Scientific Theories as Practical Thought: An Aristotelian-Anscombean reading of Duhem's *The Aim and Structure of Physical Theories*

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Abstract: This paper proposes a novel reading of Pierre Duhem's *The Aim and Structure of Physical Theories* that draws on the account of practical thought developed by Elizabeth Anscombe, Michael Thompson, and Sebastian Rödl. On this "hylomorphic" way of understanding action and activity, it will turn out that a scientific theory just is a special kind of practical thought, and that Duhem's "holism" is a manifestation of a more general indeterminacy inherent in practical thought.

1 Introduction

The goal of this paper is to sketch a way of thinking about scientific activity that fits into a broader Aristotelian account of practical thought and action. The occasion for such reflection was the 2024 Henle Conference on Hylomorphism and Contemporary Science at Saint Louis University. While most of the presenters focused on hylomorphism and the *metaphysics* of science, I wanted to direct my attention towards a different sphere in which hylomorphism has been deployed (albeit not always under that label): the Aristotelian understanding of action and practical rationality put forward by Anscombe ([1957] 2000) and her intellectual descendants. To my mind, it is this "practical" notion of hylomorphism that is of greater relevance for contemporary philosophy of science as well as for the first-order practice of science, one reason for this being that (as argued in Duhem [1914] 1991) metaphysics plays little to no direct role in understanding those goods and philosophical questions that are internal to a realistic conception of scientific practice. The picture of scientific activity that I will draw on is the one given by Duhem in his *The Aim and Structure of Physical Theories* ([1914] 1991; henceforth "AS"); my hope is to bring a crucial part of Duhem's picture into contact with Anscombe's conception of practical reasoning. More specifically, I wish to give a reading of AS on which Duhem's description of how scientific representations are made (and the indeterminacy inherent in such representations) simply turns out to be a kind of Aristotelian practical

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thought. A consequence of this approach is that it will put us in a position to understand why Duhem's so-called "holism" (much remarked upon in general philosophy) stems from a deep insight about theories, instead of a trivial observation concerning logical inference.

Those who are familiar with the recent "practical turn" in the philosophy of science will not be surprised by the suggestion that the topic of practical reasoning is foundational for any serious philosophical appreciation of scientific activity. Nonetheless, it might at first blush be thought odd that the Aristotelian-Thomistic tradition should be relevant to the crafting of scientific models and representations, because no such productive activity is discussed in this tradition. This initial impression is inaccurate, although understandable because the parts of Aquinas's corpus in which he discusses (what we would now call) the activity of modeling are less familiar within contemporary philosophy. For instance, witness Aquinas in his commentary on Boethius's *De Trinitate*: "We may add that among the other sciences these are called arts because they involve not only knowledge but also a work that is directly a product of reason itself; for example, producing a composition, syllogism or discourse, numbering, measuring, composing melodies, and reckoning the course of the stars" (1986, q. 5 a. 1 ad 3). And Duhem was himself fond of quoting *Summa Theologica*, I q. 32 a. 1, where Aquinas discusses how different hypotheses can be used to fashion an empirically adequate *model* of the astronomical data (epicycles being only one such model). Be that as it may, in what follows I will adopt a different tack from that of drawing directly on the Aristotelian tradition's discussion of modeling activity in the subalternated sciences: instead, in the next section (Section 2), I will review the "hylomorphic" version of Aristotelian practical thought that has been developed by Anscombe ([1957] 2000) and her followers, and in the following section (Section 3), I will show that a substantial portion of Duhem's thought in AS is plausibly and illuminatingly understood in terms of Anscombe's approach to practical thought and rationality.

2 Aristotelian Practical Thought: Some Background

In this section, I will review some background material on a particular Aristotle-inspired approach to action theory pioneered by Elizabeth Anscombe and further developed by various authors, although I will draw primarily on material from Frey (2019), Thompson (2008), and Rödl (2004). I will not be concerned to defend this approach (but see Frey 2019 for an overview of some of the controversies) because my goal is restricted to highlighting those features of the approach that will be helpful for understanding the "practical" dimension of the account of science given by Duhem in AS. In particular, I would like to draw our attention to two different forms of practical thought: first, one in which an action's end confers a *unity* on—and thus provides the "form of"—the subactions that are subsumed within it (in a sense to be explained further below); and second, one in which a human good or the goodness of some practice is manifested by an action. (Rödl [2004, 750n10] attempts to map the distinction between these two forms on to the distinction between *kinesis* and *energeia* in Aristotle, although I will not pursue this point here.)

