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History

The Chemical Work of Alexander and Jane Marcet

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Alexander Marcet was an authority on urinary calculi and their analysis when few medical practitioners appreciated the usefulness of chemistry in the explanation and treatment of disease. In *An Essay on The Chemical History and Medical Treatment of Calculous Disorders*, he described the discovery of an xanthine stone. He drew line illustrations of simple chemical apparatus useful for bedside analysis. His microtechnique used drops of solution and pinhead pieces of calculi; reagents were acids and alkalies and the blowpipe in conjunction with a small alcohol lamp. He reported the earliest description of a disorder later named "alcaptonuria". Marcet's work and that of a few others, on the chemical composition of urine and calculi, laid the foundations of our present knowledge. Between 1807 and 1820, his lectures to the medical students at Guy's Hospital were illustrated by experiments.

Jane Haldimand Marcet wrote the very popular *Conversations on Chemistry* (16 editions in Great Britain). Her book dominated elementary chemical instruction during the first half of the 19th century. She followed Lavoisier's scheme of classification and explained chemical reactions in terms of affinity, aggregation, gravitation, and repulsion. Her advocacy that experimentation accompany lecture was new. The availability of serious scientific education in the new women's academies set the stage for increasing women's involvement in science. She also published a series of *Conversations*. The topics were *Political Economy, Natural Philosophy*, and *Vegetable Physiology*.

Urinary Deposits and Calculi

At the beginning of the 19th century, there was a renewal of interest in the chemistry of life processes. The chemical revolution, dominated by the work of Antoine Laurent Lavoisier (1743–1794), set down the foundation of modern chemistry and presented a unified picture of chemical knowledge based on the new analytical language of chemistry. It was now possible to begin to understand in a rational manner chemical changes in nature as well as those produced artificially. However, despite improvements in analytical techniques, the complexities of animal chemistry made progress difficult.

One branch of animal chemistry in which reliable results could be obtained by the methods of inorganic chemistry was the analysis of urine and its deposits. The stimulus for this study came from medicine and, in particular, from the urgent need to solve the problem of bladder stones, which had been a scourge in some parts of Europe throughout the 18th century. The chemical study of urinary deposits was expected to lead to a knowledge of the causes of calculus and thereby assist physicians in devising methods of preventing the formation of such stones, or at least of removing them once formed. Many hospitals had large collections of calculi. The stones were usually sawed in half to show both the exterior and the internal structures. The nucleus and the layers were each described separately, together with clinical details of the case. Fine illustrations showing the layered structures of calculi were often included in medical treatises on this subject *(1)*.

Bladder stones are one of the oldest clinical conditions described in medical history *(2)* and were the first to be treated by an elective surgical procedure. For centuries, patients submitted to the agony of entry into their bladder to escape the tortures of the stones. No respecter of royalty or intellectual achievement, this ailment has afflicted many of the great figures of history, e.g., Isaac Newton, Louis XIV, Napoleon III, and Benjamin Franklin.

Light was first thrown on the composition of such stones by the discovery of uric acid. Originally called the acid of calculus, or lithic acid (Greek: *lithos*, stone) by the Swedish pharmacist Carl Wilhelm Scheele (1742–1786), who first detected it in a bladder calculus in 1776, uric acid was named "acide urique" by Antoine François de Fourcroy (1755–1809) and Nicholas Louis Vauquelin (1763–1829) in 1799. Scheele also showed that it was

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present in urine, and he believed that all urinary concretions consisted solely of that substance and were fundamentally all the same. Scheele noted the red color when the stone is moistened with concentrated nitric acid. When the moistened stone is evaporated to dryness, the addition of dilute ammonium hydroxide produces the characteristic purple-red color of the ammonium salt of purpuric acid.

By 1810, when William Hyde Wollaston (1766–1828) described cystine *(3)* (the first amino acid to be discovered) in a new and rare type of urinary calculus, he had already characterized five other chemically distinct principal constituents of urinary calculi in humans. These were lithic or uric acid, ammonium magnesium phosphate (triple phosphate), calcium oxalate, calcium carbonate, and sodium urate, which he had also discovered in gouty joints *(4)*.

