New Dictionary of Scientific Biography

VOLUME 2
CABEO–EYSENCK

2008

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EDITOR IN CHIEF

CHARLES SCRIBNER'S SONS
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after Nathan Reingold submitted his original DSB *article on Cattell. The original article also could not benefit from the post-1970 spurt of research on psychology's past and—led largely by Reingold—on the twentieth-century American scientific community.) Cattell's papers are also held in Central Files, Columbia University, New York. Although Columbia University's Manuscripts Library and the Columbiana Collection both also hold collections of Cattell material, the records of all Columbia faculty and administrative officers available in the university's Central Files are much more valuable.*

WORKS BY CATTELL

James McKeen Cattell: Man of Science, edited by A. T. Poffenberger. 2 vols. Lancaster, PA: The Science Press, 1947. Collects many of Cattell's most important scientific and programmatic papers and includes an incomplete bibliography.

"APA's First Publication: Proceedings of the American Psychological Association, 1892–1893." *American Psychologist* 28 (1973): 277–292. A facsimile reprint of a major report that Cattell edited for publication in 1894.

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———, and Patrice A. Rafail, eds. *A Guide to Manuscript Collections in the History of Psychology and Related Areas*. Millwood, NY: Kraus, 1982. Describes collections in which much of Cattell's correspondence with his psychological contemporaries may be found.

Michael M. Sokal

CAUCHY, AUGUSTIN-LOUIS

(*b.* Paris, France, 21 August 1789; *d.* Sceaux [near Paris], 23 May 1857), *mathematics, mathematical physics, celestial mechanics*. For the original article on Cauchy see *DSB*, vol. 3.

Since the publication of Hans Freudenthal's lengthy *DSB* article in 1971, several books and a host of articles have appeared exploring Cauchy's extensive contributions to mathematical science. Four books are devoted exclusively to Cauchy, by Judith Grabiner (1981), Amy Dahan-Dalmédico (1992), Bruno Belhoste (1991), and Frank Smithies (1997). Grabiner provides a detailed account of Cauchy's contributions to the foundations of calculus. In addition to presenting an extended analysis of Cauchy's science, Dahan-Dalmédico situates Cauchy within the French scientific milieu of the late eighteenth century and first part of the nineteenth century. Belhoste presents a comprehensive biography of Cauchy, giving a balanced account of his life, mathematical science, and philosophy that supersedes Claude Alphonse Valson's uncritical biography of 1868. Smithies concentrates on Cauchy's seminal role in the creation of complex function theory.

The last volume of Cauchy's *Oeuvres complètes* appeared in 1976, containing several *mémoires détachés* as well as a range of miscellaneous material. The volume ends with a detailed bibliography relating to Cauchy. In 1981 there appeared a substantial fragment of several previously unpublished lectures that Cauchy delivered in the early 1820s at the École Polytechnique in Paris on the subject of ordinary differential equations. In 1989 a conference was held at the École Polytechnique itself to commemorate the bicentennial of Cauchy's birth. The proceedings of the conference were published as the first issue of *Revue d'Histoire des Sciences* in 1992 and included a bibliography of historical literature that had appeared since 1976.

Contributions to Analysis. Historical research on eighteenth-century calculus has resulted in an increased appreciation of Cauchy's groundbreaking contributions to the foundations of analysis. Craig Fraser (1989), Marco Panza (1996), and Giovanni Ferraro (2004) have documented the conceptual gulf that separated the formal-analytic approach of Leonhard Euler and Joseph-Louis Lagrange from the arithmetic and conceptual style of Cauchy. Not only did Cauchy put calculus on a rigorous technical foundation that became standard, his work also contributed to a radical new philosophical conception of analysis and its place in exact science.

Grabiner (1981) examines the origin of Cauchy's calculus techniques in the work of earlier mathematicians, especially Lagrange, and provides English translations of some of his key results concerning functions and integrals. Smithies (1986) examines Cauchy's understanding of rigor in relation to the eighteenth-century belief in the "generality of algebra." Both Ivor Grattan-Guinness (1970) and Umberto Bottazzini (1986) include extended accounts of Cauchy's foundation within broader surveys of the history of analysis. Bottazzini's (1992) introduction to a reprint of the first part of Cauchy's 1821 treatise on algebraic analysis discusses technical, historical, and conceptual issues involved in an understanding of Cauchy's achievement. Thierry Guitard (1986) considers the relationship of the work of André-Marie Ampère and Cauchy, while Christian Gilain (1989) presents a detailed study of Cauchy's teachings on analysis from 1816 to 1830 at the École Polytechnique.

