

# THE RELATIONSHIP OF MEDIEVAL NATURAL PHILOSOPHY TO MODERN SCIENCE: THE CONTRIBUTION OF THOMAS AQUINAS TO ITS UNDERSTANDING

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Up to about seventy-five years ago, scientists and would-be historians of science blandly assumed that all modern science began with Galileo and Descartes in the seventeenth century, and that before the seventeenth century, there was no science as we know it. That is to say, modern science, particularly physics, represented a complete break with earlier thought. When it was pointed out by historians of thought that some scientific notions existed in antiquity, particularly in biology and astronomy, this was shrugged off as of little importance compared to the science par excellence of physics. The view persisted that there was no continuity between ancient and modern science. Above all, there was nothing of interest in the "scientific night of the Middle Ages." This assumption of discontinuity prevailed especially among physicists, chemists, and astronomers, while biologists and allied scientists preferred to see some kind of continuity.

The pioneer work of Pierre Duhem (1861-1916) some seventy-five years ago opened the whole field of medieval science, and made research in the area of medieval science respectable. Recently Stanley L. Jaki appraised the work of Pierre Duhem as follows:

Singlehanded he destroyed the legend of the "scientific night of the Middle Ages." Before him, the phrase was a hallowed shibboleth of a self-styled Enlightenment. After him it has become the sign of an inexcusable ignorance which unfortunately lingers on.<sup>1</sup>

Duhem proposed the notion of continuity between medieval and modern, or classical physics. For him the discovery of impetus theory by the fourteenth century Parisians, Jean Buridan, Albert of Saxony and others, led to the principle of inertia introduced by Galileo and Descartes as "the first article of the creed of science," as Whitehead calls it.<sup>2</sup> Following Duhem, a whole generation of historians grew up defending the new view of continuity.

<sup>1</sup> Pierre Duhem, *To Save the Phenomena: An Essay on the Idea of Physical Theory from Plato to Galileo*, trans. E. Doland and C. Maschler with introd. by Stanley L. Jaki (Chicago, 1969), p. xvii.

<sup>2</sup> *Essays in Science and Philosophy* (London, 1948), p. 171.

On the popular stage of controversy the debate between the view of continuity and the view of discontinuity found its followers over the past twenty years, and there could be found as many defenders of the one as of the other.

In our own day, the late Anneliese Maier (1905-1971), by far the most illustrious historian of medieval science, not only reviewed the arguments of Duhem, but contributed a vast amount of new material to the field of medieval scholarship. But instead of defending the continuity thesis of Duhem, she proved to her own satisfaction that there was no continuity between the qualitative aspects of medieval science and the quantitative character of modern physics. In fact, she maintained that there were certain basic views inherent in medieval physics that made development of modern physics impossible. In her view, one basic flaw in medieval physics was the principal "Omne quod movetur, ab alio movetur." Until this fundamental principle was rejected in the seventeenth century, there could be no classical physics.<sup>3</sup> In other words, not only did Anneliese Maier reject Duhem's thesis concerning impetus and the principle of inertia, but she insisted that the medieval principle "Omne quod movetur, ab alio movetur" is repugnant to the principle of inertia. Once the medieval principle was rejected by Galileo and Descartes, classical physics could begin. In the generation now growing up, we can expect to find ardent defenders of Maier's view of the basic discontinuity and opposition between medieval and modern science, notably physics.

However, the debate over continuity and discontinuity cannot be resolved solely on historical grounds. What is needed is a philosophical analysis of the true character of Aristotelian physics and the true character of modern science. In fact, the problem facing us is confused and almost lost by historical considerations, because, as Yves Simon has noticed, "When the historic conflict between the Aristotelian physics and the new physics opened, both sides were equally convinced that this was a conflict between two philosophies of nature."<sup>4</sup> That is to say, proponents of the two views debated as though they were talking about the same thing, whereas in fact they were talking at cross purposes. An exclusively historical consideration would lead us to believe that Aristotelian natural philosophy was completely disproved by the new physics. The physico-mathematical science founded by Galileo and Descartes was taken

<sup>3</sup> Anneliese Maier, "Ergebnisse der Spätscholastischen Naturphilosophie," *Scholastik*, 35(1960), 161-187, especially 170.

<sup>4</sup> Yves Simon, *The Great Dialogue of Nature and Space* (Albany, 1970), pp. 11.

by its proponents as a philosophy of nature and indeed as the only authentic one. The truth of the matter is that both were right and both were wrong. They were both right in seeing the novelty of the new physics. They were both wrong in seeing it as in opposition to Aristotle's natural philosophy.