Chemistry of Disease

In an age when the description of disease was often a mere catalog of symptoms, there were few medical men who appreciated the usefulness of chemistry in the explanation and treatment of disease. Investigations in the chemistry of disease during the first half of the 19th century were conducted mainly on urine and urinary calculi. In England, William Prout (1785–1850) *(5)*, Richard Bright (1789–1858) *(6)*, George Owen Rees (1813–1889) *(7)*, Henry Bence Jones (1813–1873) *(8)*, Golding Bird (1814–1854) *(9)*, and a few others *(10)* were active in this field. Except for Henry Bence Jones at St. George's Hospital, the others were connected with Guy's Hospital, the leading center for clinical chemistry in London.

The application of chemistry to medicine was new and not widespread when these investigators tried to correlate chemical tests with symptoms of a particular disease to reach a more reliable diagnosis. Although the utility of chemistry in medicine was gradually gaining recognition, the medical profession in general was still indifferent and even hostile to the idea that investigative work in animal chemistry could lead to improved methods of diagnosis, prevention, and cure of diseases. Most medical men still regarded illness as an essentially general phenomenon and did not think it necessary to look for an association between symptoms in the living and findings at autopsy. They continued to base their diagnoses on traditional clinical methods, and little use was made of the chemical analysis of body solids and fluids *(10)*. In any event, until reliable analyses of these substances in health were available, no useful deductions could be made from examining them in disease. Even as late as the 1860s, physicians were cautioned not to be ostentatious with their scientific examination of the urine because "abuse of his knowledge in this respect will stamp him in the eyes of his colleagues and of the public as a charlatan" *(11)*. Nevertheless, when it came to urine analysis, chemical information was well ahead of physiology and pathology and would remain so for most of the 19th century.

Essay on Calculous Disorders

Alexander John Gaspard Marcet (1770–1822) (Fig. 1), a Swiss-born physician-chemist whose work preceded that of those listed above, was an authority on urinary calculi and their identification by chemical reaction; he attempted to correlate the chemical composition of calculi with diagnosis of the pathology causing their formation. The first systematic attempt to present all of the available information about human urinary calculi in a form suitable for the use of medical students and physicians was made by Marcet. In a popular work entitled *An Essay on The Chemical History and Medical Treatment of Calculous Disorders* (1817 and 1819), he described his discovery of a new substance in a urinary calculus. He named it xanthic oxide (Greek: *xanthos*, yellow) because it forms a lemon-yellow colored compound when treated with nitric acid. In 1838, Justus Liebig (1803–1873) and Friedrich Wöhler (1800–1882) correctly determined that xanthic oxide contains one less atom of oxygen than does uric acid. Although Jöns Jakob Berzelius (1779–1848) called it urous acid (1840), it is now known as xanthine. Another previously unknown variety of urinary calculi was described by Marcet, the comparatively unimportant fibrinous calculus.

Marcet noted that "Physicians and chemists from Galen to Paracelsus to Van Helmont and Boerhaave" were

Fig. 1. Alexander Marcet.

Engraving by Henry Meyer from original painting by Sir Henry Raeburn. (Courtesy of the Royal College of Physicians, London.)

unable "to form any rational conjectures on the composition of urinary calculi" *(12)*. In his "Essay", Marcet brought together the then available knowledge concerning the chemical nature of urinary and other calculi, the analytical methods by which they are most easily distinguished, the geographical distribution of calculous disorders, the relative frequency of the several varieties of stones, and the prospects of treatment by methods other than surgical. Although Marcet spoke with a heavy French accent, his published writings show complete command of the English language.

Marcet dedicated the book to Wollaston, whom he credits for many of the discoveries and remarks that his book contains. He notes that Fourcroy, in his history of urinary calculi and in various papers on this subject, has "in a most unaccountable manner, entirely overlooked Dr. Wollaston's labours, and in describing results exactly similar to those previously obtained and published by the English chemist, has claimed them as his own discoveries. Yet Dr. Wollaston's paper was printed in our Philosophical Transactions in 1797, that is about two years before Fourcroy published his Memoir in the 'Annales de Chimie,'. . . .".

