'AS IF WE WERE INVESTIGATING SNUBNESS': ARISTOTLE ON THE PROSPECTS FOR A SINGLE SCIENCE OF NATURE

JAMES G. LENNOX

1. Introduction

SINCE it has been determined in how many ways nature is spoken of, we need next to study in what way the mathematician differs from the natural scientist (for natural bodies too have planes, solids, lines, and points, things which the mathematician investigates). (*Phys*. 2. 2, 193^{b}22–5)

So opens the second chapter of *Physics* 2.[1] Aristotle seems to be saying that the distinction made in the previous chapter between nature understood as the underlying matter of a natural thing and as the shape and form of a natural thing implies that the next question to clear up is how the *mathēmatikos* and *physikos* differ from

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[1] The chapters are a Renaissance invention, of course, but in this case, while the argument is continuous with the lines that precede it, the chapter division reflects a clearly marked transition.

one another. It is difficult to see why this is a natural, or even a reasonable, topic to take up at this point in the argument, however. The differences between mathematical study and natural study are interesting and we know they interested Aristotle; but such demarcation questions, if they belong anywhere within this work, would seem to belong in the first chapter or two of *Physics* 1 (presuming, as I do, that our first two books are a unit). Yet the chapter not only opens with such a discussion; this opening sentence states that this is exactly where this discussion should be.[2]

Without a compelling answer to this question, moreover, a strong case could be made that the discussion of this topic, running from $193^{b}22$ to $194^{a}12$, is an intrusion. Chapter 1 presents the case for reducing the study of nature to the study of underlying material constituents, and then defends the view that natural things have two natures, based in their matter and form,[3] and that the study

[2] Ross tries to make the connection this way: 'The previous chapter has revealed that *φύσις* has two main senses, "matter" and "form". In the present chapter Aristotle discusses the attitude of *φυσική* to these elements and distinguishes it from *μαθηματική*. . . . Physics studies forms as involving matter for their embodiment; mathematics studies them in abstraction from such embodiment' (W. D. Ross (ed. and comm.), *Aristotle's* Physics [Ross] (Oxford, 1936), 506). Note that Ross does not explain why this subject should come up here, and he misreports Aristotle's argument in an instructive way. Here Aristotle stresses that mathematics does *not* study natural forms in abstraction; rather, it studies certain proper attributes of natural things. This is an *instructive* misrepresentation of the argument because, as I shall discuss below, it is a fair representation of the way in which Aristotle discusses mathematical abstraction in the *Posterior Analytics*. Charlton does not comment directly on why this topic is discussed here (W. Charlton (trans. and comm.), *Aristotle:* Physics *I, II*, rev. edn. [Charlton] (Oxford, 1992), 93). Simplicius (*In Phys*. 290. 1–8 Diels) looks forward from the chapter's opening question without asking why Aristotle thinks the immediately preceding discussion necessitates it. Philoponus (*In Phys*. 218. 19–219. 8 Vitelli) and Mansion (A. Mansion, *Introduction à la Physique aristotélicienne* [Mansion] (Louvain and Paris, 1946), 122–4) see Aristotle as embarking on the task of differentiating natural science from the other two theoretical sciences. This, I think, gets at an important part of the truth, but still does not face the question of why this discussion is here, and why Aristotle says this is the proper place for this discussion.

[3] I say 'based in' because the connection between a natural being's matter and form and its own source of change is not quite as direct as is often assumed; Aristotle repeatedly says natural things are things with natures, and that what distinguishes things with natures from other things is the presence of a source of change in themselves ($192^{b}13$–16, 18–23, 32–3); and at $193^{a}29$–31 he distinguishes two ways in which people refer to nature, as the primary underlying matter and as the shape and form in things that have their own source of change. The two natures are thus kept conceptually distinct from the inherent source of change, a subtlety that is also found in the lexical entry on *φύσις*, *Metaphysics Δ* 4. This would make sense if, as is suggested by Allan Gotthelf ('Aristotle's Conception of Final Causality',

of form should somehow take precedence over the study of matter. If we were to remove the discussion of the differences between the mathematician and the natural philosopher, the argument would then resume with Aristotle saying: 'Since, then, nature is in two ways, the matter and the form . . .', and using an *aporia* that is a direct consequence of that duality to set up a discussion of how to investigate these two natures in a unified way ($194^{a}12$–23). A digression on how the mathematician and the natural investigator differ from one another appears to interrupt the flow of argument.

I shall argue that this is no digression and that it is critically important that Aristotle clarify the differences between the *mathēmatikos* and the *physikos* before he proceeds to discuss the question of how one science is to study two natures; and that the discussion from the beginning of book 2 to the end of our second chapter is a single, complex argument. I begin by outlining the thesis to be defended.

In *Physics* 2. 1 Aristotle introduces a distinction between a nature rooted in the underlying subject and matter, and a nature rooted in shape and form, telling us at one point that the form he is referring to is not separable other than in *logos* ($193^{b}5$). This having been done, the possibility of a serious misunderstanding of his proposal for the investigation of nature arises. Given his views about mathematical objects, it would be natural for his audience to imagine that Aristotle is proposing a bifurcation of the investigation of nature between the mathematician and the natural philosopher, the *physikos* who searches for the fundamental material constituents of things. The mathematician will study form; the *physikos* will, as he always has, study matter. Not only will this seem a perfectly natural suggestion given the variety of options available prior to Aristotle's alternative; I shall argue that certain passages in the *Posterior Analytics* could easily be taken, by an audience familiar with current discussion in the Academy, to be pointing in precisely this direction.

The chapter begins, then, by stating two reasons why this is a reasonable expectation for his audience to have—and then proceeds to argue vigorously against it. Aristotle will insist that, as he

in A. Gotthelf and J. G. Lennox (eds.), *Philosophical Issues in Aristotle's Biology* (Cambridge, 1987), 204–42 at 226 n. 51), natures are 'internalized potential-pairs'; for in this case it is not the matter and the form that are the natures but the potentials, the sources of change, possessed in virtue of the matter and form.

understands them, formal natures will not be studied by mathematicians—even those engaged in 'the more natural of the mathematical studies', i.e. astronomy, optics, and harmonics. Yet some easy ways of drawing the boundaries between mathematics and natural science are closed to him, since unlike Plato he does not believe that mathematicians study a different realm of objects from natural scientists. Nevertheless, while the ontological source of natural and mathematical concepts is the same, Aristotle insists that the processes by which we form and define them are different.

If this account of the aims of the first part of this chapter is roughly correct, it provides a very attractive way of seeing the unity of the chapter as well. For immediately after concluding the discussion of the differences between mathematical and natural investigation, Aristotle refers back to the claim that natural objects are 'spoken of just like snub nose, but not like concavity' ($194^{a}6$–7). The fact that there are two natures, he says, might well lead one to puzzle about which one the *physikos* is to investigate. This concern about whether two natures can be investigated by a single science is still on the table and perhaps in a heightened form; for the first half of the chapter has taken an initially attractive alternative for the study of the formal nature—mathematics—*off* the table. Moreover, as Aristotle immediately goes on to say, earlier *physikoi* studied only the matter of natural things. The first half of the chapter has raised the question of who is to study natural form, given that it is not the mathematician, and has forced on Aristotle's audience the *aporia* that shapes the remainder of the chapter, the *aporia* of whether the formal and material natures can be the subject of a single investigation. It motivates us to take seriously his concern about whether a unified study of nature is possible.