Of course, there were whole areas where Aristotle had to be corrected by new evidence, but this process of correcting Aristotle had been taking place since the fifth century, and was nothing new to the seventeenth. St. Thomas Aquinas himself corrected and re-shaped much that was in Aristotle's natural philosophy. What I am proposing is the objective validity of both Aristotle's natural philosophy in its main structure and the new mathematical-physical consideration of nature that, for all practical purposes, prevailed in the seventeenth century.

To establish this view there are a certain number of preliminary points to be noted. First of all, the expression "modern science" is an equivocal term designating a vast assortment of fundamentally different types of knowledge cultivated today. There is nothing intrinsic in being modern. Everything we accept today can be called modern, even though we have known it from antiquity. The problem is with the word "science." In all modern languages the term for "science" is equivocal; it stands for an amorphous type of knowledge that purports to be "scientific" or technical. The Greeks had no problem; when they used the word *episteme*, they meant knowledge of a thing or an event through its causes. It was clearly distinct from *techné*, *nous*, *sophia* or the like. When Aristotle called natural philosophy *episteme*, they all knew he meant a rational type of knowledge of nature through its sensible causes. The Latins, however, didn't fare so well. When St. Thomas called *Sacra Doctrina* a *scientia*, the commentators thought he meant scholastic theology, whereas he plainly meant *sacra doctrina*.<sup>1</sup> Nevertheless the Latin scholastics generally reserved the word "science" for knowledge through one or more causes of a thing or event. More than that, they distinguished *scientia* from art, prudence, technology, and intuition. Today too much is included in the word "science." Ideally, modern sciences are predominantly mathematical in character and experimental in practice. But it must be admitted that there are many modern sciences which are neither mathematical nor experimental. Anthropology, paleontology, botany, much of psychology, and the various life sciences continuously fail to be con-

<sup>1</sup>See James A. Weisberg, "The Meaning of *Sacra Doctrina* in *Summa Theologiae* I, q. 1," *The Thomist* 38 (1974), 49-80.

pletely mathematicized. That is to say, modern physics is a radically different kind of science from, let us say, modern biology or anthropology. This radical difference lies in the fact that modern physics, like modern astronomy, is formally mathematical in structure and method, whereas modern biology is formally sensible (*sensibilis*, or *naturalis*) in structure and method. Jacques Maritain was one of the first modern Thomists to insist on this difference between physics, which is mathematical and empiriometric in structure, and biology, which is natural and empirio-schematic in character. Unless some such distinction is made between the two ends of the modern spectrum of science, there will be endless confusion. For purposes of this paper, the expression "modern science" will be taken to mean knowledge of the physico-mathematical type exemplified by physics in all its branches and astronomy. We are not including the life sciences or the social sciences.

The second point to be noted is that knowledge of the physico-mathematical type was not unknown to the ancients. The most highly cultivated science of this type was astronomy, especially in the hands of Ptolemy. But long before Ptolemy, Plato had posed the problem to Eudoxus of discovering the mathematics of the universe. In Simplicius's Commentary on *De caelo* we find the Platonic tradition formulated in the following way:

Eudoxus of Cnidos was the first Greek to concern himself with hypotheses of this sort, Plato having as Sosigenes says, set it as a problem to all earnest students of this subject to find what are the uniform and ordered movements by the assumption of which the phenomena in relation to the movements of the planets can be saved (*sozein ta phainomena*).<sup>6</sup>

That is to say, the astronomer's problem is to discover all the hypotheses necessary to save the phenomena of planetary motion. Even the unsophisticated astronomy of Eudoxus and Callippus was considered distinct from natural philosophy by Aristotle. What would he have said about the epicycles and eccentrics of Ptolemy? Among the "more physical of the branches of mathematics," Aristotle lists not only astronomy, but also optics and harmonics.<sup>7</sup> The scholastics recognized not only the astronomy of Ptolemy and the optics of Euclid, Alhazen, Pecham and others as belonging to this category of the "more physical of the branches of mathematics," but also statics (*scientia de ponderibus*) and mechanics, the latter largely due to the mathematician Archimedes.

<sup>6</sup> Simplicius, *In II De caelo*, XII, comm.43 (Venice, 1548, fol. 74 r-v).

<sup>7</sup> Aristotle, *Physics* II.2.194a8.

