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BOOK SYMPOSIUM

# *Episteme*, demonstration, and explanation: A fresh look at Aristotle's *Posterior Analytics*

**Gregory Salmieri · David Bronstein · David Charles · James G. Lennox**

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## Aristotelian *epistēmē* and the relation between knowledge and understanding

Gregory Salmieri

A symposium on Aristotle's *Posterior Analytics* in *Metascience* invites the question of how the treatise relates to philosophy of science and epistemology, as these fields are generally understood. It is in the hope of shedding some light on this issue that I propose to discuss Aristotle's conception of *epistēmē*, his name for the *Posterior Analytics*' subject matter. The term is variously translated "science," "knowledge," and "understanding," but none of these options is ideal, and the difficulty in finding a suitable translation attests to the distance between Aristotle's thought and our own. Appreciating this somewhat alien concept will help us to better frame some interpretive questions about Aristotle's project in the *Posterior Analytics* and some philosophical questions about how his positions relate to the issues of interest to contemporary epistemologists and philosophers of science, and about whether we

G. Salmieri (✉)
Department of Philosophy, Boston University, 745 Commonwealth Ave., Boston, MA 02215, USA
e-mail: gsalmieri@gmail.com

D. Bronstein
Department of Philosophy, Georgetown University, New North 215, Washington, DC 20057, USA
e-mail: db1096@georgetown.edu

D. Charles
Oriel College, Oxford OX1 4EW, UK
e-mail: david.charles@philosophy.ox.ac.uk

J. G. Lennox
Department of History and Philosophy of Science, University of Pittsburgh,
1017 CL, Pittsburgh, PA 15260, USA
e-mail: jglennox@pitt.edu

can find in Aristotle the outlines of a viable theory. (Answering these questions, however, will have to wait for another occasion.)

"*Epistēmē*" is the noun form of "*epistasthai*," one of several Greek verbs for knowing.[1] However, in the *Posterior Analytics*, the term functions in two more specialized senses. First, "*epistēmē*" can refer to a systematic body of knowledge of the sort exemplified by geometry or astronomy. It is in this sense that the term is aptly translated "science"; the treatise provides the first extended treatment of sciences, teaching that they have an axiomatic structure. Second, "*epistēmē*" (and "*epistasthai*") can refer to a certain estimable cognitive state: the state in which the possessor of a science stands toward each of its theorems, in virtue of a demonstration of the theorem from the appropriate principles. These principles are, in turn, the objects of another cognitive state, *nous*, which is arrived at via a process of induction that is based (ultimately) on sense perception. The principles are necessary and universal, and the possessor of *nous* apprehends them as such. Moreover, the principles are causes of the objects of *epistēmē*; so, by deducing these effects from the principles, one sees the effects as following necessarily from necessary causes and one thereby grasps both that the effects are necessary and why they are so. This grasp is *epistēmē*.

Of the two specialized senses of the term, it is this second that Aristotle treats as fundamental; the sciences have the structure they do, because of the nature and requirements of this state.

Given the above sketch, two broad interpretations of Aristotelian *epistēmē* suggest themselves. Each is represented in the secondary literature on Aristotle and each corresponds to something subsequent thinkers have sought from axiomatically structured bodies of knowledge.

According to one interpretation, the function of the demonstration is to elevate the theorems from the status of (more or less probable) opinion to that of knowledge, by deducing them from the principles that are necessary and self-evident. On this view, the *Analytics* contains an epistemology of a sort familiar from such modern rationalists as Descartes, so we can speak of demonstrations as "justifying" their conclusions. This interpretation sits naturally with the traditional translations of "*nous*" as "intuition" (or "intuitive knowledge") and *epistēmē* as "knowledge" (or "demonstrative knowledge") and has been maintained by such modern scholars as Frede (1996, 158; cf. 2011, 116–118) who describes Aristotle as "the paradigm of an extreme rationalist." Of course, Aristotle regularly speaks of our "knowing" (*gignōskein*, *gnōrizein*, and *eidenai*, and even *epistasthai*) things that are neither self-evident nor demonstrated, but according to Frede, this is true "only in a debased sense of 'knowledge.'" (*ibid*., 157).

In particular, according to Frede, it is only in this debased sense that we could be said to "know" the various things from which our knowledge of the principles is induced (or from which it otherwise arises). It should be noted that much of *Posterior Analytics* concerns the progression by which we can arrive at *nous* and

[1] It is worth noting that all of these words have a fairly wide range of applications, taking as particulars and subject matters as well as facts—that is, one can be said to have epistēmē of Socrates, of Athens, or of Greek, just as one could be said to have epistēmē that twice two is four.

*epistēmē*, beginning from less rarified types of knowledge. In addition to the claim in II.19 that the principles are reached by induction, we find in II.1 a discussion of how we first establish *whether* an object exists or a fact obtains, and only once we know (*eidenai*, *gignōskein*) this do we inquire into *what it is* or its *cause*. And much of Book II concerns whether and how definitions can be established, where definitions are a type of principle. According to the reading of the *Analytics* we have been considering, none of this cognition that precedes the grasp of the principles is knowledge properly so called, and the process by which *nous* arises from this earlier cognition cannot be understood as an inferential process, in which the new knowledge is justified on the basis of old. Rather, it is to be understood as a natural, psychological process by which intuition of self-evident truths develops in us over time, or perhaps as a heuristic process, in which earlier cognitions that assist in the acquisition of intuition can then be cast away, like Wittgenstein's ladder, once the intuition is achieved.

I turn now from the first interpretation of *epistēmē* to the second. On this view, one does not need a demonstration to know fully that there are lunar eclipses, that the planets do not twinkle, or even that the interior angles of a triangle have an angle sum equal to two right angles. All of these things can be established by observation or by arguments that do not reveal their causes (or establish their necessity). What a demonstration provides is not a justification of its conclusion, but an *explanation* of it. The *Posterior Analytics* is not a work of epistemology at all. It belongs rather to the philosophy of science and contains a theory of explanation in the vein of Hempel's "covering law" model.[2] As the example of Hempel indicates, such theories of explanation have been often thought to be compatible with empiricist epistemologies.

If we view the *Posterior Analytics* as providing a theory of explanation, it is clear that the theory cannot be quite that of Hempel or the other logical empiricists. Aristotle held, contra Locke and subsequent empiricists, that we can know the real essences of natural substances, and he is committed to rejecting Hume's analysis of causality as constant conjunction in favor of a metaphysically robust view of causality according to which what something is can necessitate that it act in certain ways.[3]

This is most evident in the way Aristotle differentiates *epistēmē* from mere experience (*empeiria*).[4] To be experienced, in Aristotle's sense, is to have many

[2] Interpretations of the *Posterior Analytics* along these lines include Broadie (1972) and Hocutt (1974).

[3] See *Posterior Analytics* I.13 for the reasons why Aristotle thinks that we would need to add causal direction to any covering-law-like account of scientific explanation, and see I.4 and most of II for the importance of essences in Aristotle's account. Broadie (1972) nicely elaborates on and defends these points, arguing that Aristotle's philosophy of science offers a solution to a number of problems in the logical empiricist program.

[4] To be exact, Aristotle's subject in the portion of *Metaphysics* A.1, which I rely on for the points I go on to make, is the difference between *technē* ("art") and *empeiria*. But it is made clear in the chapter and elsewhere that *epistēmē* is like *technē* and unlike *empeiria* in the relevant respects (981b12–82a2, cf. *Posterior Analytics* II.19 100a6–9).

memories about objects of a certain kind and to have associated these memories together in a manner that enables one to reliably predict how items of that kind will act, without knowing *what the kind is* or *why* its members behave in the way that one can (accurately) predict they will.[5] A person with medical experience could treat patients in virtue of his awareness, e.g., "that this benefited Kallias when afflicted with this illness and Socrates {too} and many such particulars," but only a doctor grasps that the relevant treatment "benefited all such {people} defined according to a single form when afflicted with this illness (e.g. phlegmatic or choleric when burning with fever)," and so only the doctor will "know the why and the cause" (*Metaphysics* A.1 981a8–12, 29–30).

The medical example is significant because our term "empiricist" derives from a school of physicians in (or shortly after) Aristotle's time, who eschewed as impossible and unnecessary the causal knowledge and grasp of essences that Aristotle thought was required for science.[6] Locke and Hume's anti-Aristotelian premises concerning essences and causation are articulations of the position of such earlier empiricists (in medicine and other fields). Because of this and of the influence of Locke and Hume on the subsequent empiricist tradition, it is misleading to apply the term "empiricist" to Aristotle. Nonetheless, the theory of explanation that the present interpretation ascribes to the *Posterior Analytics* remains consistent with an *empirical foundationalism*—with the idea that all knowledge is justified ultimately on the basis of sense perception.

Putting aside the question of how this theory of explanation relates to rationalism and empiricism, it is clear that, on this interpretation, having *epistēmē* of something is not a matter of *knowing* it or of knowing it in some especially strict sense of the term; someone who cannot explain a phenomenon does not thereby know it any less well than does someone who can—at least not as we normally understand the term "knowledge." A theoretical scientist may rely on prior work by experimentalists establishing the existence of the phenomenon he is trying to explain, and even if he comes to know that his explanation is true, it seems odd to say that he knows that the phenomenon exists better than do the experimentalists on whose reports he relied. Worse, if his theory is justified (in whole or in part) on the basis of its ability to explain the phenomenon, then it cannot be that the theory is known better than the phenomenon, for knowledge of the theory depends on knowledge of the phenomenon (rather than the reverse). What depends on knowledge of the theory is not knowledge of the phenomenon, but *understanding* it. Thus, if one sees the *Posterior Analytics*' project as explanatory rather than justificatory, "understanding" becomes more natural than "knowledge" as a translation of "*epistēmē*." This

[5] I intend this description of *empeiria* to remain ambiguous on several questions that are matters of scholarly controversy, including whether the possessor of experience has a concept for the kind with respect to which he is experienced, and whether he possesses general beliefs about how members of that kind behave, or only a faculty in virtue of which he forms particular beliefs about particular kind-members on particular occasions. I discuss these controversies and my position on them in Salmieri (2010, 169–179).

[6] On the empiricist school of ancient medicine (including its relations to competing schools), see Edelstein (1967), Frede (1988), Allen (2001, 89–97), and Pellegrin (2006, 671–682).

translation is used by Barnes (1975b, 1994) and defended at length by Burnyeat (1981).[7]

Though thinking of *epistēmē* as understanding and of the *Posterior Analytics* as a treatise in the philosophy of science does shed a lot of light on Aristotle's position, this interpretation cannot be quite correct as we have stated it thus far, for the treatise contains passages, central to its argument, in which Aristotle uses *epistēmē* in a manner that evinces specifically epistemological concerns. Consider, for example, the following passage:

> Before someone can have knowledge (*epistēmē*) through a demonstration not only must he get to know (*gnōrizein*) the principles better and be more convinced of them than he is of what is being proved, also it must be that none of the opposites of the principles, from which there could be a deduction of the erroneous contrary, is more convincing or better known (*gnōrimōteron*) to him since someone who knows (*epistasthai*) simpliciter must be immovable in his conviction. (*Posterior Analytics* I.2 72a37–b4)[8]

Burnyeat (1981, 134–139) accommodates such passages by attributing to Aristotle (and Plato) the thesis that understanding is a necessary condition for knowledge—that it is part of what needs to be added to true belief to yield knowledge; thus, he speaks of an "Aristotelian (Platonic) enterprise of putting philosophy of science at the center of epistemology" (*ibid*., 138).

