[32] *Ibid.*, general file, undated. Reference to the Spaniards and the Cuban situation would suggest ca. 1898. The addressee is probably Henry Cabot Lodge, Peirce's cousin.

Peirce's genius and prophetic vision are evident in his writing of logical machines performing inferences which are subject to the rules of logic. Further details may be found in *The Collected Papers of Charles Sanders Peirce* (2.56, 2.57, 2.59).

[33] Dated May 31, 1900. Peirce discusses at some length a modification of the ideas of Dr. Mannesmann whose dissertation he had been asked to translate. The writer is indebted to the staff at the Smithsonian Institution who made it possible for her to examine this material in the archives of the Institution and to publish it.

to the work that was to make Langley a historic figure in science. It reads in part: "That the resistance to a circular disc moving normally through the air at rates of from 1 metre to 30 metres per second is sensibly proportional to the square of the velocity was a fact well enough known already from decrements of pendulum arcs on the one hand and ballistic experiments on the other. Yet it is agreeable to find it confirmed.

"For such a disk, then, moving at such a speed, we may neglect this viscosity of the air. But, neglecting that, the following proposition is evident: *It is impossible to set air in motion at any other velocity than that of sound.* Let us, for instance, suppose such a disc moving normally. At each element of time a wave compression of infinitesimal magnitude starts from each point of the forward part of the disc, and a wave of expansion from the back. They spread and by Huygen's principle the front wave reaches the back part in time, with dimmed amplitude and *vice versa.* This state of things is integrated relatively to the time. It is easy to reduce this to analytical expression, and to trace out the consequences. I should like to be employed to do it."

Peirce's many similar requests of Langley for work highlight an ironic twist of fate which had by this time brought honor to one man and adversity to the other in a way that no one could have foreseen back in the earliest days of their acquaintance in the service of the Coast Survey.[34] In those earlier days Peirce had every reason to believe he was destined for an official scientific position of considerable prestige. His father, for example, had written to Baird, when the latter was appointed Secretary of the Smithsonian in 1878, that Baird's "place of assistant will now be vacant and should unquestionably be filled by a physicist. I take the liberty to nominate Mr. Charles S. Peirce, as worthy of the position in (view) of his scientific ability (and) accuracy of thought and extensive knowledge to fill it usefully and creditably."[35]

The story of Peirce's eventual connection with the Smithsonian, primarily as a translator of foreign scientific papers, has been told elsewhere.[36] Several of the later Smithsonian communications at the turn

[34] In 1878 Peirce was influential enough to obtain for Langley the special passport that guaranteed special privileges on Langley's trip to Mt. Etna. Langley was appointed Secretary in 1887. In the Harvard University archives, a copy of an undated letter (the contents suggest ca. January 20, 1900) from Langley to Capt. C. H. Davis at the Naval Observatory reveals Langley's desire to serve Davis' cousin, Charles. The copy of a second letter to Davis, dated January 29, 1900, contains the sentence: "I have known Charles Peirce for a large part of my life, and am sincerely desirous of getting a man of his real genius a position in which he may be able to do himself justice."

[35] On June 11.

[36] The bulk of the correspondence between Peirce and Langley has been published in two papers, "The Peirce-Langley Correspondence and Peirce's Manuscripts on Hume and the Laws of Nature," by Philip P. Wiener, *Proc. Amer. Philo. Soc.*, vol. 91 (2), 1947; "The Scientist-Philosopher C. S. Peirce at the Smithsonian," by the writer, *Jour. of the Hist. of Ideas*, October 1957.

of the century[37] reflect the change that was gradually transforming Peirce, the scientific man of action into Peirce, the philosopher and logician. One especially interesting letter resulted from his critical treatment of a memoir by Henri Poincaré in which he stated a number of objections to the positivistic point of view. Peirce's fragmentary translation[38] of the memoir, which is entitled "Relations entre la Physique Expérimentale et la Physique Mathématique,"[39] is not of particular interest since it approximates those made by others.[40] But his unsolicited critical commentary on those fragments, written as critical footnotes, reveals what his thought on epistemological problems had come to be. A few brief excerpts may suffice to define his position.[41]

"Logic is the one subject in which loose thought is permissible and even advantageous. It seems to me strange that a profound mathematician, even though he be a Frenchman, should harbor such a notion; but his essay is only a fine example of the utmost that a brilliant mind can contribute toward the solution of a problem to which he comes without adequate preparation."

"It is, as the author vaguely says, indisputable that experience alone can attest the truth of any experiential proposition. But it is so far from being indisputable that all new ideas have their origin in experience,[42] which is the old stoical doctrine of the *tabula rasa*, that all modern psychologists substantially reject it. How it appears from a logical point of view, we shall see presently."

