mind, outlined the geopolitical problems facing the United States in the Caribbean at that time. Controversy marred his political life, however, and he returned to the United States in 1801. He made appearances at the American Philosophical Society meetings in 1803 and 1804, probably returning to St. Croix shortly thereafter. Little is known of Stevens' last years. David Hosack wrote to him in St. Croix on yellow fever in 1809, and in 1823 he wrote Hosack a letter introducing his son, who had also graduated at Edinburgh.

Stevens' fundamental and sound gastric studies were confirmed by Spallanzani, who augmented and added to them in masterly fashion, assuring that from then on, gastric physiology would be a well-founded science.

*BIBLIOGRAPHY*

I. ORIGINAL WORKS. "Dissertatio inauguralis de alimentorum concoctione" (1777) is transcribed, in the original Latin, in *Thesaurus Medicus*, III (Edinburgh, 1785), a selection of medical dissertations from Edinburgh, repr. by William Smellie. An incomplete English trans. of the experimental section is appended to Spallanzani's *Dissertations Relative to the Natural History of Animals and Vegetables* (London, 1784). In 1778 Stevens read a paper to the Royal Medical Society of Edinburgh entitled "What Is the Cause of the Increase of Weight Which Metals Acquire During Their Calcination." A MS copy is in the library of Edinburgh University. No copy appears to have survived of Stevens' Harveian prize thesis, "An Experimental Inquiry Concerning the Red Colour of the Blood."

II. SECONDARY LITERATURE. Stevens has received remarkably little attention. Stacey B. Day appears to be the only one who has endeavored to piece together his life and to correct the fragmentary and incorrect notes that are commonly found. See Stacey B. Day and Roy A. Swanson, "The Important Contribution of Dr. Edward Stevens to the Understanding of Gastric Digestion in Man and Animals," in *Surgery*, **52**, no. 5 (1962), 819–836. The most comprehensive account available is Stacey B. Day, *Edward Stevens, Gastric Physiologist, Physician and American Statesman, With a Complete Translation of His Inaugural Dissertation De Alimentorum Concoctione and Interpretive Notes on Gastric Digestion Along with Certain Other Selected and Diplomatic Papers* (Cincinnati–Montreal, 1969), which presents most of the biographical details of Stevens' life known today. Possibility of his kinship with Alexander Hamilton is examined. The book presents the first complete English trans. of "De alimentorum concoctione"; a trans. of the German précis by Friedrich August Weiz (1782); the exchange of letters between Stevens and Benjamin Rush; the controversy between these two physicians over the treatment of yellow fever; and a review of Stevens' role as United States consul-general in Santo Domingo. The book provides reference sources: Jefferson MSS, Pickering MSS, Hamilton Papers, Stephen Girard Papers, National Archives records, and source materials in Edinburgh and elsewhere.

STACEY B. DAY

**STEVIN, SIMON** (*b.* Bruges, Netherlands [now Belgium], 1548; *d.* The Hague, Netherlands, *ca.* March 1620), *mathematics, engineering.*

Stevin was the illegitimate son of Antheunis Stevin and Cathelijne van de Poort, both wealthy citizens of Bruges. There is little reliable information about his early life, although it is known that he worked in the financial administration of Bruges and Antwerp and traveled in Poland, Prussia, and Norway for some time between 1571 and 1577. In 1581 he established himself at Leiden, where he matriculated at the university in 1583. His religious position is not known, nor is it known whether he left the southern Netherlands because of the persecutions fostered by the Spanish occupation. At any rate, in the new republic of the northern Netherlands Stevin found an economic and cultural renaissance in which he at once took an active part. He was first classified as an "engineer," but after 1604 he was quartermaster-general of the army of the States of the Netherlands. At the same time he was mathematics and science tutor to Maurice of Nassau, prince of Orange, for whom he wrote a number of textbooks. He was often consulted on matters of defense and navigation, and he organized a school of engineers at Leiden and served as administrator of Maurice's domains. In 1610 he married Catherine Cray; they had four children, of whom one, Hendrick, was himself a gifted scientist who, after Stevin's death, published a number of his manuscripts.

