The Review of Metaphysics Volume 27 Issue 3 / March1974

William A. Wallace

Aquinas on the Temporal Relation Between Cause and Effect

IT WOULD BE DIFFICULT TO FIND VIEWS more markedly opposed regarding the temporal relation between cause and effect than those propounded respectively by Hume and Aristotle. For Hume, cause and effect must be temporally distinct; in fact, almost by definition the cause is an event anterior in time to the effect, another event. The key problem of causation in Hume's formulation is thus one of making precise the way in which these two temporally distinct events are connected, and he decides this by opting for psychological projections into reality rather than conceding the existence of necessary connections in nature. Aristotle, on the other hand, accepts the fact of productivity or causal efficacy in nature, and so defines cause as to have it actually causing only when it is producing an effect, and thus at best instantiated when cause and effect are simultaneous. While not rejecting the possibility of antecedent causation, in the sense of denying outright that the cause might somehow temporally precede the effect, Aristotle treats this possibility as troublesome and as contributing little or nothing toward the understanding of basic causal processes.[1]

Contemporary thinkers who address the problem of causal relations generally favor Hume's analysis, although some periodically manifest interest in Aristotle's exposition as an important and viable alternative. Few, however, find among the many philosophers who came between Aristotle and Hume any worthwhile contributor to the development of this problematic. Some might note, for example, Nicholas of Autrecourt as a medieval precursor of Hume, but this merely keeps the discussion fluctuating between the same two poles. This essay aims to call attention to a

different and intermediate view, not hitherto noted, that was proposed in the High Middle Ages by Thomas Aquinas. It argues that Aquinas made a significant advance beyond Aristotle in his analysis of antecedent causation, and thereby made possible the certification of some elements in Hume's analysis, without subscribing to its more extreme results. In so doing, moreover, Aquinas adumbrated some problems in contemporary analytic discussions of the causal relationships between events, and consequently may shed light on their solution.

I

Aquinas' contributions to natural philosophy and to the methodology of science are not so well known as is his work in metaphysics, but they proved considerable nonetheless. A number of his distinctive teachings in these fields, in fact, had important consequences for the origin of modern science.[2] For purposes of subsequent exposition, we shall here restrict ourselves to one such teaching that runs through his physical writings and that

gives rise to a peculiar methodological problem. This is the theme that the *scientiae naturales* are concerned uniquely with changeable being, or with being in process, which process pertains to the sensible or phenomenal order, and on this account is readily available for empirical observation and analysis. The processes that are thus studied by the natural philosopher, however, unfortunately have a contingent aspect to them, in the sense that they are not absolutely necessitated but could be otherwise than they are. If this is the case, then the possibility of attaining true demonstrative knowledge of natural processes would seem to be compromised, and the *scientiae naturales* might have to forfeit their claim to being sciences *simpliciter* in the sense of the *Posterior Analytics*. Aquinas was quite aware of this seeming incompatibility of contingent process and necessary demonstration, and nonetheless maintained that both features serve to characterize the *scientiae naturales*. In maintaining this, moreover, he was led to develop

— 571 —

a distinctive theory of proof for the natural sciences, which may be his greatest single innovation as a scientific methodologist.[3]

As regards the scientist's primary concern with the analysis of process, perhaps the following brief indications may serve to establish this general Thomistic thesis, itself quite Aristotelian in character. The first two books of the *Physics*, in Aquinas' view, are seminal for all of natural philosophy, for they serve to delineate respectively the principles of changeable being and the principles of natural science.[4] Consequent on the determination of these principles, the remaining six books of the *Physics* are devoted to a study of the general properties of process or change.[5] And the subsequent books in the Aristotelian corpus, *De caelo, De generatione et corruptione, Meteorologica*, etc., investigate in detail the various types of process found in the physical universe, viz., local motion, alteration, and growth. From these latter treatises, as is well known, were developed the modern sciences of physics, chemistry, biology, etc., which first separated themselves from the main body of philosophy and then underwent independent development. But even the last six books of the *Physics*, still generally regarded as philosophical in character, concentrate on process as their most formal concern. Thus the third book, which for Aquinas contains the first strict demonstration in natural science, establishes that change is properly found in the thing undergoing change and not in whatever initiates it, and that infinitude, insofar as it is studied by the natural scientist, is formally connected with process insofar as the latter is lodged in some way in the sensible continuum.[6] Demonstrations in Book IV show that every process takes place in time, in Book V that process is possible