St. Thomas calls this type of intermediate knowledge *scientia media*, i.e., a type of knowledge that is intermediate between pure mathematics and straight natural philosophy.<sup>8</sup> In more specific terms, *scientia media* is a knowledge of nature based on mathematical principles. The clearest example of this kind of knowledge is, of course, Newton's *Principia mathematica philosophiae naturalis*, where the very title reveals the precise nature of the work. But for Thomas the clearest example was the *Almagest* (the *Mathematical Syntax*) of Ptolemy. For Thomas it is clear that astronomy is a part of mathematics, "pars mathematicae"; the problem is how Aristotle can then go on to say that it is *magis naturalis quam mathematica*.<sup>9</sup> This is exactly what Moerbeke's translation says, and which is a legitimate translation of the Greek: *ta physikotera ton mathematon*.<sup>10</sup> Aristotle had just finished talking about how such sciences abstract from motion, and consequently from sensible and natural matter: "abstrahit a materia sensibili et naturali."<sup>11</sup> To answer the apparent problem, Thomas says:

Although sciences of this type are intermediate between natural science and mathematics, they are nevertheless said by the Philosopher to be more natural than mathematical, because everything is denominated and specified by the term (*a termino*). Hence, since the considerations of these sciences terminate in natural matter (*in materia naturali*), even though they proceed through mathematical principles, they are more natural than mathematical.<sup>12</sup>

The only way Thomas can resolve the problem is by saying that the subject matter is ultimately the same, i.e., both sciences ultimately study the same material universe. Thomas does not here say that the ultimate goal of astronomy and the other intermediate sciences is to know the ultimate natures of things. That is a different matter altogether. Rather, astronomy and natural philosophy can be said to study the same material object, although the *ratio formalis objecti* through which the conclusion is known is specifically distinct, as Thomas says in *Summa theologiae*, II-II, q. 1, a. 1.

Modern translations of the *Physics*, such as the one by Hardie and Gaye, avoid the problem by rendering Aristotle's phrase as "the more physical of the branches of mathematics."<sup>13</sup> However, the

<sup>8</sup> Thomas Aquinas, *In Boethium De trinitate*, q.5, a.3 ad 5 and ad 6; see also *In II Phys.*, lect. 3, n.8; *Summa theologiae*, II-II, q.9, a.2 ad 3.

<sup>9</sup> Thomas, *In II Phys.*, lect. 3, nn.8-9.

<sup>10</sup> Aristotle, *Phys.* II.2.194a7-8.

<sup>11</sup> Thomas, *In II Phys.*, lect. 3, nn.5-7.

<sup>12</sup> *Ibid.*, lect. 3, n. 8.

<sup>13</sup> Oxford Aristotle in *The Basic Works of Aristotle*, ed. Richard McKeon (New York, 1941), p. 239.

Loeb translation of Wicksteed and Cornford interpret the phrase as Moerbeke did, namely, "Those sciences which are rather physical than mathematical, though combining both disciplines."<sup>14</sup> Charlton's translation seems to be quite satisfactory. He translates it as "those branches of mathematics which come nearest to the study of nature, like optics, harmonics, and astronomy."<sup>15</sup>

The point I am trying to make is that Thomas was perfectly aware of that peculiar type of knowledge intermediate between mathematics and natural philosophy. He called this type *scientia media*. As far as I have been able to determine, no other writer in the Middle Ages used the expression *scientia media* in that sense. It seems to be unique to Thomas.

The next point is that while knowledge of the *scientia media* type was not new, the application of mathematical principles to the entire range of nature was indeed new to the seventeenth century. The great originality of the seventeenth century, as I see it, was the unification of celestial and terrestrial mechanics through mathematics. Perhaps the idea was not new, but the fact was new. Much has been said about the dreams of Robert Grosseteste and Roger Bacon in the thirteenth century. We are all aware of the strong language used by Roger Bacon against the neglect of mathematics. He says, for example:

The neglect [of mathematics] for the past thirty or forty years has nearly destroyed the entire learning of Latin Christendom. For he who does not know mathematics cannot know any of the other sciences.<sup>16</sup>

But Bradwardine in the fourteenth century was even more disconcerting:

It is [mathematics] which reveals every genuine truth, for it knows every hidden secret, and bears the key to every subtlety of letters; whoever, then, has the effrontery to study physics while neglecting mathematics, should know from the start that he will never make his entry through the portals of wisdom.<sup>17</sup>

I think Thomas Bradwardine, more than anyone else in the Middle Ages, saw the possibility of a unified dynamics for celestial and terrestrial motions. In the fourth and last chapter of his *De proportionibus velocitatum in motibus* of 1328, he actually sought some foundation for comparing terrestrial and celestial velocities. For Aristotle, these diverse motions are incomparable, for there is noth-

<sup>14</sup> Aristotle, *Physics* II.2 (London, 1963, p. 121).