Stevin's work is part of the general scientific revival that resulted from the commercial and industrial prosperity of the cities of the Netherlands and northern Italy in the sixteenth century. This development was further spurred by the discovery of the principal works of antique science—especially those of Euclid, Apollonius, Diophantus, and Archimedes—which were brought to western Europe from Byzantium, then in a state of decline, or from the Arabic centers of learning in Spain. A man of his time, Stevin wrote on a variety of topics. A number of his works are almost wholly original, while even those that represent surveys of science as it existed around 1600 contain his own interpretations; all are characterized by a remarkably lucid and methodical presentation. Stevin chose to write almost all of his books in the vernacular, in accordance with the spirit of self-confidence of the newly established republic. In the introduction to his *De Beghinselen der Weeghconst* of 1586, he stated his admiration for Dutch as a language of wonderful power in shaping new terms; and a number of the words coined by Stevin and his contemporaries survive in the rich Dutch scientific vocabulary.

Stevin's published works include books on mathematics, mechanics, astronomy, navigation, military science, engineering, music theory, civics, dialectics, bookkeeping, geography, and house building. While many of these works were closely related to his mercantile and administrative interests, a number fall into the realm of pure science. His first book, the *Tafelen van Interest* (1582), derives entirely from his early career in commerce; in it Stevin set out the rules of single and compound interest and gave tables for the rapid computation of discounts and annuities. Such tables had previously been kept secret by big banking houses, since there were few skilled calculators, although after Stevin's publication interest tables became common in the Netherlands.

In *De Thiende*, a twenty-nine-page booklet published in 1585, Stevin introduced decimal fractions for general purposes and showed that operations could be performed as easily with such fractions as with integers. He eliminated all difficulties in handling decimal fractions by interpreting 3.27, for example, as 327 items of the unit 0.01. Decimal fractions had previously found only occasional use in trigonometric tables; although Stevin's notation was somewhat unwieldy, his argument was convincing, and decimal fractions were soon generally adopted. At the end of the tract, Stevin went on to suggest that a decimal system should also be used for weights and measures, coinage, and divisions of the degree of arc.

In *L'arithmétique*, also published in 1585, Stevin gave a general treatment of the arithmetic and algebra of his time, providing geometric counterparts. (An earlier work, the *Problemata geometrica* of 1583 had been entirely devoted to geometry; strongly marked by the influence of Euclid and Archimedes, it contained an especially interesting discussion of the semi-regular bodies that had also been studied by Dürer.) Stevin was of the opinion that all numbers—including squares, square roots, and negative or irrational quantities—were of the same nature, an opinion not shared by contemporary mathematicians but one that was vindicated in the development of algebra. Stevin introduced a new notation for polynomials and gave simplified and unified solutions for equations of the second, third, and fourth degrees; in an appendix published at a later date he showed how to approximate a real root for an equation of any degree.

*De Deursichtighe* is a mathematical treatment of perspective, a subject much studied by artists and architects, as well as mathematicians, in the fifteenth and sixteenth centuries. Stevin's book gives an important discussion of the case in which the plane of the drawing is not perpendicular to the plane of the ground and, for special cases, solves the inverse problem of perspective, that is, of finding the position of the eye of the observer, given the object and the perspective drawing of it. A number of other works are also concerned with the application of mathematics to practical problems, and in these the instances in which Stevin had to perform what amounts to an integration are particularly interesting. While mathematicians up to his time had followed the Greek example and given each proof by *reductio ad absurdum*, Stevin introduced methods that, although still cumbersome, paved the way toward the simpler methods of the calculus.

*De Beghinselen der Weeghconst* is Stevin's chief work in mechanics. Published in 1586, some fifty years before Galileo's discoveries, it is devoted chiefly to statics. From the evidence that it provides, Stevin would seem to be the first Renaissance author to develop and continue the work of Archimedes. The book contains discussions of the theory of the lever, the theorems of the inclined plane, and the determination of the center of gravity; but most particularly it includes what is perhaps the most famous of Stevin's discoveries, the law of the inclined plane, which he demonstrated with the *clootcrans*, or wreath of spheres.

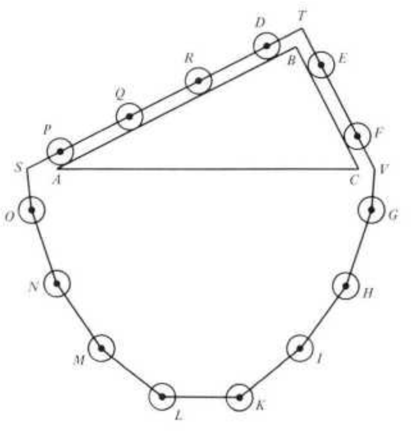

FIGURE 1

The *clootcrans*, as conceived by Stevin, consists of two inclined planes ($AB$ and $BC$), of which one is twice the length of the other. A wreath of spheres placed on a string is hung around the triangle $ABC$, all friction being disregarded. The wreath will not begin to rotate by itself, and the lower section $GH \cdots MNO$, being symmetrical, may be disregarded. It is thus apparent that the pull toward the left exerted by the four spheres that lie along $AB$ must be equal to the pull to the right exerted by the two spheres that lie along $BC$—or, in other words, that the effective component of gravity is inversely proportional to the length of the inclined plane. If one of the inclined planes is then placed vertically, the ratio between the component along the inclined plane and the total force of gravity becomes obvious. This is, in principle, the theory of the parallelogram of forces.