Seen in this light, the chapter is closely connected to the methodological discussion at the beginning of *De anima* 1. 1 ($403^{a}22$–$^{b}19$); to the discussion of the differences between mathematical and natural *episteme* in *Metaphysics E* 1 ($1025^{b}18$–$1026^{a}16$); and to a number of other passages that discuss the 'snub-like' nature of the objects of natural investigation.

2. Making the case

To make the case for this reading, I need to begin with some details about the first chapter of *Physics* 2; and a couple of those details require a brief reminder of the closing lines of *Physics* 1:

> As for the starting-point in virtue of the form [*τῆς κατὰ τὸ εἶδος ἀρχῆς*], to determine with precision whether there is one or many, and of what sort or sorts it is, is a function of first philosophy; so let us reserve this topic for the appropriate occasion. But we will speak about forms of natural and perishable things[4] in the discussions to follow. That there are starting-points, however, and what and how many in number they are, we may thus assume to be determined. Let us now proceed, beginning again from another starting-point. ($192^{a}34$–$^{b}4$)

By the end of 1. 7 Aristotle is prepared to say that the starting-points of natural change are three, and that form and underlying subject are the two fundamental ones (the third being privation of form). But the question of whether form or underlying subject has a *better* claim to be called *οὐσία* is still on the table ($191^{a}19$–22; cf. 2. 1, $193^{a}9$–10). Furthermore, in these closing chapters of book 1 Aristotle occasionally substitutes 'matter' for 'underlying subject' ($190^{b}26$, $192^{a}31$–3), but here 'underlying subject' (*ὑποκείμενον*) refers at times to the material constituent of a composite (e.g. the bronze of a goblet) and at times to the composite subject underlying its attributes (e.g. the cultured human being).

Whatever Aristotle may have in mind by postponing to first phi-

[4] The majority of manuscripts, reflected in Bekker's printed text, have *περὶ τῶν φυσικῶν καὶ τῶν φθαρτῶν εἰδῶν*. Ross follows MS E, perhaps also the text read by the Greek commentators, which omits the second article and thus suggests taking the first with *εἶδος*. Since Aristotle does not believe that natural forms are generated (*Metaph. Z* 8, $1033^{b}5$–9, $^{b}16$–21; *Z* 9, $1034^{b}7$–10) and the same arguments that lead to that conclusion should lead to the conclusion that they are not perishable, a reading that avoids attributing to Aristotle a belief in perishable forms is desirable, and there are two ways of doing so. One is to read the text as printed by Bekker and translate 'concerning forms of natural and perishable things', taking the genitive plural of *εἶδος* to be governed by *περί* and taking the adjectives *φυσικόν* and *φθαρτόν* substantivally. If one follows Ross, it is still reasonable, given Aristotle's Greek, to treat the adjectives as substantives, even in the absence of definite articles. Moreover, since Aristotle believes that there are both perishable and eternal natural things, the *καί* should not be rendered as 'i.e.', as it is in the Hardie and Gaye translation (R. P. Hardie and R. K. Gaye (trans.), *Physica*, in W. D. Ross (ed.), *Works of Aristotle Translated into English*, vol. ii (Oxford, 1930). The addition of 'perishable' here is probably intended to delimit the class of natural forms to those about to be discussed in book 2.

losophy[5] a discussion of whether there is one or more than one 'starting-point in virtue of the form' and what it is (or they are), it seems clear that the point of mentioning such a discussion here is to differentiate it from the discussion of forms to come, which will be restricted to 'forms of natural and perishable things'. As we proceed to book 2, then, what can be taken as settled is *that* there are three starting-points of natural change, the two primary being the underlying subject of change and the form towards which the change proceeds. Little has yet been said, however, about what it is to be a natural being, whether one or both of these starting-points constitutes the nature of a natural thing, whether one has priority over the other, or whether these principles of change are also causes of natural change.

While book 2 does, then, make a fresh start, it also moves swiftly to deal with a number of questions opened up by the conclusions of book 1.[6] It assumes that nature is a cause of certain *beings*, lists them, provides a definition of nature,[7] and uses that definition to differentiate natural from other beings. Less than a Bekker column into the discussion, he proclaims he has told us what nature is and what we mean by 'due to nature' and 'according to nature'. He derides the attempt to answer the 'whether it is' enquiry about nature—the investigation of nature is one of those where one must begin by assuming not only the significance of the term 'nature', but also that there is such a thing. One could 'prove' *that* there are natures, he says, only by starting from premisses less secure than the conclusion to be proved (193^{a}3–9). However, the precise nature and substantial being of natural things remain, he reminds us, a topic up for grabs.[8]

[5] Though that it may have to do with the sense or senses in which forms can be separate is suggested by the last lines of *Phys.* 2. 2, 194^{b}14–15.

[6] On the question of the independence of books 1 and 2, see Ross, introduction, 4–6. In most of our manuscripts there is no connecting particle (though in MS E there is a clear attempt to tie the closing remark of book 1, about an upcoming fresh start, to the beginning of book 2, by inserting a *γάρ*). Ross, 499, argues that the easiest way to make sense of the ancient lists of Aristotle's works is to suppose that book 1 was originally independent.

[7] Charlton's translation of the clause beginning *ὡς οὔσης τῆς φύσεως* as a new sentence, opening with 'This suggests . . .', misconstrues the *ὡς* (Charlton, 23). There is nothing tentative about the point Aristotle is making, which is that the artefacts being discussed have a nature only in so far as they are made of elements which do. The definition of nature as an inherent source of change or rest is already assumed at 192^{b}14–15.

[8] The issue here—what is it about natural things that constitutes their 'nature

The first answer canvassed is that the nature and *οὐσία* of natural things is 'the primary constituent in each thing, in itself without structure' ($193^{a}10$–11).[9] The criterion that provides this answer with its initial plausibility is *persistence*:

> . . . this seems to show that the disposition of parts customary for beds and the artistry ⟨that goes into them⟩ belong only by virtue of concurrence, and that the substantial being is that which persists uninterruptedly while being affected in these ways. ($193^{a}14$–17)

On this view one or a number of the elements is the entire *οὐσία*, everything else either being an affection, a state, or a disposition of it/them ($193^{a}24$–6).

Nature is also said to be the shape and the form that accords with the *logos* (*ἡ μορφὴ καὶ τὸ εἶδος κατὰ τὸν λόγον*) of the natural thing. Here he insists, by analogy with art, that what is flesh or bone potentially—absent the form identified by the defining account of flesh or bone—neither has its own nature nor exists by nature ($193^{a}31$–$^{b}3$). These two purported natures are at $193^{a}28$–30 and $193^{b}3$–5, given exactly parallel articulations:

> *Material Nature*: The primary underlying matter in each of those things having a source of movement and change in themselves.
> *Formal Nature*: The shape and form of those things having a source of movement in themselves.

But the account of Formal Nature adds one, critical, note:

> So in another way nature might be the shape and form of things having a source of movement in themselves—*but form not separable other than in account*.[10] ($193^{b}3$–5)

and *οὐσία*'—is not precisely the question said to be still on the table in $191^{a}19$–22, namely the question of whether the form or the underlying subject has a better claim to the title *οὐσία*. But once you start with the assumptions that there are natural things and that their nature is the cause of their being the natural things they are, the questions are very closely related. Moreover, he has just put the case for the underlying subject, and is about to put the case for form.