There is surely something right in what Burnyeat says, but I think there is something misleading about his position as well, for central to his thesis is a contrast between *epistēmē* and knowledge (*gnōsis*) that is at odds with Aristotle's way of thinking. Burnyeat (1981, 104; cf. Barnes 1975b, 90; 1994, 82), relying on Lyons' (1963) study on knowledge verbs in the Platonic corpus, maintains that *epistēmē* and *gnōsis* name distinct states within the broader genus *eidesis*.[9] Whatever may be the case in Plato, this is clearly incorrect with respect to Aristotle's usage, as Aristotle refers to *epistēmē* as a type of *gnōsis*. For example, among the puzzles raised in *Posterior Analytics* II.19, he considers a puzzle about whether our *gnōsis* of immediate principles is *epistēmē* or "some other *gnōsis*" (99b22–26). Far from being an alternative to *gnōsis*, *epistēmē* is a type of it.[10]

[7] Barnes adopts the translation primarily as part of a program of trying to put Greek and English terms in a one-to-one correspondence and stops short of claiming that "understanding" best captures Aristotle's meaning (1975b, 90, 1994, 82), but his reading of II.19 especially (see 1975b, 259, 1994, 270–271) shows him to be in sympathy with the sort of interpretation that suggests "understanding" as a translation.

[8] Cf. *Nicomachean Ethics* VI.3 1139b20–23: "We all suppose that what is known (*epistasthai*) cannot be otherwise; whenever what admits of being otherwise is outside of observation, we don't notice whether it is or not. Therefore what is known (*epistēton*) is necessary."

[9] More recently, Burnyeat (2011, 19–24) has presented a more complex version of this scheme, emphasizing that the vocabulary Aristotle uses for the genus and the two coordinate species varies. However, he still insists on the dichotomy between knowledge and understanding.

[10] *Eidesis* is clearly wider in application than *epistēmē*, but may not be as wide as *gnōsis*.

[11] One can get a sense of the term's range by considering the following passages: *Protrepticus* 76, *Posterior Analytics* II.19 99b37–100a1, *De Anima* III.3 428a19–4, *On Dreams* 1 (458b2–3), *Generation of Animals* II.23 731a30–4, *Metaphysics* I.1 1053a31–33.

A survey of the corpus reveals that *gnōsis* encompasses every state of awareness from the sensations of the most primitive animals to the erudition of a sage.[11] This is approximately the range of the word "knowledge" in common parlance (if not in the epistemology literature), so going forward I will translate *gnōsis,* knowledge.

Though Aristotle treats everything from sense perception to ordinary propositional knowledge to *epistēmē* as knowledge, he does not think that they all have equal claim to this title. Rather, knowledge comes in degrees, with some states being "more knowing" (*gnōstikōteron*) than others. In particular, perception is knowledge in a lower degree than *epistēmē* and *nous*, which are the most knowing states (II.19 100b12).

These differences in degree cannot be (only) differences in level of certainty, since perception, which is a low degree of knowledge, is "the most authoritative knowledge of particulars" (*Metaphysics* A.1 981b12). Though Aristotle never enumerates them, there seem to be several respects in which one state can be more knowing than another: It can be "truer" (II.19 100b8), more precise (II.19 100b811, cf. I.27), or it can know the object more *as the object is*, which, in the case of objects with causes, means knowing them at the level of universality required to isolate these causes and thus demonstrate the objects' existence (I.24 85b5–86a30). Aristotle says less about each of these than one might wish, and I do not have space here to attempt much of an elucidation, but I can make one point that I hope will be clarifying.

Aristotle's understanding of knowledge and related terms is more easily intelligible when we think of knowledge as an *acquaintance* with objects rather than as a state we stand in with respect to propositions.[12] Perceptual acquaintance is the model in terms of which the Greeks thought about conceptual knowledge (and Aristotle was no exception); even propositional knowledge is to be understood in terms of acquaintance with objects. A proposition combines a predicate and a subject (in a certain specialized way); for the proposition to be true is for the items referred to by the two terms to be (appropriately) combined in reality, and to know the proposition is to be acquainted with this real combination.

Just as one can *see* an object more or less well along many dimensions (blurrily or sharply, with better or worse color discrimination, from a vantage point that reveals more or less of it, etc.), so too one can *know* an object more or less well along various dimensions. Consider how this point applies to the combinations that are the objects of propositional knowledge. One crucial respect in which a combination of two terms can be known better or worse is to know better or worse *how the terms are connected*—that is to know in more or less detail or more or less accurately the middle term(s) through which the predicate belongs to its subject. For example, if ice consists in water's being solidified, then to know that there is ice is to apprehend the *belonging* of solidity to (some) water.[13] And if this *belonging* is

[12] When I speak of "acquaintance," I do not mean to imply that the state in question must be simple or immediate, as acquaintance was taken to be by many early twentieth-century epistemologists and philosophers of perception. I am simply recommending that we think of the word "know" primarily as it figures in sentences like "Do you know my cousin Fred?" rather than as it figures in sentences like "Do you know that Fred is a soldier?"

[13] My treatment if this example is based on *APo*. II.12 95a16–18.

(causally) mediated by something (e.g., the absence of heat), then the middle term is part of the *belonging*, and someone who apprehends the middle term (and its role as a middle term) will better know that ice exists than does someone who knows only that some water is solidified without knowing why. Thus, to understand *why* ice exists is not to know something *else*, over and above ice's existence; it is just to know ice's existence better—i.e., to have a more precise knowledge of the solidity of (the relevant) water.

This sort of knowledge is *epistēmē*, and, by comparison with it, other manners in which we might know the same fact are superficial and approximate. For example, if one simply perceives ice visually or tactilely (or perhaps perceives water solidifying into ice), one is acquainted in a way with the water's solidity, but one remains ignorant of what its solidity is—namely an absence of heat. Knowledge that goes beyond mere perception, but does not yet qualify as *epistēmē*, is similarly superficial and approximate. In this class would belong the knowledge of the empiricist physicians who can predict the course of diseases and the results of various treatments, but who do not know what the diseases are, why they progress as they do, and why the treatments alter their courses. The same applies for the sort of (allegedly) causal knowledge possessed by scientists according to Humean empiricists, since this amounts to nothing more than the sort of cognition enjoyed by Aristotle's merely experienced people (or by empirical doctors).

This brings us back to the relation between Aristotle's position and the traditional divide between rationalism and empiricism. When we discussed this issue above, it was in connection with the epistemological interpretation of demonstration, according to which it justifies *epistēmē* on the basis of principles that are intuited. The contrary interpretation, which regarded demonstrations as explanatory, seemed a better fit for empiricism. But, there is more to the rationalist and empiricist traditions than their disagreement about whether there is a priori intuitive knowledge.

The empiricist tradition views reality—the reality we can know, at least—as being only skin deep. It consists of a succession of appearances, and our knowledge (even scientific knowledge) simply describes and predicts this succession (in law-like ways). Opposition to this view of reality and of knowledge has been central to rationalism since at least Plato. Indeed, much of the motivation for the belief in a priori intuition was that it is thought to explain the possibility of a more robust sort of knowledge that we seem to have in the case of mathematics and that we aspire to in the case of the natural world. This more robust knowledge reaches beyond appearances to include a grasp of *why* its objects are as they are.[14]

Aristotle shares the rationalists' conviction that our acquaintance with reality goes beyond appearances. In this respect, he is no empiricist. Our own difficulty in interpreting his view of *epistēmē* is largely a result of the way that the empiricist tradition has shaped our understanding of knowledge. Hume wrote that everything is "loose and separate … *conjoined* but never *connected*."[15] Though few modern

[14] On the role of such considerations in the motivation for Plato's theory of forms, see Salmieri (2008, §1.2.3).

[15] Hume, *Enquiry Concerning Human Understanding*, IV.2.

epistemologists and philosophers of science go so far as Hume, we all tend to think of a fact and its cause as discrete existents. This is why we think of understanding a fact by knowing its cause as a matter of knowing *another fact*, rather than as knowing the initial fact *better*. Aristotle takes the contrary view because he does not separate causes and effects in this manner. For him water's being solid *just is* its lacking heat. There is a single fact that can be apprehended either in a superficial and approximate manner or in a deep and exact one. Aristotle's way of thinking comes unnaturally to us, but it would have been quite natural to the pre-Humean thinkers, especially to those with a rationalist bent.[16] Spinoza, for example, argues that a clear idea of anything actually existing includes the ideas of its essence and cause (*Ethics*, Book I, axiom 4, and Book II, propositions 44–47).

Is Aristotle, then, a rationalist after all? The answer depends on his view of how we know the principles. Unlike the paradigm rationalists, Aristotle does not believe in innate knowledge. Rather, he thinks that *nous* develops from experience—ultimately from sense perception. But it is not clear how big a difference this is. After all, even Plato (in *Republic* VII, 521c-535a) describes a process that begins with sense perception and culminates in *epistēmē*. There is no tension here with Plato's rationalism, because the process is one of "turning the soul" away from perceptible objects and developing *nous*, a faculty whose exercise is not based on perceptual content in anything like the way a conclusion is based on its premises from which it was inferred. If Frede is right about Aristotle's view of *nous* and its development, then Aristotle's position is little different from Plato's (or Leibniz's or Spinoza's), and Frede is right to view him as a rationalist. Alternately, if Aristotle thinks that the process by which *nous* arises from perception and experience is one in which the perceptual knowledge serves as a foundation upon which the principles are justified, then his position is too different from both rationalism and empiricism to fall under either heading. It represents a distinctive account of knowledge according to which deep insight into the world can be founded on an initial perceptual acquaintance with it. Though I cannot argue for this interpretation here, I think strong evidence can be found for it in Book II of the *Posterior Analytics*, especially when considered in connection with Aristotle's practice in the scientific treatises.[17] Whether or not Aristotle should be credited with such an epistemology, I submit that it provides a more promising starting point for explaining the achievements of modern science than can the rationalist or empiricist traditions. Reflecting on Aristotle's view of *epistēmē* can sensitize us to

[16] Burnyeat attributes the distance between Aristotle's view of *epistēmē* and our views of knowledge and understanding to the focus on skepticism that developed after Aristotle's time. Surely, there is some truth to this claim, but views nearer to Aristotle's than our own on these issues can be found in the works of several early modern authors. Spinoza (cited below) is the most obvious example. But similar thoughts can be found in Leibniz and even in Locke.