Beneath his diagram of the *clootcrans* Stevin inscribed a cherished maxim, "Wonder en is gheen wonder"—"What appears a wonder is not a wonder" (that is, it is actually understandable), a rallying cry for the new science. He was so delighted with his discovery that he used the diagram of his proof as a seal on his letters, a mark on his instruments, and as a vignette on the title pages of his books; the device also appears as the colophon of this *Dictionary*.

Stevin's next work on mechanics, *De Beghinselen des Waterwichts*, is the first systematic treatise on hydrostatics since Archimedes. In it, Stevin gave a simple and immediately comprehensible explanation for the Archimedean principle of displacement; before a body $C$ is immersed, consider a volume of water equal to that of $C$. Since the latter body was at rest, it must have experienced, on displacement, an upward force equal to its weight, while $C$ itself will, upon being placed in the water, experience the same degree of buoyancy. Stevin similarly chose to explain the hydrostatic paradox by imagining parts of the water to be solidified, so that neither equilibrium nor pressure was disturbed. He also wrote a number of shorter works in which he applied the principles of mechanics to practical problems of simple machines, balances, the windlass, the hauling of ships, wheels powered by men, the block-and-tackle, and the effect of a bridle upon a horse.

Stevin's chief book on astronomy, *De Hemelloop*, was published in 1608; it is one of the first presentations of the Copernican system, which Stevin unconditionally supported, several years before Galileo and at a time when few other scientists could bring themselves to do likewise. Calling the Copernican hypothesis "the true theory," Stevin demonstrated that the motions of the planets can be inductively derived from observations; since there were no complete direct observations, he used the ephemerides of Johann Stadius in their stead. He first explained the Ptolemaic model (in which the earth is at the center and the sun and planets move in epicycles) by this means, then offered a similar explanation of the Copernican system, in which he improved on the original theory in several minor points.

In a seafaring nation like the Dutch republic matters of navigation were, of course, of great importance. In addition to his astronomical works, Stevin gave a theory of the tides that was—as it must have been, fifty years before Newton—purely empirical. He also, in a short treatise entitled *De Havenvinding*, approached the subject of determining the longitude of a ship, a problem that was not fully solved until the nineteenth century. Several previous authors had suggested that longitude might be determined by measuring the deviation of the magnetic needle from the astronomical meridian, a suggestion based on the assumption that the earthwide distribution of terrestrial magnetism was known. Since the determination of latitude was well known, such a measurement would allow the sailor to chart longitudinal position against the latitudinal circle.

Stevin, in his booklet, gave a clear explanation of this method; he differed from Petrus Plancius and Mercator in that he did not rely upon a priori conceptions of the way in which geomagnetic deviation depends upon geographical position. Although he was willing to offer a conjecture about this dependence, Stevin insisted on the necessity of collecting actual measurements from all possible sources and urged the establishment of an empirical, worldwide survey. His method was sound, although as data began to accumulate it became clear that the magnetic elements were subject to secular variation. The problem of determining longitude was at last solved more simply by the invention of the ship's chronometer.

In *Van de Zeijlstreken*, Stevin set out a method, based on one proposed by Nuñez in 1534, of steering a ship along a loxodrome, always keeping the same course, to describe on the globe a line cutting the meridians at a constant angle. Although the feat was beyond the grasp of the seaman of Stevin's time, his exposition nonetheless contributed to a clear formulation of the principles upon which it was based and helped make the method itself better known both in the Netherlands and abroad.

A considerable body of Stevin's other work developed from his military duties and interests. The Dutch army had been completely reorganized through the efforts of Maurice and counts William Louis and John of Nassau; their innovations, which were widely adopted by other countries, included the establishment of regular drills and maneuvers, the development of fortifications (combined with new methods of attacking a besieged city), and army camps planned after those of the Romans. As quartermaster general, Stevin observed these reforms, as well as actual battles, and wrote in detail, in his usual lucid and systematic style, of sieges, camps, and military equipment.