"It is extremely painful to be compelled by justice to notice such an apparent want of fairness and candor, in a philosopher, who devoted a long and brilliant career to the advancement of science" *(12)*. However, Marcet does not find fault with Vauquelin, often a co-author with Fourcroy, because he was "not conversant with the English language" and it was well known "that the task of publishing the results of their common labours" always fell to Fourcroy *(12)*.

In fairness to Fourcroy *(13)*, it should be noted that he began a systematic examination of all kinds of animal concretions, including biliary, renal, and urinary calculi, as early as 1793, when the chemical compositions of calculi were poorly understood. In 1798, Fourcroy and Vauquelin issued preliminary accounts on the large number of bladder stones they received from health officials, medical schools, and colleagues in Paris and throughout France *(14, 15)*. These came in response to their call for donations of specimens of calculi with information on the age, geographical area, and state of health of the patients from whom these were obtained *(16)*. A more detailed report of analyses of nearly 300 urinary calculi was published in 1799 and may have been the "Memoir" to which Marcet referred *(17)*.

Marcet described and illustrated calculi by means of colored drawings. He listed a protocol for chemical analysis of stones and urine and included line drawings of a simple, portable apparatus (Fig. 2), which he used at the patient's bedside. Marcet wanted the average medical practitioner to have a reliable method of diagnosis requiring very little chemical skill or knowledge to easily distinguish the various kinds of urinary calculi.

The reagents that Marcet used were dilute mineral acids, acetic acid, caustic alkalies, alkali carbonates, ammonium hydroxide, ammonium oxalate, and potassium cyanide. Simple tests were given for each type of urinary calculus in terms of their chemical reactions in solution, and after incineration with the blowpipe used with a small spirit (alcohol) lamp (not a flame color test). His procedures were designed on a very small scale, using only a few drops of solution and pinhead pieces of calculi, a microtechnique that he credited to Wollaston and that he considered a development of primary importance.

Diabetes, readily detected by examination of the urine by taste or fermentation, also interested Marcet. It was the subject of his MD thesis, which was for the most part a review of other sources and showed no evidence of any clinical experience by him. Initially, in 1797, following the views of William Cruickshank (1745–1800), he believed that sugar was present in the blood of diabetics, but by 1811 he agreed with Wollaston that sugar was not to be found in diabetic blood *(18)*. It was a reasonable conclusion in the absence of chemical tests for sugar.

Marcet's "Account of a Singular Variety of Urine, which Turned Black soon after being Discharged" *(19)*

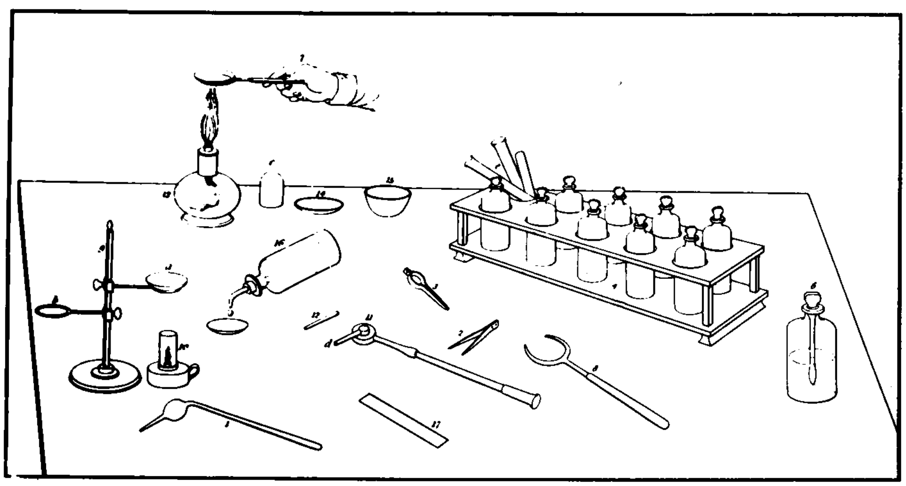

Fig. 2. Line drawing of simple apparatus for the examination of urinary calculi.