— 572 —

strictly speaking only in categories of being that allow contrariety (location, quality, and quantity), and in Book VI that everything that undergoes a process of these kinds must be a divisible or quantified body. The last two books, finally, propose to demonstrate the existence of a First Unmoved Mover, and do so, not through a metaphysical analysis of potency and act, but rather through an analysis of the requirements for initiating change in a body that has the capability of successive movement in time.[7]

The concern with spatial and temporal succession that runs through the *Physics* and the subsequent *scientiae naturales* suggests that Aquinas will also address himself to the problem of the successive and temporal relationships between cause and effect, and this does in fact prove to be the case. The principal loci for this treatment are his commentary on the second book of the *Physics*, toward the end, where he is discussing causal analysis and its mode of employment in the natural sciences, and in the commentary on the *Posterior Analytics*, where these problems are addressed more pointedly as jeopardizing the possibility of demonstrative proof when

treating of any natural process.[8] In brief, for Aquinas no special problem is presented when analyses are made in terms of intrinsic (i.e., formal and material) causality, but serious difficulties present themselves when one attempts to demonstrate through extrinsic (i.e., efficient and final) causality, particularly when treating of the sublunary world, for here efficient causes can be impeded from attaining their normal effects. Aquinas' distinctive solution is to propose that demonstrations in the *scientiae naturales* can circumvent the defective operation of efficient causes, whether these arise through material defects or "on the part of time alone," through a technique known as demonstrating *ex suppositione finis*.[9] This technique begins by studying natural processes and noting how they terminate for the

— 573 —

most part. Thus, in biological generation, it is easily noted that men are normally born with two hands, or that olive plants are usually produced from olive seeds provided that these are properly nurtured. From this information, however, one cannot be certain in advance that any particular child will be born with two hands, or that each individual olive seed will produce an olive plant. The reason for this is that the processes whereby perfect organisms are produced are radically contingent, or, stated otherwise, that generating causes do not always attain their effects. But if one starts with an effect that is normally attained, he can use his experience with nature to reason, on the supposition of the effect's attainment, to the various antecedent causes that are required for its production. It is this possibility, and the technique devised to assure it, that permit the *scientiae naturales* to be viewed as sciences in the strict sense. They can investigate the causes behind natural phenomena, they can know with certitude how and why effects have been produced, and they can reason quite apodictically to the requirements for the production of future effects, even despite the fact that nature and its processes sometimes fail in their *de facto* attainment.

To illustrate this technique the favored example of Aquinas, taken over from Aristotle and previous commentators, is the causal analysis of a lunar eclipse. Such eclipses do not always occur, but when they do occur they are caused by the earth's being "diametrically interposed between sun and moon."[10] Thus, if a lunar eclipse is to take place, this will require a certain spatial configuration between sun, moon, and the observer on earth. A similar contingent occurrence is the production of the rainbow in the atmospheric region of the heavens; this is more difficult to explain than the lunar eclipse, since it lacks even the regular movements of the celestial spheres to guarantee its periodic appearance. In fact, rainbows are only rarely formed in the heavens, and sometimes they are only partially formed; when they are formed, moreover, they seem to come about as the result of a contingent process. This notwithstanding, they can still be the subject of investigation