[9] When he summarizes the view before going on to consider form, the summary statement is 'the primary underlying matter in each of those things which have a source of movement and change in themselves'. This is critically reworded in his own voice—the substitution of 'underlying matter' for 'the primary constituent', the inclusion of the definition of nature in the statement, and the neutrality with respect to the question of whether the underlying matter might be *a* or *the* source of change.

[10] I am reading *κατά* in *κατὰ τὸν λόγον* as signalling the manner in which the form

Up to this point, then, two candidates for the nature of natural things have been identified and a case made for each.[11] The remainder of the chapter provides three grounds for the priority of form.[12]

These three arguments are very different, but each points to nature as form more than as underlying matter. The first appeals to our referential practices: when we speak of 'elm' or 'elephant', we are referring to *actual* trees and pachyderms. The unstated implication is that an elm or an elephant is *actually* such in virtue of its form more than its matter. The second argument refers us back to an earlier defence of the view that underlying matter is nature, a defence that takes as an indication of a thing's nature what arises out of the thing. Suppose you start with the assumption that both artefacts and natural things are composites of matter and form, and you are asking which of these components has a better claim to the title of the nature of the thing. In the case of artefacts, if anything meets the above standard it is their matter. But in the case of at least some natural things, Aristotle argues, it is the *form* that meets the standard. That is, it is not just the material that arises from a living thing, but another living thing, one in form with the parent.[13] The third argument appeals to an alleged derivative 'process' use of the

is separable—'being separable in account' is to be contrasted with being separable in being, and the separation in question is separation from the thing of which it is the nature. It does not follow from the fact that the form has the sort of separability that an account has that one can give an account of the form that makes no reference to matter or change.

[11] This is in line with S. Waterlow, *Nature, Change and Agency in Aristotle's* Physics*: A Philosophical Study* (Oxford, 1982), 57–8; it is odd, however, that she translates 193^{b}6–7 as 'Shape and form is nature *rather than* matter', since his repeated claim that there are two natures, form and matter, seems to require that we read *μᾶλλον* with the genitive here as 'more than'. Waterlow does not discuss chapter 2, a chapter that seems almost entirely motivated by the problem created once one acknowledges that every natural thing has both a material and a formal nature.

[12] The different arguments are signalled grammatically by the particles *γάρ* (^{b}7), *ἔτι* (^{b}8), *ἔτι δ'* (^{b}12).

[13] All the manuscripts read *τέχνη* at 193^{b}11. The evidence from the commentators that Ross gives for substituting *φύσις* for *τέχνη* is weak, and I think the passage makes tolerable sense without it. So Philoponus: 'For if the fact that what arises from the bed is not a bed but the matter of the bed, wood, means that matter is nature [in those artefact cases], then the fact that what arises from a man is a man and not the matter of man [in those natural cases] clearly means that form is nature; for this is what arises, as the matter does in the case of bed' (210. 5–9 Vitelli, trans. Lacey: A. R. Lacey (trans.), *John Philoponus,* On Aristotle, *Physics* 2 [Philoponus] (London, 1993)).

term 'nature', and insists that this derivative sense is parasitic on the term's primary reference being to the *result* of the process so called.[14] Once again, it is assumed that the result is what it is in virtue of its form. None of these arguments is intended to convince you that the form is a nature of natural things, but only that if you agree that both matter and form are natures of natural things, then form is more the nature of a natural thing than matter is.

The discussion ends with an echo of the conclusion of book 1, since it reminds us that there was a sense in which the principles of natural things were two and a sense in which they were three. At the end of book 1 we were told:

> It is clear that there must be something to underlie the opposites, and that the opposites must be two in number. Yet in another way that is not necessary. One of the opposites, by its absence or presence, will suffice to effect the change. (191^a4–7, trans. Charlton)

While 2. 1 concludes:

> But shape and nature are spoken of in two ways, for even privation is a form in a way. But whether or not there is a lack and an opposite with respect to simple generation, we must consider later. (193^b18–21)

3. The problem

What up to this point would necessitate that we immediately turn to the question of the relationship between the investigator of mathematics and the investigator of nature? The answer to that question must be approached by putting the question in context. Aristotle's treatises, whether thought of as transcripts of a series of lectures or more as 'textbooks', have a narrative structure, one which aims to start with what is familiar to the audience and move them gradually towards an increasingly sophisticated understanding of the subject being investigated. In this case Aristotle is addressing an audience that, broadly speaking, knows variants of only two models for the theoretical investigation of nature—that represented by Democritus and Empedocles, on the one hand; and that represented by

[14] English does the same thing with 'nature'. It would be quite 'natural' to refer to the process of development from egg to pupa to chrysalis to butterfly as 'nature at work'. But if asked about *which* nature is at work, we would surely say the nature of the butterfly.

Plato, mathematically minded members of the Academy, and perhaps certain Pythagoreans, on the other. For reasons to be discussed shortly, I am also going to suppose that his audience may have already studied 'analytics', as represented by the *Prior* and *Posterior Analytics*. If this is a fair representation of the background that Aristotle's audience brings to these texts (or lectures), then there are compelling reasons for Aristotle to take up the question of the differences between the mathematician and natural scientist at precisely this moment. I shall outline my reasons for saying this, and then provide a reading of $193^{b}22$–$194^{a}12$ that strongly suggests this is precisely what motivates the passage.

Up to this point in the argument, Aristotle's defence of his own theory of nature has developed a case against the all-sufficiency of the underlying matter of a natural thing as its nature; and in favour of the natural scientist investigating, in addition to matter, another aspect of natural things, variously referred to as shape (*μορφή*), form (*εἶδος*), or figure (*σχῆμα*), as being another, and indeed perhaps a better, candidate for the nature of natural things. In his three arguments for giving priority to form as the nature of things there are hints of the account of form to come—but, I shall argue, only if you already know and understand what is coming. Otherwise, you are simply told that what a thing actually is, what it is when it is an *οὐσία*, should count as nature in the strongest sense of the term, and that it is the thing's shape (*μορφή*), form (*εἶδος*), or figure (*σχῆμα*) that determines what a thing actually is.[15]

As I noted in setting up the problem posed by this discussion (pp. 151 and 155 above), when introducing nature as form to his readers Aristotle remarks, without explanation, that the form he is considering is 'not separable other than in account [*οὐ χωριστὸν ὄν ἀλλ' ἢ κατὰ τὸν λόγον*]'. As Ross notes,[16] by adding this brief clause Aristotle is reminding (or alerting) his readers that the *εἶδος* he is discussing is not that of Plato's middle dialogues. But an important ambiguity lurks in this brief aside. For in chapter 2 (at $193^{b}34$) the properties studied by mathematicians are features of natural things, but are *separable in thought*. So, while this aside might steer a reader or listener away from the assumption that

[15] To be precise, the phrases used in chapter 1 are: *μορφὴ καὶ εἶδος* at $193^{a}30$–1, $^{b}4$; *μορφή* at $193^{b}11$, 18, 19; *εἶδος* at $193^{a}35$, $^{b}1$; *σχῆμα* at $193^{b}9$. Twice the reference to *εἶδος* specifies that he is thinking of *τὸ εἶδος τὸ κατὰ τὸν λόγον* ($193^{a}31$, $^{b}1$–2).