According to the account of practical thought given by Elizabeth Anscombe, intentional action just is the kind of action of which we have (self-conscious) practical knowledge, and which is practically reasonable, i.e., it is action to which a certain sense of the question "Why?" is given application, and the answers to these questions evince the structure of the relevant practical reasoning. To use Anscombe's classic example, consider the following series of "why" questions and their answers:

> Why are you "moving your hands up and down" (*C*-ing)? In order to operate a pump connected to a cistern (*D*).
>
> Why are you "operating a pump connected to a cistern" (*D*-ing)? In order to replenish the house water supply (*E*).
>
> Why are you "replenishing the house water supply" (*E*-ing)? In order to poison the Nazis inside the house (*F*).

Thus, the practical reasoning inherent in this action has the following form:

> I am *C*-ing in order to *D*; I am *D*-ing in order to *E*; I am *E*-ing in order to *F*.

The above structure leads to our first form of practical thought. Each of these subactions is subsumed into a more inclusive action (*C* into *D*, *D* into *E*, and so on) until we arrive at the most inclusive action (*F*) that provides the *end* (i.e., poisoning the Nazis) of this series of actions. Thompson writes of such an end that it is "a sort of red thread that runs throughout this manifold of individual deeds, just as the extended process of housebuilding maintains itself through its various phases" (2008, 158). And Frey tells us that the end (*F*, in our example) confers a *unity* on its subactions (*C*, *D*, and *E*) in the sense that

> Whatever one does for the sake of [the end]—moving an arm, operating a pump, and moving water through a pipe—will be a constitutive part of this act of poisoning. By a constitutive part, I mean a part whose identity *qua* part depends on its role in realizing the whole, such that without reference to the whole there can be no identification of a part. Because moving one's arm up and down is a constitutive part of a poisoning, we can say that in moving an arm up and down, here and now, a poisoning is in the process of being realized. (2019, 1132)

By the same token, once the end has been accomplished (i.e., once we have passed from the progressive aspect "I am *F*-ing" to the perfective aspect "I have *F*-ed"), the unity that holds together all these subactions passes away.

The above conception of the unity of action is evidently a kind *hylomorphism* about intentional action: the subactions (*C*, *D*, and *E*) that fall under a broader action (*F*) provide the "matter" for the action, whereas the "form" of the action is given by *F* and the end specified therein. It is unsurprising then, that in order to explicate this point, Frey (2019) and Thompson (2008) appeal to the relationship between material processes such as mitosis and the life form of which it is a part: in an amoeba, this material process is reproduction whereas in a human being, it is growth. Similarly, the same isolated subaction description can have a radically different character (indeed identity) depending on which broader action (and thus end) it is subsumed under.

Anscombe also holds that the end of an intentional action must be seen by the agent as in some (perhaps very thin or formal) sense good or desirable. Frey further expands on this point by telling us that "The rational intelligibility of the practical determination of means or ends depends upon its inferential connection to the wider context of a life in progress, which has been and will continue to be shaped by one's general sense of how to live" (2019, 1140). Frey's observation about the relationship between an action's end and the agent's "general sense of how to live" leads us to consider a second form of practical thought that has been theorized by Thompson (2008) and Rödl (2004). Recall that the unity conferred upon an action by an end *F* expires when that end has been accomplished: to use an example from Rödl, if *F* is "repair my bicycle" then once I have repaired my bicycle, "my want ceases to be and moves me no more. It exhausts itself in explaining what it explains" (2004, 749). Rödl distinguishes this sort of "finite end" from a broader, "non-finite" notion of end that is bound up with the good of a practice, and ultimately, those goods that are constitutive of human flourishing—plausibly, it is such goods that inform an agent's "general sense of how to live." Rödl's example of such a *non-finite* end is "health," of which he writes:

> If I want health, I do various things for its sake. I go running one day, buy wholesome food the next day, and refrain from lying in the sun at noon the day after. I do not therewith diminish a distance that separates me from my end in the way in which gathering the tools, putting my bicycle upside down, and so on, bring me closer to a repaired bicycle. I never seem to be done with my health. I can never mark it off completely and move on to new projects. My wanting to repair my bicycle exhausts itself in explaining my actions. It causes its own extinction. An end such as health, by contrast, does not expend itself in explaining what it explains. As long as I adhere to it, it does not lose its power to explain what I do. (2004, 750)

In other words, when I act for the sake of health (in the sense of a non-finite end), my actions are not a (constitutive) part of the end of health but instead *manifest* the end of health. Such manifestations do not exhaust the human good of health and this good in turn grounds the desirability of finite ends such as "go for a bike ride" that might in turn subsume a subaction such as "repairing my bicycle."