— 574 —

within a science *propter quid*, if one knows how to go about formulating a demonstration in the proper way. Rainbows do not always occur, but they do occur regularly under certain conditions; they are not always fully formed, but for the most part they form a circular arc across the heavens. An observer noting the regularity of this phenomenon can rightly expect that such a regularity has a cause, and he may proceed to discover what that cause may be. If he moves scientifically, according to Aquinas, he will take as his starting point the more perfect form that nature attains regularly and for the most part, and using this as the end or final cause, will try to discover the antecedent causes that are necessarily entailed in its realization. The necessity of his reasoning is therefore *ex suppositione finis*, namely, based on the supposition that a particular end is to be attained by a natural process. *If* rainbows are to occur, they will be formed by rays of light being reflected and refracted in distinctive ways through spherical raindrops successively occupying predetermined positions in the earth's

atmosphere with respect to a particular observer.[11] The reasoning, though phrased hypothetically, is nonetheless certain and apodictic; there is no question of probability in an argument of this type. Such reasoning, of course, does not entail the conclusions that rainbows will always be formed, or that they will necessarily appear as complete arcs across the heavens, or even that a single rainbow need ever again be seen in the future. But if rainbows *are* formed, they will be formed by light rays passing through spherical droplets to the eye of an observer in a predetermined way, and there will be no escaping the necessity of the causal operation by which they are so produced. This process, then, yields scientific or epistemic knowledge of the rainbow, and indeed it is paradigmatic for the way in which the *scientiae naturales* attain truth and certitude concerning the contingent matters that are the proper subject of their investigations.

— 575 —

II

The foregoing may serve to show that Aquinas' discourse, with its concentration on natural processes that take place successively and in time, allows for the possibility of temporal intervals between cause and effect. Unfortunately his examples of the eclipse and the rainbow, concerned as they are with light rays, obscure the point somewhat, since in the Middle Ages light propagation was generally regarded as instantaneous. From other examples, however, one can be assured of Aquinas' awareness of the possibility of a time lag between cause and effect. Thus it comes as no surprise to find him treating this point explicitly in his commentary on the *Posterior Analytics*, and there registering an advance over Aristotle's analysis. The locus is chapter 12 of Book II, where Aristotle treats problems relating to the inference of past and future events, and where he raises the question whether there are, as experience seems to show, causes that are distinct in time from their effects. The answer Aristotle proposes is somewhat ambiguous; consistent with his teaching in the *Physics*, he allows that one may infer the occurrence of an earlier event from that of a later event, but denies that the inference can be made the other way around. Most of his discussion then bears on the latter impossibility, where he argues that, were a later event to be inferred from an earlier, during the interval between them it would not be true to say that the later event either has happened or will happen. Here he likens the two events to the points terminating a line segment and the interval or process between them to the line itself. Two such events cannot be either continuous or contiguous, any more than two points can be, nor can the intervening process be contiguous with either event, any more than a line can be contiguous to a point. Thus there is nothing that can serve to hold events together and so assure that any coming-to-be will actually follow upon a past event. Moreover, there always seems to be the possibility of some third event intervening between the two being considered, which could be the cause of the later event's production and therefore would render the inference invalid.
This line of argument has proved troublesome for many commentators, who question Aristotle's identification of cause and

— 576 —

effect with point-like events and wonder why he never considered the possibility of cause and effect being more similar to processes, which then could be considered as successive or continuous.[12] It is in evaluating this possibility that Aquinas' commentary proves helpful, for Aquinas does consider the latter case and indeed makes use of it in coming to a solution. In fact he devotes three *lectiones* to an exposition of this one chapter in Aristotle, and in the first two of these even attempts to show how, in accordance with the Stagirite's principles, a cause that is not simultaneous with its effect may still serve as a middle term in a demonstration.[13] The

argument Aquinas uses to support his interpretation is relatively simple: just as in any process prior and subsequent elements can be identified, so in the causal processes by which natural agents produce their effects prior and subsequent elements may similarly be noted. Or, as he puts it,

since the notions of prior and subsequent are necessarily involved in any process, in considering the causes of a process one must accept the fact that the cause and the thing caused are likewise related as prior and subsequent. For it is obvious that a natural agent cause produces its effect through some type of process; and just as the thing undergoing change is brought to the terminus of the process through the entire process itself, so through the first portion of the process it is brought to the second portion, and so on. Hence, just as the entire process is the cause of the subsequent state of rest, so the first portion of the process is the cause of the subsequent portion, and so on.[14]

Aquinas then goes on to note that this line of reasoning is applicable whether one object alone is undergoing change or whether a series of such objects are acting upon one another successively:

This analysis is true whether it is confined to one object that is in process without interruption from beginning to end, or is applied to several objects the first of which initiates change in the second, and the second in the third. And although, while the first in the series effects change in its object at the same time as the object itself