<sup>15</sup> Aristotle's *Physics* I-II, trans. W. Charlton (Oxford, 1970), p. 26.

<sup>16</sup> Roger Bacon, *Opus maius* IV.1.1.(ed. J.H. Bridges [Oxford 1897], I, 97-98).

<sup>17</sup> Thomas Bradwardine, *Tractatus de continuo*, MS Erfurt Amplon Q.385, fol. 31v.

ing in common between rectilinear motion of a body and the circular motion of a sphere. Bradwardine, however, found it in the fastest moving point of the sphere considered or imagined as a straight line. As Anneliese Maier expressed it, Bradwardine "would have wanted to write the *Principia mathematica philosophiae naturalis* of his century."<sup>18</sup>

But these were only dreams. It was not until the seventeenth century that the principle of inertia acquired the force of "the first law of nature." Giovanni Benedetti (1530-90) in the sixteenth century had already insisted that every body, naturally falling or projected, tends to move in a straight line. But it was Galileo (1564-1642) who first formulated the principle of inertia. In his *Discourses on the Two New Sciences*, the third day, he assumes that the momentum of a given body falling down an inclined plane is proportional only to the vertical distance and independent of the inclination; from this he concludes that a body falling down one plane would acquire momentum which would carry it up another to the same height. Thus Galileo says, "Any velocity once received by a body is perpetually maintained as long as the external causes of acceleration or retardation are removed, a condition which is found only on horizontal planes."<sup>19</sup> Although Christian Huygens (1629-1695) had a clearer idea of the principle and formulated it as an "hypothesis" for his work on the pendulum, it was Descartes (1596-1650) who extended the principle to cover the whole of natural philosophy by making it "the first law of nature."<sup>20</sup> The principle of inertia reached its classical formulation in Isaac Newton's *Principia*: "Every body continues in its state of rest or uniform motion in a straight line, unless it is compelled to change that state by forces impressed upon it" (Law 1). In the seventeenth century the principle of inertia served wonderfully as a working hypothesis to "save the phenomena." On such an hypothesis the mathematics of the universe could be calculated.

To put the matter in another way, the narrow limits of *scientia media* in the Middle Ages as applied to astronomy were expanded to include the whole realm of nature, now known mathematically.

<sup>18</sup> Anneliese Maier, *Studien zur Naturphilosophie der Spätscholastik*, I (Rome, 1919), 86, note 10.

<sup>19</sup> Galileo, *Discorsi . . . intorno a due nuove scienze*, giornata terza, prob. 23, scholium (Opera [Padua, 1744], III, 123).

<sup>20</sup> René Descartes, *Principia philosophiae* II.37 (*Oeuvres*, ed. Charles Adam and Paul Tannery, VIII [Paris, 1905], 62).

We have come to call this extended knowledge of nature through mathematics "modern physics," the structure and method of which is physico-mathematical, i.e., it is a *scientia media* in Thomas's sense of the phrase. Just as the epicycles and eccentrics of Ptolemy were convenient hypotheses for "saving the appearances" of celestial motions, so the principle of inertia was a convenient and fruitful hypothesis for saving the unity of locomotion in the heavens and on the earth.

Speaking in the context of Ptolemaic astronomy, St. Thomas says:

It is not necessary that the various hypotheses which [the astronomers] hit upon be true. For although these suppositions save the appearance, we are nevertheless not forced to say that these suppositions are true, because perhaps there is some other way men have not yet discovered by which the appearances of things may be saved concerning the stars.<sup>21</sup>

The same view was expressed by Thomas some six years earlier in his *Summa theologiae* when he says:

There are two kinds of argument put forward to prove something. The first goes to the root of the matter and fully demonstrates some point; for instance, in natural philosophy there is a conclusive argument to prove that celestial movements are of constant speed. The other kind does not prove a point conclusively but shows that its acceptance fits in with the observed effects: for instance, an astronomical argument about eccentric and epicyclic motions is put forward on the ground that by this hypothesis one can show how celestial motions appear as they do to observation. Such an argument is not fully conclusive, since an explanation might be possible even on another hypothesis.<sup>22</sup>

The point is that the hypotheses of astronomy, in this case Ptolemaic astronomy, are significant in that they may account for all the phenomena without forcing the mind to acknowledge their physical certainty. Speaking specifically about the movement of the earth, Thomas says that the appearances could be saved either by holding that the earth is stationary and the heavens are moving about it, or that the heavens are stationary and the earth is moving within, or that both the earth and the heavens are moving. These are different hypotheses—in the classical sense of the term—that can all "save the appearances," *sozein ta phainomena*, i.e., render systematic intelligibility to all the known facts.

