Deutschen Mathematiker-Vereinigung, **23** (1914), 431–444, with portrait.

Bruno Schoeneberg

WEBER, MAX WILHELM CARL (*b.* Bonn, Germany, 6 December 1852; *d.* Eerbeek, Netherlands, 7 February 1937), *zoology*.

After attending schools in Oberstein an der Nahe, Neuwied, and Bonn, Weber began the study of medicine at the University of Bonn. His teachers included the zoologists Franz Hermann Troschel and Franz von Leydig (for whom he worked as an assistant) and the anatomist Adolph La Valette St. George. In the winter semester of 1875–1876 Weber studied at Berlin, mainly under the zoologist Eduard von Martens. In 1877 he received the Ph.D. from Bonn for the dissertation "Die Nebenorgane des Auges von einheimischen Lacertiden." Soon afterward he was invited by the anatomist Max Fürbringer to serve as prosector at the anatomy institute of the University of Amsterdam. In 1879 he went to the University of Utrecht as lecturer in anatomy. He was recalled to Amsterdam in 1883 to teach zoology and comparative anatomy.

Weber went on an expedition in the North Atlantic, primarily to study the anatomy of whales. He was aided in this research by his wife, Anna van Bosse, who had studied under Hugo de Vries. Their findings were published in 1886 as the first part of his *Studien über Säugethiere*. In 1888 the couple traveled to the Dutch East Indies, where they visited Sumatra, Java, Celebes, and Flores. On Flores especially, Weber gathered extensive zoological material, as well as ethnographic data. A number of scientists collaborated in publishing descriptions of this material in *Ergebnisse einer Reise nach Niederländisch Ost-Indien* (Leiden, 1890–1907). Weber himself described the freshwater sponges, the trematode genus *Temnocephalus*, and several fish, reptiles, and mammals. With his wife he also investigated the symbiotic algae of the freshwater sponge *Spongilla*. The Webers soon embarked on another voyage, this time to South Africa. Their findings were published in 1897.

The second part of *Studien über Säugethiere* appeared the following year. In 1899 Weber and his wife participated in the Dutch Sibolga expedition, which was sent to examine the marine fauna and flora of Indonesia. Weber himself recorded part of the findings in *The Fishes of the Indo-Australian Archipelago* (Leiden, 1911–1936); the seven-volume work contained descriptions of 131 new species. Weber had acquired an interest in biogeography during his first trip to the Dutch East Indies, and the studies of the Sibolga expedition on freshwater fauna led him to reexamine the well-known differences between the freshwater fauna of Java, Borneo, and Sumatra, on the one hand, and of Celebes, Timor, and Flores, on the other. Weber drew attention to the zoogeographical differences between the northern and southern halves of Celebes and noted the existence of the deepwater zone around the island, the temperature of which differs markedly from that of the rest of the ocean.

During the period of his expeditions and of assessing the material they yielded, Weber also worked on his greatest scientific publication, *Die Säugetiere* (1904), an exposition of both the anatomy and the systematics of the mammals; the second edition is still a standard work.

Weber confined his scientific labors to descriptive zoology. He explicitly defended the old methods of comparative anatomy, although he also recognized the importance of the new experimental areas of biological research.

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A list of Weber's more important works follows D'Arcy Wentworth Thompson's biography in *Obituary Notices of Fellows of the Royal Society of London*, **2** (1938), 347–352, with portrait. They include *Studien über Säugethiere*, 2 pts. (Jena, 1886–1898), comprising "Ein Beitrag zur Frage nach dem Ursprung der Cetaceen" and "Über Descensus testiculorum, Anatomische Bemerkungen über Elephas"; the results of Weber's voyage to South Africa, published as "Zur Kenntnis der Süsswasser-Fauna von Südafrika," in *Zoologische Jahrbücher*, **10** (1897), 135–200; *Der indo-australische Archipel und die Geschichte siener Tierwelt* (Jena, 1902); and *Die Säugetiere* (Jena, 1904), which appeared in a 2nd, enl. ed., 2 vols. (Jena, 1927–1928), completed by a section on paleontology by Othenio Abel.

