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JOSEPH EWAN

BETANCOURT Y MOLINA, AUGUSTIN DE (*b.* Tenerife, Canary Islands, 1758; *d.* St. Petersburg, Russia, 14 July 1824), *physics, engineering.*

Betancourt was a descendant of the Norman navigator Jean de Béthencourt, who discovered the Canary Islands in 1402. After completing his studies in Paris, he was sent by the Spanish government to France, England, Germany, and Holland to study methods of shipbuilding, navigation, mechanics, and using steam engines. He brought back a number of drawings and models which formed the nucleus of the scientific cabinet of the king of Spain. While in France he submitted two important reports to the Académie des Sciences of Paris. In the first he revealed to the Continent the double-action steam engine, which he had observed in action in England. This memoir led Jacques-Constantin Périer to construct the first double-action steam engine in France.

In the second report (1790), Betancourt gave the results of a series of measurements establishing the relation of temperature and steam pressure. This was the first work of its kind, but Betancourt underestimated the importance of the disturbances caused by the presence of even a minimum quantity of residual air.

After another trip to England to study its mining industry Betancourt returned to France. There he became interested in the optical telegraph invented by Claude Chappe, and constructed a line from Madrid to Cadiz. He was then entrusted with the organization of a school of civil engineering in Spain, and became its inspector general. Disturbances in Spain led him to settle temporarily in Paris, where he became well known, especially for a system of water-saving locks.

In 1808 Betancourt accepted an offer from the Russian government, and on 30 November was made chief of staff of the czar's retinue. In Russia he improved the arms industry and constructed bridges using a new system of arches. In collaboration with Carbonnier, Betancourt built the riding school of Moscow, which was then the largest hall without inner supports; the span of its roof was said to be forty meters. He also constructed the aqueduct of Taïtzy and set up a state paper industry. In 1810 a school of civil engineering was founded in St. Petersburg, and Betancourt became its inspector as well as a professor; in 1819 he was made director of the Central Administration of Civil Engineering.

On 22 August 1822 Betancourt was summarily retired when an official investigation revealed numerous irregularities in the running of the Central Administration of Civil Engineering. Undoubtedly he was simply caught up in a general wave of reform, for he did not lose the czar's favor. He was in the midst of rebuilding St. Isaac's Cathedral when he died.

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JACQUES PAYEN

BETTI, ENRICO (*b.* near Pistoia, Italy, 21 October 1823; *d.* Pisa, Italy, 11 August 1892), *mathematics.*

Since his father died when Betti was very young, the boy was educated by his mother. At the University of Pisa, from which he received a degree in physical and mathematical sciences, he was a disciple of O. F. Mossotti, under whose leadership he fought in the battle of Curtatone and Montanara during the first war for Italian independence.

After having taught mathematics at a Pistoia high school, in 1865 Betti was offered a professorship at the University of Pisa; he held this post for the rest of his life. He also was rector of the university and director of the teachers college in Pisa. In addition, he was a member of Parliament in 1862 and a senator from 1884. His principal aim, however, was always pure scientific research with a noble philosophical purpose.

In 1874 Betti served for a few months as undersecretary of state for public education. He longed, however, for the academic life, solitary meditation, and discussions with close friends. Among the latter was Riemann, whom Betti had met in Göttingen in 1858, and who subsequently visited him in Pisa.

In algebra, Betti penetrated the ideas of Galois by relating them to the previous research of Ruffini and Abel. He obtained fundamental results on the solubility of algebraic equations by means of radicorational operations. It should be noted that the most important results of Galois's theory are included—without demonstration and in a very concise form—in a letter written in 1832 by Galois to his friend Chevalier on the eve of the duel in which Galois was killed. The letter was published by Liouville in 1846. When Betti was able to demonstrate—on the basis of the theory of substitutions, which he stated anew—the necessary and sufficient conditions for the solution of any algebraic equation through radicorational operations, it was still believed in high mathematical circles that the questions related to Galois's results were obscure and sterile. Among the papers in which Betti sought to demonstrate Galois's statements are "Sulla risoluzione delle equazioni algebriche" (1852) and "Sopra la teorica delle sostituzioni" (1855). They constitute an essential contribution to the development from classical to abstract algebra.

Another area of mathematical thought developed by Betti is that of the theory of functions, particularly of elliptic functions. Betti illustrated—in an original way—the theory of elliptic functions, which is based on the principle of the construction of transcendental entire functions in relation to their zeros by means of infinite products.