Shown are a glass blowpipe, small platina tongs, rack of bottles and test tubes, bottle with tube for dispensing one drop of solution, support-stand for watch-glasses over a flame, brass blowpipe and platina tip fitting, spirit lamp with a glass cup cover when not in use, watch-glass and glass capsule, bottle with tube to dispense water dropwise, slip of common window glass. From Marcet A *(12)*, plate X.

was the earliest description of a case of alcaptonuria in a male infant 17 months of age. The child's diaper was stained a deep purple color immediately after birth. The urine turned black soon after being voided and exposed to the air. It exhibited rapid blackening with alkalies and a failure of acids to restore the original color. The reducing property of the urine was not measured because at that time reduction tests for detection of sugars were still unknown. The black color was produced by an unknown principle, which when combined with ammonia, was appropriately named "melanic acid" by William Prout. The substance involved, called "alkapton" by C.H.D. Boedeker in 1859, is homogentisic acid (2,5-dihydroxy-phenylacetic acid), a product of protein metabolism.

CHEMICAL LECTURES

Alexander Marcet was a physician at Guy's Hospital (1804–1819), and in 1807 he joined William Babington (1756–1833) and William Allen (1770–1843) in giving courses of chemical lectures to the medical students and illustrating them by demonstration experiments. Chemistry assumed even greater significance in the medical curriculum at Guy's after 1802 when Allen, the Quaker pharmacist, began to assist Babington with the chemical lectures. With his appointment, chemistry became the first of the collateral sciences to be given up to a specialist outside the medical profession. These lecture courses were well established before Marcet took part in them; they were intended to familiarize the students with the main facts of general chemistry. Marcet brought some new developments in medical chemistry to Guy's. More attention was paid in the lectures to animal chemistry. When the medical students expressed an interest in the causes and nature of urinary calculi, a much more common ailment at that time than it is today, Marcet began to include some lectures on this subject in the chemistry course. He started with the analyses already made by Wollaston and by Fourcroy *(10)*.

Berzelius copied Marcet's plan of illustrating lectures with the accompanying experiments and went on to elaborate this lecture style in his own courses as professor of medicine and pharmacy at the Karolinska Institutet in Stockholm. This endorsement by the famous Swedish physician-chemist of Marcet's method of teaching established a method that became a model for the other chemical schools of Europe *(20)*. Marcet's papers dealing with the chemical composition of urinary calculi contributed to the foundations of our present knowledge.

When his wife inherited a large fortune of money and property after her father died, Marcet decided to retire from medical practice and pursue scientific research. In 1819, he resigned his position as physician at Guy's, but continued to lecture on chemistry until the following year. Free from the routine of calling on patients, he took up shooting and hunting, the pleasures of a country gentleman. Alexander Marcet died in 1822 after a sudden attack of "gout in the stomach". No name was given to the illness, and the record does not provide a more definitive diagnosis *(21)*.

COLLEAGUES IN ANIMAL CHEMISTRY

Although Marcet made few fundamental discoveries, his contributions to clinical chemistry were considerable. He applied chemical analysis to animal substances and used the results to make diagnosis and medical treatment more reliable. This approach was extended by William Prout, who at Marcet's request had analyzed the black urine in the earliest description of alcaptonuria. Prout was the most celebrated of all English animal chemists in the first half of the 19th century *(22)* and the most successful systematist of the subject before Leibig. Henry Bence Jones credited Prout with being the first to make the true connection between chemistry and medical practice *(23)*. Prout strongly believed that benefits would be derived from the application of chemistry to physiology and medicine and that physiological processes would ultimately be explained in chemical terms. Prout noted the lack of progress in animal chemistry and attributed this partly to the lack of understanding by the pure (inorganic) chemist of the unfamiliar field of biology. Prout's remedy was for physiologists to become chemists *(24)*.

Prout also proposed a list of tests, chemicals, glassware, and small apparati that can be packed into a small portable case easily carried by the physician for simple reliable tests on the urine and urinary products *(25)*. Barely a year later, Richard Bright's studies of renal disease would add a spoon to this portable laboratory, for revealing the presence of albumin in heated urine *(26)* and making the correlation of edema, albumin in the urine, and diseased kidneys observed after death.