One of the most fruitful hypotheses devised in the seventeenth century was the principle of inertia. We have already noted that the late Anneliese Maier insisted on seeing a radical opposition between the medieval principle of "Omne quod movetur, ab alio movetur" and the seventeenth-century principle of inertia. The radi-

<sup>21</sup> Thomas, *In I De caelo*, lect. 3, n. 7.

<sup>22</sup> Thomas, *ST*, I, q.32, a. 1 ad 2.



cal incompatibility of these two "principles" for Maier leads, of course, to the inevitable view of discontinuity between medieval and modern classical physics.

In two studies previously published,<sup>23</sup> I have tried to show that Maier completely misunderstands the medieval principle "*Omne quod movetur, ab alio movetur*." Or more precisely, she understands the medieval principle solely through the eyes of Averroes, whose interpretation was explicitly rejected by Thomas Aquinas, Albert the Great, and many others in the thirteenth century. For St. Thomas the principle—which for him was demonstrated by Aristotle with *propter quid* certainty in Book VII of the *Physics* and proved inductively in Book VIII—does not mean that every motion here and now requires a mover, a *motor coniunctus*, to explain its continuation here and now in time. That is to say, the principle does not mean that everything here and now moving is moved here and now by something else. For Thomas, once a heavy body is generated, i.e., brought into existence, it spontaneously falls to the ground, if there is no obstacle, without any other cause moving it.<sup>24</sup> The efficient cause of this free fall of heavy bodies is none other than the agent which generated the body in the first place. From one point of view, the position of Aristotle is much more sophisticated than Averroes and Anneliese Maier give him credit for. On the other hand, Anneliese Maier and the seventeenth-century philosophers like Galileo, Descartes, Beeckman and others, were too hasty in accepting as "the first law of nature" a principle that can be nothing more than an hypothesis in the classical sense of the term.

I say that the principle of inertia is no more than a hypothesis because it is neither self-evident nor demonstrable. It is a likely extrapolation, which is not a proof. Terrestrial motions known in human experience all come to an end; they do not move in a straight line; and they are not uniform—they are rather accelerated or decelerated. Furthermore, celestial motions are neither straight nor are they uniform, but they are perpetual. If celestial motions ever came to an end, it would be disastrous for the universe. But all this proves is that celestial motions, unlike terrestrial motions, are

<sup>23</sup> James A. Weisheipl, "The Principle *Omne quod movetur ab alio movetur* in Medieval Physics," *Isis*, 56 (1965), 26-45; "Motion in a Void: Aquinas and Averroes," *St. Thomas Aquinas 1274-1974: Commemorative Essays* (Toronto, 1974), pp. 467-488.

<sup>24</sup> See Thomas, especially *In III De caelo*, lect. 8, n. 9; J.A. Weisheipl, *Nature and Gravitation* (River Forest, Ill., 1955).

not designed to come to an end as to a final cause. That is to say, the causalities involved in terrestrial and celestial motions are somehow different.

It is commonly claimed that the greatest triumph of the seventeenth century was to rid the celestial spheres of spiritual movers and to effect a unification of celestial and terrestrial mechanics. As Herbert Butterfield puts it, "The modern law of inertia, the modern theory of motion, is the great factor which in the seventeenth century helped to drive the spirits out of the world and opened the way to a universe that ran like a piece of clockwork."<sup>25</sup> This is quite true. But it must be noted that the crux of the solution rests on the principle of inertia.

For Descartes, who first suggested the universality of the principle, the principle of inertia is founded on the conservation of momentum, measured by mass times velocity. Descartes contended that in the beginning God created not only matter, but also a determined *quantitas motus*, which could neither be increased nor decreased, for otherwise God would have to continue creating motion, which would be contrary to his immutability!<sup>26</sup> Throughout the entire universe the "quantity of motion" remains constant so that when one body is at rest, another is in motion; when one moves twice as fast, another moves half as fast as previously, and so on. Change then was to be explained as the transference of momentum from one body to another through impact. Thus for Descartes, as for Spinoza after him, the principle of inertia was based on the conservation of momentum ( $mv$ ), and conservation was thought necessary because of the immutability of God.<sup>27</sup>

Leibniz, however, pointed out that momentum is not constant in the universe, for it cannot be shown that every body imparts the same quantity of motion to some other body.<sup>28</sup> Furthermore, Leibniz maintained that it is not momentum which accounts for movement, but a certain *vis viva*, *lebendige Kraft*, which is measured

<sup>25</sup> Herbert Butterfield, *Origins of Modern Science* (London, 1951), p.7; see also Charles Singer, *A Short History of Science* (Oxford, 1943), pp. 212-217.