Hans Querner

WEBER, WILHELM EDUARD (*b.* Wittenberg, Germany, 24 October 1804; *d.* Göttingen, Germany, 23 June 1891), *physics*.

Weber was one of twelve children of Michael Weber, professor of theology at the University of Wittenberg. Of four brothers and a sister who lived to an advanced age, the eldest brother became a minister, while the other brothers turned to science and medicine. Ernst Heinrich, who was almost ten years older than Wilhelm, became a leading anatomist and physiologist, and a professor at Leipzig. Eduard, a year and a half younger than Wilhelm, also became professor of anatomy at Leipzig. The interest of the three brothers in science was undoubtedly awakened by the family friends Christian August Langguth, professor of medicine and natural history, in whose house the Webers lived, and the acoustician E. F. Chladni, a fellow lodger.

Langguth's house was burned during the bombardment of Wittenberg by the Prussians in 1813, and in the following year the Webers settled in Halle. Michael Weber became professor of theology at the University of Halle, with which the University of Wittenberg officially merged in 1817. Here Wilhelm began his first scientific work, in collaboration with Ernst Heinrich. The resulting publication, *Wellenlehre, auf Experimente gegründet* (1825), which contains experimental investigations of water and sound waves, made Wilhelm's name known in scientific circles. Some of the experimental work on waves was done before Wilhelm entered the University of Halle in 1822. There he was most influenced by the physicist J. S. C. Schweigger and perhaps by the mathematician J. F. Pfaff. Weber wrote his doctoral dissertation on the theory of reed organ pipes in 1826 under Schweigger. His *Habilitationsschrift* (1827) treated such systems as coupled oscillators, as did four papers in Poggendorff's *Annalen der Physik und Chemie* (1828, 1829). Weber became lecturer and then assistant professor (1828) at Halle. He traveled to Berlin in September 1828 with Ernst Heinrich to attend the seventh meeting of the Gesellschaft Deutscher Naturforscher und Ärzte, organized by Alexander von Humboldt. He delivered a talk on his work on organ pipes that attracted the notice of Humboldt and Gauss. At this time Humboldt interested Gauss in his work on geomagnetism, and Gauss saw in Weber a worthy co-worker if a position became available for him at Göttingen.

In April 1831 the professorship of physics at Göttingen, vacated upon the death of Tobias Mayer, Jr., was offered to Weber; and six years of collaboration and close friendship with Gauss followed. At the end of 1832 Gauss read his paper "Intensitas vis magneticae terrestris ad mensuram absolutam revocata," written with Weber's assistance. In this paper he introduced absolute units of measurement into magnetism; that is, the measurement of the strength of a magnetic property was reduced to measurements of length, time, and mass, and thus became reproducible anywhere without the need of a particular precalibrated magnetic instrument. One of the major themes of Weber's later work was to extend this idea to electrical measurements.

Gauss and Weber founded the Göttingen Magnetische Verein to initiate a network of magnetic observatories and to correlate the resulting measurements. This was to be a more sophisticated version of Humboldt's project. In 1833 they set up a battery-operated telegraph line some 9,000 feet long between the physics laboratory and the astronomical observatory, in order to facilitate simultaneous magnetic observations. This was one of the first practical long-range galvanic telegraphs. A year later, induced currents were used in place of the battery. The *Resultate aus den Beobachtungen des Magnetischen Vereins* for the years of its existence (1836–1841), published from 1837 to 1843, contain mostly articles by Gauss and Weber, although in the later volumes observations were published from many stations throughout the world. Weber's major contribution during this period was the development of sensitive magnetometers and other magnetic instruments.

Busy as he was with magnetism at Göttingen, Weber found time to collaborate with his younger brother Eduard on *Mechanik der menschlichen Gehwerkzeuge* (1836). This work on the physiology and physics of human locomotion represented a continuation of the close bond of the three brothers in scientific research, which had begun with the *Wellenlehre*.