[17] Some support for this interpretation can be found in Jim Lennox's contribution to this symposium. See also Gotthelf (2012a, b), Salmieri (2008), and Lennox (2011). Salmieri (2008) and Gotthelf (2012a) (along with much of the secondary literature cited therein) concern the evidence involved in the establishing and defining of kinds. Gotthelf (2012b) concerns Aristotle's scientific method more generally, and Lennox (2011) focuses on the norm-governed character of Aristotelian inquiry. For alternative views of how Aristotle reaches principles that also support this general interpretation, see Ferejohn (1991) and Bolton (2012).

some of the limitations of the contemporary epistemology that has descended from these traditions.

## Aristotle's theory of demonstration revisited

David Bronstein

In the first book of the *Posterior Analytics*, Aristotle presents his theory of demonstration (*apodeixis*). In doing so, he explains the relationship between demonstration and scientific knowledge (*epistêmê*).[18] He defines scientific knowledge as knowledge of the explanation and necessity of a fact. Demonstration is a special type of argument, or syllogism, by means of which a fact is proven necessary and its explanation is revealed. Demonstration, therefore, is constitutive of scientific knowledge: Having scientific knowledge consists in grasping a demonstration, and demonstration is the means by which a scientist expresses what she knows scientifically. Demonstration is also the means by which the body of facts that make up a science is organized. A science is a chain of interconnected demonstrations in which the highest ones have as their premises the first principles of the science (mainly definitions) and the lower ones include among their premises conclusions of demonstrations higher up. In short, Aristotle's theory of demonstration in *Posterior Analytics* I contains an account of the structure of science and the nature of scientific knowledge.

In a highly influential article first published more than 40 years ago, Jonathan Barnes (1975a, originally published in 1969) argued that there is more and less to Aristotle's theory of demonstration than has often been thought. There is more to it because in addition to describing the structure of science and the nature of scientific knowledge, the theory of demonstration also "offers a formal account of how an achieved body of knowledge should be presented and taught" (Barnes 1975a, 85). There is less to the theory because demonstration is not a tool for discovery or research: "The theory of demonstrative science was never meant to guide or formalise scientific research … it does not describe how scientists do, or ought to, *acquire* knowledge" (Barnes 1975a, 77).

[18] How best to translate *epistêmê* (and its verbal cognate *epistasthai*) is a matter of scholarly controversy. Barnes (1994) opts for "understanding," a decision defended by Burnyeat (1981). For cogent criticisms of Burnyeat's view, see Gregory Salmieri's contribution to this symposium (see also Bronstein 2010, 122). I have opted for "scientific knowledge" in order to bring out the fact that *epistêmê* is a special type of knowledge (*gnôsis*), the type characteristically possessed by scientists. For it is scientists who characteristically meet the requirements for possessing *epistêmê* (which requirements I discuss below). I argue below that it is possible to have knowledge (*gnôsis*) of a set of facts that admit of scientific knowledge (*epistêmê*) without having scientific knowledge of them and that progress in science can be made by advancing from non-scientific to scientific knowledge of such facts.

[19] See Burnyeat (1981, 116), McKirahan (1992, 233), Mendell (1998, 197), Sorabji (1980, 194), and Wians (1989). On the other hand, Barnes' positive, teaching thesis has not gained wide acceptance. See Burnyeat (1981, 115–120), Ferejohn (1991, 141), and Wians (1989). Barnes himself offers a partial retraction in 1994, xviii–ix.

Barnes' second, negative thesis is now widely accepted.[19] And for good reason, it seems to rescue the theory of demonstration from the attacks of the *Posterior Analytics*' modern foes, who, in turn, took themselves to be rejecting the views of its scholastic friends. Modern foes such as Francis Bacon understood the theory—especially in its scholastic incarnations—as outlining a method of scientific discovery. As such, they saw it as a major obstacle to scientific progress. In the *Novum Organum* Bacon writes: "Bad demonstrations are the defences and fortresses of the idols; and the demonstrations which we have in dialectic do no more than addict and enslave the world wholly to human thoughts and thoughts to words" (Bacon 2000 [I 69]). He continues: "The method of discovery and proof, which first sets up the most general principles, and then compares and tests the intermediate axioms by the general principles, is the mother of errors and the annihilation of all the sciences"[20] (Bacon 2000 [I 69]). Bacon's argument is a powerful one. The idea that from his prior knowledge that (1) all Bs are A and (2) all Cs are B, a scientist discovers, if (1) and (2) meet a strict set of requirements, that and why (3) all Cs are A is a silly scholastic fantasy, which should be discarded along with the Aristotelian theory from which it derived—or so the *Analytics*' modern foes argued.

As a matter of historical fact, it is doubtful whether any serious scholastic ever subscribed to the fantasy.[21] Nonetheless, Bacon's attack stuck. Writing in 1961 G.E. M. Anscombe called *Posterior Analytics* I Aristotle's "worst book" (Anscombe and Geach 1961, 6), and we can imagine that she was not alone in thinking this. Barnes' view, therefore, is attractive, for he shows us that we can be modern friends of the *Posterior Analytics* if we reject the assumption shared by its modern foes and (allegedly) its scholastic friends alike: the assumption that demonstration is a tool for scientific research and that it is one of the means by which scientists learn.

My aim in this essay is to argue for a different way of being a modern friend of the *Posterior Analytics*. The theory of demonstration *does* describe how scientists make (some of their) discoveries, but not in the way Barnes envisaged when he rejected this view. My strategy will be to try to explain the meaning of a key phrase in the *Posterior Analytics*: "learning by demonstration" (*APo*. I.18 81a39–40, *Metaphysics* I.9 992b30–33). Aristotle's use of the phrase suggests that he takes demonstration—at least in some sense and in some cases—to be a way of gaining new knowledge, not merely a way of exhibiting or imparting old knowledge. I will argue that it is expert scientists in particular who learn by demonstration. This approach, I will argue, is more faithful to Aristotle's text—and hence more friendly to it.

[20] Bacon was attacking the views contained in the late-sixteenth-century handbooks of dialectic that he would have read as a student at Cambridge. He was only indirectly attacking the *Posterior Analytics*, which he may never have read. See Jardine (1974, 84).

[21] Scholastics in the late Medieval and Renaissance periods developed the Aristotelian theory of demonstration in subtle and interesting ways (see Jardine 1974; Longeway 2007; Randall 1940). Zabarella's method of *regressus*, for example, presents demonstration as a tool for scientific research and discovery, but his account is much more sophisticated than the caricature in Bacon's attack.

*APo. I.2 on scientific knowledge (epistêmê) and demonstration (apodeixis)*

*APo*. I.2 contains Aristotle's most developed discussion of the nature of scientific knowledge. He defines it as follows:

**T1** We think that we have scientific knowledge (*epistasthai*) of each thing without qualification (*haplôs*), and not in the sophistic sense accidentally, whenever we think that we know (*ginôskein*) the explanation (*aitian*)[22] because of which the object (*to pragma*) exists, that it is the explanation of that thing, and that this [thing] cannot be otherwise.[23] (71b9–12)

To have scientific knowledge of *x* is to know that *y*, the explanation (or cause) of *x*, *is* the explanation of *x* and that *x* is necessary. Focusing on the first part of the definition, we can say that to have scientific knowledge of *x* is to know *x*'s explanation *as* its explanation, or—what amounts to the same thing—to know *x as* explained by that which explains it.

Aristotle's claim that scientific knowledge is knowledge of the explanation *as* the explanation entails at least two different ways in which one can fail to have scientific knowledge. First, one fails to have scientific knowledge of *x* when one thinks that its explanation is something other than it is. Second, and more interestingly, one fails to have scientific knowledge of *x* when one knows what is in fact *x*'s explanation without knowing it *as* its explanation (see Kosman 1973, 383–384). That this is possible is clear from Aristotle's discussion in *APo*. I.13 (see also II.16) of two syllogisms, one "of the fact that" (A) and another "of the reason why" (B).[24]

| (A) | (B) |
|---|---|
| The planets do not twinkle. | The planets are near. |
| What does not twinkle is near. | What is near does not twinkle. |
| Therefore, the planets are near. | Therefore, the planets do not twinkle. |

(A) is "of the fact that" (*to hoti*) and (B) is "of the reason why" (*to dihoti*) because the nearness of the planets explains their non-twinkling and not vice versa. The person who grasps only syllogism (A) knows the fact that the planets do not twinkle and the fact that they are near, but she fails to connect these facts in such a way that the real explanatory relation between them is revealed to her. That is, she knows what is in fact the explanation of the planets' non-twinkling (their being near) without knowing it *as* the explanation. It follows that, for Aristotle, it is possible to know a set of facts (including at least some of the non-explanatory inferential relations among them) that *are* explanatorily connected without knowing them *as* explanatorily connected. That

[22] *Aitia* may also be translated "cause." I follow Barnes in adopting "explanation," but we should hear this as shorthand for "causal explanation": the explanation that gives the real cause of the explanandum. For a discussion of Aristotle's theory of explanation and its metaphysical underpinnings, see David Charles' contribution to this symposium.

[23] Translations are my own, although I draw on Barnes (1994).

[24] For further discussion of the two syllogisms, see James Lennox's contribution to this symposium.

is, it is possible to *know* a set of facts without having *scientific knowledge* of them. This is the situation of the person who grasps only syllogism (A). She knows *x* and *y*, where *y* is the explanation of *x* and *x* is explained by *y*, but she does not know *x* or *y as such*—so she does not have *scientific knowledge* of *x*.

Aristotle's discussion of the two syllogisms makes it clear that syllogism (A) is not an example of what philosophers of science call "inference to the best explanation," despite the fact that the conclusion states (what turns out to be) the explanation of a fact stated in the premises. The reason has to do with the cognitive state of the person who grasps (A): She does not succeed in grasping the conclusion as explanatory of any fact stated in the premises. If she did succeed, then she would grasp not only (A) but also (B), and her knowledge would be not merely of "the fact that" but also of "the reason why." But in (B) the explanation is stated in the premises, not in the conclusion, so it too is not an example of inference to the best explanation. For Aristotle, demonstrations represent inferences *from* the best explanation, not inferences *to* them.

Explanation and necessity are the essential ingredients of scientific knowledge; they are also essential to demonstration:

**T2** We say that we have scientific knowledge through demonstration (*di' apodeixeôs*). By "demonstration" I mean a scientific syllogism (*sullogismon epistêmonikon*), and by "scientific" I mean that in virtue of which, by means of having it, we know scientifically. So then if scientific knowledge is the sort of thing we have posited [it to be], it is also necessary that demonstrative scientific knowledge be from things that are true, primary, immediate, better known than, prior to, and explanatory of the conclusion; for in this way too the principles (*archai*) will be appropriate to the thing proven. For there will be a syllogism even without these things, but there will not be a demonstration; for it will not produce (*poiêsei*) scientific knowledge. (*APo*. I.2 71b17–25)

Given that scientific knowledge is of the explanation and necessity of a fact, and given that one has scientific knowledge in virtue of grasping a demonstration, a demonstration must perform two functions: It must prove that the relevant fact (stated in the conclusion) is necessary and it must make clear or reveal its explanation (stated in the premises). It is important to see that, as I noted above, a demonstration reveals the explanation without deducing it as a conclusion. The conclusion of a demonstration is not the explanation but the fact to be explained (the explanandum). It is the premises—and in particular the middle term—that contain the explanation. For Aristotle, in virtue of grasping a demonstration, one has scientific knowledge of the explanation of a fact *as* its explanation. The explanation is revealed *as* the explanation over the demonstration as a whole.

