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(*b*. Pavia, Italy, 24 September 1501; *d*. Rome, Italy, 21 September 1576),

medicine, mathematics, physics, philosophy.

Cardano was the illegitimate son of Fazio Cardano and Chiara Micheri, a widow of uncertain age who was both ignorant and irascible. The early years of his life were characterized by illness and mistreatment. Encouraged to study the classics, mathematics, and astrology by his father, a jurist of encyclopedic learning and a friend of Leonardo da Vinci, Cardano began his university studies in 1520 at Pavia and completed them at Padua in 1526 with the doctorate in medicine. Almost immediately he began to practice his profession in Saccolongo, a small town near Padua, where he spent nearly six years; he later recalled this period as the happiest of his life. Having been cured of impotence, which had afflicted him throughout his youth, he married Lucia Bandareni in 1531; they had two sons and a daughter.

In 1534, sponsored by noblemen who were friends of his father, Cardano became a teacher of mathematics in the "piattine" schools of Milan. (These schools, founded by a bequest of Tommaso Piatti [*d*. 1502], taught Greek, dialectics, astronomy, and mathematics.) He simultaneously practiced medicine, achieving such success that his colleagues became envious. His first work, *De malo recentiorum medicorum usu libellus* (Venice, 1536), was directed against them. Within a few years Cardano became the most famous physician in Milan, and among the doctors of Europe he was second only to Vesalius. Among his famous patients was John Hamilton, archbishop of Edinburgh, who suffered from asthma. Cardano remained in Scotland for most of 1552 in order to treat the archbishop and a number of other English noble-men.

In 1539, while awaiting the publication of *Practica arithmetice*, his first book on mathematics, Cardano learned that Nicolò Tartaglia knew the procedure for solving third-degree equations. He succeeded in obtaining this information by promising, possibly under oath, not to reveal it. After having kept the promise for six years, he considered himself released from it when he learned that the credit for the discovery actually belonged to Scipione dal Ferro. He therefore published the method in his *Artis magnae sive de regulis algebraicis liber unus* (1545), commonly called *Ars magna*, his greatest work in mathematics. Its publication angered Tartaglia, who in his *Quesiti et inventioni diverse* (1546) accused Cardano of perjury and wrote of him in offensive terms that he repeated in *General trattato di numeri et misure* (1556–1560). The latter work was well known among mathematicians and thus contributed greatly to posterity's low opinion of Cardano.

In 1543 Cardano accepted the chair of medicine at the University of Pavia, where he taught until 1560, with an interruption from 1552 to 1559 (when the stipend was not paid). In 1560 his elder son, his favorite, was executed for having poisoned his wife. Shaken by this blow, still suffering public condemnation aroused by the hatred of his many enemies, and embittered by the dissolute life of his younger son, Cardano sought and obtained the chair of medicine at the University of Bologna, to which he went in 1562.

In 1570 Cardano was imprisoned by the Inquisition. He was accused of heresy, particularly for having cast the horoscope of Christ and having attributed the events of His life to the influence of the stars. After a few months in prison, having been forced to recant and to abandon teaching, Cardano went in 1571 to Rome, where he succeeded in obtaining the favor of Pope Plus V, who gave him a lifetime annuity. In Rome, in the last year of his life, he wrote *De propriavita*, an autobiography—or better, an *apologia pro vitasua*—that did not shrink from the most shameful revelations. The *De propria vita* and the *De libris propriis* are the principal sources for his biography.

Cardano wrote more than 200 works on medicine, mathematics, physics, philosophy, religion, and music. Although he was insensitive to the plastic arts, his was the universal mentality to which no branch of learning was inaccessible. Even his earliest works show the characteristics of his highly unstable personality: encyclopedic learning, powerful intellect combined with childlike credulity, unconquerable fears, and delusions of grandeur.

Cardano's fame rests on his contributions to mathematics. As early as the *Practica arithmetice*, which is devoted to numerical calculation, he revealed uncommon mathematical ability in the exposition of many original methods of mnemonic calculation and in the confidence with which he transformed algebraic expressions and equations. One must remember that he could not use modern notation because the contemporary algebra was still verbal. His mastery of calculation also enabled him to solve equations above the second degree, which contemporary algebra was unable to do. For example, taking the equation that in modern notation is written $6x^3 - 4x^2 = 34x + 24$, headded $6x^3 + 20x^2$ to each member and obtained, after other transformations,

$4x^2(3x + 4) = (2x^2 + 4x + 6)(3x + 4)$, divided both members by 3x + 4, and from the resulting second-degree equation obtained the solution x = 3.