<sup>26</sup> Descartes, *Principia philosophiae* II.36. (ed.cit., VIII,61).

<sup>27</sup> Ibid. II.37 (ed. cit.); see Spinoza, *Renati Des Cartes Principiorum philosophiae pars I et II more geometrico demonstratae* (*Opera*, ed. J. Van Vloten and J.P.N. Land, 3rd edition [The Hague, 1914], IV, 159).

<sup>28</sup> Principally in his *Système nouveau de la nature*, ed. C.J. Gerhardt, *Die philosophischen Schriften von G.W. Leibnitz* (Berlin, 1890), IV. For the controversy between the followers of Descartes and Leibniz on this point, see W.H.B. Joseph, *Lectures on the Philosophy of Leibniz* (Oxford, 1949), pp. 27-54.

not by  $mv$ , but by mass times velocity squared ( $mv^2$ ).<sup>29</sup> Thus for Leibniz the principle of inertia is based on the conservation of energy ( $mv^2$ ), instead of on Descartes' momentum. However, as Leibniz denies any real interaction between the unextended monads which make up the real world, the conservation of energy is a *phenomenological principle* which depends upon "pre-established harmony" in which God alone is the true cause. For Leibniz the phenomenological world may be described through mathematical and mechanical laws, but the real world and even the foundation of mechanical laws are to be found in realms beyond mechanics.<sup>30</sup> Thus the conservation of *vis viva* in the world depends upon the will of God.

Although a much more satisfactory presentation of the principle of inertia is to be found in Sir Isaac Newton's *Principia*, it must be noted that Newton does not attempt to demonstrate it, but assumes it without offering any philosophical or theological foundation. It is in this latter context that Newton says, "Hypotheses non fingo," that is to say, Newton was unwilling to offer metaphysical causes for the principle, but insisted that such principles of nature must be true. In other words, the whole structure of the universe for Newton presupposes the validity of the principle of inertia.<sup>31</sup> Newton, furthermore, discovered or devised an hypothesis which had far greater power than the basic law of motion, namely the hypothesis of universal gravitation, or attraction. With these two fruitful hypotheses Newton could present the system of the world.

Pierre Duhem was so struck by this hypothetical feature of ancient astronomy and of modern physics that he developed his own philosophy of science, which refused to project mathematical hypotheses and mathematical entities into physical reality. For Duhem, scientific laws are not extra-mental laws in nature, but mere conventionalism (*commodisme*), mental constructs temporarily accepted by scientists as useful expressions of reality, much like the conventional use of grammar among peoples of a particular group. The purpose of "physical theory," Duhem insisted, is to save the appearances, *sozein ta phainomena*. Perhaps Duhem went too far in thinking that all physical laws are hypotheses, but he was not wrong in his appreciation of what an hypothesis really is. It would

<sup>29</sup> On the importance of the squared velocity in Leibniz, see Joseph, *Lectures*, pp. 41-61.

<sup>30</sup> Leibniz, *Système nouveau* (*Philosophische Schriften*, ed. Gerhardt, IV, 444).

<sup>31</sup> For a clarification of the true foundation of the principles of inertia, see Weisheipl, *Nature and Gravitation*, pp. 48-64.

seem, however, that modern physics as well as ancient astronomy has the right to concoct as many hypotheses as may be necessary to "save the appearances," to make sense out of the known facts.

With this in mind, I would like to make my next point. Just as the structure of Ptolemaic astronomy as a *scientia media* could co-exist in medieval education and thought with Aristotle's natural philosophy, so too can modern physics, which in my view is a *scientia media*, co-exist with a structured natural philosophy which is not a *scientia media*. I am not talking about details, but about basic structure, method, and principles.

One of the characteristics of modern science is sometimes thought to be experimentation and prediction, verifying the theory or hypothesis. But experimentation as such does not distinguish the sciences, not even controlled experimentation and prediction. What distinguishes the sciences is the content, or modality of the concepts, definitions, and the middle term of the proof. By modality I mean type of materiality and immateriality involved in the concepts, definitions, and proofs. Experimentation or the "tempting" of nature is common to all natural sciences in varying degrees. One might even go so far as to say that some kind of experimentation is involved in every human knowledge, even in politics and economics. There is, of course, a radical difference between experimentation in modern physics and experimentation in Aristotle's physics. In modern physics the intrinsic value of experimentation is taken as its ability to yield a numerical content of knowledge, i.e., a mathematical number, ratio, or symbol, which makes up the equation. Experimentation for Aristotle is revelatory of the physical structure or its physical causes. This is not to say that these two types of experimentation are contradictory, but only that they are radically different in content and goal. The modern physicist and the Aristotelian could be interested in the same experiment, but they would each get something different out of it.

