in *Giornale dell'Istituto lombardo,* **9** (1856), 485–489; and G. Cantoni, "Sopra due strumenti metereologici ideati da Angelo Bellani," in *Rendiconti dell'Istituto lombardo,* **10** (1877), 17–23; **11** (1878), 873–880.

The transactions of the congresses of Italian scientists, in which Bellani participated actively, contain extensive extracts of his remarks.

In agriculture he collaborated on the *Giornale agrario lombardo-veneto,* contributing articles on the cultivation of the silkworm, wood, malaria, and the function of the roots of plants.

GIORGIO PEDROCCO

BELLARDI, LUIGI (*b.* Genoa, Italy, 18 May 1818; *d.* Turin, Italy, 17 September 1889), *paleontology, entomology.*

Although a native of Genoa, Bellardi spent most of his life in Turin, where, following the wishes of his family, he studied law. Since his early youth, however, the natural sciences had attracted him; and in his leisure time he collected the Cenozoic Mollusca abundant in the hills around Turin, Superga, Asti, and Tortona. At the age of twenty he published his first paper on the gastropod genus *Borsonia,* and from that time on, his major scientific activity concentrated on the Cenozoic Mollusca of the Piedmont and of Liguria. He also visited the Middle East, particularly Egypt, bringing back extensive collections for comparative study.

Between 1854 and 1874 a variety of circumstances prevented Bellardi from dedicating himself entirely to paleontology, and he therefore undertook entomological research, mostly on the diptera of the Piedmont. He also took some interest in botany and agriculture, being the first in Italy to discuss the phylloxera and its relationship to viticulture.

Upon the introduction of evolutionary ideas into paleontology, Bellardi immediately understood their fundamental importance, and his last works show the relationships between the different forms of Mollusca, and their probable filiation through geological time. During the last twenty years of his life he returned entirely to paleontology, but never completed his extensive and important *I molluschi,* which is characterized by perfectionism in presentation and content. With a similar attitude, he taught natural history for thirty years at the Liceo Gioberti and was curator of the paleontological collection of the Royal Geological Museum of Turin, to which he made many contributions. His desire to increase interest in natural history led him to write several elementary textbooks, also characterized by clarity of expression and precision of data.

Bellardi was elected an honorary member of many academies and scientific societies, and King Victor Emmanuel requested him to teach the natural sciences to his sons, an assignment that Bellardi particularly enjoyed.

BIBLIOGRAPHY

Among Bellardi's works are "Saggio orittografico sulla classe dei gasteropodi fossili dei terreni Terziarii del Piemonte," in *Memorie della Reggia Accademia delle scienze di Torino,* 2nd ser., **3** (1841), 93–174, written with G. Michelotti; "Description des cancellaires fossiles des terrains Tertiaires du Piémont," *ibid.,* 225–264; "Monografia delle pleurotome fossili del Piemonte," *ibid.,* **9** (1848), 531–650; "Monografia delle columbelle fossili del Piemonte," *ibid.,* **10** (1849), 225–247; "Monografia delle mitre fossili del Piemonte," *ibid.,* **11** (1851), 357–390; and *I molluschi dei terreni Terziarii del Piemonte e della Liguria,* 30 vols. (Turin, 1873–1904), I–V by Bellardi and VI–XXX by F. Sacco—I–VIII, XI, and XIII also in *Memorie della Reggia Accademia delle scienze di Torino,* 2nd ser., **27–44** (1873–1894).

ALBERT V. CAROZZI

BELLARMINE, ROBERT (*b.* Montepulciano, Italy, 4 October 1542; *d.* Rome, Italy, 17 September 1621), *theology, philosophy.*

Third of the twelve children of Vincenzo Bellarmino and Cynthia Cervini, half-sister of Pope Marcellus II, Robert joined the newly founded Jesuit order in 1560 and took a master's degree in philosophy at the Spanish-staffed Roman College in 1563. Natural philosophy formed an important part of his studies there, but it appears to have been wholly and routinely Aristotelian in character. Ordained priest in 1570, he completed his theological studies in Louvain.

The struggle between the Catholic and Protestant wings of Christendom had by then attained an extraordinary ferocity all over Europe. One of the major theoretical issues separating the two groups concerned the norms for the proper interpretation of Scripture. Because of his profound scriptural scholarship and his thorough grasp of the major Protestant writers (both of these achievements very rare in the Catholic church of the day), Bellarmine soon became the leading theologian on the Catholic side of the debate. His three-volume *Disputationes de controversiis* was by far the most effective piece of Catholic polemic scholarship of the century. After its appearance in 1588, he was recognized as the leading defender of the papacy; successive popes forced on a man whose natural temperament was at once gentle and gay the uncongenial role of controversialist and apologist.