With the death of William IV in 1837, Victoria became queen of England and her uncle, Ernst August, acceded to the rule of Hannover and at once revoked the liberal constitution of 1833. Weber was one of seven Göttingen professors who signed a statement of protest. (The others of the "Göttingen Seven" were F. E. Dahlmann, W. E. Albrecht, Jakob and Wilhelm Grimm, G. Gervinus, and G. H. von Ewald.) At the king's order all seven lost their positions; and Dahlmann, Gervinus, and Jakob Grimm were exiled from Hannover. The Seven received much sympathy from all over Germany; in particular, a committee was formed at Leipzig to raise funds to support them. Despite the loss of his position, Weber continued to work for the Magnetische Verein in Göttingen. Gauss and Humboldt attempted to obtain Weber's reinstatement; but the king insisted on a public retraction, which was unacceptable to Weber. Between March and August 1838 he traveled to Berlin; to London, where he spoke with John Herschel about extending the network of magnetic observing stations; and to Paris, becoming acquainted with many of the leading scientists of his time.

After several years in Göttingen without a university position, Weber became professor of physics at the University of Leipzig in 1843, joining his brothers Ernst Heinrich and Eduard. This position had been held by G. T. Fechner, a close friend of the Webers. Because of severe eyestrain induced by his psychophysical experimentation, which led to temporary blindness, Fechner had to relinquish the post, turning afterward to philosophy and psychology. At Leipzig, Weber formulated his law of electrical force, published in the first of his *Elektrodynamische Maassbestimmungen* (1846). Weber and Fechner, who was a staunch atomist, often discussed scientific matters; and the law is adumbrated in a semiquantitative treatment by Fechner in 1846, which refers to Weber's forthcoming work.

The upheavals of 1848 forced a greater liberality upon Ernst August, and in the following year Weber was able to return to his old position at Göttingen. At his request his replacement, J. B. Listing, was retained, thus creating a double professorship in physics. Weber became director of the astronomical observatory and was closely associated with Rudolph Kohlrausch, a friend for some years who had proposed to test Weber's force law directly, using mechanically accelerated charges. As this was not feasible, Weber in 1856 collaborated with Kohlrausch, then at Marburg, to determine the ratio between the electrodynamic and electrostatic units of charge (the former being greater than the presently used electromagnetic unit by the factor $\sqrt{2}$). This measurement was later used by Maxwell as a crucial support for his electromagnetic theory of light. In 1857 Kohlrausch moved from Marburg to Erlangen and began research with Weber on electrical oscillations, but died in the following year. His son, Friedrich, received the doctorate in 1863 at Göttingen with a thesis on elastic relaxation in metal wires, written under Weber's direction, thus extending an investigation Weber had made on nonmetallic fibers. Friedrich later became lecturer at Göttingen and organized the physical laboratory course at Weber's request.

Weber's later years at Göttingen were devoted to work in electrodynamics and the electrical structure of matter. He retired in the 1870's, relinquishing his duties in physics to his assistant, Eduard Riecke. Toward the end of the century, the latter began the development of the electron theory of metals from Weber's ideas, a development soon carried to its completion in classical physics by Paul Drude and H. A. Lorentz.

Weber's closest collaborator in his last years was the Leipzig astrophysicist J. K. F. Zöllner, with whom he worked on electrical conductivity. Zöllner envisaged a physics based solely on the interaction of atoms of the two kinds of electricity, a conception taken up by Weber after Zöllner's death in 1882 and left in manuscript as the last of the *Elektrodynamische Maassbestimmungen.*

The career of Hermann von Helmholtz touched that of Weber at several points, and relations between the men were strained. Results in Helmholtz' memoir on the conservation of energy (1847) were at first taken to imply that Weber's force law violated that principle. By introducing a velocity-dependent potential energy, Weber was able to demonstrate that the criticism was unfounded. But in 1870, while investigating the rival electrical theories then extant, Helmholtz found that Weber's law could lead in certain circumstances to states of motion that appeared to be disallowed physically. Weber and his supporters attempted to refute Helmholtz' arguments; and a rather sterile but sometimes bitter dispute lasted for several years, with Zöllner championing Weber's cause with more ardor than tact. At an international congress on the electrical units held in Paris (1881) Helmholtz, the leader of the German delegation, proposed the name "ampere" for the unit of current, although "weber" enjoyed some use at that time. The term "weber" was officially introduced for the practical unit of magnetic flux in 1935.