### *Against learning by demonstration by expert scientists*

With this account of scientific knowledge and demonstration in place, we can now turn to the topic of learning by demonstration. Let us begin with a Barnes-style argument purporting to show that expert scientists cannot learn in this way. Two considerations seem to force us to this conclusion. The first is Aristotle's view that

demonstration requires prior knowledge of its premises or principles (*archai*). The expert scientist surely possesses this knowledge, for this is the mark of scientific expertise. The second consideration is taken from one of the most important principles of Aristotle's account of scientific inquiry: We know the facts to be explained before we know their explanations; indeed, prior knowledge of the explanandum (*to hoti*) is a necessary condition for seeking the explanans (*to dihoti*) (see, e.g., *APr* I.30 46a17–27, *APo*. II.1–2, *de An* I.1 402a13–15, 402b16–403a2, *HA* I.6 491a7–14 with Lennox 1987). Since the conclusion of a demonstration is an explanandum and its premises supply the explanans, it follows that by the time the expert scientist is set to demonstrate she will already know both the fact that the demonstration proves (as its conclusion) and the explanatory premises that prove it. And since it is commonly (and crucially) assumed that learning by demonstration would be—if it were possible—a method for coming to know new conclusions from known premises,[25] it follows that the expert scientist cannot learn by demonstration, for she already knows the very thing the demonstration would teach her. In short, learning by demonstration, if it were possible, would proceed from known premises to new conclusions. But Aristotelian learning proceeds from known conclusions to new premises. Therefore, learning by demonstration is not Aristotelian learning.

I will now argue that experts can learn by demonstration, and then I will explain how.

### *In defense of learning by demonstration by expert scientists*

In T2 Aristotle says that we have scientific knowledge in virtue of grasping a demonstration. He also says that demonstration *produces* or *causes* (*poiêsei*) scientific knowledge. How are we to take this second claim? Barnes and other modern friends of the *Analytics* who deny that scientists learn (i.e., acquire scientific knowledge) by demonstration must take Aristotle to be saying that demonstration is the means by which the scientist expresses or actualizes a piece of scientific knowledge she already possesses and previously acquired by non-demonstrative means. However, a more natural reading is that demonstration is a way of acquiring scientific knowledge in the first place. To be sure, demonstration is also the means by which a scientist expresses her old scientific knowledge. But if it were not also a way of acquiring new scientific knowledge, then Aristotle should not have said that it *produces* scientific knowledge. Recall too that Aristotle uses the expression "learning by demonstration." It is natural to think that learning by demonstration is the process in which demonstration produces new scientific knowledge.

Barnes might respond that when Aristotle speaks of demonstration as productive of scientific knowledge, he *does* have learning by demonstration in mind, except that the learning is accomplished by a student of a science, not an expert. That is, Barnes might claim that demonstration is expressive of old scientific knowledge in scientists and productive of new scientific knowledge in students.

[25] This is the second of the two possibilities Barnes considers for how demonstration might be a tool for scientific research. (Barnes 1975a, 84–85. See also Burnyeat 1981, 116–117; Wians 1989, 48–49).

However, Aristotle's claim in T2 that demonstration produces scientific knowledge cannot be taken in this way. The reason is this. In *APo*. I.2 Aristotle says that a requirement for (demonstrative) scientific knowledge is that one finds the premises or principles of one's demonstration more convincing than its conclusion (72a25–37; see also *EN* VI.3 1139b33–5)—in fact, one must find the principles most convincing of all (72a37–72b4). So the person in whom demonstration produces new scientific knowledge must already be thoroughly convinced of the principles. But this describes the cognitive state of the scientist, not the student, for it is the scientist who has made what is better known and more convincing by nature (the principles) better known and more convincing to her, and it is the student who is on her way to this condition (*Metaph* VII.3 1029b1–8, *Topics* VI.4 142a9–11). So T1 and T2 must be describing the epistemic state of the working scientist, not the state of a student being taught by one. I conclude, then, that when Aristotle says that demonstration produces scientific knowledge, he means that it produces new scientific knowledge in the expert scientist. Scientists learn by demonstration.

*What is learning by demonstration?*

We are now in a position to see what Aristotle means by learning by demonstration. Recall two claims I argued for above: (1) It is possible to know a set of facts that are explanatorily connected to each other without knowing them as such (i.e., without having scientific knowledge of them) and (2) demonstration reveals the explanation, not by deducing it as a conclusion, but by exhibiting it as the syllogism's middle term in such a way that the explanatory relation among the syllogism's three terms is revealed. On my account, (1) roughly describes the epistemic state of the scientist prior to the occasion of her learning, and (2) roughly describes how her learning comes about. As we saw above, (1) entails that, prior to learning, a scientist can know a fact, which will turn out to be the conclusion of her demonstration, without knowing it *as* explained by what will turn out to be the demonstration's premises, which she also knows, or—what is the same thing—she can know the demonstration's premises without knowing them *as* explanatory of its conclusion, which she also knows.

Learning by demonstration, I suggest, does not consist in deducing a new conclusion from known premises. Rather, it consists in discovering a previously unknown explanatory connection among facts the scientist already knows but not scientifically. Prior to learning, she knows $x$ and $y$, where $y$ is the explanation of $x$ and $x$ is explained by $y$, but she does not know $x$ or $y$ as such. She learns by demonstration when she apprehends $y$ as explanatory of $x$, or—what is the same thing—$x$ as explained by $y$. As a result of her learning, she now has scientific knowledge of $x$, which she previously knew only non-scientifically. Learning by demonstration, then, effects not so much the change from ignorance to knowledge as the change from non-scientific to scientific knowledge (see Burnyeat 1981, 115–120, who makes a very similar point about how students (but not experts) learn). And this is possible because of the way in which a demonstration carries out its explanatory function: by revealing, without deducing, the explanation *as* the explanation. While it is true that the expert scientist cannot learn by demonstration

what she already knows scientifically, she can learn by demonstration what she already knows non-scientifically (see *APo*. I.1 71b7–8).

Recall once again the two syllogisms of *APo*. I.13. As we saw above, I can know that the planets are near and that they do not twinkle and that what does not twinkle is near. But so long as I do not connect these facts in such a way that the actual explanatory relation among them is revealed to me, I will fail to have scientific knowledge of the planets' non-twinkling. This failure is one of the conditions for the possibility of learning by demonstration. Since I know the three facts, but do not know their explanatory relation, I am in a position to acquire knowledge of their relation—that is, scientific knowledge—as captured in syllogism (B) (see Lennox 1987, 1991). Demonstration is productive of new scientific knowledge because scientific knowledge is of the explanation *as* the explanation and this is what demonstration reveals.

Learning by demonstration differs from another type of scientific discovery (discussed at length in *APo*. II) in which an inquirer who knows that some fact is the case seeks and discovers the middle term that explains why it is the case. This differs from learning by demonstration because the inquirer does not find the explanation among the explanatory first principles she already knows. For she does not yet know first principles; she is an inquirer, not yet an expert scientist. This is why Aristotle does not call this type of learning "learning by demonstration": The inquirer lacks the requisite prior knowledge of the principles.

Above I argued that the two syllogisms in *APo*. I.13 are not examples of inference to the best explanation. The same holds in general for the reasoning by which one discovers the explanation, in either of the two ways I just discussed. In inferences to the best explanation, the facts that are to be explained and that are stated in the premises provide support or justification for the fact that does the explaining and that is stated in the conclusion: Given facts $x$ and $y$, since $z$ is the best explanation, infer the truth of $z$. For Aristotle, this may represent the order of discovery, but it does not represent the order of justification. For it is always the explanans that provides justification for the truth of the explananda.

## *Conclusion*

I have argued that in Aristotle's view an expert scientist can learn by demonstration. She does so not in the way the *Posterior Analytics*' modern foes and friends envisaged—syllogistically deducing new conclusions from known premises—but by apprehending an explanatory connection among facts she already knows. In the end, however, this much of the modern foes' and friends' account holds true: Aristotle's theory of demonstration does not set out a method of scientific discovery—that is, a set of rules or recommendations a scientist should follow in order to make discoveries. Rather, the theory of demonstration gives us, in part, a faithful description of the culminating moment of the successful application of such a method. Looking at the theory of demonstration does not tell us much about how an

[26] Many thanks to Jim Lennox for helpful comments on a previous draft of this paper, and to David Bloch, John Longeway, and Bernardo Mota for help in discussion of medieval theories of demonstration.

Aristotelian scientist should go about inquiring and learning, but it does tell us about what happens when she makes a (certain kind of) discovery, when she learns (in a certain way). Aristotle's remarks on inquiry come later in the *Posterior Analytics*, beginning especially in Book II. If the central character of Book I is the expert scientist, then that of Book II is the researcher, the inquirer. In this paper I have sought to show that even the expert of Book I may have something to learn and that she can do so by means of demonstration.[26]

## Aristotle: definition, explanation, and essence

David Charles

My aim in this essay is to outline Aristotle's approach to definition and explanation in *Posterior Analytics* II and to consider one aspect of its philosophical significance.

### *Some questions in the Analytics*

Near the beginning of *APo.*, Aristotle writes:

> In all these cases, it is clear that what it is and why it is are the same. What is an eclipse? Privation of the light from the moon by the screening of the earth? Why is there an eclipse? Or why is the moon eclipsed? Because the light leaves it when the earth screens it. What is harmony? An arithmetical ratio of high and low. Why does the high harmonise with the low? Because there is an arithmetical ratio between them. (*APo.* II.2, 90a14ff)

Later, in a key chapter on definition, he returns to this theme with another example:

> "Why does it thunder?" Because the fire is extinguished in the clouds. But "What is thunder?" Noise of fire being extinguished in the clouds. Hence the same account is used in different ways: in one way as a continuous demonstration, in the other a definition. (*APo.* II.10, 94a4ff).

In this passage, Aristotle considers two questions:

(1) What is thunder?, and
(2) Why does it thunder?
His answer to question (1) is:
Noise [A] in the clouds [C] brought on by the fire being extinguished [B].[27]

A full specification of *definiens* and *definiendum* would be:

[27] "[A]," "[B]," and "[C]" stand for terms used in the definition or demonstration.

[28] In this essay, I am concerned with individual members of those kinds.