— 577 —

undergoes change, nevertheless the object thus changed continues to initiate change in another object even after it ceases to be changed itself. In this way several movable objects undergo change successively, with the one being the cause of the change induced in the other, and so on.[15]

The example Aquinas supplies here is that of the projectile, which, though faulty from the viewpoint of modern science, was readily understood by his contemporaries; the point would be better illustrated in our day with the propagation of water waves by a stone dropped into a mill pond, for the case of the single object, and with the successive falls of a row of dominoes, for the case of the plurality of objects. In such instances, as in the example Aquinas supplies,

... the cause is not simultaneous with that of which it is the cause [i.e., the effect], insofar as the first portion of the process is the cause of the second, or the object first undergoing change induces a change in the second.[16]

Having therefore conceded the possibility of antecedent causality, or of a temporal interval between cause and effect, both of which he likens to the parts of a process, Aquinas then takes up the more difficult question as to how antecedent causes can serve as middle terms in scientific demonstrations. To clarify his exposition he introduces an example that is particularly apposite in that it expands the time interval between cause and effect considerably beyond that noted in cases involving the transmission of light rays. The example is that of a person taking medicine and subsequently being cured, either at some specified time, such as "he will be cured on such and such a day," or at some unspecified time, such as simply "he will be cured in the future."[17] In terms of this illustration it is easy for Aquinas to explain why Aristotle has reservations about syllogizing from an earlier to a later event, and why he seems to countenance the possibility of the reverse procedure. Once a person has been cured, it does seem reasonable to attribute the cause of his cure to his prior taking of the medicine. But from the fact that a person takes medicine at a particular time, one may not infer scientifically that he will

— 578 —

be cured either at some specified later date or indefinitely in the future. The reason for this is that, as Aristotle indicates, after taking the medicine there will always be some intervening time "in which it is true to say that he had drunk the medicine but not yet true to say that he has been cured,"[18] or, and this is Aquinas' emendation,

that "having posited what is prior, the subsequent does not necessarily follow in cases where the effects of the causes can be impeded."[19]

A difficulty yet remains, however, and this relates to the type of syllogizing to which Aristotle apparently has given approval, namely, that of drawing an inference from a later to an earlier event. Here too, in the intervening time, it would seem always possible to find an intermediate event, different from the taking of the medicine, that could yet serve as the cause of the person's cure. If this possibility exists, then one can never be sure that he was cured by the taking of the medicine, and thus scientific knowledge would seem to be precluded even through this *a posteriori* reasoning process.[20]

The problem, of course, already exists for Aristotle, but the solution he devises is not at all clear, and one suspects that this is why he prefers to insist on the simultaneity of cause and effect whenever necessary demonstrations are required.[21] Here Aquinas' commentary again proves helpful, for the Common Doctor attempts to meet the objection and thus still guarantee the possibility of demonstrating in natural science through antecedent causality. Aquinas admits that if one conceives of events as point-like completions of processes, there will always be an infinite number of such completions or partial completions, and on this basis alone it will be impossible to know where to start or to terminate in any demonstrative process. The practical problem is not insoluble for him, however, for he notes that one can always begin with the point-like event that corresponds to the moment "now," and from this reason back to a cause that is ultimately

immediate with respect to the process that produces the noted effect. To illustrate this he extends the example of the person taking the medicine to include a further process consecutive on his being cured, namely, "his performing the tasks of a healthy man."[22] Should the sick person now be observed performing such tasks, one can reason back that it was necessary for him to have been cured at some time previously, and if he has been so cured, it is further necessary that he previously have taken the medicine. Thus, if *D* stands for "performing the tasks of a healthy man," *C* for "being cured," and *A* for "taking medicine," *C* can function as a *causa cognoscendi* that serves to connect *D* with *A* as its ultimate cause. On this basis, writes Aquinas,

we can conclude that if *D* has come to pass, it is necessary that *A* have previously come to pass; and we take as cause that which took place in the interim, namely, *C*. For *D* having come to be, it is necessary that *C* have previously come to be; and *C* having come to be, it is necessary that *A* have previously come to be; therefore, *D* having come to be, it is necessary that *A* have previously come to be. For example, if this person has now performed the tasks of a healthy man, it follows that previously he had been cured; and if he was cured, it is necessary that previously he had taken the medicine.[23]