The novel conception of analysis at the base of Cauchy's work brought with it a new understanding of mathematical existence. Solutions to differential equations were no longer assumed to be given but rather constructed through specified processes of analysis. Gilain (1981) provides a historical account of existence questions for ordinary differential equations; his essay appears as the introduction to the 1981 edition of Cauchy's lectures. A useful overview of existence theorems is given by Morris Kline (1972, chapters 28 and 29), who also situates Cauchy within the broader development of nineteenth-century analysis. Kline (p. 671) asserts that during this period partial differential equations "became and remain the heart of mathematics" and describes a fundamental existence theorem from the subject first obtained by Cauchy. A detailed account of Cauchy's work on partial differential equations is given by Dahan-Dalmédico (1992, chapter 7).

Two special topics concerning Cauchy's calculus should be mentioned. The first is the relationship of his ideas to those of his contemporary Bernhard Bolzano, a subject that is explored by Grattan-Guinness (1970), Hans Freudenthal (1971) and Hourya Sinaceur (1973). The other concerns the place of infinitesimals in Cauchy's calculus and the possible relevance of such modern theories as nonstandard analysis to an historical appraisal of his achievement. Studies here have been written by Imre Lakatos (1978), Gordon Fisher (1978), Detlef Laugwitz (1978, 1989) and Detlef D. Spalt (2002). Laugwitz's thesis is that certain of Cauchy's results that were criticized by later mathematicians are in fact valid if one is willing to accept certain assumptions about Cauchy's understanding and use of infinitesimals. These assumptions reflect a theory of analysis and infinitesimals that was worked out by Laugwitz and Curt Schmieden during the 1950s.

Cauchy was a formative figure in the creation of complex analysis, one of the most impressive branches of mathematics to emerge in the nineteenth century. The subject was a prominent one in Freudenthal's original article and has since attracted considerable historical attention. Detailed accounts are given by Bottazzini (1986, chapter 4), Belhoste (1991, chapter 7), Grattan-Guinness (1990, chapter 10.2) and Smithies (1997). Cauchy's investigations grew out of a new conception of integration. In the eighteenth century, integration was understood as the algorithmic inverse of differentiation: The primitive or integral of a given function was the function that when differentiated produced the given function. What later became known as the definite integral was understood as the difference between the values of the primitive at two values of the independent variable. By contrast, Cauchy envisaged the integral as the limit of a sum and recognized that it was necessary to show that such a limit exists. In the investigation that was stimulated by the new definition, he was led to consider definite integrals in which the limits of integration are complex numbers. This point of view was combined with the formal theory he had developed for complex functions and singular integrals. A stream of important researches beginning in 1814 culminated in 1825 with the appearance of his masterpiece, "Sur les intégrales prises entre des limites imaginaires." This work laid the foundation for the calculus of residues and was the basis of subsequent researches by Cauchy up to the late 1840s.

Physical Science and Continuous Media. A prominent area of historical work since the 1970s has been the study of the mathematization of physical science in France in the early nineteenth century. Dahan-Dalmédico (1992) identifies several different styles of mathematization that were at work and gives an account of Cauchy's contributions to hydrodynamics and elasticity. An important

Augustin-Louis Cauchy. © BETTMANN/CORBIS.

theme of Belhoste's (1991) biography is that even results that have traditionally been viewed as part of pure analysis were connected to techniques and problems arising in physical science. Cauchy's various contributions to analysis and applied mathematics are described in some detail by Grattan-Guinness (1990).

Cauchy's interest in continuous media originated in a study beginning around 1815 of the propagation of waves at the surface of a liquid of specified depth. Continuum mechanics as a coherent branch of mathematical science was set forth in a major paper composed in 1822 as well as in several lengthy papers written later in the decade. In the original *DSB* article Freudenthal wrote, "Never had Cauchy given the world a work as mature from the outset as this," and asserted that a developed theory of elasticity was his most important contribution to science, elevating him to the ranks of the greatest scientists. The circumstances of the competitive scientific research environment of the period as well as an account of Cauchy's theory are provided by Belhoste (1991). Dahan-Dalmédico (1992, part 4) examines the interconnected researches of Siméon-Denis Poisson, Claude Navier, and Cauchy. The role of Cauchy's theory in the history of tensor calculus is described by Dieter Herbert (1991, chapter 2).

During the late 1820s Cauchy turned to the elaboration of a molecular model of a continuous media, following the prevailing notions of Laplacian physics. This research was closely connected to an interest in Auguste Fresnel's wave theory of light, a topic that occupied Cauchy's attention increasingly during the 1830s. An account of this transition in Cauchy's scientific thought as well as an exposition of his optical theory is given by Dahan-Dalmédico (1992, chapter 13). Cauchy's conception of a molecular or punctiform optical ether is analyzed by Jed Buchwald (1980), who also situates Cauchy's optical researches in the context of Fresnel's theory.