[16] Ross, 504, ad $193^{b}4$–5.

the formal natures investigated by the *physikos* are ontologically separate, it might encourage him to think that they may be most properly investigated by a distinct, mathematical science.

Aristotle is, then, rejecting full-blown materialism and is endorsing form as an alternative candidate for the nature of a natural body—a candidate there is good reason to think will be given priority over matter. The form to be investigated by natural science will not be ontologically 'separate', however, but an aspect of natural bodies variously referred to as their shape, figure, and form.[17] Guided only by what is said in chapter 1 about that option, a member of Aristotle's audience would, I suggest, have an obvious thought. Investigating nature is a hybrid project, involving the traditional *physikos* investigating the underlying subject and matter of natural things, and the mathematician investigating their shape, figure, or form. And the following passage from the *Posterior Analytics*, with which I am supposing members of his audience would be familiar, might well encourage them to think along these lines, though I do not think it forces one to do so:

> The reason why differs from the fact in another way, in so far as each is studied by a different science. Such are those studies related to each other so that the one falls under the other, e.g. optical investigations are related to geometry, mechanical investigations to solid geometry, harmonic investigations to arithmetic, and the making of observations to astronomy. Some of these sciences are practically synonymous, as with mathematical and nautical astronomy, and mathematical and acoustic harmonics.[18] For here it is for the observers [*τῶν αἰσθητικῶν*][19] to know the fact, and for the mathematicians to know the reason why. For they possess demonstrations

[17] A likely source working in the Pythagorean tradition who might encourage Aristotle's audience to think in this direction is Archytas. In a recent paper Myles Burnyeat, noting that Diogenes Laertius (2. 25) attributes three books *On the Philosophy of Archytas* to Aristotle, points to similarities in the wording of certain fragments of Archytas and Aristotle's description of the subordinate sciences in *Post. An.* 1. 7–13 (M. F. Burnyeat, 'Archytas and Optics' [Optics], *Science in Context*, 18/1 (2005), 35–53 at 42). Cf. C. A. Huffman, *Archytas of Tarentum: Pythagorean, Philosopher and Mathematician King* (Cambridge, 2005), ch. 1.

[18] It is interesting to compare this passage with *Philebus* 57 A–E. Socrates there makes the point that though it is important to distinguish the 'exact' and 'philosophical' use of numbers and measurement from that of the non-philosopher, they often and confusingly go by the same name: 'there are two arts of numbering and two arts of measuring, and plenty of other kindred arts which are similarly paired as twins, though they share a single name' (54 D 5–6, trans. Hackforth).

[19] This is an unusual use of *αἰσθητικός*, which Aristotle typically uses substantively to refer to bodily organs, capacities of the soul, or to animals with such organs or capacities. It has been variously translated 'observers' (Ross), 'empirical observers'

of the causes, and in many cases do not know the fact, even as those who are studying the universal in many cases do not know some of the particulars because of a lack of investigation. These [investigations] are those which, while they are somehow different with respect to substantial being [*οὐσίαν*], make use of forms [*κέχρηται τοῖς εἴδεσιν*].[20] For the mathematical investigations are concerned with forms [*περὶ εἴδη*]; that is, they are not investigations of a certain underlying subject [*καθ' ὑποκειμένου*]; for even if geometrical investigations are of a certain subject, they are nevertheless not of that subject *qua* that subject. ($78^{b}36$–$79^{a}11$)

Slightly later, at $79^{a}11$–13, in a discussion of the hierarchy of optical investigations, Aristotle explicitly identifies the *physikos* as the one who investigates the facts and the optical scientist (using the term either in an unqualified way or with reference to mathematical optics) as the one who is concerned to know the reason why.

The focus of the last two sentences is on the 'mixed' or 'subordinate' sciences, in which features of natural phenomena studied by the student of nature are explained by appeal to arguments developed within geometry, stereometry, or arithmetic. In understand-

(Mure), 'empirical scientists' (Barnes), and 'osservatori' (Mignucci). Sir Thomas Heath (*Mathematics in Aristotle* (Oxford, 1949), 59), in an attempt to capture something of its usual force, renders it 'the business of perception'; but this (*a*) ignores the plural and (*b*) forces a most inelegant contrast with 'the mathematicians'. So reluctantly I follow Ross. The idea being conveyed is that the facts in need of explanation are acquired by investigators who rely on their perceptive capacities.

[20] There are a number of decisions that need to be made in reading the Greek here. The reference of *ταῦτα* at $79^{a}7$ is unclear. I take it to be picking up on the general subject under discussion, namely the different sorts of mathematical investigations being discussed. The reason most translators do not go this route is the participial clause that suggests the subject must be 'somehow different in respect of *οὐσία*', apparently an odd thing to say about mathematical investigations. On the other hand, if one supposes that Aristotle is *not* discussing investigations but rather the objects being investigated, it is hard to make any sense of his assertion that the subject being discussed 'makes use of forms'. Aristotle's reasoning is much easier to understand if one takes the subject to be as I have suggested. And branches of mathematics can 'differ in respect of *οὐσία*' if one takes *οὐσία* here to refer to the underlying subject, a reading supported by $79^{a}8$–10, as I discuss below. The other important decision concerns the interpretation of *εἶδος* in this passage. Burnyeat has argued that the *Posterior Analytics*, along with the rest of the *Organon*, eschews the matter/form distinction at the core of his natural philosophy (M. F. Burnyeat, *A Map of* Metaphysics *Zeta* (Pittsburgh, 2001), 8, 87). But here *εἶδος* appears to have the sense it has when Aristotle treats it, in *Physics* 2. 1, as interchangeable with *μορφή* or *σχῆμα*. It clearly is not being used here to refer to Platonic forms (as it is at $77^{a}5$), yet it *does* refer to items that can be present in a subject but considered apart from being in a subject. As Burnyeat notes ('Optics', 42), the phrase *κέχρηται τοῖς εἴδεσιν* here finds a close parallel at *Rep.* 510 D 5, where Plato is discussing the use of visible shapes by geometers.

ing the meaning of *οὐσία* here it is helpful to look forward to *Post. An.* 1. 27. There, in the context of giving grounds for one science being more exact or precise (*ἀκριβεστέρα*) than another, Aristotle distinguishes 'unit' from 'point' by saying that the unit is an *οὐσία* without position and the point is an *οὐσία* with position. In this context, then, *οὐσία* refers to the primary subject of the science, even if that subject is as 'insubstantial' as a point or unit. This very brief later chapter helps with the interpretation of 1. 13 in another respect as well. For it also claims that one science is more exact than another if the one is *not* *καθ' ὑποκειμένου* while the other *is* *καθ' ὑποκειμένου* ($87^{a}32$–4)—precisely the distinction Aristotle introduces in 1. 13 to explicate the idea of a science 'concerned with forms'.