The foregoing is merely illustrative of the procedure Aquinas would recommend to pass through various mediate events or processes until one finally is able to demonstrate the immediate cause of the effect being investigated. So he continues:

Therefore, by always taking a middle in this way, for example, something else between *C* and *A*, as *C* was taken as middle between *D* and *A*, one will come to rest somewhere at something immediate.[24]

This is as far as Aquinas goes with that particular example, but perhaps its further consideration in the light of present-day knowledge may serve to clarify his point. Let us assume, in Aquinas' example, that the person who takes the medicine is incapacitated by severe stomach acidity, and that the medicine he drinks is some form of alkalizer. If one is to believe television commercials, the essential mechanism of the resulting cure will be provided by some intermediate process or event, which may be

— 580 —

designated as *B*, and which will consist in a chemical reaction whereby the alkali ions neutralize the acid ions in the sick person's stomach, and thereupon gradually restore him to health. Thus understood, the entire process of the cure may be seen as made up of four partial processes: *A*, the ingestion of the medicine; *B*, the neutralization of the stomach acidity; *C*, the restoration of normal functioning to the other organs of the body; and *D*, the performance of the tasks of a healthy man. All of these components, it may be noted, are themselves processes, although they begin and terminate with point-like events, up to and including the moment "now" from which the reasoning process started. From the viewpoint of modern medicine, what is most important is that the proper or immediate cause of the cure is best seen microscopically as the event-like combination or neutralization of the alkali and acid ions, where for each particular combination the particles come into contact, and where, in this micro-process, partial cause and partial effect are themselves simultaneous. But such individual micro-processes aside, the entire neutralization process is *not* simultaneous, being made up of a series of such micro-processes taking place over a time interval, and the same is true of the taking of the medicine and the final effecting of the cure, both of which depend on the movement of medicine and the redistribution of organic fluids, and thus are time-consuming processes.

On an understanding such as this, based on Aquinas' recommended method, it would seem possible to have scientific knowledge of processes wherein efficient causality is exercised over a period of time, and where the initiating cause is temporally antecedent to the completed effect. The methodology of demonstrating *ex suppositione finis* then can be seen as applying to such cases, just as it does to the cases of the lunar eclipse and the production of the rainbow. Some medicines, it is true, prove to be ineffective, and some people are not cured—a state of affairs completely analogous to that in the example, based purely on nature's operation, that not every human being is born with two hands. But such defects arising either from matter or from the fact that nature acts over an extended period of time, while complicating the methodology whereby demonstrations can be attained, in no way nullify the possibility of scientific or epistemic knowledge of nature and its processes.

— 581 —

III

This much said, some differences between the Humean and the Aristotelian views of causality may now be clarified in the light of Aquinas' commentary. Hume, it would appear, was accurate in his intuition that the exercise of efficient causality, as observable at the phenomenal level and so of particular interest to the scientist, would involve sequential series of events wherein the cause would generally be apprehended prior to the effect. Once he had decided on an event-like analysis of cause and effect, moreover, he was correct in maintaining that such an analysis can never yield knowledge of necessary connections in nature. Aristotle's difficulty in analyzing cases where cause and effect are punctiform, with the infinite number of possibilities they provide between the extremes of any natural process no matter how short, already signals the conclusion to which Hume would be forced once he had restricted himself to a consideration of atomic events alone. On the other hand, Hume's limitation lay in being too precipitate when urging that the only meaningful analysis of causation would have to remain at the phenomenal level, and there invoke merely an event ontology. The experience of recent science has shown, for example, the poverty of such dogmatic empiricism for providing knowledge of the entities and mechanisms that underlie observable events and that now serve to reveal their actual connectedness.