Weber died peacefully in his garden at the age of eighty-six. He had received many honors from Germany, France, and England, including the title of *Geheimrat* and the Royal Society's Copley Medal. He was described as being friendly, modest, and unsophisticated. His reputation had suffered in the 1870's when Zöllner introduced the American medium, Henry Slade, into the Leipzig circle of which Fechner and the Webers were the leading lights. Weber enjoyed hiking and did much traveling on foot. He never married, his household being sometimes managed by his sister and, in his later years, by his niece.

Wellenlehre, auf Experimente gegründet, which marks the beginning of Wilhelm's scientific career, describes experiments on surface waves in liquids, and on sound and light waves. It is dedicated to Chladni, the family friend who was famed for his experiments on standing waves in plates. The immediate inspiration was the chance observation of standing waves in mercury by Ernst Heinrich. Traveling and standing water waves are described and illustrated in engravings made by the brothers. Using a narrow channel with glass walls, they investigated the dependence of wave velocity on the depth of the water, noted the dispersion of wave packets and the distinction between capillary and gravity waves, and investigated the effect of oil on water and wave interference. The elliptical motion of particles in the water as a wave passes was described. In a historical section they compared their results with contemporary theory, particularly Poisson's. Vortices were treated briefly, without proper comprehension of their peculiarities, an understanding of which did not come until later in the century. The section on sound waves treated the problems connected with resonance in pipes, a field that formed the subject of Wilhelm's next works. Ernst Heinrich also utilized the fruits of this investigation in a later treatise on the circulation of the blood.

Weber's early scientific work—before he was called to Göttingen—centered on acoustics. Several of the earlier papers involve the repetition of experiments of previous investigators. Others develop the discovery in the *Wellenlehre* of the distribution of sound around a tuning fork. His doctoral dissertation (1826) and *Habilitationsschrift* (1827) deal with the acoustic coupling of tongue and air cavity in reed organ pipes. This experimental and theoretical investigation was pursued in papers in *Annalen der Physik und Chemie* (1828–1830). One of the subjects treated was the use of this coupling to maintain constancy of pitch of a pipe under different intensities of blowing, and the possibility that this might provide an improved standard of pitch.

The *Mechanik der menschlichen Gehwerkzeuge* (1836) was a collaborative work by Wilhelm Weber and his younger brother, the anatomist Eduard. It contains an anatomical discussion of the joints used in walking and running, measurements made on living subjects, and a mathematical theory relating the length and duration of a step to anatomical parameters. Drawings were made on the basis of the theory and viewed stroboscopically. Among other results, the work corrected misconceptions about posture and recommended its conclusions to the attention of artists. The introduction suggests the development of a walking machine for traversing rough terrain.

The papers contributed by Weber to *Resultate aus den Beobachtungen des Magnetischen Vereins* (1836–1841) are concerned partly with the construction of galvanomagnetic instruments, including a beautifully designed portable magnetometer, magnetometers working by electromagnetic induction, and a dynamo. This led him to investigate the dependence of magnetization on temperature and inspired other investigations of unipolar induction and elasticity. Working with the silk fibers used in the magnetometer suspensions, Weber found that aside from the immediate elastic response to a change in load, there was a slow but apparently elastic relaxation (*elastische Nachwirkung*) involving a delayed stretching or shrinking as the stress increased or decreased, respectively. Weber sought to provide a molecular explanation for the phenomenon, and his papers on the subject were published in 1835 and 1841. In the later volumes of the *Resultate*, Weber summarized the results obtained from the various geomagnetic observing stations and helped to create the lithographed maps showing the earth's magnetism. They also contained Weber's first work on extending the idea of absolute units, introduced into magnetism by Gauss, to galvanic measurements.

In the *Resultate* for 1840, Weber defined the absolute electromagnetic unit of current in terms of the deflection of the magnetic needle of a tangent galvanometer. He determined the amount of water decomposed by the flow of a unit of current for one second—that is, by a unit of charge. In the first of the *Elektrodynamische Maassbestimmungen* (1846) he introduced his electrodynamometer, in which a coil is hung by its leads in bifilar suspension in the field of another coil and the current is passed through both. This instrument was used to determine the electrodynamic unit of current, defined in terms of the force between two current elements using Ampère's law, and having a magnitude $\sqrt{2}$ greater than the electromagnetic unit. The response of the electrodynamometer depends on the square of the current and thus is suited for alternating currents. With it Weber measured currents alternating with acoustical frequencies.