The philosophy usually considered to be congenial to the new physics is "mechanical" or "corpuscular" philosophy, such as developed in the seventeenth century. But, it could be argued, this is only a first impression. Nature is not mechanical. Therefore it cannot be justified in a mechanistic philosophy. The dynamic character of *phusis*, or *natura* requires its justification in a philosophy that recognizes natural principles, causes, and elements. Such a philosophy would not be based on mathematical principles, legitimate as they are, but on principles that are truly "natural," i.e., active and passive principles of movement and rest in those things

to which they belong *per se* and not *per accidens*.

Once the basic structure of the physico-mathematical sciences is understood, it becomes clear that there is no radical opposition between modern science and a philosophy of nature such as devised by Aristotle and St. Thomas. Such a natural philosophy is not only valid, but even necessary for the philosophical understanding of nature itself. That is to say, there are realities in nature that are not accounted for by physico-mathematical abstraction, realities such as motion, time, causality, chance, substance, and change itself. The definition of motion, for example, given by Aristotle<sup>32</sup> may be of no use to the modern physicist, but it is the only definition that can be given without including the thing to be defined in the definition. To define motion as "the change of a body from one position to another" is not to define it at all. The measurement of time is well known to the physicist, but as Bergson pointed out a long time ago, the reality that is time itself escapes completely.<sup>33</sup> The physicist is concerned with the length of time, not with the time that is always passing away. The physicist needs mechanical causes, such as matter and force, but the nature of causality as such is beyond mathematics, where even final causality is out of place. Concepts such as potency and act, matter and form, substance and accident, quite useless to the modern physicist, are established in a realistic natural philosophy.

The aforementioned concepts are not established in metaphysics, and in this connection it is important to stress the differences between metaphysics and natural philosophy and to indicate the nature and relationship of each. Whereas modern physicists tend to reject natural philosophy as an unwelcome part of metaphysics, it is interesting that many modern Thomists tend to reject outright the validity of natural philosophy and to put in its place modern physics. The former confuse natural philosophy with metaphysics as the latter confuse it with modern physics. The result has been to overload metaphysics with innumerable problems and areas of concern that rightly belong to the natural philosopher. This is a perversion of metaphysics as understood by St. Thomas. We do not wish here to justify natural philosophy against the claims of the modern Thomistic metaphysician, but rather to point out the relation between modern science and a realistic natural philosophy

<sup>32</sup> Aristotle, *Phys.* III.1.201a10-11.

<sup>33</sup> Henri Bergson, *Essai sur les données immédiates de la conscience* (Paris, 1911, his doctoral dissertation presented in 1898).

which is quite distinct from any metaphysics, even from Thomistic metaphysics. To amalgamate natural philosophy and metaphysics is to exaggerate the one and disparage the other. The whole structure of human knowledge is thus perverted and nothing is rightly understood.

This point can be put in another way. For Thomas Aquinas metaphysics presupposes natural philosophy for at least two reasons. First, it is natural philosophy that discovers the existence of separated substances, i.e., some non-material being, and thus establishes the subject matter of a new science, namely the science of being as such. In Book VI of the *Metaphysics* Aristotle says: "If there were no substance other than those which are formed by nature, natural science would be the first science; but if there is an immovable substance, the science of this must be prior and must be first philosophy."<sup>34</sup> Thomas not only comments on this clear statement, but he repeats it twice more in his commentary.<sup>35</sup> Thomas puts it this way:

If natural substances, which are sensible and mobile substances, are first among all being, then natural science would be the first among all the sciences. . . . But if there is another nature and substance besides natural substances, which is separable and immobile, it is necessary that there be another science about the very *esse* of that thing, which would be prior to the natural.<sup>36</sup>

But for St. Thomas there are two ways to establish the existence of such a substance separate from matter and motion. The first is through a consideration of physical motion, such as Aristotle undertakes in Books VII and VIII of the *Physics*, where he demonstrates that the cause of all physical motions in the world must itself be immaterial and immovable. The second is through a consideration of human intellection and volition, such as Aristotle gives in Book III of *De anima*, where he demonstrates that the human intellectual soul must be immaterial and immortal. Even if the existence of only one such separated substance is proved, there is the foundation of a new science. Actually Aristotle thought that there were a great number (if not an infinite number) of separated substances. But only one is sufficient to constitute a new first philosophy in which not only this one separate substance is studied, but also all those terms which are analogically applicable to both material and immaterial being.