Aristotle, as has been observed, is enigmatic with respect to the problem considered in this essay. One could

maintain, and indeed some Aristotelian Thomists would be so inclined, that the interpretations here attributed to Aquinas are actually those of Aristotle himself. That this is unlikely may be seen from an examination of the commentaries on the Greek text of the *Posterior Analytics*, and also from a study of the major commentators in the Latin West, including Averroes, Robert Grosseteste, Albert the Great, and extending even to Jacopo Zabarella. Aquinas' interpretations may be seminal in Aristotle, but their distinctive articulation is not to be found elsewhere in the commentatorial tradition. With regard to the *ipsa verba* of Aristotle, it should be noted that he himself suggested event-like analyses as appropriate for dealing with problems of antecedent causality, and thus is

— 582 —
partly responsible for the difficulties into which an exclusive concern with such analyses would later lead. The reason for this suggestion is probably associated with his view of substantial generation or change, which takes place at an instant of time and therefore is best described as a point-like event. Since such substantial change is the normal terminus of many of the natural processes studied in the *scientiae naturales*, it is not surprising that punctiform events should have emerged large in Aristotle's thought. In his favor, however, it should be noted that he himself was quick to realize the difficulties inherent in event analysis, and possibly for this reason consistently de-emphasized antecedent causality, preferring rather to discuss cases where cause and effect are simultaneous. Such a preference, as it turns out, was methodologically sound, for the reduction of causal processes to their immediate initiators at the micro-level brings one ultimately to instantiations of simultaneous causality. The search for such deeper levels of explanation also takes one beyond the phenomenal order to regions of ontological depth where otherwise hidden mechanisms can be explored and the ways in which these serve to connect phenomenal events made apparent.

Aquinas, as we have attempted to show, combines both Humean and Aristotelian elements in his treatment of causal processes. The cases of temporal succession that interest Hume and that led to his causation doctrine were clearly of interest to Aquinas also. The ambiguity in Aristotle as to whether some causes actually do precede their effects or merely appear to do so, is resolved by Aquinas in a way that legitimizes the temporal-succession aspect of Hume's analysis. Moreover, in view of Aquinas' interest in process, and then considering the subsequent development of modern science with its pervasive spatio-temporal descriptions of physical events, it is probable that Aquinas would have admitted that antecedent causality *is* more frequently encountered in the investigation of natural processes that interest the scientist. On the other hand, Aquinas's empiricism could not restrict itself to a Humean form of phenomenalism, but would use the succession of observable events as a springboard to search for their deeper underlying connections. In such a search his sympathies would be with Aristotle and the ultimate resolution of antecedent causation to cases of simultaneous causality. Otherwise the advantage

— 583 —
of Aquinas' "middle of the road" view is that it provides a framework in which both ways of studying causal processes acquire a certain legitimacy. The phenomenal method, with its stress on the regularity of succession of events in temporal sequences, and thus in its concern with antecedent causation, serves to isolate instances of natural phenomena whose study may lead to scientific or epistemic knowledge, whereas the more noumenal method, with its search for causal efficacy, underlying mechanisms, and micro-processes that lay bare the connections between events, and this in terms of simultaneous causality, itself results in the sought-after knowledge.

Finally, contemporary analytic discussions of causal relations are not without relevance to the problematic under

discussion. For the most part analytical philosophers have given up on Hume's insistence that temporal sequence is essential to causation and its recognition, and are now willing to countenance the view that cause and effect, even when seen uniquely as events, can be simultaneous.[25] Recently, however, an attempt has been made to argue "for a qualified endorsement of Hume's intuition," by showing that there must always be a time difference between cause and effect for the cases "in which cause and effect are modifications of the same physical object."[26] The case proposed is rather peculiar and, although discussed with considerable analytical acumen, seems to have been contrived mainly to accommodate a growing body of what the author regards as "non-problematic" statements concerned essentially with event ontology.[27] It would take us too far afield to survey this literature and evaluate the various moves made therein for the description and recognition of events,[28] but the general impression one gets is that it shows little awareness of the actual problems one encounters when employing causal reasoning in scientific explanation. Much more attractive than this Humean exercise are the proposals of other recent writers

who question the adequacy of any event ontology to deal with causal processes, and turn instead to an investigation of generative mechanisms and structures at the micro-level that explain natural phenomena in terms of the factors that can actually account for their production.[29]

It would be too much to say that all of this problematic has been adumbrated by Aquinas and its solution already anticipated by this renowned thirteenth century thinker. Yet, temporally situated as he was between Aristotle and Hume, Aquinas does provide an original intermediate viewpoint. While not completely embracing the opposed positions, perhaps his thought can serve to illumine the strengths and weaknesses of both extremes and so reconcile some of the competing claims that continue to be made on behalf of antecedent and simultaneous causality.