Made rector of the Roman College in 1592, cardinal in 1599, and archbishop of Capua in 1602, Bellarmine was never far from Rome, and in his last years lived at the Vatican as the pope's major theological adviser.

Bellarmine's relevance to the history of science comes only from his role in the Galileo story. In 1611 he was among the Roman dignitaries whom Galileo invited to see the new-found wonders in the sky. The old man was disturbed at the implications of what he saw, and asked the astronomers of his old college (among them Clavius) to test the accuracy of Galileo's claims. This they soon did. Galileo sent him a copy of his important and effectively anti-Aristotelian work on hydrostatics (1612), to which Bellarmine replied that "the affection you have thus shown me is fully reciprocated on my part; you will see that this is so, if ever I get an opportunity of doing you a service." The opportunity was not long in coming.

The Aristotelian cosmology was crumbling in the face of the new astronomical evidence, notably that of the phases of Venus and the sunspots. The Aristotelians of the universities fell back on the authority of Scripture as a last desperate expedient to save their case. Galileo answered them in his brilliant *Letter to the Grand Duchess Cristina of Lorraine* (1615). Two rather different, and ultimately incompatible, positions were argued by him. On the one hand, he argued with great cogency that the language in which the scriptural writers described physical phenomena could not possibly have been intended to carry any probative weight in questions of natural science. On the other hand, he also appeared to concede the traditional Augustinian maxim: So great is the weight of authority behind the words of revelation that the literal sense ought to be taken as the correct one in every case, except where such an interpretation could be strictly shown, on commonsense or philosophical grounds, to lead to falsity.

In a letter written at this time to Foscarini, a Carmelite who had defended similar views on the nonrelevance of scriptural phrases to problems of physical science, Bellarmine accepted the Augustinian maxim, but went on to emphasize that since the heliocentric theory of Copernicus could in no way be "strictly demonstrated," the troublesome scriptural phrases about the motion of the sun could not be regarded as metaphorical. If, of course, a "strict proof" of heliocentrism were to be found (a contingency he regarded as in the highest degree unlikely but, significantly, did not wholly exclude), the scriptural texts would have to be reexamined. To argue that the celestial appearances are "saved" by supposing the earth to go around the sun does not constitute a strict proof that this is what really happens. When a vessel recedes from the shore, the illusion that the shore is moving is corrected by *seeing* the ship to be in motion. Likewise, the experience of the wise man "tells him plainly that the earth is standing still."

This is the sort of unshakable trust in the ultimacy of observation that had made Aristotle (who had once seemed so dangerous an intellectual threat to Christian beliefs) a congenial cosmologist for those who regarded the Hebrew turn of phrase about sun or stars as somehow carrying a special authority. In Bellarmine's view, Solomon's phrase about the sun "returning to its place" carried far more weight than did the Copernican theory. The latter was no more than a "hypothesis," whereas Solomon had his wisdom from God.

A year later, a specially appointed tribunal of eleven theologians went much further than Bellarmine had, and advised the Congregation of the Holy Office that the heliostatic view was formally heretical, because it called into question the inspiration of Scripture. No account of the tribunal's deliberations survives, but presumably its arguments were the standard ones summarized in Bellarmine's letter.

The consequences, both for science and for the church, of the ensuing decree (1616) suspending the work of Copernicus "until it be corrected" can scarcely be overestimated. Once this decree was put into effect, the die was cast; and although later incidents (notably Galileo's trial) would come to have a greater symbolic and dramatic significance, it was with the decree of 1616 that the parting of the ways really came. The disastrous potentialities for conflict that were latent in Augustine's theory of scriptural interpretation were now for the first time realized. If the literal sense of Scripture is to be retained unless and until its untenability be *strictly* demonstrated, an impossible burden is laid on theologian and scientist alike. Each will be called on to evaluate the arguments of the other. And the argument of the scientist will not be allowed *any* weight until it is conclusive, when all of a sudden it will be conceded. The notions of evidence and probability underlying this approach (which originally derived from Augustine's theory of divine illumination as a basis for all human knowledge) are ultimately inconsistent.