<sup>34</sup> Aristotle, *Metaphysics* VI.1.1026a27-31.

<sup>35</sup> Thomas, *In VI Metaph.* lect. 1, n. 1170; see also *In III Metaph.* lect. 4, n. 398; *In XI Metaph.* lect. 7, n. 2267. Cf. *In IV Phys.* lect. 1, n. 1.

<sup>36</sup> Thomas, *In XI Metaph.* lect. 7, n. 2267.

This brings us to the second reason why natural philosophy must precede metaphysics. This is demanded by the nature of analogous concepts. Analogous concepts are not abstracted, but are constructed by the human mind. The prime analogue of our concept of "being," or "thing" is the sensible, material, concrete reality of things around us. The moment we realize that there is at least one thing that is not sensible, material, and movable, we break into the realm of analogy. From that moment on, terms such as "thing," "being," "substance," "cause" and the like are no longer restricted to the material and sensible world. We thereby stretch and enlarge our earlier conceptions to make them include immaterial reality. Such are our analogous concepts of being, substance, potency, act, cause, and the like. Such terms are seen in metaphysics to be applicable beyond the realm of material and sensible realities. The prime analogue *quoad nos* of all these concepts is material, sensible, movable being, which is the realm of the natural philosopher.

Thus, for St. Thomas, natural philosophy is prior *quoad nos* to metaphysics. Natural philosophy establishes by demonstration that there is some being which is not material. This negative judgement, or more properly, this judgement of separation is the point of departure for a higher study, which can be called "First Philosophy" or metaphysics. Consequently this new study is "prior" and "first" in itself, i.e., according to nature, but it is not first *quoad nos*.

Whenever Thomas presents the proper order of learning for philosophers or even for the learned man, he always lists natural philosophy before ethics and metaphysics. Thus Thomas says in his commentary on the *Ethics*:

The fitting order of learning, therefore, will be that boys are first instructed in logic, because logic teaches the method for all philosophy. Second, that they be instructed in mathematics, which neither requires experience nor transcends the imagination. Third, [instruction] in natural science, which even though it does not transcend sense and imagination, requires a great deal of experience. Fourth, in morals, which require experience and a soul free from passions, as was pointed out in the first book. Fifth, however, [instruction] in wise and divine things, which transcend imagination and require a strong intellect.<sup>27</sup>

That is to say, natural philosophy is indispensable to ethics and metaphysics. That ethics presupposes psychology is easier to see than the equal truth that metaphysics presupposes natural philosophy. A Thomist who rejects the valid and legitimate area of natural

<sup>27</sup> Thomas, *In VI Ethic.*, lect. 7, n. 1211; see also *In lib. De causis, Proem.* ed. H.D. Saffrey (Fribourg, 1954), p. 2.

philosophy distinct from modern science and from metaphysics, does so at great peril. He not only loses the right to speak in the name of Thomas, but more important, he loses the foundation for every valid metaphysics.

If a realist natural philosophy is valid as a study becoming to man, then surely its value lies in the unique kind of knowledge provided, a knowledge distinct from the physico-mathematical knowledge supplied by modern physics and astronomy. The value of natural philosophy does not lie in pointing the way to new scientific discoveries, but rather in supplementing one's basic knowledge of reality. Nature cannot be exhausted by any one type of knowledge. The totality of nature cannot be boxed in an equation. Natural philosophy, therefore, is not only valid, but also valuable in giving us another avenue to understand the physical world.

The natural philosophy of which I speak includes not only the entire area of what Aristotle called the *libri naturales*, extending from a general analysis of motion and its causes in the *Physics* to detailed information about the structure, generation, and classification of plants, animals, and minerals, but would also include what today has come to be known as the history and philosophy of science. The critiques scientists themselves give of their work, principles, assumptions and hypotheses, properly belong to the realm of philosophy, specifically to the realm of natural philosophy. The critiques of such men of science as Duhem, Eddington, Jeans, Plank, Poincaré, and Whitehead are works of philosophy and pertain not to metaphysics, but to natural philosophy in its properly critical role. The history of science, too, belongs to natural philosophy in this same role. Thus the extent of natural philosophy, as I see it, is truly vast. No one man can possibly know it all. But even some acquaintance with it is better than nothing at all. The point I have been trying to make is that natural philosophy is a valid study of the sensible world, one to which St. Thomas Aquinas contributed heavily. Such a philosophy is not only valid, but also valuable; and its value lies in the kind of knowledge natural philosophy (side by side with modern physical science and metaphysics) can provide for modern man.