> Thunder is the type of noise in the clouds that is brought on by fire being extinguished.[28]

Aristotle reformulates question (2) to obtain the right *explananda,* replacing "thunder" with "noise in the clouds." His question is:

> (2)* Why does noise [A] occur in the clouds [C]?
>
> to which his answer is:
>
> because fire is extinguished [B].

A full specification of *explanandum* and *explanans* runs as follows:

> A certain type of noise in the clouds occurs because fire is extinguished where "a certain type of noise" refers to a determinate type of noise (yet to be fully specified).

Aristotle, in considering this structure, explicitly identifies the cause (e.g., fire being quenched in the clouds), marked out by the middle term, with the essence (90a1, 90a15, 93b8). The cause is that which makes the phenomenon the one it is (its basic essence).[29] This is a basic and controlling thought in his discussion of definition and explanation in *Posterior Analytics* II. To assess it, we need to grasp (a) why Aristotle identified the basic essence with the cause, the starting point of the relevant causal explanation, and (b) how he conceived of the feature which was to be both the essence and the fundamental cause. Consideration of these issues reveals his understanding of essences and forms, basic elements in his ontology.

## *The interdependence of definition and explanation (demonstration) in the Analytics*

### *[A] The order of definitional priority rests on the order of causal priority*

Aristotle offers two syllogisms in *APo.* II.8 to illustrate the connection between the practice of definition and of demonstration. I shall focus on his discussion of eclipse:

[E.1] Being eclipsed belongs to all cases of being screened by the earth
Being screened belongs to the moon (or to all moons of kind K)
Being eclipsed belongs to the moon (all moons of kind K). (93a30-31)

In [E.1] the middle term ("being screened") specifies the efficient cause of an eclipse of the moon. This syllogism captures the fact that being screened by the earth is causally more basic than the occurrence of the eclipse (or light failing).[30] On the basis of [E.1], we can grasp which feature is definitionally prior: the one that is

[29] Aristotle elsewhere uses the phrase "What it is to be the thing" (*to ti en einai*) to refer to the entity referred to as the basic cause by the middle term in the demonstrative syllogism: see *Metaphysics* Z.17, 1041a28–31, *De Anima* 430b28, *APo.* 93a18–20. This usage should be distinguished from another in which specifying what a thing is involves both the basic causal term and what is explained by it (see 94a5). In this essay, I shall use the phrase "basic essence" to refer to the basic cause, marked out by the relevant middle term.

[30] In this essay, I use interchangeably as translations for "*aition*" cause, causal explanation, and explanation. The term refers to grounds as well as causes.

prior in the order of efficient causation. Screening, or quenching of fire, is the start of a causal process which culminates in the relevant result.

It is important to note that in Aristotle's account it is not merely that we *know* that certain features are definitionally prior because they are causally prior (II.8, 93a3–5). Rather, as he emphasizes in I.2, 71b31,

> things are prior (i.e. by nature) since they are causes.

The order of definitional priority is metaphysically dependent on the order of causation. Fire being quenched is definitionally prior to noise in the clouds because it is causally prior as the efficient cause. *What it is to be thunder* (as captured in the definition) and the basic relevant cause are one and the same. Our practice of definition rests on that of causal explanation because the basic essence is identical with the basic cause. Why is this so?

In Aristotle's picture, if one traces the relevant causal line back from the effect, one will find *one* feature (*the* cause) that explains why (in the case of thunder) noise occurs in the clouds. This feature will also explain why each case of thunder possesses its other necessary properties: Why it is accompanied by lightning (for example), why it is noisy, etc. The presence of these latter properties is explained because fire, when quenched, produces noise and flashes of light. There is *one* efficient cause that accounts for the presence of the other necessary properties of thunder. Each case of thunder is one unified phenomenon because there is *one* common (efficient) cause that explains the presence of its necessary properties. Since the essence of thunder is what underwrites the unity of each case of thunder (by making each one unified thing), Aristotle identifies it with the basic cause. It is the presence of this causally basic feature that grounds the unity of the individual object, or process, in question.

In Aristotle's model, certain features are definitionally basic because they are causally prior. But are essences, for Aristotle, simply the starting points of causal explanation? There are reasons to doubt that this was his considered view.

*[B] Explanation and definition: a more complex story*

In *APo.* II.11, Aristotle discusses the possibility that there are both efficient and teleological explanations of the occurrence of thunder (94b31–34) as there are for a variety of other natural phenomena (94b35–37). However, only one of these causes is, in his view, the essence of the kind or feature in question: *What it is to be the kind or feature itself.* Why does one (and only one) of them play the definitional role of accounting for the unity of the phenomenon in question. There has, it seems, to be some further factor at work which makes one (and only one) of these causally basic features definitionally basic. What is it?

Consider Aristotle's example of a house: Both the efficient cause (the art of house building) and the teleological cause (provider of safety for goods, etc.) appear specific enough to account for the relevant necessary features of a house. Why is it that the teleological and not the efficient cause which makes a house the unified object it is?

In Aristotle's account, if the efficient cause is the art of house building, the builder's actions will be guided by his idea of a house and what houses are for (the relevant teleological goal): providing security and protection for the occupier and his/her goods. The art of house building is the art it is because it aims at constructing houses with these goals. By contrast, the teleological goal is definitionally prior both

to the art of house building and to the house constructed because it makes both the art and the house the type of things they are. There is, it seems, a definitional order in which the teleological cause is prior both to the house and to the efficient cause.

What principles govern definitional order? In the case of the house, the teleological causal starting point meets the following condition:

> [I] It is what it is it independently of the other causal features (the efficient cause in the case of the house) while other elements in the causal story (such as the efficient cause) are defined in terms of it.

In the definitional order: (1) the goal: securing the safety of oneself and one's belongings, (2) a house, and (3) the art of house building; (1) is definitionally prior to (2) and (3) because what it is to be a house and what it is to be the art of house building are both defined in terms of the teleological goal. The definitional order captures the order of metaphysical priority: The goal is what makes a house and an art the ones they are. It makes them the objects and the craft they are.

Consider an attempt to reverse Aristotle's definitional order and begin with the efficient cause. Since this cannot now be defined as the goal-directed art of house building, it has to be defined in terms of, e.g., certain movements of hands and implements. The resulting building will, in consequence, be defined (simply) as the product of these hand (and implement) movements, one which happens (non-essentially) to play a teleological role as the protector of goods and people.

However, this model comes under immediate pressure. Which movements are definitionally basic? The builder's actual bodily movements cannot be the ones: For these could have been somewhat different (e.g., if he had needed to find different ways to achieve his goal) and the result still been a house (indeed the very same house). The relevant movements, it seems, have to be the ones directed by the builder's skill with the aim of achieving his (or her) goal. And at this point one has, as Aristotle predicted, to refer to the goal itself to fix the identity of the efficient cause.

There is a further condition that essences must satisfy: They are what makes particular houses the unified objects they are. But what makes something to continue to exist as a unified object (a house) must be something that exists (and continues to exist) as long as that object exists. Its continued actual presence is what makes a particular house the object it is. The efficient cause cannot play this role. Even if it causes the coming into being of this house, it is no longer actually present to account for its continued existence. By contrast, the continued existence of a house (as the object it is) can be understood in teleological terms as what is capable of providing safety for goods and people. It is because the object in question continues to be capable of achieving this goal that it continues to be this object. Its continued goal directedness fixes its continued identity as the object it is. Remove that goal and one has a different object. The house has fallen apart, and one has a pile of bricks or a roofless ruin. This is why the goal, rather than the efficient cause, determines what it is to be a house.

This point can be generalized: A causal starting point is definitionally prior only if

(II) presence grounds the continued existence of the particular objects to be defined.

(I) and (II) are both necessary conditions for a feature being definitionally prior over and above its being causally basic in some order of causal explanation. While definitional priority requires the item in question to be prior in some causal order, being definitionally prior does not rest solely on causal priority. When a causally basic factor also meets conditions [I] and [II], it is the (basic) essence of the house in question.

*Two aspects of Aristotle's account*

The (basic) essence, in Aristotle's account, simultaneously defines what it is to be a house (and so grounds the unity of particular houses) and explains why houses are as they are: Why they possess those properties they must have to be a house. The requirement that there is one feature which plays both these roles is of central importance for his account of definition and of explanation in the *Analytics* and beyond. It is important to note two of its consequences.

*[A] Definition*

In Aristotle's account, there is one feature which (a) explains why individual members of a kind (qua members of that kind) must have certain features and (b) grounds their unity as the objects they are (accounting for their continued existence as those very objects). Aristotle claims that his account makes the kind and its members thoroughly known to us (see II.3, 90b16, *Topics* Z.4, 141a27ff). We can now see why this is so: Individual members of a kind cannot lack the necessary properties they have qua members of a kind because these are explained by the presence of a feature that makes the objects in question the ones they are.

In Aristotle's example of thunder, being noise in the clouds is a necessary property of any case of thunder because it is the efficient causal consequence of fire being quenched (in the clouds), the common cause that makes each case of thunder the very phenomenon it is. There is, to generalize, one cause whose presence simultaneously makes the objects in question the ones they are and explains their possession of the distinctive necessary properties of the kind to which they belong. This is why they could not be those very objects without these properties being present. For the only way in which the latter could fail to be present would be as a result of the absence of that feature that makes them the objects they are.

*[B] Explanation*

Aristotle's suggestion that there is one feature which fixes the identity of members of a kind and explains their necessary properties is central for his account of demonstration (ideal explanation).

Consider his claim that there cannot be demonstrative explanatory chains of infinite length (*APo.* I.19, 82a8).[31] He argues for this as follows: If there were such chains, one could not arrive at knowledge of what the kinds are or of their definitions (I.22, 82b37–83a1). This argument, at first sight, appears weak. What

[31] I am indebted at this point to discussion with Henry Mendell.

prevents there being explanations of infinite length which do not begin with definitions? Why does definition play a central role in the practice of demonstration?

The argument of the previous section provides an answer. Demonstrations, as Aristotle conceives them, must begin with statements concerning the essences of the kinds in question. This is a constraint on what demonstrating is: To demonstrate is to give an argument which begins with a statement about the causally basic (non-demonstrable) feature invoked to answer the "What is F?" question. If demonstrations are to make the kind (and the objects that comprise it) fully intelligible to us, they must begin with definitions that reveal the relevant essences. The practice of demonstration is constrained (in his account) by considerations that flow from the practice of definition. One might call this form of explanation "structural causal explanation." Such explanations must take as their starting point basic essences that simultaneously fix the identity of members of a kind and explain their necessary properties.

Aristotelian enquirers, in seeking an explanation of this type, are governed by their search for essences. When they ask such questions as:

> Why do broad-leaved trees—not any old object but broad-leaved trees—behave in a given way? (98b36–38)
>
> or
>
> What is it in the nature of broad-leaved trees as such which explain why they react in this way in certain conditions?

they are looking for answers that point to distinctive features of broad-leaved trees, which they could not lack while being the objects they are, ones which constitute the essence (or nature) of these trees.[32] Thus, in grasping the relevant essence, we come to understand why the particular tree in question could not lack its distinctive necessary features, while remaining the object it is. For the feature grasped is (i) explanatorily basic and (ii) what fixes the identity of the object in question. It simultaneously determines the filling of the two asterisked positions in the sentence:

> This is an instance of a tree of kind * which must act in way S*.