"The assertion of the author that as the human mind develops men generalize less and less is open to serious question. It would be a

[37] The Peirce letters in the Smithsonian files were written in the periods 1894–1896; 1900–1906.

[38] Peirce Collection, Widener Library archives, IB2, Box IV. The draft seems to have been written and rewritten in haste.

[39] Peirce had been asked to translate and to condense this important Poincaré paper which the French scientist had read in 1900 at the International Congress of Physics in Paris.

[40] A translation by George K. Burgess, Docteur de L'Université de Paris, Instructor in Physics at the University of California, was published in the *Monist*, 12: 516–543, July 1902. The Poincaré paper was later incorporated in *Science and Hypothesis* and may be found as Chapters IX and X in the English translation by George Bruce Halstead of the *Foundations of Science*.

[41] The translation opens with a parenthetical description of Poincaré as a "Member of the French Institute, and a mathematician of high genius. He has of late been putting forth views on the logic of science which are somewhat startling to the older physicists. Boltzmann, who opposes the new opinions, calls those who adopt them the 'impressionist school in physics.'" Peirce then explains that "This article has been put into English and greatly condensed (since lack of space forbade inserting it entire) by Mr. C. S. Peirce, at Milford, Pa." Langley, incidentally, was unwilling to publish the adverse criticism of Poincaré (Widener Library archives, Peirce Collection, VB2C).

[42] Peirce frequently attacks the positivist position. For example, in the *Collected Papers*, 1.404, he writes: "I am very far from holding that experience is our only light; Whewell's views of scientific method seem to me truer than Mill's; so much so that I should pronounce the known principles of physics to be but a development of original instinctive beliefs" (1890).

tenable position to maintain that men generalize more and more critically, as their logic improves, and that the greater solidity of the structure of their inferences enables them to throw their arches over wider and wider spans. In Poincaré's own science, mathematics, the reasoning of our time exceeds that of the Greeks in exactitude, and that of the Leibnizian epoch in its wide generality."

"That we ought to experiment without preconceived ideas is one of those vague logical maxims which characterizes the loose reasoner. An experiment has been well called the putting of a question to Nature, which she answers mostly by 'no' or 'yes.' To have no preconceived idea in experimentation is to take an interrogatory position without putting any question. To be wedded to a preconceived idea is to replace interrogation by affirmation and not listen to what Nature has to say. . . . . Unless there be some truth in our hereditary metaphysics, unless the nature of the mind is such that the right idea will be developed at last, unless the number of utterly wrong guesses that we should ever make is finite, no number of questions, however large, will bring us measurably nearer the truth than we were at the outset.

"The principle of pragmatism is applicable here. In reference to any particular investigation that we may have in hand, we must *hope* that, if it be persistently followed out, it may ultimately have some measure of success; for if it be not so, nothing that we can do can avail, and we might as well give over the inquiry altogether, and by the same reason stop applying our understanding to anything."

"The author undertakes to describe how we reason when we generalize. In doing so he limits himself to induction, which is only a particular species of generalization, but that is, perhaps, not a very serious fault. He seems to range himself squarely in the ranks of those logicians who regard induction as regulated by the doctrine of chances. He would consequently reject along with several other theories, all those which make the validity of induction to depend upon a particular constitution of the universe, such as Mill's 'uniformity of nature,' the different uniformities upon which Philodemus relied, etc. This, however, is not as clear as it would be if M. Poincaré did not point to the principle of causation as the anchor of certainty. Whether he would prove the truth of this principle by the simplicity of nature, or how else, he does not tell us."

When Poincaré writes: "Every generalization is a hypothesis," Peirce counters with: "What would M. Poincaré say to a person who should discourse upon the theory of light and throughout his reasonings confuse the amplitude of an oscillation with its wave length? Why should logic be regarded as the one subject concerning which

muddled thought is permissible, if not decidedly superior to exactitude? By 'generalization,' Poincaré no doubt means an *induction;* for that is a confusion of thought universal among the French. In fact, two species of generalization are induction and hypothesis."