In the foregoing, I have reviewed two forms of practical thought in the Aristotelian tradition as developed by Anscombe. They correspond respectively to what I called "finite ends" (which confer a unity on their constitutive subaction parts, but which unity passes away once the end has been achieved) and "non-finite ends" (whose goodness is manifested by indefinitely many actions of an agent and is inexhaustible as a source of such goodness). In the next section, we will see that a version of these two forms of practical thought is in play in Duhem's conception of the scientific enterprise.

3 Duhem's *The Aim and Structure of Physical Theory* (AS) as a Description of Practical Thought in Science

Duhem's AS is divided into two parts: Part I discusses the *aim* of a physical theory, whereas Part II primarily discusses the *structure* (or we might say, "form") of a physical theory. This bipartite distinction should remind us of our consideration of practical reasoning in the previous section, which is both goal-directed and has a teleological structure that Anscombe spells out in terms of the ". . . in order to . . ." relation. (Although this connection between AS and practical reasoning has been mostly ignored in the Anglophone literature, it is noted in passing by Jules Vuillemin in his introduction to the 1991 edition of AS.)

Despite Duhem's manifestly teleological account of science in AS, the aspect of this work that has most captured the Anglophone philosophical imagination, viz., the "holist" thesis that no hypothesis of a theory can be tested in isolation, has been received in a way that shows no connection to Duhem's overarching teleological conception of the *activity* of science. In this section, I will primarily draw on Part II of AS in order to uncover how Duhem's explanation of the structure of physical theory fits into Anscombe's schema for practical reasoning that we discussed above. By doing so, we will see that Anscombe's neo-Aristotelian conception of practical reasoning (and thus of human intentional action) provides a unifying framework for understanding how the different bits of Part II of AS fit together: as a particular application, we will find that the so-called Duhemian "holism" of scientific theories is merely a corollary of a general insight concerning the indeterminacy of practical reasoning. At the end of the section, I will also offer some suggestive remarks about how the Thompson-Rödl conception of practices and non-finite aims can help us make sense of Duhem's general claim about the aim of physical theory.

For ease of notation in what follows, I will frequently use the practical reasoning schema that I introduced in the last section:

I am *X*-ing in order to *Y*

where "*Y*-ing" (in keeping with Duhem's conception of the aim of physical theory) will characteristically denote the crafting of some kind of scientific representation, and where *X* will be a subaction that constitutes *Y*.

Upon dispensing with a preliminary discussion of quantity and quality at the beginning of Part II of AS, Duhem proceeds in Chapter III (henceforth all chapter numbers will refer to Part II of AS) to outline a generic feature of how the schema "I am *X*-ing in order to *Y*" is used in physical theory. In his view, any physical theory will involve bits of practical reasoning where *X* stands for concrete manipulations of concrete objects (e.g., blocks of ice, lab apparatus, etc.) and *Y* is an action that involves a symbolic and mathematical description of the relevant physical quantity (e.g., I am adjusting this mercury-filled tube of glass in such-and-such a manner in order to measure the temperature of the liquid). What Duhem wants to impress upon us is that the non-trivial part of such a piece of practical thought consists in bringing the concrete description *X* under the theoretical description *Y*—this will involve the exercise of prudence (or even practical wisdom) concerning the sensitivity of the measuring instruments and there will generally be an indeterminacy about how to fit some set of theoretical descriptions to the concrete facts, which is in turn resolved by the scientist's practical judgment—to use Duhem's own example, given some particular experimental context and the sensitivities of the relevant instruments, one might judge that temperature values of 10C, 9.99C, and 10.01C are all equally good representations of the temperature. (Although this kind of indeterminacy is not the focus of Anscombe's discussions of practical thought, it has important analogs in the non-scientific case. One example is that of Leontes in *The Winter's Tale*, who begins to interpret his wife's previous actions as betrayal where he had formerly interpreted them as faithful.) Duhem also considers the reverse direction of reasoning in which one is performing some mathematical deductions at the level of *Y* in order to apply them (perhaps for the purpose of prediction) to some concrete laboratory setup *X*: again he stresses the necessity for an exercise of prudential judgment to determine how and whether *Y* is actually a representation of *X* (one of his favorite examples is a scenario where some system of partial differential equations fails to represent the motion of a body because it is not well-posed, and thus ineligible for the task of empirical representation).