In grasping which feature plays this role, Aristotelian enquirers gain a thoroughly perspicuous explanation of the kind and its distinctive activities (and features).

In sum: when we seek, in Aristotle's account, to answer the "What is G?" question, we aim to find that which makes a G what it is: G's basic essence. To be a basic essence (or underlying nature) is to be the one feature that *both* fixes the

[32] Aristotle is committed to the idea that the object in question is essentially a "this such," one which needs its suchness to be and to persist as the object it is. Its suchness is what makes the object in question the persisting unity it has to be to that very object. (This is not equivalent to the claim that its essence is what marks the object out as different from other objects of the same species.) There may be quite different answers to the questions:

[1] "What makes this the unified particular it is?

and

[2] 'What makes this unified particular different from all other particulars of the same species?"

identity of cases of thunder a*nd* explains thunder's necessary properties. Aristotle's account of both explanation and definition is governed by the search for essences of this type. His ideas of good definition and good explanation themselves rest on the explanatorily rich and more basic idea of essence just outlined. He is, in effect, offering an essence-first account both of definition and of the relevant type of explanation.

*Two misunderstandings of Aristotles essentialism*

Aristotle, in identifying the answers to the "What is F?" and "Why is F as it is?" questions, rejects two important claims:

(1) that definitional questions can be satisfactorily answered without drawing on resources taken from scientific explanation and
(2) that explanatory questions can be satisfactorily resolved without drawing on resources taken from our definitional practices.

It is a major paradox that Aristotelian essentialism has often been characterized, by friends and foes alike, precisely as the acceptance of one or other of these rejected claims. Here are two examples.

(1) Popper (1952, vol. 2, 12) once suggested that the "aim of all inquiry (for Aristotle) is the compilation of an encyclopaedia containing intuitive definitions of all essences." So understood, Aristotle's definitional concerns stand in the way of scientific progress. In a similar vein, Quine (1966, 174) once spoke of "the metaphysical jungles of Aristotelian essentialism" a landscape cut off from, indeed standing in the way of, science. Popper is the more explicit: He suggested that "Aristotle held that… we possess a faculty, intellectual intuition, by which we can visualise essences and find out which definition is the correct one…." For these writers, definitional questions are (for Aristotle) to be resolved in ways independent of our scientific explanatory practices. Popper and Quine (and many others) find this unacceptable, taking scientific explanation as the proper route to knowledge (in the relevant areas).

Aristotle, however, rejects all versions of essentialism which rest on the assumption that it is possible to answer definitional questions, and so find out what is essential, without relying on information drawn from our practices of scientific explanation. In the *Analytics*, a good definition, as we have seen, is one that captures the nature (or essence) of the phenomenon to be defined, the feature that causes it to have certain derived necessary features. We grasp something as the nature of the phenomenon in question only when we see it as playing a causal role of this type: as the required causally basic factor.

Aristotle's explanation-based account of definition (as developed in the *Analytics*) involves an epistemological route to knowledge of essences fundamentally different from the one Popper envisaged (and rejected). For Aristotle, part of what it is to be an essence is to be that feature that causally determines the necessary properties of the phenomenon in question. If the goal of good scientific practice is to find essences of this type, they cannot represent the impediments to scientific progress which Quine feared. There is clearly no need to call in the "logging

companies" to cut down the forests of Aristotelian essentialism (even if we are right to reject some of his teleologically based views of certain essences).

(2) Some recent essentialists (see Ellis 2001) have taken essences simply as scientifically basic features, the starting points of scientific explanation. In their view, we should begin with an account of adequate explanation (without resting on the idea of nature or essence as what fixes the identity of the kind) and then label the starting points of such explanation as "essences." Indeed, some take this to be a form of Aristotelian essentialism.

From Aristotle's viewpoint, however, while one may be able to account in the way just proposed for, e.g., thunder's possession of certain properties (in this and close possible worlds), one will not be able to show why all particular cases of thunder *must* have such properties if they are to exist at all. Without a satisfactory answer to this challenge, one will not be able, by focusing on essence-free explanation alone, to generate essentialist claims about thunder. Aristotle, by contrast, proceeded from a different starting point, taking as basic an essence-involving form of explanation. In his view, questions such as

Why is it that *elms* as such—not any old trees but elms—shed their leaves?

require answers that appeal to the natures, or essences, of the elms one encounters. For he is asking what it is about these trees—as the ones they are—which accounts for their shedding their leaves, seeking a feature that they cannot lack (while being the objects they are) which accounts for their deciduousness. His idea of what is explanatorily basic rests on the thought that these very trees have distinctive natures (or essences) which make them the objects they are.

For contemporary "scientific essentialists," by contrast, once explanation has been separated from definition, it is we who choose to regard explanatorily basic features as constituting the essence of members of a kind. Our choice, of course, is not an arbitrary one, since we may reasonably wish to have definitions that refer to explanatorily basic features. But, nonetheless, it is we who convert explanatorily basic features into essential ones. For Aristotle, by contrast, essences are required as part of the causal order of the world to ground satisfactory causal explanations of why elms, those very trees, *as such* behave as they do.

There is a further, more specific, point of contrast: In Aristotle's view, the essence of the elm must be (a) specific to the type of substance in question, (b) something that is actually present throughout the continued existence of any particular elm (as the ground of its existence as one unified object), and (c) the cause of the actual presence of the other necessary properties of that individual. However, some scientific essentialists have sought to identify Aristotelian essences with dispositions to behave (or act) in certain ways in certain conditions. In one version of this account, to be an elm is simply to be disposed (*inter alia*) to shed leaves at certain times of the year, and to be an axe is to be disposed to cut wood in certain conditions. So understood, to be an axe is just to be potentially a cutter of wood, and to be an elm is to be potentially a leaf shedder. Nothing more is required to ground the relevant disposition (or potentiality). In this pure dispositionalist account, it is barely true that if the axe were used in a given way in certain conditions, it would cut wood.

However, the dispositionalist proposal, so formulated, does not capture Aristotle's idea of what it is to be an elm or an axe. An axe is always actually an axe (as long as it actually exists). But, under Aristotle's condition (b), what grounds the continued existence of something actual must be something actual. An actual power, present as long as the axe exists, is needed to ground the actual existence over time of the axe. While axes are, of course, disposed to cut wood in certain conditions, this pure dispositional property is, in Aristotle's view, the consequence of their power to cut wood; it does not constitute it. His essentialism rests on an ontology not of bare dispositions but of powers.[33]

What supports this understanding of condition (b)? Essences, under condition (c), actually cause the continued presence of other necessary features of the axe. As such, they have to be present as actual causes for as long as the axe (in question) survives. But the disposition to cut wood (understood as in the pure dispositional account) can only be an actual cause when it is realized (and wood is cut). Pure dispositions are, at best, potential causes, which only produce actual results when actualized. Since the cause has to be actual to be the cause of the continued presence of the axe's other necessary features, the essence (as a cause) cannot be identified with the pure disposition to cut wood in certain conditions. By contrast, the power to cut wood is actually present for as long as the axe survives, explaining (as the relevant teleological cause) its other features: its continued shape, strength, material constitution, etc. Indeed, the relevant power may need to be defined in matter-involving ways to play this role (for further discussion, see Peramatzis 2011).

Aristotle's views on the interconnections between essence and causal explanation are distinctive and philosophically interesting. The assessment of their important consequences remains a major task for metaphysicians, epistemologists, and philosophers of science alike.[34]

## Preparing for demonstration: Aristotle on problems

James G. Lennox

Aristotle's discussion of the path to first principles in the last chapter of the *Posterior Analytics* II.19 has occasioned persistent and understandable disappointment among commentators.[35] In this essay I argue that one reason for this disappointment is the failure among commentators to see the relevance to chapter 19 of the concerns of the preceding five chapters. These chapters demonstrate that Aristotle sees the process of establishing scientific principles as proceeding through two stages, stages not adequately distinguished by commentators: An inquiry aimed

[33] For further discussion of this and related issues, see Cartwright (1989).

[34] For further discussion of some of these issues, see Williams and Charles (forthcoming 2013).

[35] The legitimate grounds for this disappointment are discussed in the section "Aristotle: definition, explanation and essence" below.

[36] "Problem" (*problêma*) in the context of Aristotle's logic has a technical meaning (roughly, a factual attribution in need of proof or demonstration). See Lennox [1995 (2001)].

at formulating scientific *problems* [*problêmata*] at the correct level of universality for proper demonstration, and a stage aimed at searching for "the reason why and the causes" of those problems.[36] In this essay I focus on Aristotle's discussion of methodological norms that guide the first of these stages of inquiry and on his exploration, in chapters 16–18, of a number of *aporiae* related to discovering causes among sets of coextensive attributes. This part of his discussion is exploratory and inconclusive, and I will conclude with some thoughts about why that might be.

## *APo. II: On inquiry*

The second book of the *Posterior Analytics* (*APo.*) opens by distinguishing four forms of inquiry (*zêtêsis*), corresponding to four sorts of things we know: [i] inquiries into whether something exists which, if successful, lead to [ii] inquiries into *what a thing is*, and [iii] inquiries into whether an attribute belongs to some subject, which, if successful, lead to [iv] inquiries into *the reason why* it does. The first pair of inquiries eventuate in a *definition*, and the second in a *demonstration*, in which the middle term refers to *the cause* of that state of affairs. The next nine chapters explore how these two pairs of inquiries are related, concluding that they are tightly interwoven—indeed, one type of definition prevalent in science as Aristotle depicts it can be reformulated as a demonstration.[37]

Among the concerns that lie behind these distinctions is avoiding the *Meno* paradox—often presented as an epistemic paradox, it is explicitly a paradox about inquiry.[38] Aristotle sees inquiry as a process with distinguishable stages, beginning with our perception of distinct particulars and ending with knowledge of first principles that are universal, indemonstrable truths, and which identify fundamental causes constituting the essences of things. Worries arise over whether this process is guided by norms sufficiently strong to reliably guide us to such principles.

In this essay I address an important but neglected *intermediate* stage, which involves moving from "partial" universals to *coextensive* universals, the kinds of propositions that Aristotle thinks form the core of any science, properly so called.[39] This is the stage of inquiry on which Aristotle is focused in chapters 14–18 of *APo.* II. Here he is exploring, albeit in a somewhat preliminary and "aporetic" way, the process of advancing from early, factual (*to hoti*) stages of inquiry to the point where we have knowledge of commensurate relationships among universals. This leads him to discuss an issue familiar to contemporary philosophers of science: Among robustly correlated attributes of a kind, how does one identify those that are causally fundamental and provide answers to inquiries into the reason why (*to dioti*) and the essence (*to ti esti*)? On the interpretation I offer, then, these chapters provide

[37] David Charles' contribution to this symposium is a detailed exploration of the metaphysical underpinnings of the relationship between definition and causal explanation in *APo*. II.