In his criticisms of this approach, Galileo showed himself a better theologian than Bellarmine and the consultors. He had a far keener appreciation of what language is, and what the conditions for communication are. That his opponents did not accept his arguments, cogent as they seem to us today, was due mainly to the fact that the norms for the proper interpretation of Scripture were one of the two main issues then dividing Protestants and Catholics. Any liberalizing suggestion in this quarter was hardly likely to meet with favor on either side. It was a far cry from the calmer days of Oresme and Cusa, two centuries before, when similar suggestions about the interpretation of Scripture scarcely caused a ripple.

In his *Système du monde,* Duhem suggests that in one respect, at least, Bellarmine had shown himself a better scientist than Galileo by disallowing the possibility of a "strict proof" of the earth's motion, on the grounds that an astronomical theory merely "saves the appearances" without necessarily revealing what "really happens." This claim has often been repeated, most recently by Karl Popper, who makes Bellarmine seem a pioneer of the nineteenth-century positivist theory of science. In point of fact, nothing could be further from the case. Bellarmine by no means denied that strict demonstrations of what is "really" the case could be given in astronomical matters. In his view, however, such demonstrations had to rest on "physical" considerations of the type used by Aristotle, not on the mathematical models of positional astronomy.

This distinction between two epistemologically different types of astronomy was a time-honored one, taking its origin in the medieval debates over the relative merits of the Aristotelian and Ptolemaic astronomies. The former clearly gave a good causal account of *why* the planets moved, but was quite unable to provide any practical aids for the compiling of calendars and the like. On the other hand, it appeared impossible to account for the complex and eccentric epicyclic motions of Ptolemaic astronomy in causal terms, even though they did provide a good descriptive and predictive account of apparent planetary positions. The orthodox Aristotelian reading of this situation, such as one will find in writers like Aquinas, was that *real* motion could be asserted only on the basis of demonstrations of a properly "physical" sort; the models of the mathematical astronomer did not lend themselves to dynamic explanation because their purpose was merely that of computation.

Although the phrase "saving the appearances" was often used in reference to mathematical astronomy, it is important in this context to distinguish between the Aristotelian and Platonic views of what physics in general could accomplish. Aristotle argued that a strict science of physics can be achieved, one that tells us how the world really is. Plato, on the other hand, held that physical inquiry could at best only "save the appearances." Admittedly, such a "saving" provided some sort of insight into the physical world because of the relation of image between it and the domain of Form, but the insight is a limited and defective one because the imaging is such a flickering and uncertain affair.

Bellarmine's comments in his letter to Foscarini cannot be construed as a protopositivist declaration. He was, indeed, just as much of an "essentialist" in his theory of science (to use Popper's term) as either Aristotle or Galileo. Even if he had been a Platonist, and extended the notion of "saving the appearances" to all of physics and not just to mathematical astronomy, it still would not be correct to take this in the positivist sense favored by Duhem.

To refute the Aristotelian separation between the two types of astronomy, it would be necessary to construct a dynamical substructure for Copernican kinematics, something Galileo could not do. It was not until Newton that the new mathematical astronomy was given an adequate causal interpretation in terms of central forces. In his *Dialogo,* Galileo attempted to meet Bellarmine's challenge to provide a dynamical proof of the earth's motion, but the tidal arguments he used carried little conviction. Galileo's opponents could, therefore, claim that the Copernican theory was still no more than a "hypothesis," in the traditional sense of a fictional account, because it lacked the "physics" (i.e., the dynamics) that, in their view, it would need to transform it into a claim about the nature of the real.

When the decree outlawing Copernicanism was promulgated in 1616, Galileo was in Rome. He was not mentioned in the decree, probably because of the respect in which he was held and the support of his many friends in Rome. But since he was the main protagonist both of Copernicanism and of the views on the interpretation of Scripture that were disapproved, he obviously was the person most affected by it. Wishing to make sure that Galileo appreciated the gravity of the matter, the pope asked Bellarmine to call him in and notify him officially of the contents of the decree before it was made public. If he showed himself unwilling to accept it, he was to be enjoined personally not to support or even discuss Copernicanism in any fashion.

What happened at this famous interview has been the subject of endless controversy in the past century, since the documents of the "Galileo case" have been made public. According to a document introduced in evidence at Galileo's trial nearly twenty years later, the personal injunction apparently *was* given to him, and the prosecution made much of the fact that its existence had not been made known to the censors in charge of licensing the *Dialogo.* Galileo protested that he could recall no such formal injunction, although he remembered the interview with Bellarmine well enough. In addition, he produced an attestation drawn up by Bellarmine before Galileo left Rome in 1616, in which the aged cardinal affirmed that Galileo had not been forced to abjure Copernicanism, as rumor had claimed. Bellarmine's note, whose existence obviously had not been suspected by the prosecution, forced an alteration in the strategy of the trial; in its later stages, the personal injunction was not mentioned.