These excerpts serve also to explain the eagerness of several publishers to bring Peirce's challenging ideas to the attention of their readers.[43] Paul Carus, the editor of the *Monist*, was one of these and Peirce wrote many papers for him during the late nineties and the early years of this century. When the Open Court presses were set to publish the first edition of the English translation of Mach's classic *Die Mechanik in ihrer Entwickelung, historisch-kritisch dargestellt*, Peirce was invited to read the proofs of the whole work and to rewrite Section 8 of Mach's treatment of the material on Units and Measures.[44] This he did with characteristic assurance not failing, incidentally, to include criticism of official procedures. Work with the elements of metrology had been the core of Peirce's daily routine in the Coast Survey for many years and Carus was cognizant of the value of such experience. Indeed, Peirce himself was once moved to write to Carus, "Few philosophers, if any, have gone to their work as well equipped as I, in the study of other systems and in the various branches of science."[45]

Very little has been said, in this brief survey of Peirce's scientific life, of his contributions to the mathematical thought of his time, some of which grew out of the needs of technological application. Peirce staked numerous priority claims for himself in several mathematical fields, and—perhaps—none is of greater interest than his development of nonions, where he and the illustrious Sylvester clashed head on. Nevertheless Sylvester greatly respected Peirce's skill in mathematics, as well as in logic, on which Peirce lectured under Sylvester's sponsorship at the Johns Hopkins University (1879–1884). The full story of Peirce's mathematical inventiveness must await separate treatment.

The last lonely years of Peirce's life were spent with his second wife

[43] Such opportunities dwindled as time went on, but only because of Peirce's inability to break the bonds of personal eccentricity that made it difficult for him to meet deadlines and conform to fixed schedules of work.

[44] On April 27, 1892, Carus informed Peirce that he intended to publish an English translation by Mr. McCormack of Mach's book. He continued: "Although the translation is made with great care, I should nevertheless like someone who is an authority in this province, or at least in similar fields of investigation, to look over the proofsheets before they go to press. . ." (Peirce Collection, Publisher's Correspondence). Peirce's unabridged Section 8 is found in the 1902 edition only. In the translator's preface to this, the second English edition, McCormack wrote in February, 1902: ". . . the text . . . has had the sanction of the author and the advantage of revision by Mr. C. S. Peirce, well known for his studies both of analytical mechanics and of the history and logic of physics. . . ."

[45] *Ibid.*, undated, first page missing.

Juliette, at "Arisbe," the dream house in Milford, Pennsylvania, which he had originally hoped would one day become a Mecca for his philosophical adherents. He worked on such tasks as an occasional memoir for the National Academy of Sciences, a book review for Garrison and the *Nation*, some lectures in the vicinity of Cambridge, or a translation for Langley. His voluminous writings in logic and philosophy in this period, draft after draft, were composed primarily to satisfy a relentless urge to get his ideas expressed fully and clearly. But much of his time and energy had to be devoted to the performance of the daily household and farm chores forced on him by poverty. Existence itself was made possible during the very last years by the generous financial support of a group of loyal supporters under the leadership of William James. Although Peirce remained interested in contemporary scientific developments, it is apparent that his scientific productivity had burned itself out by the time he reached this last decade of his life.

It has been possible to present but a part of Peirce's scientific thought in this paper. But there is ample evidence that he earned for himself a place of honor among the scientists of nineteenth century America. He was aware of this just as he was aware of the value of his scientific experience to his creative thought in logic and philosophy. In conclusion it seems appropriate to permit him to express himself once more on this point by quoting from an undated letter to John Dewey[46] in which he declares, "Again you take as premises of a confirmatory argument that any non-genetic logic will reach no conclusions that have any *meaning* in their real applications. But all my studies are conducted in full view of actual scientific memoirs and other record of scientific inquiry, in which they lead to denials of conclusions to which bad logic has lead their authors; and some of my non-genetical studies have lead directly to discoveries in mathematics and others to instituting experimental researches about the reality if not the solidity, of which there can be no question; and in short I should like to know what generic logician ever came to have such close quarters with actual science as I have done."[47] And, finally, there is the clear statement of purpose in the words: "Thus, in brief, my philosophy may be described as the attempt of a physicist to make such conjecture as to the constitution of the universe as the methods of science may permit. . .The best that can be done is to supply a hypothesis, not devoid of all likelihood,

[46] Draft in Peirce Collection, General Correspondence, Box VB2a(1).

[47] In the same file, a letter to F. S. C. Schiller at Corpus Christi College, May 23, 1905 reads: "I am trying to do what I can toward rendering philosophy scientific in the sense of the sciences in which I was bred, and especially to bring into philosophy the ethics of these sciences."

in the general line of growth of scientific ideas, and capable of being verified or refuted by future observers."[48]

Peirce's thread of thought, woven so ingeniously into the tapestry of scientific progress, must shine brilliantly to any observer of the scientific scene in America.[49]

[48] *Collected Papers*, (1.7).

[49] This paper is in part an expansion of references to Peirce's Coast Survey experience in an address of the same title read by the writer before the New York Section of the History of Science Society on November 26, 1956.

CAROLYN EISELE

HUNTER COLLEGE