Stevin's *De Sterctenbouwing* is a treatise on the art of fortification. Although cost prohibited the implementation of the ideas Stevin set out in it, these notions were put to practical effect a century later by Vauban and Coehoorn. *De Legermeting* is a less theoretical work, a description of field encampment during Maurice's campaigns, with the encampment before the Battle of Juliers (in 1610) as a particular example. Stevin gave an account of the layout of the camp, inspired by the writings of Polybius (since later Roman authors were not then known), together with the modifications made by Maurice. He listed all the equipment required in the campaign, and gave detailed instructions concerning the building of huts and the housing of dependents and suppliers. In the last section of the work he made a comparative study of the different methods of deploying soldiers in files and companies, and again recommended distribution by a decimal system. All told, his book gives a vivid impression of the army life of his period.

Of his works on engineering, two books are devoted to the new types of sluices and locks that Stevin himself had helped to devise. He cites their particular usefulness in scouring canals and ditches through the use of tidal action, and cites their application for the waterways of Danzig and other German coastal cities. In these short works he also discusses the formation of sandbanks, peat and quicksand, and the modifications of the course of a river; his explanation of the changes of the surface of the earth, which he attributes to natural forces only, is quite modern.

In *Van de Molens*, Stevin discusses wind-driven drainage mills, crucially important to the flat regions of the Netherlands. Stevin proposed the construction of a new type of mill with more slowly revolving scoop wheels and a smaller number of wider floats, and he further modified the means of transmission of power by making use of conical toothed wheels. A number of mills were built or rebuilt according to his specifications; that they were not completely successful may lie in imperfections in the execution of his design. Stevin also applied the principles of mechanics to windmills, in a series of computations that allowed him to determine, given the size and the number of the cogs, both the minimum wind pressure required on each square foot of the sails to lift the water to the necessary height and how much water is raised by each revolution of the sails. He gave the results of his measurement of fifteen mills.

In another book, *Van de Spiegeling der Singconst*, Stevin turned to the theory of musical tuning, a subject that had enthralled mathematicians from antiquity on. Musicians had also long been concerned with devising a scale in which the intervals of the pure octave (2:1), the pure fifth (3:2), and the pure third (5:4) could be rigorously combined. The chief problem lay in the resolution of the progression by four fifths (96:144:216:324:486) and the interval with the double octave ($96 \times 2 \times 2 = 384$); this ratio, which should be the third, 480:384, is rather the imperfect ratio 486:384. While a number of other mathematicians and musicians had attempted to reach a resolution by minor modifications in the scale, Stevin boldly rejected their methods and declared that all semitones should be equal and that the steps of the scale should each correspond to the successive values of $2^{n/12}$; he dismissed the difference between the third and the fifth as unimportant. Stevin's scale is thus the "equal temperament" now in general use; at the time he proposed it he had been anticipated only by Vincenzio Galilei (1581) and the Chinese prince Chi Tsai-Yü (1584). It is unlikely that Stevin knew the latter's work.

Another of Stevin's many publications was a book on civic life, *Het Burgherlick Leven*. The work is a handbook designed to guide the citizen through periods of civil disorder, a matter of some concern in a nation that had only recently won its freedom through rebellion, and in which religious freedom was still a matter for discussion. Stevin only rarely refers to these circumstances in his book, however; he rather presents his precepts as being completely objective and derived from common sense. The first of his tenets is that the citizen should obey anyone in a position of *de facto* authority, no matter how this authority has been obtained. Since history consists of a succession of princes, Stevin questions how historical rights can be established, then goes on to state that the citizen's duty is to obey the laws, no matter if they appear wrong or unjust. He cites the necessity of religion as a means of instilling virtue in children, but adds that if a man's religion is different from that of his countrymen, the dissenter should either conform or leave. All told, his views are typical of those current in a post-revolutionary period in which consolidation was more important than individual freedoms.

In the last years of his life, Stevin returned to the study of mathematics. He reedited his mathematical works and collected them into the two folio volumes of his *Wisconstighe Ghedachtenissen* (published in 1605–1608). These mathematical memoirs were also published, at almost the same time, in Latin and French translations.

Stevin's writings in general are characterized by his versatility, his ability to combine theory and practice, and the clarity of his argument. They demonstrate a mind confident of the prevalence of reason and common sense and convinced of the comprehensibility of nature. His style, especially the personal way in which he addresses the reader, is particularly charming.