Having explained the role of practical thought in crafting even very small-scale and piecemeal representations, Duhem proceeds in Chapter IV to address a more familiar unit of activity in scientific thought, viz., where *Y*-ing is "performing an experiment." In performing the experiment, Duhem holds one is trying to make an abstract and symbolic judgment in which the practical intellect has succeeded in bringing data and concrete facts (*X*) under the theoretical description of that experiment (*Y*). For instance, he gives an example where *Y* is "verifying the statement that if we increase the pressure by *A* atmospheres, we increase the electromotive force of a battery by *B* volts" (148). Here he takes the opportunity to reinforce the indeterminacy in the kinds of *X*-es that can be subsumed under *Y*, and the open-endedness available in the practical thought that accomplishes this subsumption. He writes that the experimenter may

> exert the pressure by pouring mercury into a tube, by raising a reservoir full of liquid, by manipulating a hydraulic press, or by plunging the piston of a screw pump into water. He may measure this pressure with an open-arm manometer, with a closed-arm manometer, or with a metallic manometer. . . . Each new arrangement of the apparatus will furnish him with new facts to observe; he will be able to employ arrangements of apparatus which the first author of the experiment did not suspect, and see phenomena which this author will never have seen. However, all these diverse manipulations, among which the uninitiated would fail to see any analogy, are not really different experiments; they are only different forms of the same experiment; the facts which have been really produced have been as dissimilar as possible, yet the perception of these facts is expressed by a single proposition: The electromotive force of a certain battery increases by so many volts when the pressure is increased by so many atmospheres. (149)

The situation here is very much analogous to the case where *Y* is "pleasing my mother on her birthday" and there are many different constitutive means *X* (e.g., "grilling some steaks," "taking her to the zoo," etc.) that might be adequately brought under *Y* through a sufficient exercise of the practical intellect. Duhem also holds that this kind of practical reasoning is inherent in experimentation all the way down: by his lights, one cannot even have a scientific notion of an "instrument" without bringing the concrete instrument (*X*) under the theory-inflected description of what he calls "an ideal instrument" (*Y*). (To be clear, by this he does not mean that the ideal instrument stands apart as a standard to be met, but rather that that theoretical description is itself "made for" the scenario at hand as an exercise of practical rationality.)

In my reading, Duhem's long discussion of the kind of practical reasoning involved in experiment is propaedeutic to the main thrust of his Chapter VI, of which VI.2 is perhaps the best known section because it contains a statement of his so-called "holism":

> If the predicted phenomenon is not produced, not only is the proposition questioned at fault, but so is the whole

> theoretical scaffolding used by the physicist. The only thing the experiment teaches us is that among the propositions used to predict the phenomenon and to establish whether it would be produced, there is at least one error; but where this error lies is just what it does not tell us. The physicist may declare that the error is contained in exactly the proposition he wishes to refute, but is he sure that it is not in another proposition? (185)

The point that a particular hypothesis cannot be tested in isolation is typically taken to be one of the key insights of AS, but as we will see, on an (Aristotelian-cum-Anscombean) action-theoretic reading of AS it is really just a corollary of his general approach to practical thought in science, and an extension of the material that we have just discussed on the indeterminacy (and open-endedness) in subsuming a subaction *X* under a broader action *Y*.