The Catholic University of America.

Footnotes

[1] For the basic texts and a discussion of the problematic and its history, see J. S. Wilkie, "The Problem of the Temporal Relation of Cause and Effect," *British Journal for the Philosophy of Science* (1950), pp. 211-29. [2] A brief sketch of these contributions is given in my article on Aquinas in the *Dictionary of Scientific Biography*, Vol. 1. (New York: Charles Scribner's Sons, 1970), pp. 196-200. [3] This theme is developed at some length throughout my two-volume study, *Causality and Scientific Explanation* (Ann Arbor: University of Michigan Press, 1972-74); see Vol. 1, pp. 71-80, 102, 104, 143, and Vol. 2, pp. 247, 250, 293, and 354. [4] *In II Physicorum*, lect. 1, n. 1. [5] *In III Physicorum*, lect. 1, n. 1. [6] There has been no satisfactory full-scale study of the various demonstrations that are to be found in Aristotle's physical works; for a preliminary outline, indication of sources, etc., see my "Some Demonstrations in the Science of Nature," *The Thomist Reader 1957* (Washington, D.C.: The Thomist Press, 1957), pp. 90-118. [7] For some details, see my "The Cosmological Argument: A Reappraisal," *Proceedings of the American Catholic Philosophical Association* (1972), pp. 43-57. [8] *In II Physicorum*, lect. 11-15; *In II Posteriorum Analyticorum*, lect. 9-12. [9] *In I Posteriorum Analyticorum*, lect. 16, n. 6; *In II Posteriorum Analyticorum*, lect. 7, n. 2

and lect. 9, n. 11; *In II Physicorum*, lect. 15, n. 2; see also the references given in note 3 above. [10] *In I Posteriorum Analyticorum*, lect. 16, n. 6. [11] The details of this mechanism were not known to Aquinas but were discovered shortly after his death by another Dominican who had studied at Paris, Dietrich or Theodoric of Freiberg, whose contribution to optical science is discussed in my article in the *Dictionary of Scientific Biography*, Vol. 4 (1971), pp. 92-95. For a full analysis of Theodoric's optical methods, see my *The Scientific Methodology of Theodoric of Freiberg* (Fribourg: The University Press, 1959). [12] See, for example, W. D. Ross, *Aristotle's Prior and Posterior Analytics*, a Revised Text with Introduction and Commentary (Oxford: Clarendon Press, 1949), pp. 80-81 and 648-53; and Hugh Tredennick, *Aristotle's Posterior Analytics*, The Loeb Classical Library (Cambridge, Mass.: Harvard University Press, 1960), pp. 13-15 and 219-27. [13] *In II Posteriorum Analyticorum*, lect. 10-12. [14] *Ibid*., lect. 10, n. 2. [15] *Ibid*. [16] *Ibid*. [17] *Ibid*., nn. 8 and 9. [18] *Ibid*., n. 8. [19] *Ibid*., n. 9. [20] *Ibid*., lect. 11, n. 5. [21] Cf. *ibid*., lect. 10, n. 9. [22] *Ibid*., lect. 11, n. 4. [23] *Ibid*. [24] *Ibid*. [25] For example, Arthur Pap, *Elements of Analytic Philosophy* (New York: The Macmillan Company, 1949), pp. 220-24. [26] Carl G. Hedman, "On When There Must Be a Time-Difference Between Cause and Effect," *Philosophy of Science* (1972), p. 507. [27] *Ibid*., pp. 507, 510. [28] Hedman gives a brief bibliography on p. 511. [29] For a survey of this literature, see Edward H. Madden, "Scientific Explanations," *The Review of Metaphysics* (1973), pp. 723-43.