Bright left the urinalysis to John Bostock (1773–1846), an Edinburgh MD graduate (1798). Bostock gave up the practice of medicine to concentrate on chemistry and later succeeded Alexander Marcet as lecturer in chemistry at Guy's Hospital Medical School, thus placing the chemical lectures firmly in the hands of chemists. Bostock heated urine in a spoon over the flame of a candle and observed formation of large amounts of coagulated albumin before the urine reached the boiling point in patients with renal disease. This was chemistry's first useful diagnostic laboratory test with an impact on clinical medicine.

Another of Bright's assistants, G.O. Rees, continued the pattern of investigation with his book *On the Analysis of the Blood And Urine, in Health and Disease. With Directions for the Analysis of Urinary Calculi* (1836), one of the earliest in English on animal chemistry. This was written as a manual for the medical practitioner who might wish to do his own analysis: "Since chemists are not physicians, we shall scarcely benefit by their art, except by making the physician a chemist" *(27)*.

Like Marcet and Prout, Golding Bird devoted much of his chemical work to a study of urine analysis and urinary calculi. He made extensive use of the microscope to illustrate the crystals of the various urinary deposits and regarded the nucleus as the key ingredient leading to formation of a calculus *(28)*. For the first time, chemistry was related to organs rather than to the total animal. Bird listed the chemical composition of the constituents of the blood and some of their most important chemical modifications that are eliminated by the liver and the kidneys. Bird also weighed 24-h urine collections and measured their specific gravities. From these values and a formula, he calculated the quantity of solids. However, the information was of more interest than utility. He also described the examination of diabetic urine with a simple polariscope and with Trommer's test (solutions of caustic potash and copper sulfate).

Bird was awarded the licence of Apothecaries' Hall without examination, based on his reputation as a chemist while a student at Guy's Medical School. In 1838, on payment of the fees and armed with the appropriate letters of recommendation and testimonials, but without residence or course work—a common practice—he was awarded an MD degree from the University of St. Andrews.

REVOLUTION, EXILE, LICENTIATE, MARRIAGE, CITIZEN

Alexander Marcet was born in Geneva, the son of an old family of Huguenot descent to which the Emperor Charles V had granted armorial bearings. Young Alexander promised his dying father that he would study commerce and trade. However, after a time he developed a dislike of commercial life and decided instead on a career in the law. Before completing his studies, he became involved in the unstable political situation that developed in Geneva after the Revolution in neighboring France. The goals of the Revolution were welcomed in Geneva with sympathy and approval *(21)*. How these events affected Marcet requires explanation.

Throughout the 18th century, Geneva had experienced class conflicts and recurrent social and political crises between a majority of the people and the ruling minority aristocratic clique. Power resided with a limited number of patrician families who monopolized rights and privileges. The far more numerous noncitizens, descendants of relatively recent settlers, were barred from voting, were excluded from many civil rights and privileges of citizenship, and were denied access to the best trades and professions. Discontent and opposition to domination by the patrician families grew. Some citizen groups also opposed their rule.

The events in Geneva paralleled the pattern in France. A popular uprising was followed by overthrow of the oligarchy and setting up of a Constituent Assembly, which framed a democratic constitution. But political advantage shifted again as the more experienced oligarchy regained its power. There was another uprising in 1794, mob rule, wholesale arrests of members of the patrician families, and a Revolutionary Tribunal. A Parisian style "reign of terror" was short-lived and less violent. Some prisoners were condemned and executed, but most were released, fined, or banished. Anyone who had spoken against the new ruling party or had served in the National Militia of the old régime was subject to arrest. Marcet was charged with both and was imprisoned in 1794 *(20, 21)*.

After the death of Robespierre in the same year, Marcet was released from prison and banished from Switzerland for 5 years. He traveled to Edinburgh, studied medicine, and was granted the MD degree in 1797. Moving to London, he became a Licentiate of the Royal College of Physicians in 1799. In the same year he married Jane Haldimand (1769–1858), daughter of a wealthy Swiss merchant who lived in London with his English wife and was very successful in banking, trading, and real estate development. In 1800, Alexander Marcet became a naturalized British subject by a special Act of Parliament.