These discussions in the *Posterior Analytics* are, then, suggestive of a way of viewing the relationship between the mathematical and natural sciences. In *Post. An.* 1. 13 and 27 the investigations that are somehow different in respect of *οὐσία*, but make use of forms, are the subordinate sciences, such as astronomy, optics, or harmonics. Being different in respect of *οὐσία* may refer to differences between them and their respective mathematical foundations—geometry, stereometry, arithmetic—or it may refer to a difference among them in the subject-matter to which mathematics is being applied, i.e. to acoustical, visual, mechanical, or celestial subjects. In either case, the next sentence aims to explicate these ideas, as the *γάρ* indicates. These sciences *use* forms (i.e. shapes, figures, ratios) in so far as they are based on mathematical sciences, which, Aristotle tells us, are *about* forms.[21] The mathematical sciences are not, however, about forms predicated of a subject, for even if those forms in fact belong to some subject or other, geometry does not study them as such.

These passages in the *Posterior Analytics* can easily send the following message: the traditional *physikos* has been demoted; he is the under-labourer of the mathematician. And even if we allow for the fact that geometric forms are 'of a subject', geometers do not study them *as* belonging to a particular subject.[22] That is the job

[21] The fact that harmonics is among the sciences being discussed suggests that we should take the reference to *εἴδη* at least broadly enough to include ratios and proportions (recall that Aristotle's first example of the formal cause in *Phys.* 2. 3, $194^{b}26$–9, is the ratio 2 : 1). On the other hand, Aristotle's thoughts may be primarily focused on geometry, as the substitution of *τὰ γεωμετρικά* for *τὰ μαθήματα* at $79^{a}9$ suggests.

[22] *Metaph. B* ($998^{a}7$–19) and *M* ($1076^{a}32$–$^{b}10$) describe a position in the philosophy

of those sciences that take their *propter quid* from mathematics and apply it to the *quia* discovered in the investigation of nature.

I do not want to be misunderstood here—there are ample examples in the *Posterior Analytics* of Aristotle discussing natural phenomena that are not amenable to such an understanding of natural investigation and which cry out for the sort of natural investigation towards which Aristotle is aiming.[23] I am pointing to this passage about the 'mixed' or 'subaltern' or 'subordinate' sciences to suggest an obvious and natural response to Aristotle's critique of materialist natural philosophy and his defence of the priority of form in the study of nature in the opening pages of *Physics* 2. The natural response among those who see the fundamental alternatives as between some traditional *physikē* as described in the *Phaedo* or in *Physics* 1,[24] on the one hand, and some form of Platonism or, to use Julia Annas's term, 'partial platonism',[25] on the other, would be to imagine that Aristotle is recommending that all natural study

of mathematics whereby the mathematicals are neither separate objects intermediate between forms and sensibles nor merely attributes of natural bodies, but are rather ontologically distinct objects in some way embedded within perceptual objects. Aristotle rejects this as having ontologically impossible implications, and it may well be among the positions he wants to distance himself from here. Thanks to my colleague Helen Cullyer for pointing this out to me.

[23] Thus the standard examples used during the discussion of how definition and demonstration are related in *Post. An.* 2. 1–10 are eclipses (e.g. $90^{a}15$–17, 25–30, $93^{a}23$, 30–1, 37–8, $93^{b}5$–7, $98^{b}17$–22) and thunder ($93^{a}22$–3, $93^{b}7$–12, $94^{a}3$–5); in 2. 13, in discussing division as an aid to hunting the essence, he notes that whole-winged/split-winged is not an appropriate division of animal but only of *winged* animal ($96^{b}35$–$97^{a}6$); and in 2. 14 the discussion of constructing problems for demonstration uses only biological examples, including some requiring detailed biological knowledge such as that animals with few upper front teeth and horns also have multiple stomachs and that certain cephalopods have rudimentary skeletal structures ($98^{a}1$–23). Finally, in the discussion of how to move from problems to demonstrative explanations the examples include periodic flooding ($98^{a}31$), rainbows ($98^{a}28$), leaf-shedding ($98^{a}35$–$^{b}16$, $98^{b}36$–8, $99^{a}23$–9), and longevity in quadrupeds ($99^{b}5$–7). In these chapters a mathematical and a natural example are occasionally used together to illustrate the same point (e.g. $99^{a}16$–28).

[24] See the discussion of 'that wisdom they call *περὶ φύσεως ἱστορία*' at *Phaedo* 96 A–98 B 5; and the contrast with the Eleatics Aristotle has just finished discussing implied by the opening words of *Physics* 1. 4: *ὡς δ' οἱ φυσικοὶ λέγουσι* . . . In both cases the intended reference is to a group that seek material-level explanations and eschew teleology.

[25] See J. Annas, *Aristotle:* Metaphysics *M, N* (Oxford, 1976), 137–9. She argues that the first section of *Metaphysics M* 2 is an attack on a view, which might be neo-Pythagorean, which takes the objects studied by mathematics to be distinct constituents of the world apart from, yet 'within', the changing physical objects of our experience.

be modelled on astronomy or optics, as outlined in *Post. An.* 1. 13. The *physikos* as traditionally understood provides us with an account of natural objects as bodies constituted of various materials and looks to the mathematician to provide a formal account of these natural objects. The mathematician studies forms in abstraction; the *physikos* studies the matter and underlying subject and (perhaps) also makes use of the results of the mathematician in a study of the forms of natural things. Perhaps certain attributes will be explained by reference to their formal, mathematical structure and others by reference to the materials from which they are constituted.

Before beginning to develop his own understanding of how the natural scientist investigates both matter and form, Aristotle must disabuse his readers of this understanding of the study of nature. That is why *Physics* 2. 2 opens by claiming that the results of the discussion of the various referents of 'nature' in chapter 1 require that we next consider the ways in which the natural scientist and the mathematician differ. Once we understand those differences, one way of imagining how the two natures will be investigated, one that calls into question the unity of such an investigation,[26] will be blocked, and the way will be open for a radically different approach to the investigation of nature.

4. Blocking demotion

Up to this point I have been arguing that, on a plausible construal of Aristotle's audience as he begins his 'fresh start' in *Physics* 2. 1, his delineation of two ways in which nature is spoken leaves room for a serious misunderstanding of the science of nature he is proposing. That misunderstanding derives from a mistaken view about the relationship between mathematics and natural science, a view that one might be encouraged to believe by certain key passages in the *Posterior Analytics*. At this point Aristotle needs to clear up the question of how the modes of investigation of the mathematician and the natural scientist differ in order to foreclose that misunder-

[26] Recall that the general topic of *Posterior Analytics* 1. 13 is how knowledge of the fact and of the reason why differ. The subordinate sciences are discussed because they present the special problem of knowledge produced when the fact and the reason why are investigated by different sciences; cf. $78^{b}34$–9.

standing. Mathematics, it will turn out, is not suited to investigating 'forms of natural and perishable things'.

It is of some interest, and of some importance, that this chapter not only begins by asking about the difference between the mathematician and the natural scientist—it *closes* by distinguishing the way in which form is investigated by the natural philosopher and by the first philosopher:

> But it is the work of first philosophy to determine the character of the separable and what it is.[27] ($194^{b}14$–15)

That is, one overarching purpose of the chapter is to situate the study of *natural* form with respect to theoretical sciences.[28] And the key question will be how form, as the 'prior' nature of natural things, is to be investigated if it is *not* to be investigated by mathematics or metaphysics. Since, in the first chapter of *Physics* 2, Aristotle makes no clear distinction between shape, form, and figure, and allows that the form studied by the natural scientist is separable from its underlying subject *κατὰ τὸν λόγον*, his audience will view the thought that it is to be investigated by mathematics (or, depending on the character of its separability, first philosophy) as a real possibility.