Betti published these results in a paper entitled "La teorica delle funzioni ellitiche" (1860–1861). These ideas were further developed by Weierstrass some fifteen years later. However, Betti, who in the meantime had turned to another theory of elliptic functions—this one inspired by Riemann—did not wish to claim priority. These two methods are linked with the two basic aspects of Betti's mathematical thought: the algebraic mode of thought, which went deep into Galois's research, and the physicomathematical mode of thought, developed under Riemann's influence. Betti, an enthusiastic supporter of theoretical physics, had turned toward the procedures already started in electricity and subsequently applied to analysis.

Among Betti's physicomathematical researches inspired by Riemann are *Teorica della forze newtoniane* (1879) and "Sopra le equazioni di equilibrio dei corpi solidi elastici." A law of reciprocity in elasticity theory, known as Betti's theorem, was demonstrated in 1878. Having mastered the methods by which Green had opened the way to the integration of Laplace's equations, which constitute the basis for the theory of potentials, Betti applied these methods to the study of elasticity and then to the study of heat.

Of particular interest is Betti's research on "analysis situs" in hyperspace, which is discussed in "Sopra gli spazi di un numero qualunque di dimensioni" (1871). This research inspired Poincaré in his studies in this field and originated the term "Betti numbers," which subsequently became common usage for numbers characterizing the connection of a variety.

Betti played an important role in the rebirth of mathematics after the Risorgimento. He loved classical culture, and with Brioschi he championed the return to the teaching of Euclid in secondary schools, for he regarded Euclid's work as a model of discipline and beauty. This led to *Gli elementi d'Euclide* (1889).

His enthusiasm and brilliance made Betti an excellent teacher. At the University of Pisa and at the teachers college, he guided several generations of students toward scientific research, among them the mathematicians U. Dini, L. Bianchi, and V. Volterra.

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ETTORE CARRUCCIO

BEUDANT, FRANÇOIS-SULPICE (*b.* Paris, France, 5 September 1787; *d.* Paris, 9 December 1850), *mineralogy, geology.*

Educated at the École Polytechnique and the École Normal Supérieure in Paris, Beudant began his career as *répétiteur* at the latter institution, leaving this post to become professor of mathematics at Avignon (1811) and then professor of physics at Marseilles (1813). During these years his primary interests were zoology and paleontology, tastes he acquired while studying with Gilet de Laumont. He studied species of coelenterates and mollusks, trying to determine whether freshwater varieties could adapt to saltwater and whether marine forms could have originated from freshwater fauna. Some of his observations were included in "Mémoire sur la possibilité de faire vivre des mollusques fluviatiles dans les eaux salées et des mollusques marins dans les eaux douces . . . "

Louis XVIII appointed Beudant as assistant director of his cabinet of mineralogy in 1814, charging him with the task of cataloguing the enormous mineralogical collection of the Comte de Bournon, which was to be moved to Paris from England the following year. This work directed Beudant's attention from natural history to mineralogy and geology, with which he was thereafter concerned. In 1818 he was sent by the state on a scientific expedition to Hungary, where he gathered masses of important data that were published in his three-volume *Voyage minéralogique et geólogique en Hongrie* (1822).

In 1820 Beudant became professor of mineralogy and physics on the Faculty of Sciences at the Sorbonne but resigned the chair of physics so that Ampère might have it. In 1839 he left the university and became *inspecteur général des études,* which was equivalent to being supervisor for the entire French educational system. He held this position until his death. In 1841 he wrote a grammar of the French language that was favorably received by his contemporaries.

Mineralogical investigations, particularly experiments with carbonates and other salts, revealed to Beudant a principle of the combination of mineral substances that he expressed in Beudant's law. Essentially, he found that some compounds dissolved in the same solution would precipitate together, forming a crystal whose properties they determined in common. The interfacial angles of this new crystal would have a value intermediate between the angles of the original compounds, proportional to the quantity of each. The same idea had been put forth by Robert Boyle in "The Origine of Form and Qualities" (1666). Beudant was rather conservative about the generality of his proposition, although Delafosse enthusiastically maintained that it should apply to all crystals.

The generalization of this idea, the law of isomorphism, was proposed by Mitscherlich in 1819.

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MARTHA B. KENDALL

BEXON, GABRIEL-LÉOPOLD-CHARLES-AMÉ (*b.* Remiremont, France, 10 March 1747; *d.* Paris, France, 15 February 1784), *biology.*

Bexon, whose short scientific career was closely linked with that of the great French naturalist Buffon, received his early education from his parents, Amé Bexon, a lawyer, and Marthe Pillement. Having shown considerable intelligence, he was sent north to the seminary at Toul to continue his education and prepare for the clergy. He completed the course of study and received his doctorate in theology at the