Alexander and Jane Marcet shared a strong interest in science and intellectual questions that led them to engage the potential of chemistry. Alexander, in the practice of medicine, used chemical analysis in an effort to improve diagnosis and treatment of urinary tract disease, and Jane, as writer and educator, popularized chemistry and other topics that she directed toward young women. Despite Dr. Marcet's considerable accomplishments in clinical chemistry, his memory is overshadowed by that of his wife *(29)*. Jane Marcet's entry in the *Dictionary of National Biography* is nearly two times that of Alexander's one column.

Jane Haldimand Marcet

Jane Haldimand's (Fig. 3) life was one of privilege. She and her brothers and sisters were educated at home by the best available tutors in a cultured and intellectually stimulating environment. In the Swiss tradition, she was taught the same subjects as her brothers. She studied chemistry, biology, history, and Latin in addition to the more usual lessons for girls in art, music, and dancing. Jane was 15 when the unexpected death of her mother in childbirth, at age 39, suddenly thrust her into new responsibilities. She was expected to manage the large household and a sizable family in addition to serving as hostess for her father's frequent parties. Haldimand entertained lavishly with dinner parties two or three times a week to which scientists, writers, intellectuals, important visitors to London, and other stimulating people would be invited. Customarily, approximately 40 guests would be hosted for these parties, and after dinner, more guests would arrive for desserts, wine, and brandy *(30, 31)*.

After Jane's marriage at age 30 to Alexander, the party guest list included some of her husband's friends who were particularly interested in the physical sciences. This brought her into contact with many distinguished personalities of the period in science, literature, and philosophy, including Berzelius, Wollaston, Humphry Davy (1778–1829), the botanist Augustin de Candolle (1778–1841), the mathematician Horace Benedict de Saussure (1740–1799), the physicist Auguste de La Rive (1801–1873), other

Fig. 3. Jane Haldimand Marcet.
From Polkinghorn, 1993. (Reproduced by kind permission of the Pasteur family.)

chemists, writers, and the political economist Thomas Malthus (1766–1834) *(32, 33)*. These connections, in addition to her husband's knowledge of chemistry, gave her access to new ideas, which she utilized in a long and productive writing career.

DAVY AND THE ROYAL INSTITUTION

Mrs. Marcet's interest in chemistry was stimulated by the public lectures and elegant demonstrations of Humphry Davy at the Royal Institution, which she initially found confusing. When the basic concepts of the new chemistry were explained to her in private instruction "with a friend"—no doubt her husband, who also encouraged her study—"and of repeating a variety of experiments, she became better acquainted with the principles of that science, and began to feel highly interested in its pursuit". Consequently, "she had the gratification to find that the numerous and elegant illustrations, for which that school is so much distinguished, seldom failed to produce on her mind the effect for which they were intended". From this she inferred "that familiar conversation was, in studies of this kind, a most useful auxiliary source of information; and more especially to the female sex, whose education is seldom calculated to prepare their minds for abstract ideas, or scientific language" *(34)*.

Mrs. Marcet "was more than once checked in her progress by the apprehension that such an attempt might be considered by some, either as unsuited to the ordinary pursuits of her sex, or ill-justified by her own imperfect knowledge of the subject. But, on the one hand, she felt encouraged by the establishment of those public institutions, open to both sexes, for the dissemination of philosophical knowledge, which clearly prove that the general opinion no longer excludes woman from an acquaintance with the elements of science; and, on the other, she flattered herself, that whilst the impressions made upon her mind, by the wonders of Nature, studied in this new point of view, were still fresh and strong, she might, perhaps, succeed the better in communicating to others the sentiments she herself experienced" *(34)*.

The principal educational function of the Royal Institution was to provide public enlightenment through popular lectures. Science was then in fashion and chemistry was all the rage. The lectures had a syllabus, but they were not intended to be a formal course leading to anything like a qualification or to systematic knowledge. These demonstration lectures on science at this time were genuinely theatrical spectacles and attracted large and fashionable audiences. Under Davy, the Royal Institution became simply the most elegant and fashionable center for such rational entertainment *(35)*. Davy was a showman, and he attracted capacity audiences. By about 1810, as many as 1000 came to see and hear him, including the aristocracy *(36)*.