We are now ready to return to the opening lines of *Physics* 2. 2, which present an *aporia* intended to make this possibility even more vivid:

> Since it has been determined in how many ways nature is spoken of,[29] we need next to study in what way the mathematician differs from the natural

[27] The conjunction 'and' here harbours a troubling ambiguity. Aristotle may be saying that it is a task of first philosophy to investigate the manner in which the separable exists and what the separable is; or he may be distinguishing the question of how the separable exists and how 'the what is it' exists, the latter being shorthand for the topic assigned to first philosophy at *Phys.* 1. 9, $192^{a}34$–6. Recalling that this paragraph opens by asking about the limitations of the natural scientist's knowledge 'of form and what something is', and answers by indicating a limited sort of separability for natural form, I am inclined to the second alternative, keeping in mind, however, that they are intimately related questions. Waterfield's translation favours the first alternative: 'Questions remain—in what sense is anything separable? What is it that is separable?—but it is the job of first philosophy to answer them' (R. Waterfield (trans., with introduction and notes by D. Bostock), *Aristotle:* Physics [Waterfield] (Oxford, 1996), 38).

[28] A point stressed by Mansion, 122–43; Simplicius and Philoponus consider the opening of *Physics* 2. 2 to be aimed at situating natural science among the theoretical sciences, yet they provide no motivation for this topic being taken up here. See n. 2 above.

[29] The λ group of manuscripts and Philoponus read *λέγεται* after *ἡ φύσις*. But

scientist (for natural bodies also have planes, solids, lines, and points, things which the mathematician investigates). Moreover, is astronomy different from or a part of natural science? For it would be odd if it were up to the natural scientist to know what the sun or the moon is, but to know none of their proper attributes, especially since those who discuss nature apparently also discuss the figure of the moon and sun, as well as whether the earth and the cosmos are spherical in form or not. ($193^{b}22$–30)[30]

The need to take up this issue is a consequence of the argument in chapter 1 that there are both formal and material natures, along with the absence of any clarification of what an investigation of formal natures will look like. This lack of clarification leaves open the possibility that it will be the subject of a distinct, perhaps mathematical, science. The above passage now heightens the concern by immediately blocking one response—namely, that the things that mathematicians study are *not* features of natural things. This answer will not do, Aristotle insists, because the things mathematicians investigate *are* features of natural things—not only that, but natural scientists actually study at least some of those features.

The above passage suggests that two distinct questions are being asked. The first raises a concern about whether, given that the items studied by mathematicians (points, lines, etc.) are present in the very objects studied by the *physikos*, there is a difference between them. The second is a more specific question about whether astronomy, in particular, is different from or part of natural science. The second question is not motivated solely by Aristotle's reflections on his predecessors. *De caelo* 2. 4, $286^{b}10$, announces its aim to prove that 'it is necessary for heaven to have a spherical figure [*σχῆμα . . . σφαιροειδές*]', and 2. 14, $297^{a}8$, claims it will prove the same conclusion regarding the earth.[31] The relation of astronomy

whichever text one reads, I take it that Aristotle has given us a core definition of nature (source of change and stability in the thing itself), has identified two distinct natures (underlying matter and form), and has provided arguments for giving priority to nature as form.

[30] In a rich and valuable study of this text, Ian Mueller has made a convincing case for reading *ἔτι ἡ* at $193^{b}25$, which is found in all the manuscripts, as opposed to *ἔτι εἰ ἡ* adopted by Ross following a suggestion by Susemihl. As well as a penetrating treatment of the interpretations of this passage provided by Ross, Simplicius, Thomas Aquinas, and Averroes, Mueller gives a thorough analysis of the history of the printed texts and translations of $193^{b}22$–$194^{a}12$ (I. Mueller, 'Physics and Astronomy: Aristotle's *Physics* II. 2. $193^{b}22$–$194^{a}12$' [Mueller], *Arabic Sciences and Philosophy*, 16 (2006), 175–206.

[31] As Simplicius stresses: *In Phys.* 290. 20–4 Diels.

to natural science is raised as a *distinct* question because later in the chapter Aristotle will draw a clear, though subtle, distinction between 'the more natural of the mathematical sciences', including astronomy ($194^{a}7$–8), and the mathematical sciences *tout court*. In the end, though closely related, the answer to the question of how the *geometer* differs from the natural scientist is quite different from the answer to the question of whether *astronomy* is part of natural science or not.[32]

What is interesting about this opening passage is that the problems that are raised for differentiating mathematics and natural science are problems generated by Aristotle's own philosophy of mathematics and his cosmological practice. For that reason, variants of a Platonic or Pythagorean answer to the question are not available; the problem is urgent because the view that is taken to generate it is the view that the mathematician and the natural scientist are enquiring about features of the very same objects. It is part of the task of natural science to know what things like the sun and moon are. But it would be odd to suppose that it should know what these heavenly bodies are, but not know their proper attributes—one of the primary tasks of a science, on the *Analytics* model, is to prove that the proper attributes of a kind must belong to that kind from a knowledge of the kind's essence. Not only do other natural philosophers study things like the *figure* (*σχῆμα*) of the sun and moon, and ask questions about whether the earth or the whole cosmos has the *form* of a sphere (*σφαιροειδής*)—Aristotle himself aims to answer these questions in the *De caelo*. The worry expressed here arises from Aristotle's own theory and practice.

Given the examples that are used, one might expect Aristotle to be focused on the 'second' question, that of whether astronomy is a part of natural science or not; but in fact he begins to develop his positive answer by developing his views on the ways in which the natural scientist and the 'pure' mathematician differ, returning to astronomy when considering 'the more natural of the mathematical sciences'.

Aristotle insists that though the mathematician and the natural

[32] Note, however, that in the pairing of mathematical and observational investigations at *Post. An.* 1. 13, $78^{b}35$–9, astronomy is on the side of geometry, stereometry, and arithmetic. Similarly, 1. 14 opens by claiming that the mathematical sciences demonstrate through the first figure, and cites arithmetic, geometry, *and optics* as evidence ($79^{a}18$–21).

scientist may investigate the same objects, the ways in which they investigate these objects are fundamentally different:

> The mathematician also makes a study of these things, *but does not treat each as a limit of a natural body; nor does he study these attributes as being attributed to such bodies*. And for that reason he separates; for each of these attributes can be separated from change by thought and it makes no difference, nor does falsity arise in separating them. (193^b31–5)

What he accepts from the *aporia* that suggests mathematics can in some way be identified with natural science is as critical as what he rejects. While he rejects the idea that the mathematician studies these features *as* attributes, specifically limits or boundaries, of natural substances, he nevertheless accepts the view that they *are*, ontologically, *attributes of natural bodies*. In contrast to the discussion in the *Posterior Analytics* we looked at earlier, however, he is careful *not* to make use of the language of form as a description of the relation of mathematical properties to their natural bearers—they are limits of bodies, which are among their attributes (*συμβεβηκότα*).[33] His positive response thus has two important features. First, he is stressing that the mathematician makes use of a special sort of *cognitive separation* in his study of certain attributes of natural body; second, he carefully avoids referring to what is cognitively separated as the form of a natural body.[34]

A brief return to *De caelo* 2. 14 is useful here. It presents an extended argument that the earth is 'by nature spherical'—and I take 'by nature' seriously. The arguments are *natural* arguments, arguing that the earth must be spherical from premisses about natural place and the tendencies of the natural elements to move towards those places. Once, however, during this argument, he refers to 'statements derived from the mathematicians concerned with astronomy' (297^a3–4) in support of his argument, stressing that he is borrowing from another science. So our *Physics* passage should not be thought to argue that the *physikos* cannot provide explanations of attributes such as the spherical shape of the earth. What

[33] Not that this language would be inappropriate in all contexts—in a purely mathematical context where the language of intelligible matter might be acceptable, talking about the form of a triangle would not, perhaps, be out of place. But here we are discussing the proper way to study formal natures, or natural forms.