His major work, though, was the *Ars magna*, in which many new ideas in algebra were systematically presented. Among them are the rule, today called "Cardano's rule," for solving reduced third-degree equations (i.e., they lack the second-degree term); the linear transformations that eliminate the second-degree term in a complete cubic equation (which Tartaglia did not know how to solve); the observation that an equation of a degree higher than the first admits more than a single root; the lowering of the degree of an equation when one of its roots is known; and the solution, applied to many problems, of the quartic equation, attributed by Cardano to his disciple and son-in-law, Ludovico Ferrari. Notable also was Cardano's research into approximate solutions of a numerical equation by the method of proportional parts and the observation that, with repeated operations, one could obtain roots always closer to the true ones. Before Cardano, only the solution of an equation was sought. Cardano, however, also observed the relations between the roots and the coefficients of the equation and between the succession of the signs of the terms and the signs of the roots; thus he is justly considered the originator of the theory of algebraic equations. Although in some cases he used imaginary numbers, overcoming the reluctance of contemporary mathematicians to use them, it was only in 1570, in a new edition of the *Ars magna*, that he added a section entitled "De aliza regula" (the meaning of *aliza* is unknown; some say it means "difficult"), devoted to the "irreducible case" of the cubic equation, in which Cardano's rule is extended to imaginary numbers. This was a recondite work that did not give solutions to the irreducible case, but it was still important for the algebraic transformations which it employed and for the presentation of the solutions of at least three important problems.

His passion for games (dice, chess, cards) inspired Cardano to write the *Liber de tudo aleae*, which he completed in his old age, perhaps during his stay at Bologna; it was published posthumously in the *Opera omnia*. The book represents the first attempt at a theory of probability based on the philosophical premise that, beyond mere luck, laws and rules govern any given case. The concept of probability was introduced, expressed as the ratio of favorable to possible cases; the law of large numbers was enunciated; the so-called "power law" (if ϱ is the probability of an event, the probability that the event will be repeated n limes is ϱ^n) was presented; and numerous problems relating to games of dice, cards, and knucklebones were solved. The book was published, however, subsequent to the first research into the theory of games developed in the correspondence between Fermat and Pascal in 1654; it had no influence on the later development of the field.

Cardano published two encyclopedias of natural science: *De subtilitate libri XXI* (1550) and *De rerumvarietaie* (1557), a supplement to *De subtilitate*. The two works, written in an elliptical and often obscure Latin, contain a little of everything: from cosmology to the construction of machines; from the usefulness of natural sciences to the evil influence of demons; from the laws of mechanics to cryptology. It is a mine of facts, both real and imaginary; of notes on the state of the sciences; of superstition, technology, alchemy, and various branches of the occult. The similarities between the scientific opinions expressed by Cardano in these two works and those of Leonardo da Vinci, at that time unpublished, has led some historians, particularly Pierre Duhem, to suppose that Cardano has used Leonardo's manuscript notes; others insist that the similarity is entirely coincidental. Be that as it may, Cardano must always be credited with having introduced new ideas that inspired new investigations. In the sixteenth century there were five editions of *De rerum varietate* and eight of *De suhtilitate*, as well as seven editions of the French translation of the latter.

Cardano reduced the elements to three (air, earth, water), eliminating fire, which he considered a mode of existence of matter; and he reduced the four qualities to two (hot and moist). His magic was, above all, an attempt to interpret natural phenomena in terms of sympathy and antipathy.

In mechanics, Cardano was a fervent admirer of Archimedes. He studied the lever and the inclined plane in new ways and described many mechanical devices, among them "Cardano's suspension," known in classical antiquity, which he attributed to a certain Jannello Turriano of Cremona. Cardano followed a middle road between the partisans of the theory of impetus and the supporters of the Aristotelian theory, who attributed the movement of projectiles to pushing by the air: he favored the idea that at the beginning of its trajectory the projectile was moved by the impetus of the firing mechanism but subsequently was accelerated by the movement of the air. Notable is his observation that the trajectory described by a projectile is not rectilinear at the center, but is a line "which imitates the form of a parabola." Cardano's chief claim to fame, however, was his affirmation of the impossibility of perpetual motion, except in heavenly bodies.

Cardano's contributions to hydrodynamics are important: counter to contemporary belief, he observed that in a conduit of running water, the water does not rise to the level from which it started, but to a lower level that becomes lower as the length of the conduit increases. He also refuted the Aristotelian "abhor-rence of a vacuum," holding that the phenomena attributed to this abhorrence can be explained by the force of rarefaction. Cardano investigated the measurement of the capacity of streams and stated that the capacity is proportional to the area of the cross section and the velocity. He observed that a stream presses against its banks and, counter to contemporary opinion, he held that the upper levels of moving water move faster than the lower levels.

In his *Opus novum de proportionibus*, Cardano turned to problems of mechanics, with the principal aim of applying quantitative methods to the study of physics. His use of the concept of moment of a force in his study of the conditions of equilibrium in balance and his attempt to determine experimentally the relation between the densities of air and water are noteworthy. The value that he obtained, 1:50, is rough; but it is the first deduction to be based on the experimental method and on the hypothesis that the ratio of the distances traveled by bullets shot from the same ballistic instrument, through air and through water, is the inverse of the ratio between the densities of air and water.

Geology is indebted to Cardano for several theories: that the formation of mountains is often due to erosion by running water; that rise of the ocean floor is indicated by the presence of marine fossils in land that was once submerged; and the idea—then novel—that streams originate from rainwater, which run back to the sea and evaporates from it, to fall back to earth as rain, in a perpetual cycle.

The many editions of Cardano's works and the citations of them by writers of the second half of the sixteenth century demonstrate their influence, especially as a stimulus to the study of the particular and the concrete.

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