CONVERSATIONS ON CHEMISTRY

Mrs. Marcet's *Conversations on Chemistry*, first published in 1806, was the most popular book on chemistry in the first half of the 19th century and made Mrs. Marcet the leading popularizer of the subject. In the preface she states: "In venturing to offer to the public, and more particularly to the female sex, an Introduction to Chemistry, the author, herself a woman, conceives that some explanation may be required: and she feels it the more necessary to apologize for the present undertaking, as her knowledge of the subject is but recent, and as she can have no real claims to the title of chemist" *(34)*.

The book was an unheard-of success and went through 16 editions (1806–1853) in Great Britain. Published anonymously at first to avoid a conflict of interest with her husband's research in chemistry, her works were often attributed to other women writers. Sometimes male authorship was credited, although every edition carried Mrs. Marcet's self-deprecating preface, which was clearly written by a woman and was unchanged for 44 years. Mrs. Marcet's name eventually appeared as author in the 13th edition (1837). From 1806 to 1850, American publishers made 23 impressions of various editions of the work, often by competing publishers in the same year. There were also 12 American printings of a derivative and highly imitative text, *New Conversations on Chemistry* (1831–1850) by Thomas P. Jones, a college professor of chemistry and a popular lecturer on chemistry. He followed Mrs. Marcet's format in terms of the data presented, but eliminated the humor and personal commentary of the original. He believed that these digressions in the original work were now an impediment to the rapid assimilation of new facts *(32)*.

It was a time in which elementary instruction in science was hard to come by and in which scientific lectures were extremely popular *(35)*. Mrs. Marcet's book was directed at beginners in science and women in particular because few women had access to scientific friends such as she had. *Conversations* was not intended to be used as a textbook or for a particular course of instruction, but to provide background for those attending lecture courses such as Davy's *(29)*. The text is illustrated with engravings made from her own admirable drawings, and experiments are described in detail. This reflects the change that had occurred from large-scale experiments involving furnaces to a small-scale with spirit lamps that can be done on a table *(35)*.

In Great Britain, the book was apparently used as Mrs. Marcet expected, as a guide to popular lectures on chemistry or natural philosophy. In America, however, it became the most successful elementary chemistry text of the first half of the 19th century, with sales reported to be ~160 000 copies of all of her editions. The book was an introduction to the most important chemical theories of her day and was widely used in the new women's seminaries. It was no dry catalog of chemical facts or recipes, but rather a scheme that tied together chemical reactions and thermal and optical phenomena. Many young men and women had their first serious exposure to chemistry in the form of a lively dialog, interspersed with questions, between a teacher, Mrs. B., and two teenage pupils, Emily and Caroline, the characters Mrs. Marcet used to express her ideas.

Written dialog was an important way of conveying knowledge and was used by Plato, Galileo, Boyle, and others. Conversation, especially if it involved women, was about 1800 recognized as the civilized way to education *(35)*. Mrs. Marcet's strength lies in her literary adeptness coupled with a good solid understanding of her subject. Her characters have their own distinct personalities. Mrs. B. reveals a systematic mind and a clear and concise style. She is led by Emily's innocent questioning into explaining more difficult concepts from a variety of angles. Caroline provides the spirit of dissent and brings a breath of fresh air and even levity to the serious discussions. She wants to think for herself and does not accept any authority. This questioning attitude and freshness of approach lie at the heart of Mrs. Marcet's success *(37)*.

The book first interested the young Michael Faraday (1791–1867) in chemistry during his apprenticeship to a bookbinder. Not deterred by its being aimed at girls, it was in those books in the hours after work that he found the beginnings of his interest in science, and he credited Mrs. Marcet's *Conversations on Chemistry* with his introduction to chemistry *(33, 38)*.

