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# CHRISTOPHER CLAVIUS AND THE CLASSIFICATION OF SCIENCES

ABSTRACT. I discuss two questions: (1) would Duhem have accepted the thesis of the continuity of scientific methodology? and (2) to what extent is the Oxford tradition of classification/subalternation of sciences continuous with early modern science? I argue that Duhem would have been surprised by the claim that scientific methodology is continuous; he expected at best only a continuity of physical theories, which he was trying to isolate from the perpetual fluctuations of methods and metaphysics. I also argue that the evidence does not support the conclusion that early modern doctrines about mathematics and physics are continuous with the subalternation of sciences from Grosseteste, Bacon, and the theologians of fourteenth-century Oxford. The official and dominant context for early modern scientific methodology seems to have been progressive Thomism, and early modern thinkers seem to have pitted themselves against it.

When considering the various historical doctrines relating science and mathematics, we should keep in mind three important facts. (1) Early modern science considered mathematics as the foundation of physics or natural philosophy – witness Galileo's famous assertion that "the great book of nature is written in the language of mathematics and its characters are triangles, circles, and other geometrical figures" (1960, p. 25). (2) It wasn't always that way. Aristotle in the *Physics* discussed how the mathematician differs from the physicist (1930, II, chap. 2). He asserted that physicists deal with physical bodies and their essential attributes; physicists treat of surfaces and volumes, lines and points, but as the limits of physical bodies. Mathematicians also treat of surfaces and volumes, points and lines, but not as physical, separating them from their essential attributes and from motion. Geometry investigates physical lines, but not qua physical; the more physical branches of mathematics such as optics, harmonics, and astronomy, investigate mathematical lines, qua physical, not qua mathematical. Instead of mathematics being the foundation of physics, Aristotle conceived of mathematics and physics as different sciences separated by their different objects. And (3) the medievals were not univocal in their support of the Aristotelian position. They interpreted Aristotle's remarks so variously that they can be considered as making up at least two distinct

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traditions, roughly that of Thomas Aquinas and that of Robert Grosseteste.

Thomists standardly held that physics, metaphysics, and mathematics are not part of one large science, but constitute three (or more) radically different sciences, differing in their subject and method: metaphysics considers being in common, physics considers natural being, and mathematics considers quantified being. Some such schema was adopted widely, with many variations. What all such schemas had in common was the rejection of a universal science (whether or not based on mathematics). Mathematics usually filled the lowest rank in these classifications (typically, the least perfect of the speculative sciences). Mathematical sciences, such as astronomy, astrology, and optics were called middle sciences because they were thought to occupy a middle position between mathematics and physics; they were thought to depend on mathematics, but also to consider the mathematical object as applied to a physical object. The typical doctrine was that the middle sciences were more mathematical than physical, since the mathematical object was more essential to them than their condition of application. Thus, the middle sciences would have been unfit to provide support for physics. Implicit in all this is the doctrine that a higher science cannot derive its principles from a lower science, so that physics cannot derive principles from mathematics or from any middle science.

The followers of Grosseteste, including Roger Bacon and scholars from fourteenth-century Oxford, held a doctrine that could easily have been derived from the writings of Aristotle, but that seems discontinuous with the Thomist line. While agreeing with the basic intuition that the higher sciences provide the reason for the lower sciences (the subalternated sciences), Grosseteste disagreed about the status of the important composite sciences. He argued that composite sciences have an additional nature about which the higher sciences say nothing; ultimately he asserted that only mathematics can provide the reason for a subalternated science and even for natural philosophy. Roger Bacon followed him in this. In the *Opus Majus* and *Opus Tertium*, Bacon detailed a view of human knowledge as a hierarchy of knowledge in which mathematics is antecedent to natural philosophy and to metaphysics: "without mathematics no science can be had" (1859, p. 35; also 1928, I, p. 109). Steven Livesey, in his paper, discusses this tradition in fourteenth-century Oxford.