Had it actually been delivered? The record in the Holy Office file is not signed in the usual form, and Bellarmine's attestation strongly suggests that it could not be valid. Some have claimed that it was forged by enemies of Galileo, either in 1616 or in 1633, with a view to trapping him. Others have suggested that it *was* delivered in 1616, but that there were no legal grounds for doing so. Still others argue that a genuine injunction was given, and that Bellarmine's attestation was the action of a friend protecting Galileo's reputation. We shall never know for sure. And in any event, it makes little difference, since the trial verdict would very likely have been the same whether or not a special injunction had been given to Galileo in 1616. Once the decree of 1616 implied that the heliocentric view is formally heretical, the writing of a book like the *Dialogo* automatically gave grounds for the suspicion of heresy, if the pope or the Holy Office cared to press the charge. This was where Bellarmine and the theologians of 1616 failed. Beset by the polemics of Reformation and Counter-Reformation, they did not grasp the limits of scriptural inspiration that were already becoming evident to the pioneers of the new sciences. One can account for their failure easily enough, but it was to have disastrous consequences for their church and for religion in general.

BIBLIOGRAPHY

The relationship between Bellarmine and Galileo is fully covered in James Brodrick, *Robert Bellarmine* (Westminster, Md., 1961). Brodrick's earlier *Life and Work of Robert Francis Bellarmine* (London, 1928) is quite defective in its treatment of the Galileo case. The most colorful recent account of the Bellarmine-Galileo dispute is Giorgio de Santillana, *The Crime of Galileo* (Chicago, 1955); a quite different reconstruction of the circumstances under which the disputed injunction came to be entered into the file is given by Stillman Drake in the appendix to his trans. of Ludovico Geymonat, *Galileo Galilei* (New York, 1965). Popper's view of Bellarmine as an "instrumentalist," in contrast with Galileo, the "essentialist," is worked out in his "Three Views Concerning Human Knowledge," in H. D. Lewis, ed., *Contemporary British Philosophy* (New York, 1956), pp. 355–388.

ERNAN MCMULLIN

BELLAVITIS, GIUSTO (*b.* Bassano, Vicenza, Italy, 22 November 1803; *d.* Tezze, near Bassano, 6 November 1880), *mathematics.*

Bellavitis was the son of Ernesto Bellavitis, an accountant with the municipal government of Bassano, and Giovanna Navarini; the family belonged to the nobility but was in modest circumstances. He did not pursue regular studies but was tutored under the guidance of his father, who directed his interest toward mathematics. Soon he surpassed his tutor and diligently pursued his studies on his own, occupying himself with the latest mathematical problems.

From 1822 to 1843 Bellavitis worked for the municipal government of Bassano—without pay for the first ten years—and conscientiously discharged his duties, occupying his free time with mathematical studies and research. During this period he published his first major works, including papers (1835, 1837) on the method of equipollencies, which were hailed as one of his major contributions. On 26 September 1840 Bellavitis became a fellow of the Istituto Veneto, and in 1843 he was appointed professor of mathematics and mechanics at the *liceo* of Vicenza. He then married Maria Tavelli, the woman who for fourteen years had comforted and encouraged him in his difficult career.

On 4 January 1845, through a competitive examination, Bellavitis was appointed full professor of descriptive geometry at the University of Padua. On 4 July 1846, the university awarded him an honorary doctorate in philosophy and mathematics. He transferred in 1867 to the professorship of complementary algebra and analytic geometry. On 15 March 1850, Bellavitis became a fellow of the Società Italiana dei Quaranta, and in 1879 a member of the Accademia dei Lincei. In 1866 he was named a senator of the Kingdom of Italy.

Bellavitis' method of equipollencies belongs to a special point of view in mathematical thought: geometric calculus. According to Peano, geometric calculus consists of a system of operations to be carried out on geometric entities; these operations are analogous to those executed on numbers in classical algebra. Such a calculus "enables us to express by means of formulae the results of geometric constructions, to represent geometric propositions by means of equations, and to replace a logical argument with the transformation of equations." This approach had been developed by Leibniz, who intended to go beyond the Cartesian analytic geometry, by performing calculations directly on the geometric elements, rather than on the coordinates (numbers). Moebius' barycentric calculus finds its expression within this context, but Bellavitis made special reference to