Duhem begins Chapter VI by reminding us that

> the sole purpose of physical theory is to provide a representation and classification of experimental laws; the only test permitting us to judge a physical theory and pronounce it good or bad is the comparison between the consequences of this theory and the experimental laws it has to represent and classify. (180)

In order to understand Duhem's statement of this aim, we should remind ourselves that for Duhem, the crafting of experimental laws already involves the "*X* in order to *Y*" schema, where the scientist is working to subsume some more concrete description *X* under the unity of some more theoretical description *Y*—for instance, Kepler's laws (which Duhem would call "experimental laws") already assume those practical judgments that represent the motion of the planets by means of the mathematical medium of ellipses and which incorporate prudential judgments about the sensitivities of one's measuring devices. What Duhem is trying to explicate then, is not some new kind of practical thought, but rather an extension of the earlier kind of practical thought that subsumes smaller practical judgments (i.e., those involved in crafting experimental laws such as Kepler's laws) into a larger unity of practical judgment (e.g., further theoretical principles such as Newton's laws being used to subsume Kepler's laws).

To illustrate this kind of large-scale practical thought, consider Duhem's example of Arago trying to show that Newton's "theory of emission is in contradiction with the facts" (AS 186). Duhem observes that

> Arago had indicated an appropriate procedure for comparing the velocity of light in air with the velocity of light in water; the procedure, it is true, was inapplicable, but

> Foucault modified the experiment in such a way that it could be carried out. (187)

The first point to note in this passage is that, as discussed above, the scientist's practical reasoning is already exercised in the notion of experiment—it took a Foucault to complete Arago's chain of practical thought. The second point to note is that, based on Duhem's discussion of Newton and Kepler in VI.4, a kind of practical judgment (which Duhem vehemently emphasizes is not to be confused with "induction"), prudence, and exercise of the imagination is what is used to subsume experimental laws under more general and symbolic descriptions, and this creative subsumption is *itself* an essential element of practical thought. In other words, we can understand Arago and Foucault as jointly enacting a more complex action of experimentation that unites various chains of practical reasoning, and in which prudence is being exercised to subsume subactions at various levels of generality and symbolism, all the way up from the manipulation of instruments to "the corpuscular hypothesis."

Of this complex, Duhem writes: "I say the *system* of emission and not the *hypothesis* of emission; in fact, what the experiment declares stained with error is the whole group of propositions accepted by Newton" (AS 187). It would be glib here to focus on Duhem's use of "propositions"—these are merely abstractions from genuine thought, and at any rate, Duhem is amply clear that it is the scientists' practical judgments and doings which are the source of our inability to "subject an isolated hypothesis to experimental test" (187). The kind of unity at issue here is less felicitously described in terms of propositions and deductive inference, and more aptly summed up in Duhem's conviction that

> physics is not a machine which lets itself be taken apart; we cannot try each piece in isolation and, in order to adjust it, wait until its solidity has been carefully checked. Physical science is a system that must be taken as a whole; it is an organism in which one part cannot be made to function except when the parts that are most remote from it are called into play, some more so than others, but all to some degree. If something goes wrong, if some discomfort is felt in the functioning of the organism, the physicist will have to ferret out through its effect on the entire system which organ needs to be remedied or modified without the possibility of isolating this organ and examining it apart. (187–188)

At this point, we should be reminded of the first form of practical thought introduced in the previous section, viz. the unity conferred by an action's end on the subactions that it subsumes, as well as the hylomorphic observation about this unity that is urged upon us by Frey (2019), viz., that the constitutive subactions have an identity that is determined by the end of the broader action. (One might also add here the inverse hylomorphic observation that the broader action—the *form*—only has its existence through being realized in the *matter* of some particular series of subactions.) Frey's and Thompson's analogy of "mitosis" having a different broader meaning (over above its isolated description as a material process) in the context of different life-forms is precisely the kind of analogy that Duhem appeals to in order to explain the deeper significance of his so-called "holism." In other words, the reason some particular hypothesis (i.e., part of a representation) cannot be falsified in isolation is not ultimately to be found in modus tollens and a conjunction of premises but rather the idea that these constituent parts gain their identity from being part of a "life-form," viz., the unity conferred by the overarching practical thought of the particular scientific theory in question.