All three above facts can be subsumed under the heading of scientific methodology and have relevance to the now-popular variation to Duhem's thesis of the continuity of physical theory, namely, the thesis of the continuity of scientific methodology. The questions I wish to pose are: (1) would Duhem have accepted such a thesis? and (2) to what extent is the Oxford tradition of classification/subalternation continuous with early modern science? The answer to the first question is relatively simple. Duhem would have been surprised by the claim that scientific methodology is continuous; he expected at best only a continuity of physical theories, which he was trying to isolate from the perpetual fluctuations of methods and metaphysics. Duhem addressed the issue of the classification or subalternation of sciences in medieval science, though in bits and pieces, here and there. What he said allows us to surmise his views. In the *Système du Monde*, Duhem spoke harshly about Roger Bacon's arguments against infinite divisibility, which use the certainty of geometry to oppose the existence of indivisibles. Duhem then praised John Buridan's view, in which "the proposition, continuous magnitude is not composed of indivisibles, is not viewed by Buridan as a corollary whose truth is assured by the necessity of not contradicting geometry"; Duhem said that Buridan "sees in it a principle whose truth the geometer is obliged to admit in order to construct his science . . . . Far from geometry's certainty guaranteeing the truth of the proposition, it is the truth of geometry that is subordinated to the correctness of the proposition; and the correctness of the proposition is not for geometry, but for physics or metaphysics to establish" (1985, pp. 19–20). Duhem detailed an interpretation of Buridan as keeping separate a geometry which considers lines and surfaces as nothing but constructions of the mind and a physical geometry, in conformity with reality, which only treats bodies. By reasoning about the former, we achieve results in conformity with measurements carried out on real bodies (1985, pp. 32–33). But Duhem recognized that Buridan's views were not accepted by his successors: "Doubtless Buridan's notion was too profound since it does not appear to have been adopted by even his most faithful disciples. Albert of Saxony and Marsilius of Inghen . . . did not hesitate to rely on geometry in order to refute the hypothesis [of infinite divisibility]" (1985, p. 20).

The answer to the second question is considerably more complex (and controversial). Setting aside the general question of the continuity of scientific methodology, I wish to ask specifically about the early modern scholastic doctrines concerning the relations between mathematics and physics.

Now, the broad outlines of seventeenth-century Scholasticism were Thomist. There was a renaissance in Thomistic philosophy during the second half of the sixteenth century. This renaissance was felt most strongly in Jesuit philosophy. Saint Ignacius of Loyola, founder of the Jesuits, advised the Jesuits to follow the doctrines of Saint Thomas in theology. Naturally, it would be difficult to follow Saint Thomas in theology without also accepting much of Aquinas's and Aristotle's philosophy. Loyola's advice was made formal in the Jesuits' *Ratio studiorum* of 1586: "In logic, natural philosophy, ethics, and metaphysics, Aristotle's doctrine is to be followed" (Rochemonteix 1889, vol. IV, p. 8n).

The flavor of the advice can be captured through a circular from the chief of the Order of Jesuits to the Superiors of the Order, written just after the end of the Council of Trent and imbued with the spirit of the Council and Loyola's advice. The circular announces specific doctrines "that must be held in theology and in philosophy", for example, "Let no one defend anything against the axioms received by the philosophers, such as: there are only four kinds of causes; there are only four elements; there are only three principles of natural things; fire is hot and dry; air is humid and hot" (Rochemonteix 1889, vol. IV, pp. 4n–6n). These 'axioms' are sufficient to banish Stoic, Epicurean, and Atomist philosophies; moreover, the circular also rejects doctrines that might have been accepted by non-Thomist scholastics – Ockhamists, for instance: "Let no one defend anything against the most common opinion of the philosophers and theologians, for example, that natural agents act at a distance without a medium." The circular continues with specific opinions that Jesuits must teach and hold as true – all in conformity with Thomist doctrines and against Averroist and Franciscan doctrines – but the crux of the matter seems to have been: "Let no one introduce any new opinion in philosophy or theology without consulting the Superior or Prefect." The circular ends with: "Let all professors conform to these prescriptions; let them say nothing against the propositions here announced, either in public or in private; under no pretext, not even that of piety or truth, should they teach anything other than that these texts are established and defined. This is not just an admonition, but a teaching that we impose."

Later circulars reaffirmed the same position. For example, the Jesuit Thomist stance is upheld even in a discussion of the thorny question of divergent authorities. The following can be read in a circular from another General of the Jesuits, to the Superiors, written in order to express clearly the basic tenets underlying the *Ratio studiorum* of 1586:

> No doubt we do not judge that, in the teaching of scholastic theology we must prohibit the opinion of other authors when they are more probable and more commonly received than those of Saint Thomas. Yet because his authority, his doctrine, is so sure and most generally approved, the recommendations of our Constitutions require us to follow him *ordinarily*. That is why all his opinions whatever they may be . . . , can be defended and should not be abandoned except after lengthy examination and for serious reasons. (Rochemonteix 1889, vol. IV, pp. 11n–12n)

This interpretation of Loyola's advice draws a fine line between following Thomas's opinions *ordinarily* and abandoning them for extraordinary reasons, after lengthy examination. But the circular continues: "One should have as the primary goal in teaching to firm up the faith and to develop piety. Therefore, no one shall teach anything not in conformity with the Church and received traditions, or that can diminish the vigor of the faith or the ardor of a solid piety." The intent of the circular is clear. The primary goal in teaching is the maintenance of the faith, and nothing should be allowed to interfere with it. And since the received traditions are known to conform to the faith, they should be taught and novelties are to be avoided. The circular continues:

> Let us try, even when there is nothing to fear for faith and piety, to avoid having anyone suspect us of wanting to create something new or teaching a new doctrine. Therefore no one shall defend any opinion that goes against the axioms received in philosophy or in theology, or against that which the majority of competent men would judge is the common sentiment of the theological schools. . . . Let no one adopt new opinions in the questions already treated by other authors; similarly, let no one introduce new questions in the matters related in some way to religion or having some importance, without first consulting the Prefect of studies or the Superior.