In America, Mrs. Marcet's books were commonly attributed to the male editors whose names appeared on the title pages. They believed that she went too far in promoting the latest chemical theories and discoveries of Davy *(32, 33)* and dangerous experiments for beginners. The book was theoretical rather than practical, and American editors objected to her advancing theoretical opinions that were not founded on demonstration. A book designed for the instruction of youth ought to contain only established principles. Mrs. Marcet's most frequent American editor was John Lee Comstock (1789–1858), a former Army surgeon, whose comments first appeared anonymously in an 1818 edition. His name first appeared in an 1822 edition. Beginning in 1826, Comstock's commentary and a series of "study questions", numbering in the hundreds as footnotes provided by the Rev. John Lauris Blake (1788–1857), an Episcopalian minister in Boston, were the standard format for most American editions throughout the rest of the book's publication history *(32)*. Other editors added dictionaries of terms, guides to the experiments, and critical commentaries. These amendments for the classroom were not a marketing strategy, but the response of professional chemists and educators to the book's growing use as an introductory chemistry text. In the absence of international copyright law, Mrs. Marcet received no income from these American editions, nor did she have any control over the additions and improvements. Protection for American authors was established in 1790 and for foreign authors a century later *(32)*.

After the success of *Conversations on Chemistry* came other introductory books: the highly praised *Conversations on Political Economy* (1816), *Conversations on Natural Philosophy* (1820), and *Conversations on Vegetable Physiology* (1829), all initially published anonymously. Mrs. Marcet also wrote many other books of stories and conversations directed to children of all ages. Between publication of new subjects, she revised her previous books for new editions.

NEW EDITIONS

Born in the same year as Napoleon and growing up in the age of phlogiston, Jane Haldimand was 20 years of age when Lavoisier published his *Traité Élémentaire de Chimie*. Her death at age 89 occurred before Dimitri Mendelejeff's (1834–1907) periodic arrangement of the elements in 1869. Mrs. Marcet followed Lavoisier's scheme of classification of the elementary substances as set out in the 1796 English translation and considered light, electricity, and heat or caloric as "imponderable agents". She used a Newtonian corpuscular theory of matter and explained chemical reactions in terms of affinity, aggregation, and repulsion. Her informal dialog described the discoveries of Galvani, Volta, Franklin, Count Rumford, Priestley, Cavendish, Davy, and others. There was no mention, however, of John Dalton's (1766–1844) atomic molecular hypothesis of chemical combination (atomic theory; 1808) until well after 1828, and even then she expressed doubts about its validity. This reflected Davy's skepticism, which was widely shared until as late as the mid-19th century. Mrs. Marcet corrected and updated her treatment of important ideas in later editions as chemical knowledge grew. In 1845, in her 76th year, she wrote to Faraday for information about his latest discovery for mention in her new edition *(33, 38)*. In an era of rapid growth of chemistry, an amateur would find it harder to keep up and would need a period of consolidation to make choices *(35)*.

LABORATORY INSTRUCTION

Mrs. Marcet's advocacy of the teaching of chemistry to beginners by experimental laboratory demonstration was new and came at a time when the value of this was not fully recognized. But it was not until after the Civil War that laboratory instruction for beginning students became the norm in American schools. The Boston Girls' High and Normal School is credited with being the first to begin laboratory teaching in chemistry in 1865. By 1871, the laboratory method spread rapidly through the larger city school systems in Massachusetts *(39)*. Despite competition from numerous other texts, Jane Marcet's *Conversations on Chemistry* dominated elementary chemical instruction in the female academies. Administrators could have chosen texts that emphasized useful applications. Instead, they chose her book for its up-to-date review of European chemical theory, illustrated by experiments; its use of the new chemical terminology; and its emphasis of hands-on instruction with laboratory equipment and chemicals for beginners.

The popularity of Mrs. Marcet's book during the early years of the 19th century suggests that there was growing acceptance by American educators of the need to include the basics of theoretical and experimental science in the education of young ladies. The availability of serious scientific education in the new women's academies set the stage for increasing women's involvement in science. The access to introductory science instruction in a formal laboratory setting—rather than through a male family member or a brother's tutor—legitimized feminine interest in scientific theory, and as a result, numerous women achieved prominence as scientists in the second half of the century *(32, 37)*.

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