Although Duhem does not use the terminology of "hylomorphism," there is ample evidence that he would support the hylomorphic insights that I have just invoked. For instance, when he discusses Kepler's laws being subsumed by Newton's laws (AS 193), he goes as far as to say that, strictly speaking, it is not precisely Kepler's laws which are subsumed into Newton's theory. In today's physics terminology, we would paraphrase Duhem as making the relatively uncontroversial point that what Newton's theory contains is rather an *effective* understanding of Kepler's laws, and we can understand this as the idea that when subsumed into Newton's theory, what we had previously regarded as Kepler's laws (in a stand-alone fashion) now acquire a new identity that is conferred upon them by the broader representational ends of Newton's theory. Another example of such hylomorphic commitments arises in Duhem's discussion of "hypotheses whose statement has no experimental meaning" (AS 212). Duhem's point here is that there are some principles which are so foundational for a theory (e.g., the principle of inertia in classical mechanics) that it is hard to assign any physical meaning to them in isolation; however, Duhem still holds that they undergo testing holistically—in his words, such a principle can "crumble with the system it supported under the weight of the contradictions inflicted by reality on the consequences of this system taken as a whole" (AS 216). Against the background of the reading proposed in this paper, it is natural to understand these "foundational principles" (and also a good fit with Duhem's own examples) with action/representation descriptions at a very broad/high level of generality (which thus provide the *form* of the theory), whose testing can only proceed by means of testing the constituent parts (albeit not in isolation) that the principle unifies hylomorphically. Indeed, testing the constituent parts holistically enough just *is* to test the high-level principle—here one is reminded of Wittgenstein's famous aphorism: "The human body is the best picture of the human soul" (2009, 187e).

We have just surveyed how the bulk of AS—which is concerned with the *structure* of science—is actually concerned with the *structure* of a certain kind of practical thought that is implicated in scientific representation; in the previous section, we gave this form or structure the label of a "finite end." I want now to briefly discuss how Duhem's own remarks about the ultimate *aim* of scientific theories are related to our second form of practical thought, which we labeled "non-finite ends" (i.e., those ends whose goodness is manifested by indefinitely many actions of an agent and is inexhaustible as a source of such goodness). Duhem is very brief, albeit emphatic, about what the ultimate end of scientific representation is: he says that it is "natural classification," which results when "physical theory through its successive advances tends to arrange experimental laws in an order more and more analogous to the transcendent order according to which the realities are classified" (AS 297). The key idea here is that physical theory aspires to an *analogical* (and in particular *not* literal) representation and understanding of natural reality, in an analogous way to how a great portrait discloses (again analogically) the personality and *animation* of its subject. What is the relationship between this kind of "end" proposed by Duhem and the particular actions and activities of building scientific representations? The answer must remain somewhat speculative since Duhem is so telegraphic about the notion of a natural classification, but I submit that we might reasonably think of natural classification as a non-finite end. Duhem is clear that natural classification is associated with an "esthetic emotion" (AS 24) as well as an understanding and contemplation of natural reality that is analogically related to the project of articulating a philosophical cosmology (AS 305), and "understanding" is precisely an example of such a non-finite end. Any well-functioning scientific theory is going to *manifest* an understanding of nature and this end of understanding cannot be exhausted by the activity of creating scientific theories; indeed, this is one of the deepest grounds of the desirability characteristics that enter into the activity of scientific representation.

4 Conclusion

In this paper, I have tried to make the case that Duhem's *The Aim and Structure of Physical Theories* is principally concerned with the kind of practical thought implicated in crafting scientific representations. If this is right, then the unity of a physical theory consists in the unity of a kind of practical reasoning; moreover, it is akin to the unity of a *practice* or a *life-form*. There is however an important lacuna in my reading: in AS, Duhem takes great pains to give his own interpretation of the history of physics (and its vexed relationship to failed attempts at metaphysical explanations). Indeed, he greatly prizes the ability to tell an accurate narrative history of physics in the domain of pedagogy, as well as for the sake of understanding how to "go on" in rationally extending present theory. In my view, Duhem's focus on narrative history (and its relationship to the philosophical understanding of a physical theory) should remind us of MacIntyre's famous claim that the

> best account that can be given of why some scientific theories are superior to others presupposes the possibility of constructing an intelligible dramatic narrative which can claim historical truth and in which such theories are the subject of successive episodes. It is because and only because we can construct better and worse histories of this kind, histories which can be rationally compared with each other, that we can compare theories rationally too. (1977, 470)

It would thus follow that a more thorough investigation of Duhem's thought requires a deeper understanding of the relationship between practical scientific thought (in particular model-building) and narrative explanation of just the kind that Duhem tries to give in AS—I leave this important task to future work.

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