It is not surprising that the philosophy textbooks written by Jesuit authors – those of Portuguese Jesuits, the Coimbrans, and such Collegio Romano Jesuits as Franciscus Toletus – though not identical with one another, generally preserved basic Thomistic doctrines. The same can be said about the question of the classification of sciences as reflected in the *Ratio studiorum*, including the key questions about the utility of mathematics to natural philosophy and the status of such mathematical sciences as astronomy and optics.

The extreme Jesuit view about mathematics and natural philosophy can be represented by Ludovico Carbone (a non-Jesuit) (1599; cf. Wallace, 1984, especially pp. 126–48). Carbone details eleven doubts about the mathematical sciences. Some of these doubts concern the type of abstraction characteristic of mathematics: mathematicians consider bare quantity without any connection to substance; the intelligible matter they arrive at when they set aside sensible matter is merely fictive and cannot be defined in terms of true genus and difference; they abstract from being and the good; they abstract from motion and the natural forces that produce it; they abstract from all kinds of cause and so cannot use causal reasoning in any of their demonstrations. (1599, pp. 240–43). Though Carbone was not a Jesuit, he studied at the Collegio Germanico, annexed to the Jesuits' Collegio Romano. His works were influenced (perhaps overly so) by those of Collegio Romano professors. In any case, one can find similar views in the works of some Jesuits, Piccolomini and Pereira, for example (see Crombie 1977.) Carbone's views about mathematics and the mathematical (or middle) sciences fit very well with sixteenth-century scholastic doctrines, of Thomist descent, about the order and classification of the sciences.

It is against this background that Christopher Clavius proposed his reform of mathematics, arguing its importance to natural philosophy. In an essay for the *Ratio studiorum* on the teaching of mathematical disciplines he wrote:

> Physics cannot be understood correctly without [the mathematical disciplines], especially what pertains to that part concerning the number and motion of the celestial orbs, of the multitude of intelligences, of the effect of the stars, which depend on the various conjunctions, oppositions, and other distances between them, of the division of continuous quantities to infinity, of the tides, of the winds, of comets, the rainbow, halos, and other meteorological matters, of the proportion of motions, qualities, actions, passions, reactions, etc., concerning which the *calculatores* wrote much. (1901, p. 472)

In the same vein, Clavius disputed the common opinions that the mathematical sciences are too abstract and fictive:

> It will contribute much to this if the teachers of philosophy abstained from those questions which do not help in the understanding of natural things and very much detract from the authority of mathematical disciplines in the eyes of the students, such as those in which they teach that mathematical sciences are not sciences, do not have demonstrations, abstract from being and the good, etc. (1901, p. 471)

Obviously Clavius has in mind the kind of views represented by Carbone and others. This is significant, since Clavius was responsible for the training of Jesuit mathematics professors and the content of their teaching.

Clavius concentrated on showing that mathematics and mathematical sciences are useful and more certain than the other sciences. However, a science's degree of certainty is not proportional to its degree of perfection, so that, in spite of his pronouncement that physics cannot be understood correctly without the mathematical sciences, his view does not alter the basic Thomistic scheme. That scheme claims that the subjects of the sciences are different, and more or less perfect; it is consistent with it that a less perfect science, such as mathematics, might have results that are certain, with respect to a particular subject, such as abstract or quantified being. The difference between Clavius and Carbone is not really a difference of theory but a difference of emphasis within the same general theory. Clavius, the champion of mathematics in the Collegio Romano, does not seem to appeal to the Oxford doctrine of classification/subalternation in order to defend mathematics.

It would be pleasant to think that the early modern doctrines about the relations between mathematics and physics are continuous with the subalternation of sciences from Grosseteste, Bacon and the theologians of fourteenth-century Oxford. Unfortunately, thus far the evidence does not support such a conclusion. The official and dominant scholastic context for early modern doctrines seems to have been progressive Thomism, and early modern thinkers such as Descartes seem to have pitted themselves directly against it. From his earliest writings, the 'Private Thoughts', for instance, we have Descartes's dream of a chain of sciences that would be no more difficult to retain than a series of numbers (1974, p. 214), and from Rule I of the *Rules for the Direction of the Mind*, we have an explicit denial of the doctrine that the sciences should be distinguished by the diversity of their subjects, "all the sciences being in effect only human wisdom, which always remains one and identical to itself, however different are the objects to which it is applied" (1974, p. 360).

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