[38] The "*aporia* of the *Meno*" is explicitly referred to at *APo*. I.1 71a29 (as is the doctrine that learning is recollection at *APr*. II.21 67a21). But it is also clearly in the background of the *aporia* that introduces *APo*. II.19. Cf. Charles (2010a, b).

[39] By "partial universal" I refer to attributes that Aristotle describes as "belonging to all (of a kind) but extending beyond"—e.g., "angles equal to two right angles" belongs to all scalene triangles, but extends to *all* triangles.

important context for the discussion in *Apo*. II. 19. They are exploring the question of how to move to knowledge of commensurate universals as a critical part of the process of grasping first principles.

*Inquiry as an epistemological subject*

Aristotle characterizes the path to first principles in II.19 as *induction*, but it is often claimed that this path, as it is described, could not provide the requisite epistemic warrant for its destination. Nothing is said, for example, about how, among the universals arrived at, one would be able to determine which features are *essential* or *causally fundamental* to the kinds at which the process arrives. As Myles Burnyeat (1981, 133) put it in a classic discussion of the theory of knowledge of the *Posterior Analytics*, "[h]is treatment of this process in B 19 is by our standards perfunctory in the extreme." Nor has the discussion in *APo*. II.1–10, of the *stages* of inquiry and the relationship between definition and demonstration at each stage, provided that. Describing the product achieved at each stage of an inquiry, and how each stage differs from the previous, is very different from defending the *correct procedures for achieving* each stage and highlighting the signs along the way that you are on the right track.

*Scientific problems: APo. II.14–18*

*APo*. II.13 begins with a highly condensed but accurate summary of what Aristotle has accomplished by the end of II.10, after which he announces a discussion of "hunting down what is predicated in [accounts of] what something is." Often, commentators talk as if this refers only to chapter 13, but it accurately describes chapters 13–18. These are the chapters where Aristotle has an extensive discussion of how to formulate scientific problems as a preliminary stage in the search for causes.

Before turning to those chapters, however, there is some valuable context provided in *APo*. I. As others in this symposium discuss, Book I presents and defends Aristotle's concept of demonstrative knowledge, the idea that to know something scientifically is to have a demonstration of it. There are severe constraints placed on the *premises* of a *demonstrative* syllogism: that they be true, primary, and immediate (i.e., not themselves conclusions derived from more basic premises), and that they be better known than, prior to, and causally explanatory of the explanandum identified in the conclusion. (*APo*. I.2 71b20–22; these conditions are then explained and defended from 71b26 to 72b3.) This will guarantee that the principles will be *appropriate* (*oikeia*) to what is to be proven.

But what does it mean for scientific principles to be *appropriate*? It means that the premises of a science that meet the *first* three conditions mentioned above are related to its conclusions in the way specified by the *last* three conditions. In fact, the concept is first introduced in *APo*. immediately after those six conditions are presented:

[40] And compare: "For it is not what is reputable that we count as a principle, but rather what is primary in the kind with which the proof is concerned—and not every truth is appropriate (*oikeion*)" (*APo*. I.6 74b24–6).

> … demonstrative understanding in particular must proceed from items that are true, primitive, immediate, and more familiar than, prior to and causes of the conclusion. In this way the principles will also be appropriate (*oikeiai*) to what is being proved. (71b20–23)[40]

One way to frame the concerns people have about how Aristotle grounds his first principles is in terms of the question of how you could start with relatively unsystematic experience of a subject and end up confident that you have knowledge of premises that actually *meet* the above, very robust, conditions.

Two related passages that close *APo*. I.4 and 5, respectively, deal with just this issue: How does one determine whether a feature holds both *primarily* and *as such* of some subject—this is the mark of a predicative relationship "ready" for scientific demonstration, and chapter 5 discusses ways in which we mistakenly believe we have grasped such a relationship when in fact we have not. It will help to see these passages together:

> Something holds universally when it is proved of an arbitrary and primary case; e.g. having two right angles [2R] does not hold universally of figures—you may indeed prove of a figure that it has 2R, but not of any arbitrary figure; for quadrangles are figures but do not have 2R. An arbitrary isosceles *does* have 2R—but it is not primary; triangles are prior. Thus if an arbitrary primary case is proved to have 2R (or whatever), then it holds universally of this primarily, and the demonstration applies to it universally and in itself. To the other items it applies in another way, not in themselves—it does not apply to the isosceles universally, but extends further. (*APo*. I.4 73b33–74a4)

Two features of this passage are of note: First, it describes a *procedure* for finding the kind to which an already grasped attribute belongs *primarily* and *in virtue of the kind it is*; second, it notes that belonging to all instances of a kind is not sufficient for belonging universally—a universal attribute must be commensurate with the kind. This point is driven home in the conclusion of chapter 5.

> Does it [2R] belong to them as triangle or as isosceles? And when does it belong to something in itself and primarily? And to what does the demonstration apply universally? Plainly to the first item after the removal of which it no longer belongs; e.g. two right angles will belong to bronze isosceles triangles—and also when being bronze and being isosceles have been removed, but not when figure or limit have been. But they [figure and limit] are not the first. Then what is first? If triangle, it is in virtue of this that [having angles equal to two right angles] belongs to the other items, and it is to this that the demonstration applies universally. (*APo*. I.5 74a36–b4)

Here, we learn a bit more about the procedure implicit in the previous passage. You believe that the figure before you, which is a bronze, isosceles, triangular figure, has interior angles equal to two right angles (2R). But *in virtue of* what, *qua* what, does this figure have that attribute? In virtue of being bronze? If so, a triangle drawn in the dirt should not have it, while any random bronze thing should. In virtue of being isosceles? Then a scalene triangle should not have it. In virtue of being a

plane figure? Then non-triangular geometric figures should have it. Eventually, by a sort of pincer movement, you zero in on "triangle" as the kind to which the attribute belongs as such—it is in virtue of being triangular that this, or any, figure has the property 2R. There are clear procedures for testing each of these options and for finding the subject to which the property in question belongs in itself and as such.

From the first passage, we see that Aristotle's characteristic way of describing the "isosceles" case is to say that the 2R property belongs to every member of the kind but "extends beyond" it. We also see there explicit recognition of a *self-correcting procedure* for zeroing in, as it were, on a subject/attribute relation that is per se and *as such*—you can test whether triangles have this property because they are figures by looking at an arbitrary selection of plane figures *other than* triangles, and you can test whether it is in virtue of being the kind of triangle it happens to be by looking at other kinds of triangles to see whether they too have the property.[41]

In these passages, as commentators have noted, Aristotle is adopting a strong notion of "universality," which he stipulates in chapter 4: "I call 'universal' what holds of every case and in itself and as such" (73b25–6). As he points out earlier in the chapter, you might have proven on different occasions that scalene, isosceles, and equilateral triangles each have interior angles equal to two right angles and thus have proven it of all triangles—but unless you did so knowing that it is *qua* triangle that they have this property, your proofs fall short of providing unqualified scientific knowledge.

These two passages in Book I suggest, then, that for the purposes of achieving demonstrative knowledge identifying those features that belong to a kind primarily and in virtue of the specific nature of that kind is very important and that Aristotle has reflected on the problems of identifying features that belong in this way. Moreover, he goes on in chapter 6 to argue that the middle term that identifies the cause in virtue of which these per se features belong to a kind must also belong to the kind per se and as such (cf. *APo*. I.6 74b5–12, 74b27–32). Chapters 14–18 of *APo*. II explore how to identify predications that are universal in this strong sense through an iterated procedure involving "why" questions, and they raise a number of puzzles about how to identify *causal primaries* among the universals thus achieved.

### *In search of appropriate problems*

A "problem" (*problêma*) in the context of Aristotle's *Analytics* has a precise meaning: It is a proposition about which one is seeking, but does not yet have, a proof. Once one does have a proof, the same proposition is a conclusion (*sumperasma*).[42] These concepts are first distinguished in *Prior Analytics* I.27–30

[41] People familiar with Bacon's *Novum Organum* will see obvious affinities to the description in that work of procedures for creating "tables of presence and absence" (Bacon 2000, [II. 11, 12]).

[42] On the concept of a problem in Aristotle, see Lennox (2001, 13–15, 48–53, 76–91) and Byrne (1997, 55–80).

during the discussion of how to find the appropriate middle term relative to a given problem and appear for the first time in *Posterior Analytics* in *APo*. II.14–18, when Aristotle begins discussing the search for universal propositions appropriate for demonstration and raises questions about how to identify the cause (i.e., the *explanatory* middle term) among many commensurately universal properties.

In a *demonstrative* context, problems are stated as *why-questions* for which we seek causal explanations,[43] and as Aristotle says in the *Physics*, in introducing his four kinds of cause: "We think we have scientific knowledge of a thing only when we can answer the question 'why?', and that is to grasp the primary cause" (194b18–21).

*APo*. II.14 sketches a methodology for grasping problems by "selecting" information from "dissections and divisions," relying heavily on methods outlined in the *Prior Analytics*. Aristotle begins with familiar subjects and attributes and then moves on to unfamiliar cases drawn from his own biological investigations. Here is his first, familiar example:

1. Posit a higher kind common to all the objects being studied (e.g., animal)
2. Select from your dissections[44] and divisions what belongs to all members of that kind (e.g., select what belongs to every animal)
3. Then select what follows (=belongs to)[45] all of the "first remaining things" (from his examples, he means to select attributes that belong to all the groups you come to by dividing animal into subkinds).

He then says why we are doing this:

> For it is clear that *we will already be able to state the reason why* the attributes that follow belong to these sub-kinds under the common kind, e.g. why they belong to man or horse. Let A be assigned to animal, B to what follows every animal, and C, D, E to specific animals; surely it is clear why B belongs to D, for it is due to A. (98a7–11)

The "explanation" formalized here is *not*, however, a demonstration according to the standards articulated in Book I: If the conclusion here predicates of one specific

[43] Indeed, in the "Problems" tradition, which may have been inspired by these chapters of the *Posterior Analytics*, this becomes a trope: Virtually, every chapter of the 38 books of *Problems* (now generally assumed to be composed by later members of Aristotle's school rather than by Aristotle) that run from 859b1 to 967b26 in the Bekker edition of the Aristotelian Corpus begins with the expression *dia ti* (why?). I have made some tentative suggestions about how these books may be connected to the distinction, in Greek geometry, between theorems and problems in Lennox 1995 (reprinted in Lennox 2001).

[44] *Pace* Ross (1949, 663–664), there are compelling reasons to consider the expression *tas anatomas* (the dissections) to be a reference to the lost collections of anatomical diagrams referred to 28 times in Aristotle's zoological works. First, every other use of this term by Aristotle refers to dissections, so that if it had a different sense here it would be unprecedented; second, as we will see, unlike other chapters in the *APo*, *all* the examples in this chapter are zoological, and the second and third are *technical* examples that require knowledge of animals that can *only* be acquired by wide ranging dissections on many different kinds of animals.