*BIBLIOGRAPHY*

I. Original Works. A committee of Dutch scientists has edited *The Principal Works of Simon Stevin*, 5 vols. (Amsterdam, 1955–1968), which contains a bibliography and extensive introductions to each of the works.

Stevin's major works include *Tafelen van Interest* (Antwerp, 1582; Amsterdam, 1590), a French trans. of which appears in *De Thiende* (Leiden, 1585); *Problematum geometricorum-Libri V* (Antwerp, 1583); and *De Thiende* (Leiden, 1585; Gouda, 1626, 1630; Antwerp–The Hague, 1924). Translations of *De Thiende* are H. Gericke and K. Vogel, *De Thiende von Simon Stevin* (Frankfurt am Main, 1965); Robert Norton, *Disme, the Art of Tenths* (London, 1608); J. Tuning, "La disme," in *Mémoires mathématiques* (Leiden, 1608), also reprinted in *Isis*, **23** (1925); Henry Lyte, *The Art of Tenths* (London, 1619), and "The Disme of Simon Stevin," in *Mathematics Teacher*, **14** (1921), 321, also in D. E. Smith, *Source Book of Mathematics* (New York–London, 1929).

Subsequent writings include *L'arithmétique* (Leiden, 1585, 1625), which contains French translations of *Tafelen van Interest* and *De Thiende*; *Vita Politica, Het Burgherlick Leven* (Leiden, 1590; Amsterdam, 1939); *De Stercktenbouwing* (Leiden; 1594; Amsterdam, 1624), also trans. by G. A. von Dantzig (Frankfurt, 1608, 1623), and by Albert Girard, *Les oeuvres mathématiques de Simon Stevin* (Leiden, 1634); *Castrametatio, Dat is legermeting. Nieuwe Maniere van Stercktebou door Spilseuysen* (Rotterdam, 1617), trans. in French (Leiden–Rotterdam, 1618) and in Albert Girard, trans., *Les oeuvres mathématiques de Simon Stevin* (Leiden, 1634), and in German (Frankfurt, 1631); *Van de Spiegeling der Singconst. Van de Molens* (Amsterdam, 1884).

II. Secondary Literature. A bibliography of Stevin's works is in *Bibliotheca Belgica. Bibliographie générale des Pays-Bas*, ser. 1, XXIII (Ghent–The Hague, 1880–1890). On Stevin and his work, see R. Depau, *Simon Stevin* (Brussels, 1942), which is in French and contains a bibliography of the articles on Stevin; E. J. Dijksterhuis, *Simon Stevin* (The Hague, 1943), in Dutch, with bibliography of Stevin's works, and which is in an abbreviated English version: R. Hooykaas and M. G. J. Minnaert, eds., *Simon Stevin: Science in the Netherlands Around 1600* (The Hague, 1970); and A. J. J. van de Velde, "Simon Stevin 1548–1948," in *Mededelingen Kongelige Vlaamse Academie*, **10** (1948), 10.

M. G. J. Minnaert

**STEWART, BALFOUR** (*b.* Edinburgh, Scotland, 1 November 1828; *d.* Drogheda, Ireland, 19 December 1887), *physics, meteorology, terrestrial magnetism.*

Son of William Stewart, a tea merchant, and named Balfour after his grandmother's family, Balfour Stewart was educated at the universities of St. Andrews and Edinburgh, and then embarked upon a mercantile career. His interest in the physical sciences had, however, been sparked in the natural philosophy class of James D. Forbes at Edinburgh; and after ten years in the business world, Stewart sought a career in science—first, briefly, as an assistant at the Kew observatory and then as an assistant to Forbes at Edinburgh, where he soon made original contributions to the study of radiant heat. In 1859 Stewart returned to Kew as director; and for twelve years he was involved with the continuing missions of that institution, including the study of meteorology, solar physics, and terrestrial magnetism. During this period he was elected a fellow of the Royal Society of London; he married Katharine Stevens, daughter of a London lawyer; and he was awarded the Rumford Medal by the Royal Society for his earlier work on radiant heat. In 1870 Stewart was appointed professor of natural philosophy at Owens College, Manchester. He was subsequently president of the Manchester Literary and Philosophical Society, the Physical Society, and the Society for Psychical Research.

The heart of Stewart's contributions to the study of radiant heat (infrared radiation), and to thermal radiation in general, came in "An Account of Some Experiments on Radiant Heat, Involving an Extension of Prévost's Theory of Exchanges"