In 1846 M. H. von Jacobi circulated an especially prepared copper wire to be used as a resistance standard. Weber was dissatisfied, however, with standards depending on the resistance of a particular object or on the resistivity of a particular substance, and in the *Elektrodynamische Maassbestimmungen* of 1852 he defined an absolute measure for electrical resistance. By use of Ohm's law and the absolute measure of current, the problem is reduced to that of voltage measurement. Weber defined this by the voltage induced in a loop rotating in a given magnetic field. Several practical methods of determining resistance were presented.

In 1855 Weber collaborated with R. Kohlrausch on the measurement of the ratio between the electrodynamic and electrostatic units of charge; their results were published in 1857 as one of the *Elektrodynamische Maassbestimmungen*. A definite small fraction of the charge used was drawn off a large capacitor and measured electrostatically by a Coulomb torsion balance, and the remaining charge was discharged through a ballistic galvanometer. Converting to the ratio between the electromagnetic and electrostatic units, the ratio found was 3.1074×10^8 meters/second, close to the speed of light; but the researchers took no special notice of this.

Weber's greatest theoretical contributions appear in the *Elektrodynamische Maassbestimmungen*, seven long works published from 1846 to 1878, besides a manuscript published posthumously. In the first of these, Weber introduced his dynamometer to test Ampère's law of force between electric current elements, to a degree of precision exceeding Ampère's, and also to investigate electromagnetic ("Volta") induction. Convinced of the validity of Ampère's law, Weber proceeded to a theoretical derivation of a general fundamental law of electrical action, expressing the force between moving charges. Essential to the derivation were the assumptions of central forces and of currents as consisting of the equal and oppositely directed flow of the two kinds of charge. The law contains the expression

$$F=\frac{e_1e_2}{r^2}\left[1-\frac{1}{c^2}\left(\frac{dr}{dt}\right)^2+\frac{2r}{c^2}\frac{d^2r}{dt^2}\right]$$

where dr/dt is the rate at which the separation r between the charges e_1 and e_2 increases (or the relative radial velocity), while d^2r/dt^2 is the relative radial acceleration, and c is a constant expressing the ratio between the electrodynamic and electrostatic units of charge. On the basis of Maxwell's theory, we know today that c is $\sqrt{2}$ times the speed of light.

The dominant term in the expression is the Coulomb force e_1e_2/r^2. The remaining terms modify this attraction or repulsion when the charges are in motion relative to each other. Thus, envisage, as a simple example, two straight, parallel wires carrying identical currents in the same direction, and consider the forces between elements of the two wires that are side by side. Like charges in the two elements have no motion relative to each other and will repel with the Coulomb force. Unlike charges, at the point where they move past each other, are neither approaching nor receding from each other; but the acceleration d^2r/dt^2 is positive. This serves to augment the Coulomb attraction between unlike charges in the two wires, which otherwise would simply cancel the repulsion between the like charges. A net attraction between the parallel currents, and hence between the wires, results, in agreement with Ampère's findings.

Suppose, instead, that only one of the wires, A, carries a current initially and that the other wire is moved toward it. Consider the forces on the charges contained in an element B of the second wire. Charges in A that are approaching the point C opposite B are associated with higher values of $(dr/dt)^2$ than charges in A that have moved beyond this point, because of the approach of B to A. Since the velocity-dependent term always diminishes the effect of the Coulomb force, the positive charge in A approaching C has a diminished repulsion on the positive charge in B and the negative charge in A approaching C from the opposite direction has a diminished attraction—that is, more diminished than the forces excited by charges moving away from C. The resultant force on the positive charge in B is opposite to the motion of the current (that is, the positive charge) in A. The force on the negative charge in B is of the same magnitude and in the opposite direction. The net effect on the charges in B is to accelerate them in directions opposite to their counterparts in A—that is, to induce a current in B opposed to the direction of that in A. In fact, Weber's law succeeded in encompassing Ampère's force and the facts of induction, as well as Coulomb's law of electrostatics. Note, however, that if the assumption of the equal and opposite flow of unlike charges in a current is dropped, a constant current would generally exert a force on a static charge, contrary to experience. An abridged version of the paper published two years later also gives a potential function from which the force may be derived.

