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CLAVIO, CRISTOFORO

SEE **Clavius, Christopher**.

CLAVIUS, CHRISTOPH

(*b.* Bamberg, Germany, 25 March 1538; *d.* Rome, Italy, 6 February 1612), *astronomy, cosmology, mathematics, education.* For the original article on Clavius see *DSB*, vol. 3.

Clavius offered the last serious defense of the ancient Ptolemaic cosmology and published one of the earliest critiques of Copernican theory. Along with his students, he authenticated Galileo’s early telescopic discoveries and prominently recognized their epochal significance in his widely used textbook of elementary astronomy. Clavius attained international esteem for his exposition of Euclid’s *Elements* and spent much of his career establishing an important place for mathematical studies in Jesuit schools. He was also a member of the papal commission that planned and executed the Gregorian calendar reform of 1582 and through subsequent publications became the principal expositor and defender of the Gregorian calendar.

Biographical Background. Other than his birth date in Bamberg, Clavius’s origins are unknown, including his original family name, which might have been Clau, Schlüssel, or some variant. Any details of his early life in Bamberg are also absent, and he never returned there, although he took an interest for the rest of his life in the city and its fortunes amidst the Counter-Reformation. Horst Enzensberger’s “Società, cultura e religione a Bamberga” (1995) provides a sketch of the intellectual and political context that must have shaped Clavius’s early life. He entered the Society of Jesus on 12 April 1555 and was then sent to study at the University of Coimbra, which he entered in 1556. His first recorded astronomical observation took place at Coimbra: the total solar eclipse of 21 August 1560. By May 1561 he had returned to Rome to begin advanced studies in theology and other subjects at the Jesuit Collegio Romano and was ordained in 1564. Clavius began teaching mathematics at the Collegio Romano, as he would for nearly all his career, as early as 1563. With rare good fortune for a person in that era, he witnessed on 9 April 1567 a second total solar eclipse in Rome. His account of the eclipse, published in his *Sphere* commentary, attracted attention in its day because of his controversial conclusion that it was an annular eclipse. At the turn of the twenty-first century, F. Richard Stephenson, J. Eric Jones, and Leslie Morrison used his report to investigate long-term variations in the rotation rate of the Earth (1997). During a brief stint in Messina working with Francesco Maurolico, in 1574, he acquired many unpublished mathematical treatises, including Maurolico’s treatise on the nova of 1572 and a manuscript on light, which Clavius would eventually publish. Aside from another sojourn at the Jesuit College in Naples in 1596, Clavius spent the rest of his long career in Rome, where he died on 6 February 1612. A more complete biography can be found in James Lattis's *Between Copernicus and Galileo* (1994).

Mathematics. Clavius published his edition of Euclid's *Elements* in 1574. More a commentary enhancing access to the work than a philological edition of the Greek text, it achieved great popularity and influence. Revising and republishing it at least five times, Clavius went beyond the strict bounds of Euclid's material to introduce new materials, including his own proof of Euclid's fifth postulate and his solution to the problem of squaring the circle. Vincent Jullien (1997) and Sabine Rommevaux (2005) show the broad significance of Clavius's *Euclid* for many seventeenth-century mathematicians, not only Jesuits, and Paolo Palmieri (2001) finds connections between Clavius's theory of proportions and Galileo's own struggles with the concept.

Clavius's other original mathematical contributions include a digression on combinatorics in his *Sphere* commentary in 1581, which Eberhard Knobloch (1979) judges a seminal text, and his publication of the *Spherics* of Theodosius (in 1586). He also published a variety of practical textbooks on arithmetic, geometry, gnomonics, and the construction of instruments. Music, one of the four mathematical sciences of the traditional Quadrivium (along with arithmetic, geometry, and astronomy), was another area of interest for Clavius. His surviving works include eleven motets and two songs, none of which have yet received significant study.

Astronomy. Clavius authored one of the most influential astronomy textbooks in history, his *Commentary on the Sphere of Sacrobosco,* which remained a standard for astronomy instruction for three-quarters of a century. It was published at least sixteen times between 1570 and 1618 by printers spread across Europe. He revised the text seven times, often expanding it greatly in scope and detail and taking note of new discoveries and controversies.

In lengthy digressions in his *Sphere*, Clavius defended the Ptolemaic cosmology (a blending of Aristotelian physics and mathematical models of Ptolemy's *Almagest* into a physical cosmos) against a variety of critics. The critics included both skeptics who doubted that knowledge about celestial causes is even possible, as well as those who advocated alternatives to the Ptolemaic cosmos. Clavius's "realist" views, which hold that it is possible to deduce celestial causes from observations of the motions of celestial bodies, resonated strongly (if only at the epistemological level) with those of Johannes Kepler, as Nicolas Jardine discusses in "The Forging of Modern Realism" (1979). Prominent among the alternative cosmologies criticized by Clavius stands Copernicus's heliocentric cosmos. Clavius's criticisms of the Copernican cosmos included its inconsistencies with common sense, Aristotelian physics, and the testimony of Scripture, as well as a flawed methodology that would, he said, prevent it from providing reliable astronomical knowledge.