[34] On the crucial role of the *qua*-operator as a predicate filter in this cognitive separation, see J. Lear, 'Aristotle's Philosophy of Mathematics', *Philosophical Review*, 91 (1982), 161–92.

he could *not* do, on Aristotle's view, is use proofs that start with premisses about spheres as such to explain certain other attributes of the earth that it has because it is a sphere—*that* would be a task for the astronomer.

It is, I think, revealing of the motives lying behind our passage in *Physics* 2. 2 that the transition to comparing the way the natural scientist studies these attributes with the way the mathematician does is effected by pointing out the problems of 'those who speak of the ideas':

> Yet it escapes the notice of those who speak of the ideas that they too are doing this; for they separate natural things, which are less separable than mathematical properties. ($193^{b}35$–$194^{a}1$)

The fact that the 'friends of ideas' consider natural forms[35] in separation shows us that it has escaped their notice that they are merely separating the objects of study *in thought from change*—if they realized this is what they were doing, they would realize that, while it is possible to do so in the case of mathematical attributes, you cannot separate natural forms from change without introducing serious errors, since these are capacities of natural bodies to function in various ways:[36]

[35] Aristotle refers to these 'friends of the ideas' as mistakenly separating *τὰ φυσικά*; but since they are assumed to be 'speaking about ideas', I take it that what they are mistakenly separating are natural forms (which after all in their view would be what natural things really are, if they really are anything). Ross claims that Aristotle is charging the Platonists with 'doing improperly with regard to *τὰ φυσικά* what mathematicians do rightly with regard to *τὰ μαθηματικά*, not charging them as he often does with asserting ontological separation for Forms' (Ross, 506–7, ad $193^{b}22$–35; cf. Bostock's note in Waterfield, 239–40; and P. Pellegrin (trans. and comm.), *Aristote: Physique* [Pellegrin] (Paris, 2000), 123). But Aristotle's charge against these Platonists is rather that they fail to recognize what mathematicians are actually doing, and their attempt to separate 'naturals' is evidence of that failure. If they did realize that there was a special form of cognitive separation peculiar to mathematics, they would not make the mistake they do. And the reason why they do not realize what is going on in mathematics might well be that they think of mathematics not as based on a cognitive separation, but on a cognition of separables.

[36] In this paragraph I assume answers to two questions: what does *τοῦτο* at $193^{b}35$ refer to? and why does Aristotle say only that *τὰ φυσικά* are *less separable* than *τὰ μαθηματικά*? I take it that what the Platonists do not understand is that in mathematics separation is the result of an act of cognition, not a mere recognition of the actual separate existence of mathematicals; it is that separation is a 'doing' that they miss. On the other hand, natural forms are only *less* separable because they are, in their own way, separable. Cf. $193^{b}3$–5 and $194^{b}12$. As I shall discuss shortly, I see Aristotle articulating two distinct kinds of 'abstraction' here, one appropriate for mathematics and another for natural science.

And this[37] would become clear if one were to attempt to state the definitions of these things and their attributes. For on the one hand it will be possible to give definitions of odd, even, straight, curved, and again of number, line, and figure, without change, but not of flesh, bone, and man—these things are spoken of just like snub nose, but not like concavity. (194^a1–7)

The error of treating natural things as *equally* separable is revealed once you attend to the differences in the way concepts in the two domains are defined. The cognitive isolation involved in mathematical concept formation is an isolation of certain attributes of physical objects from change, while change is at the very heart of the science of nature. Thus in framing a definition of unit or odd in arithmetic, or line or triangle in geometry, it is as if they are eternal and immutable. But the objects investigated by natural science are essentially material bodies with their own capacities for change. To leave that out of account would be to fail to understand them at all.

This is the theme that ties this discussion to what immediately follows, and I shall return to it shortly. But it is important that we do not leave the discussion of how the natural scientists and the mathematicians differ without considering the *other* evidence that Aristotle insists points to the error of the Platonists, namely the investigations of optics, harmonics, and astronomy, the 'subordinate' sciences. Considering them returns us to the second question with which Aristotle began, whether or not astronomy is a part of natural science:

And this is also clear with respect to the more natural of the mathematical sciences,[38] e.g. optics, harmonics, and astronomy, for they are in a way the reverse of geometry. For while geometry investigates natural line, but not

[37] Again the precise reference of *τοῦτο* is not obvious. I am taking it to refer to the general idea that natural forms are less separable than the attributes separated in thought by mathematicians (cf. Pellegrin, 123 n. 4).

[38] *τὰ φυσικώτερα τῶν μαθημάτων*. J. Barnes (trans. and comm.), *Aristotle:* Posterior Analytics, rev. edn. (Oxford, 1993), 159, erroneously cites this passage and a number of others as saying the opposite, that these are 'the more mathematical of the natural sciences'. And as Mueller notes (Mueller, 178) while Ross translates correctly, in his commentary he makes the same error (Ross, 507). A more subtle mistake is made in the translations of Charlton ('those branches of mathematics that come nearest to the study of nature') and Waterfield ('the branches of mathematics that are closest to natural science'). Translating the comparative as if it were making a point about proximity misses Aristotle's point: these special mathematical investigations use a distinct *method*, considering certain mathematical lines *as natural*. These recent translators, along with Pellegrin ('les parties plus physique des mathématiques'), also treat optics, harmonics, and astronomy as 'branches' or 'parts' of mathematics. There is nothing in the Greek that requires that—'the more natural of the mathematical

as natural, optics studies mathematical line, however not as mathematical but as natural. (194^a7–12)

What is meant by the claim that these sciences reverse the procedure in geometry, and why would this fact help to make the error of the Platonists clear? I take the point to be this: since ontologically speaking lines are limits of body, the geometer is, in a qualified sense, investigating natural lines. But since, for example, the properties of a curve are what they are regardless of whether it is the curve of a nose, a mollusc shell, a shoreline, or an astronomical body, one can cognitively isolate curvature from the natural contexts in which it is found, and investigate it and its properties independently of those contexts. In optics, on the other hand, you may base your proofs on geometrical propositions and constructions having to do with arcs and tangents of a semicircle or circle, that is, with those very mathematical properties of curvature; but you then must specify those arcs and tangents and semicircles as features of a particular kind of natural phenomenon.[39] Phenomena such as eclipses and rainbows cannot be discussed without such a specification, which will introduce premisses regarding movement and relative spatial position. Comparing geometry with optics once again reveals the error of the friends of ideas, who think that in these studies too you can separate without loss.[40] Again, Aristotle carefully avoids the suggestion of *Post. An.* 1. 13 that these subordinate sciences study the mathematical *form* as the *form* of a natural subject. But how these 'more natural of the mathematical sciences' are to be distinguished from natural science is by no means clear at this point.