In the meantime, Helmholtz' memoir on the conservation of energy had appeared, which seemed to disallow velocity-dependent forces. Weber's law depended on the radial components of the relative velocity and acceleration of the charges; but Weber was able to show in 1869, and in greater detail in another of his long papers of 1871, the consistency of his law with energy conservation in a somewhat extended sense. Most decisive for the eventual rejection of Weber's law was its gradual replacement by Maxwell's field theory, particularly with the demonstration of electromagnetic radiation by Hertz in 1888.

From 1848 to 1852 Weber reported his careful quantitative experimental work on the diamagnetism of bismuth. Diamagnetism had been investigated in 1845 by Faraday, who initially interpreted the phenomena in terms of diamagnetic polarity, that is, a reversed magnetic polarity created in the substance when it is introduced into a magnetic field. In 1848 Weber claimed that he had observed induction in a coil caused by the diamagnetism of a piece of bismuth moving in a magnetic field, but at this time he did not distinguish this effect from that of the bulk currents induced in the body of the bismuth. Faraday was unable to observe such an effect attributable to the diamagnetic, rather than to the conducting, property of his samples; and partly as a result, he relinquished his conception of diamagnetic polarity. In research reported in his *Maassbestimmungen* of 1852, however, Weber was able to isolate and demonstrate the existence of the diamagnetic effect. He utilized the effective uniformity of the magnetic field in a long, straight solenoid. A bismuth cylinder moving well inside such a solenoid will not have bulk currents induced in it, but through its motion its diamagnetism will affect surrounding magnetic detectors. In Weber's beautifully designed experiments, such an effect was demonstrated both by the motion of a suspended magnetic needle and by the induction of a current in a surrounding coil.

Weber extended Ampère's theory of magnetism to cover the phenomenon of diamagnetism. In Ampère's theory, ordinary magnetism is accounted for by assuming the existence of permanent molecular electric currents circulating in the molecules of ferromagnetic substances. In an external field these molecules align themselves to give the resulting magnetization. According to Weber, diamagnetism occurs when resistanceless molecular currents are induced in diamagnetic substances. These substances are characterized by molecules that do not contain permanent currents and that have fixed orientation in the substance.

From 1852 Weber attempted to comprehend electrical resistance as a result of the motion of electric fluids or particles. Resistance was presumed to have its cause in the repeated combination and separation of the particles of the two electric fluids, the opposite motions of which composed a current. The existence of permanent Ampèrian currents led Weber to assume that the electric fluids do not interact directly with the material atoms composing the substance, and that in magnetic atoms the two kinds of fluid circulate in different, nonintersecting paths about the atoms. At this time he discussed, as a model, a lattice of fixed positive charges about which negative particles rotate in Keplerian ellipses. On application of an electric potential, the negative particles move in widening spirals until they pass over to the region of influence of the neighboring atom, thus migrating along the conductor.

In his article of 1875 and his final, unpublished paper, Weber developed these ideas in an attempt to derive an expression for electrical conductivity in terms of molecular parameters. Success in this was not achieved until the work of Eduard Riecke, Paul Drude, and H. A. Lorentz around the turn of the century; their work introduced the idea of treating the conduction electrons as a gas. Interest in the particulate theory of electricity quickened in the last decades of the century, especially after J. J. Thomson's investigation of cathode rays and Lorentz' interpretation of the Zeeman effect. Nevertheless, Weber's attempts to understand electrical conductivity, as well as thermal conductivity in metals, and thermoelectricity by means of the motion of the electric particles were a very important influence on the later investigations.