Christoph Clavius. *18th Century engraving.*

Despite his antipathy toward the Copernican cosmos, Clavius's *Sphere* expressed admiration for Copernicus's mathematical skill, and he ultimately incorporated several ideas from Copernicus's work into his own version of the Ptolemaic cosmology, most notably Copernicus's model for representing what later would be called the precession of the equinoxes, which motion Copernicus attributed to the Earth, but which Clavius located in the outer spheres of the Ptolemaic cosmos. Clavius also confronts and rejects the cosmological theory of homocentric spheres at considerable length and with even greater vigor than he devotes to Copernican theory, and goes on to reject other cosmic concepts as well. His treatment of these rivals to Ptolemaic cosmology shows that the cosmological debates of the late sixteenth and early seventeenth centuries were far more complex than a simple confrontation between Ptolemy and Copernicus.

Clavius also used his *Sphere* as a vehicle for commentary on the remarkable novas of 1572, 1600, and 1604. In the 1585 (and every subsequent) edition, he published his conclusion that the nova of 1572 must have been located in the firmament of the fixed stars—thus demonstrating, contrary to Aristotle, that celestial matter was capable of qualitative change. He based his conclusion firmly on observations reported by correspondents widely placed across Europe showing that all had observed the nova to be in the same location with respect to nearby stars, putting, in effect, an upper limit on the parallax of the nova. Clavius's measurement of the location of the nova was thus in agreement with but independent of Tycho Brahe's more famous conclusion. Galileo's celebrated discoveries of 1609 and 1610 were also reported in the *Sphere.* In April 1611, Cardinal Bellarmine requested of Clavius an opinion concerning Galileo's sensational telescope discoveries, which the astronomers of the Collegio Romano then confirmed with their own telescopes. In his final version of the *Sphere*, published in 1611, Clavius noted Galileo's findings, including the phases of Venus and moons of Jupiter, and famously recognized their significance by calling upon astronomers to accommodate them in astronomical theory. A fuller account of Clavius's astronomical career and significance is found in Lattis's *Between Copernicus and Galileo.*

Although Clavius's *Sphere* was the book by which his astronomical teaching reached the world at large, it is not, as Ugo Baldini (2000) points out, an adequate measure of the level of his astronomical research. Clavius never finished his more advanced treatise in theoretical astronomy, but the surviving parts (fragments of his solar and lunar theories) are interesting and perhaps unique examples of how advanced astronomical theory was taught in the late sixteenth century. The surviving solar theory has been published by Baldini in *Legem impone subactis* (1992), and further discussed, along with the lunar theory, in his *Saggi sulla Cultura della Compagnia di Gesù* (2000). Baldini, in his *Saggi*, judges it doubtful that, even if it had been finished, his theoretical work would have resulted in anything other than an ad hoc adjustment to the established Ptolemaic theories. Clavius found even the geocentric system of Tycho to be incomprehensible as a representation of reality and remained committed to the Ptolemaic cosmos. Clavius's level of expertise was also very high in the area of instrument design as indicated by his several books on the construction and use of astrolabes, sundials, and meridian instruments. Baldini and Juan Casanovas (1996) identify the sole surviving example of one of Clavius's instruments, namely a celestial globe constructed in 1575, in which he adopted from Copernicus the location of the vernal equinox and updated star positions.

Galileo drew heavily on Jesuit sources during his early academic career, as is documented by William Wallace in *Galileo and His Sources* (1984), and had personally conferred with Clavius. His cordial relationship with Galileo endured through the end of Clavius's life and generally extended to the other Jesuit astronomers of the Collegio Romano who collectively celebrated Galileo's telescope discoveries with a ceremony at the Collegio Romano on 18 May 1611. Although Clavius had endorsed and confirmed the observations themselves, he originally expressed reservations about the full meaning of Galileo's discoveries. Yet the doubts of the senior astronomer seem not to have dampened the enthusiasm of the younger ones, which included Christoph Grienberger, Odo van Maelcote, Paul Guldin, Paolo Lembo, and Gregory of St. Vincent. Relations between Galileo and the Collegio Romano astronomers soured only after Clavius's death in the wake of Cardinal Bellarmine's restrictions on the teaching of Copernicanism and the controversies that grew out of Galileo's feuds with Jesuits Orazio Grassi and Christoph Scheiner.

Gregorian Calendar. Sometime between 1572 and 1575, Pope Gregory XIII convened a commission to make recommendations on the reform of the Julian calendar, and the young Clavius was tapped to serve as the commission's technical expert. As such, he reviewed and explained the various issues and proposed reform schemes and specified the technical terms of the reform that the commission eventually decided on. This, however, was only the beginning of the work, because Clavius went on to write and publish the fundamental works promulgating and explaining the new Gregorian calendar and the transition process from the old calendar to the new. A collection of articles explaining various aspects of the calendar reform appears in *Gregorian Reform of the Calendar* (Coyne, et al, 1983). Many critics, among them Joseph Scaliger and Michael Maestlin, found fault with the calendar reform, and the task fell to Clavius to respond to them in print. An overview of Clavius's role in the reform and his responses to the critics can be found in Carmelo Oñate Guillen's "Christopher Clavius y el Calendario Gregoriano" (2000). A proper history of the Gregorian calendar reform has as of 2007 yet to be published.