[45] The expressions "select what follows S" and "select what S follows" are introduced in the *Prior Analytics* chapters referred to earlier and are roughly equivalent to the expressions "belongs to every S" and "S belong to every one of."

kind of animal a property that is common to *all* animals, it follows that it does *not* belong to the subject of the conclusion "in virtue of itself and as such" and is thus not being demonstrated from *appropriate* premises. The property *may* belong per se to *animal*, but even that is not guaranteed by the method outlined here, since something could belong to every animal because it is a property that belongs to every organism.

What, then, is the purpose of the outlined procedure? Here I follow W. D. Ross, who in turn is following the sixteenth-century Paduan Aristotelian Zabarella: "This chapter is concerned with advice not as to the solution of *problêmata* … but as to their proper formulation" (Ross 1949, 662; cf. Lennox 1994/2001). As is made more clear in subsequent chapters, an investigation may start with problems such as "Why do birds have hearts?" and "Why do fish have hearts?" The recommendation here is to posit what is common to the various things being investigated, in this case "animal," and then select what is common to every animal. Among the things you will find are hearts.[46] And there is now a *sort* of answer to your initial problems: Birds and fish have hearts *because they are animals*, all of which have hearts. But that implies that hearts do not belong to birds *qua* bird or to fish *qua* fish, but to both *qua* animal. This is an exact analogue of the example we looked at in *APo*. I.4–5: It is precisely like moving from knowledge that isosceles and scalene triangles each have 2R to knowledge that they have 2R *qua* triangle.

But note that, in each case, what Aristotle has not even *hinted* at is *why* all triangles have 2R or *why* all animals have hearts—other than to say "because they are all triangles" or "because they are all animals." Were one able to answer *these* questions successfully, one would then know something essential about animals or triangles, something that would explain why they have these features. To this point the "problems"—the why-questions about some fact taken as known—are not of the kind prepared for strict demonstration. But by searching for *preliminary* answers to these lower-level problems, we will find *candidates* for strict demonstration, properties that belong (in this case) to animal *qua* animal.

Two, more technical, examples follow. In these cases there is no familiar "kind term" for that which is common. In the second example, the objects of investigation are characterized by three verbal phrases referring to the possession of multiple stomachs, few upper teeth and horns. It is likely no coincidence that there is an extensive discussion of the relationship among these three features in Aristotle's *On the Parts of Animals* (cf. Gotthelf 1987/2012, Lennox 1987/2001) which stresses that these three properties are [i] coextensive[47] and [ii] causally connected (cf. *PA* III.2 662b35–663a7, 663b28–664a2; III.14 674a30–b17). Without him saying so, then, what Aristotle has provided here is a *problem* formulated appropriately for a demonstrative solution. The possession of horns is here identified as the feature that explains the possession of the other two—but in our passage (unlike the *Parts of Animals*) he provides no grounds for that choice. That, as we will see, is significant:

[46] Aristotle actually would say "heart or heart analogue."

[47] Actually, this is not strictly true, as Aristotle explains, since the camel lacks horns yet has the other two features. See *PA* III.14 674a27-b7 and Gotthelf (1987, 184–185).

A major theme running through chapters 15–18 is precisely the question of how to identify, among coextensive properties, which is causally fundamental.[48]

Chapter 15 focuses on identifying the different ways in which apparently different problems may be related to each other. He distinguishes three types of relation:

1. It may turn out that the same middle term has been posited for apparently distinct problems leading to the conclusion that they are instances of a single, more abstract problem.
2. The problems may be genuinely different, but be *generically* the same (*APo*. II. 15 98a28–9). What distinguishes this case from the first is that here the causes are really different: It is not that we mistakenly thought these were different phenomena—they actually are formally distinct, though generically identical.
3. Finally, some problems are related because, while they are different, the middle term that explains one problem is subordinate to the middle term that explains the other (*APo*. II.15 98a31–3).

In these cases, what is a premise in the explanation of a less universal problem becomes a more universal problem in the second, more universal explanation. What unites all three cases of related problems is that one discovers *that* distinct problems are related, and *how* they are related, *during the process of causal search*. And that, apparently, points Aristotle immediately to his next concern. For what is in our modern editions the next chapter opens with the following *aporia*:

> Concerning a cause and that of which it is a cause one might be puzzled whether, when the effect (*to aitiaton*) is present, the cause (*to aition*) is also present (so if there is a shedding of leaves or an eclipse, the cause of there being an eclipse or a shedding of leaves will be present; e.g. if this [the cause of leaf-shedding] is the possession of broad leaves or, of the eclipse, the earth being in the middle; or if it is not present, some other thing will be the cause of these things); and likewise if the cause is present at the same time the effect also [is present] (e.g. if the earth is in the middle an eclipse occurs, or if broad leaves, leaf shedding occurs). (98a35–b4)

Aristotle is pointing to the classic "length of shadow/height of flagpole" problem —if the two properties are commensurate, how do you decide which is explanatory of which? The next sentence in the text reads: "If this is how things are, [cause and effect] would be simultaneous and could be proved through one another" (98b4–5). Aristotle had already discussed this issue in *APo*. I.13, in the context of distinguishing two different kinds of demonstration, one proceeding "through the

[48] This is precisely the issue in terms of which certain counterexamples were posed to the deductive-nomological account of explanation proposed by Hempel and Oppenheim (for a nice summary of the examples and the issues at stake, see Salmon 1990, 46–50). For example (due originally to Sylvain Bromberger), if light shines on a flagpole of height *h* at a given angle *a*, there will be a shadow of length *l*. You can deduce the length of the shadow from the height of the flagpole and vice versa. But since the interaction between the light and flagpole determines the length of the shadow, while the shadow is not similarly implicated in determining the height of the flagpole, there seems to be more to explanation that mere deducibility. Aristotle, as we will see, discusses a number of similar examples.

fact" and another "through the reason why." Aristotle's concerns are two: First, is there something in the nature of the relationship between cause and effect that *requires* that they be commensurate? Second, once you have achieved the stage of an inquiry where you have identified a number of properties that belong to a kind of thing as such and are commensurate, what does justify the identification of one as causally fundamental and explanatory of the others?

He begins to move toward a resolution of these issues immediately, with a biological example. He asks whether "if problems are always universal and the cause is something whole, then that of which it is the cause must be universal" (98b32–3)[49]. Picking up his earlier example, he urges us to an affirmative answer:

> For example: shedding leaves is determined to some whole, even if this has forms, and it holds of these universally (either of plants or plants of a certain form). Hence in these cases the middle term and that of which it is the cause must be equal [in extension] and convert. For example, why do trees shed their leaves? If it is because of solidification of their moisture, then if a tree sheds its leaves solidification must hold, and if solidification holds—not of anything whatever but of a [sort of] tree—then the tree must shed its leaves. (98b32–37)

Without fanfare, the "middle" that would provide an interim explanation for why grape vines and fig trees shed their leaves—being broad-leafed—has now (implicitly) become the minor (subject) term of a commensurately universal conclusion, and a material/efficient cause takes up residence as the causal middle term. As in all the examples in these chapters, Aristotle has sketched a cognitive ascent to a level where subject and predicate in the conclusion are commensurate and a new middle term is identified as the cause.

Aristotle finally reaches an interim solution to his *aporia* about identifying the causal middle among commensurate universals in chapter 17—the abstractness of his solution indicated by his alternating between a geometric and our botanic example:

> The cause, that of which it is the cause, and that for which it is a cause are interrelated in this way. If the subjects are taken case by case, that which is caused has a wider extension (e.g., having external angles equal to four right angles extends further than triangle or rectangle); but if they are taken together, the effect is equal in extent (for just so many have external angles equal to four right angles); and likewise with the middle term [i.e. the cause]. *And the middle is the definition of the first extreme, which is why all sciences come about through definition.* For example, shedding of leaves follows every grape vine, and extends beyond, and follows every fig tree and extends beyond, but it does not extend beyond all. *Indeed if we grasp the primary middle, it will be an account of leaf shedding.* For there will be a first middle in the one direction (that all are such and such); and then a middle for this (that

[49] Here again, it is important to remember the root meaning of the Greek term *katholou* "with respect to the whole." The question at issue is "If the cause belongs to the whole class identified in the problem, then must that of which it is the cause belong to the whole class as well?"

> sap solidifies, or some such). *What is the shedding of leaves? The sap solidifying in the connection with the seed.* (*APo*. II.17 99a16–29)

The reader should hear echoes of *APo*. I.4–5. When Aristotle here refers to "a first middle in the one direction," I take it he is referring to the identification of the appropriate subject of shedding leaves—being broad-leafed—that can be used as the middle term in accounting for why specific *kinds* of broad-leafed trees shed their leaves. This interpretation is confirmed by him next saying that there will also be a middle "for this"—because the reference of "this" is the problem of *why* broad-leafed trees lose their leaves. Here Aristotle also ties his discussion of finding problems appropriate for causal demonstration back to the account of the relationship between definition and demonstration in *APo*. II.8–10: He tells us that the causal middle will be a definitional account of the explanandum. As with eclipse and thunder in those earlier chapters, so too with leaf shedding.[50]

*Identifying causes*

I conclude by drawing attention to what is *not* discussed in these chapters that one might expect to be, given the questions about which Aristotle is concerned. First, the process by which we get from knowledge of a commensurate relationship between 2R and triangle, or shedding leaves and being broad-leafed, or having multiple stomachs and lacking upper teeth, to the identification of the *causes* that explain these relationships is never described. Take "solidification of fluid" in the last example we looked at (presumably the fluid is "sap" which ordinarily provides fluid nutrition to the leaf): Aristotle identifies it as the causal middle, but says nothing about how one might arrive at that identification. Similarly, Aristotle never mentions what it is about triangles that explains their having 2R, or why it is *possession of horns* that explains few teeth or multiple stomachs, rather than the other way around. So while we may reconstruct Aristotle's ideas about how to move from "close to perception" experience of some subjects ("This kind of tree sheds its leaves") to the kinds of commensurate universal truths that a science seeks to understand, the *causes* that are identified in these discussions come, as it were, "out of the blue." This may appear to lend credence to the "insight" reading *APo*. II.19. But it would be a mistake to draw any such inference. There is a more attractive alternative: In order to understand Aristotle's views about proper norms for causal search, we need to look beyond the *Posterior Analytics*, to the many methodological reflections in his scientific treatises. Those texts suggest that Aristotle thinks the search for causes is governed by norms and methods that are specific to specific domains[51] and thus impossible to characterize adequately in a work as abstract as the *Posterior Analytics*.[52]

[50] This interdependency of definition and causal demonstration is one of the primary themes in the contribution to this symposium by David Charles. Cf. Charles (2000), which discusses the appearance of this interdependency in the passages I am discussing in pp. 204–209.

[51] I am currently working on a book that explores this theme.

[52] I take this opportunity to thank Greg Salmieri for written comments and discussion on earlier drafts of this paper.

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