In metals, heat presumably was conducted by the jumping of electric particles between the ponderable molecules, those jumping from hotter molecules possessing greater speeds. In insulators, where such a mechanism was ruled out, Weber believed that heat was distributed by radiation through the ether permeating the material (articles of 1862 and 1875). In his doctoral dissertation (1858) Carl Neumann had attempted to explain the magnetic rotation of the plane of polarization of light by assuming an interaction between the Weberian molecular currents and the neighboring ether. Extending these ideas, Weber suggested that the frequency of light emitted by molecules would be the same as the frequency of motion of the electrical particles in the molecular currents. In this connection he developed his planetary model in 1862 and 1871, with charge of one sign fixed to the massive molecule and the oppositely charged electrical particles orbiting around it in accordance with his law of force.

An interesting consequence of Weber's law is that stable, bound orbits exist for two particles of the same sign of charge. Weber speculated that the ether might be composed of particles of like charge bound together, and that the development of the theory of their motion in accord with his law might lead to an understanding of the laws of light and heat radiation. In implementing this view, however, he succeeded no better than Ampère, who had indulged in similar speculations.

Toward the end of his life, Weber developed ideas appearing in Zöllner's *Die Principien einer elektrodynamischen Theorie der Materie* (1876). These included the concept of all matter being compounded of electrically charged particles, held together in various stable configurations by the action of the Weberian law of force. Even gravitation could be subsumed in this unitary picture by adopting in essence the earlier hypotheses of Aepinus and of Mossotti, that the attractive electrostatic forces between unlike charges slightly outbalance the repulsive forces between like charges.

Although he was perhaps most widely known during his life for his law of force, which was discarded with the triumph of Maxwell's field theory, Weber left his more lasting impression on physical theory with his atomistic conception of electric charge and his vision of the role of such charges in determining the electrical, magnetic, and thermal properties of matter.

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A. E. WOODRUFF

WEBSTER, JOHN (*b.* Thornton, Craven, England, 3 February 1610; *d.* Clitheroe, England, 18 June 1682), *chemistry, medicine, education.*

Although Webster implied that he studied at Cambridge, there is no record that he was ever a regular student. He also referred to his study of chemistry (*ca.* 1632) under the Hungarian alchemist John Hunyades, who arrived in London sometime after 1623. As with other Renaissance chemists, Webster's interest in chemistry was easily coupled with his concern for religion, and he was ordained a minister sometime after July 1632. Two years later he appears in the records as the curate of Kildwick, in Craven.

Paracelsian chemistry had a special appeal for surgeons, and there is a large iatrochemical literature specifically aimed at the military surgeon. As a Puritan, Webster served both as a surgeon and as a chaplain in the Parliamentary army during the Civil War. By 1648 his opposition to the established church had pushed him into the ranks of the nonconformists; and after the Restoration he was forced to support himself as a "practitioner in Physick and Chirurgery."

It was his concern for those who were preparing for the ministry that led Webster to write the *Academiarum examen*, in which he attacked the English universities. The traditional emphasis on books and disputations, as well as on the "heathen" authors Aristotle and Galen, seemed to him improper for Christians, who should study the glories of the universe (and thus, the Creator) through observation and personal experience. Webster argued against the use of mathematical abstraction in the study of nature, because for him this seemed to emphasize deductive logic. In contrast, the laboratory observations of the chemists offered the proper inductive approach exemplified in the writings of Helmont and Francis Bacon. The *Academiarum examen* is deeply indebted to Robert Fludd's Rosicrucian apology, *Tractatus apologeticus* (1617); and Webster points to Fludd and Bacon as the two authors most to be relied upon in formulating a new philosophy of nature. The most notable reply to Webster's call for educational reform was *Vindiciae academiarum* (1654) of Seth Ward and John Wilkins, in which Webster was taken to task for not having kept abreast of recent changes at the universities that did reflect the new science. He was accused of not having properly understood Bacon and Descartes and also was criticized for his reliance on the chemists. His espousal of Fludd's texts was especially condemned. The conflict between Webster, Ward, and Wilkins clearly points to the sharp division then existing between the chemical philosophers and the early mechanists.

Webster's belief that the aim of true natural magic was to uncover the "secret effects" of nature led him to extend warm support to the foundation of the Royal Society of London; and there is no indication that he was ever disappointed with the course taken by its members. He referred with approval to the society's work in his *Metallogra-*