Institution Building. Jesuit scholars achieved great respect for their contributions to mathematical sciences, and Clavius was the architect of the mathematical curriculum in the Jesuit educational establishment. His influence on the *Ratio studiorum*, the plan of studies for Jesuit schools, published in final form in 1599, established mathematics as a vital component in an era when mathematical subjects were rarely or inconsistently taught in many institutions of higher learning. His concerns went beyond curriculum parameters and extended to measures intended to enhance the prestige of mathematical work and the respect accorded its specialists. Dennis Smolarski surveys Clavius's pedagogical efforts and his influence on the development of the *Ratio studiorum.* In addition to establishing a curriculum that specified the study of Euclid, arithmetic, astronomy, cosmography, optics, timekeeping, and instrument construction, Clavius's lifetime of writing provided teachers, Jesuit and otherwise, with textbooks to cover almost the entire mathematical curriculum. By the end of his career, Clavius's efforts had led to a required rotation of mathematics courses in the hundreds of Jesuit schools and to a growing number of skilled teachers and practitioners of the mathematical sciences. Alistair Crombie, in "Mathematics and Platonism" (1977), largely credits Clavius's policies and efforts for Jesuit achievements in science during the seventeenth century. Clavius's impact also went well beyond Europe, carried by mathematically trained Jesuit missionaries such as Matteo Ricci and Johann Adam Schall. Notwithstanding his significance for helping scholars understand the development of early modern science, Clavius's greatest legacy and impact might be found in his efforts as a teacher and builder of educational institutions.

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James M. Lattis

CLEMENTS, FREDERIC EDWARD

(*b.* Lincoln, Nebraska, 16 September 1874; *d.* Santa Barbara, California, 26 July 1945), *botany.* For original article on Clements see *DSB,* vol. 3.

Clements is best known for his theory of community development or plant succession. He claimed that a plant community underwent a predictable series of developmental stages that was comparable to the development of an organism. The final stage or climax community was determined by the climatic conditions of a geographic area. For Clements, the plant community was, in fact, a "complex organism" with a physiology that could be studied with the same precision as an organism in the laboratory. These organismal ideas were both influential and controversial during Clements's lifetime. They focused considerable attention on plant succession as a major research area for American ecologists during the early decades of the twentieth century, when the discipline was becoming established. Although widely rejected by later ecologists, Clements's organicism and physiological perspective persisted in attenuated form even after World War II.

Plant Communities. Historians are in general agreement that Clements drew his idea of the plant community as a complex organism from Herbert Spencer and other late nineteenth-century social thinkers who employed similar organic analogies. This idea was central to Clements's attempt to create a science of ecology based on the model of laboratory physiology with its rigorous experimental and quantitative methods. Historian Sharon Kingsland asserts that the organismal idea also allowed Clements to situate human activities within ecology. Knowing the natural patterns of development in plant communities provided a way to understand and correct the pathological disturbances caused by human activities. Damaged lands could be rescued from overgrazing and other unwise agricultural practices, but only if agriculture was based on sound ecological principles. Throughout his career Clements emphasized the practical role that ecology could play in setting public policy regarding land use and resource management. As Kingsland points out, Clements's view of the social dimension of ecology was in tune with the Progressive Era ideas of efficiency and scientific management and also with later New Deal policies. This belief in the public role of ecology met a critical challenge during the Dust Bowl years of the 1930s.

The importance of the prairie and the Dust Bowl for Clements's career has been the focus of considerable interest by historians. Both Donald Worster and Ronald Tobey emphasize the formative influence of growing up on the prairie for Clements's thinking about succession. Both of these historians portray Clementsian ecology as a broad, philosophical perspective on nature exemplifying what Thomas Kuhn referred to as a scientific "paradigm." According to Worster and Toby, Clements's paradigm was established in opposition to a less deterministic theory of succession proposed by Henry Chandler Cowles at the University of Chicago and the later "individualistic" concept of the plant community championed by Henry Allan Gleason of the New York Botanical Garden. Both historians present the Dust Bowl as a critical challenge to the explanatory power of Clements's theory of succession. By emphasizing his determinism Worster and Tobey claim that Clements's had an almost metaphysical commitment to the lawlike development of vegetation that could not adequately account for the calamitous effects of the Dust Bowl.

This historical interpretation has been challenged by Christopher Eliot, who argues that Clements was much more attuned to the complexity of nature than his critics allege and that textbook descriptions of the Clements-Gleason controversy present a caricature of differences between the two ecologists' philosophical commitments and explanatory strategies. Nonetheless, the traumatic episode of the Dust Bowl undoubtedly weakened the hold that Clements's ideas had on plant ecologists, and