Algebra, Theory of Errors. In the field of algebra, Luboš Nový's (1973) history of this subject contains a detailed discussion of Cauchy's results on permutation groups; this account is a shortened version of the author's studies in Russian from 1966. Dahan-Dalmédico (1980–1981) considers this subject as well as the relationship of Cauchy and Évariste Galois. The latter relationship is also the focus of an article by René Taton (1971). Thomas Hawkins (1975) documents some of Cauchy's results in linear algebra concerning the eigenvalues of linear transformations, a subject that the author calls "spectral theory."

Cauchy's contributions to the theory of errors were comparatively minor but still noteworthy. Two studies related to what is known as the Cauchy distribution have been published by Stephen Stigler (1974) and Ivo Schneider (1987). Cauchy's disagreement with his contemporary I. J. Bienaymé about the value of Pierre-Simon Laplace's theory is documented by Christoper C. Heyde and Eugene Seneta (1977).

Reception and Reputation. Since 1971 a sizable literature has developed on the reception of Cauchy's mathematical science in various countries of Europe. Jesper Lützen (1990) considers the French scene at the middle of the century, Bottazzini (1989) examines Cauchy and Italian analysis, H. Niels Jahnke (1987) and Reich (2003) explore the reception of Cauchy's ideas in Germany, and Adrian Rice (2001) looks at the introduction of his calculus into Britain. Schubring (2005) provides a contextual study of Cauchy's work on the foundations of analysis, confirming his status as a critical figure in the development of nineteenth-century mathematical thought.

René Taton wrote a short introduction to the reprint in 1970 of Valson's biography of Cauchy. Taton opened with the comment that, after Carl Friedrich Gauss, whose preeminence was beyond discussion, Cauchy was one of the leading mathematicians of the first half of the nineteenth century. In the period since 1970 it is significant to note that Cauchy has attracted considerably more historical attention than has Gauss, a fact that speaks to the historical importance of the French savant. The evidence that has accumulated suggests that Taton's ranking might be challenged, and that while Gauss's achievements were certainly monumental, it was Cauchy who was the preeminent mathematician of his time.

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Craig Fraser

CAVENDISH, MARGARET, DUCHESS OF NEWCASTLE

(*b.* Colchester, England, 1623 [?]; *d.* Welbeck Abbey, Nottinghamshire, 15 December 1673), *atomism, materialism, vitalism, women in science.*

Cavendish was the first woman to write about science in English. She developed a unique natural philosophy, as well as publishing poetry, romances, plays, and essays. Her importance as a thinker has been recognized by the inclusion of the second edition of her most important treatise, the 1668 *Observations upon Natural Philosophy,* in the Cambridge *Texts in the History of Philosophy* series. Cavendish's natural philosophy is the first example of the reception and reconstitution of the ideas of New Science by a woman. Her significance lies in her priority and in her originality: She felt her sex ultimately enabled rather than hindered her ability to be a natural philosopher and to be the peer of masculine interpreters of nature.

Family Connections. Gender shaped both the articulation and content of her philosophy. Cavendish was poorly educated, although she was a member of a prominent gentry family, the Lucases of Colchester in Essex who had risen to preeminence during the Tudor period. Her widowed mother, Elizabeth Lucas, preferred her daughters to be schooled in virtue rather than learning and the tutors she employed "were rather for formality then benefit" (Margaret Cavendish, *A True Relation of my Birth, Breeding and Life* [1656], in Bowerbank and Mendelson, *Paper Bodies,* 43). Cavendish embraced an epistemology that

Margaret Cavendish. © BETTMANN/CORBIS.

privileged introspection and imagination over logic and experimentation. She was skeptical that perception based only on the senses could do anything but delude the observer. Her most developed natural philosophy was a kind of vitalistic materialism that she composed as a response to and repudiation of mechanistic materialism. Cavendish was not a brilliant natural philosopher. Her style was abstruse and some of her theories are strange, even in the context of her own time. But her idiosyncrasies reveal how gender and culture functioned in the seventeenth century, a period when women were increasingly excluded from all intellectual activities.

Cavendish was first exposed to new scientific ideas by her brother, John Lucas; her husband, William Cavendish, the Duke of Newcastle; and her brother-in-law, Sir Charles Cavendish. William was a patron of the arts and letters. Sir Charles was an amateur mathematician. After Margaret Cavendish joined the royal court in exile in 1644, she met and married Newcastle. He entertained Pierre Gassendi, Marin Mersenne, and René Descartes, and had a long association with Thomas Hobbes. Cavendish's direct contact with these thinkers was limited, but her husband and brother-in-law