Introducing at this juncture the idea that the objects to be investigated by natural science are defined 'like snub nose' rather than like 'concavity' is revealing in two respects that I will attempt to bring out during the discussion of the second, constructive part of the chapter in the next section. This concept, along with the nominalized adjective 'the snub' and the abstract noun 'snubness'

sciences' does not impose a view about how these sciences are related to geometry and arithmetic.

[39] Compare the argument against the separation of the objects of astronomy, optics, and harmonics at *Metaph. M* 2, 1077^a1–8, which concludes with the thought that consistency must force the Platonists to accept natural objects such as animals that are separate from the perceptual ones.

[40] Indeed, Plato's attitude in the *Republic*, only slightly modified in *Phileb.* 57 ff., is that you gain in understanding by such separation, in view of the lack of exactness introduced by attempting to number and measure in the realm of becoming.

introduced in the very next sentence, plays both a negative and a positive role in the Aristotelian corpus. The philosophical literature on Aristotle's views about essence and definition focuses almost exclusively on its negative role of pointing to certain problems that arise when one seeks to model definitions of substances on those of *per se* attributes such as straight and curved, in which the subject (line) must appear in the definition. In *Metaphysics E* 1 and here in *Physics* 2. 2, however, 'the snub' is used as a model for how natural objects, in contradistinction from the objects of mathematics, are to be defined.[41] How these two sorts of passage are to be understood relative to one another is the topic for another occasion; but I will here suggest that even in *Physics* 2. 2 Aristotle uses it both to point out a unique feature about natural definitions and to point to a way in which this model can foster misunderstanding.

5. The unity problem

To sum up the discussion to this point: according to the interpretation of $193^{b}22$–$194^{a}12$ on offer, Aristotle is ruling out one reasonable expectation an audience might have about how to investigate nature once presented with the idea that natural objects have two natures, the primary one being their configuration, shape, or form. Nature understood as the form of a natural object will *not* be investigated by mathematics. The mathematician cognitively isolates certain attributes from the very changes that natural science seeks to understand. Not even in the case of the 'more natural of the mathematical sciences' is it their role to study natural form. Rather, those sciences are restricted to explaining certain mathematical attributes of natural objects and processes by reference to more fundamental mathematical properties.

However, while the idea of a hybrid science of nature with mathematics investigating formal natures has been rejected, no positive picture has been presented to take its place. It is clear from the very

[41] There are interesting discussions of 'the snub' in D. M. Balme, 'Aristotle's Biology is not Essentialist' [Balme], in Gotthelf and Lennox (eds.), *Philosophical Issues in Aristotle's Biology*, 291–312; M. Ferejohn, 'The Definition of Generated Composites in Aristotle's *Metaphysics*' [Ferejohn], in T. Scaltsas, D. Charles, and M. L. Gill (eds.), *Unity, Identity, and Explanation in Aristotle's Metaphysics* (Oxford, 1994), 291–318; and M. L. Gill, *Aristotle on Substance: The Paradox of Unity* [Gill] (Princeton, 1989).

next lines that it is the task of the remainder of the chapter to do just that. This passage deftly imports the one positive suggestion from the first part of the chapter and uses it to raise the key problem still on the table:

> Since nature is in two ways, the form and the matter, we should study it as if we were investigating what snubness is; we should study such things neither without matter nor according to matter. For indeed someone might very well raise a problem about this investigation: since there are two natures, about which is it for the natural scientist to study? Should he study the composite of both? But still, if he studies the composite of both, he also studies each one. So then, is it for the same or for a different science to know each nature? (194^{a}12–18)

Recall that Aristotle thinks that the error of the Platonists becomes clear when you compare definitions of concepts such as concavity, with those of, say, flesh or bone. The latter are referred to in the way that snub noses are, rather than in the way that curvature is. He now ties the thought that natural things have two natures to that very way of differentiating natural from mathematical investigation. His only hint here, however, about what such investigations are like is that they are carried out neither without matter nor simply in accordance with matter (194^{a}12–15).[42] However the investigation of these two natures is to be carried out, it will not be by means of the kind of separation practised appropriately by mathematicians.

The precise form of this methodological recommendation provides us with some additional interpretative clues. The model investigation is a *τί ἐστι* investigation *περί σιμότητος*. The object of investigation is not 'snub nose', which suggests a property predicated of a subject, but the abstract property 'snubness', and we are aiming to understand its essence.[43] This suggests that natural science will study universals that will refer to natural objects *as* material/formal unities. One cannot aim to know what natural things are *qua* natural by cognitively isolating their form

[42] For the force of 'not without matter', compare *DA* 3. 4, 429^{b}13–14: *ἡ γὰρ σὰρξ οὐκ ἄνευ τῆς ὕλης, ἀλλ' ὥσπερ τὸ σιμόν, τόδε ἐν τῷδε*; cf. *Metaph. E* 1, 1026^{a}6.

[43] I think this passage speaks against the statement in Gill, 114–15, that 'the essence of snubness is simply concavity'. Gill recognizes that what Aristotle says in what I have referred to as the 'positive' discussions of snubness runs counter to the implication of the *aporia* in *Z* 5. I of course am arguing that Aristotle is aware of the limitations of 'snubness' as a model for the unity of a natural composite.

from matter and change—snubness is necessarily concave flesh and bone.[44]

While 'snubness' is a fine model for making this point (since it is both an abstract noun and refers to a composite), it fails to solve the key problem that now needs to be solved, the problem of the nature of the unity of such composites. Before turning to Aristotle's solution, it is worth considering the limitations of 'snubness' as a model for the object of natural investigation.[45]

Aristotle sometimes claims that if we were to state what snubness is it might be something like 'concavity in a nose' or 'concavity in flesh and bone'. Defined in this way, he notes, the property of 'snubness' has certain affinities to the second sort of *per se* attribute discussed in *Post. An.* 1. 4, of which 'odd' and 'even' or 'male' and 'female' are good examples.[46] A number may be odd or even, but in defining 'odd' or 'even' you must mention 'number', and in defining male and female you must mention animal. Likewise, not every nose is snub, but in defining snubness you must mention nose.

To this point, the parallel is instructive. However, the proposed definition reduces snubness to the concavity of a certain sort of matter, or material part. If that is what snubness is, however, it is strikingly different from 'odd' or 'male'. For there are an indefinite number of concave things that are not noses, and a variety of noses that are not concave. It seems that 'the snub' refers to a contingent relationship between a certain geometric shape and certain materials. And thus the question of whether the two natures Aristotle has introduced his audience to have the requisite unity to be studied by a unified science of nature is still pressing.

Moreover—to anticipate the model of the unity of a natural object that Aristotle will soon begin to sketch—snubness fails to capture the most important fact about natural unity for Aristotle, its dynamic character. It is often noted, but as often ignored, that when Aristotle stresses the differences between mathematical and natural abstractions, it is typically by stressing that the mathematician studies his objects in separation from *change*, while the natural scientist

[44] This is stressed at *DA* 1. 1, 403^{a}25, with the pregnant phrase *λόγοι ἔνυλοι*, which pointedly puts matter in the adjectival position.

[45] For insightful discussion of Aristotle's use of this example to raise puzzles about definitions of natural substances in *Metaphysics Z*, see Balme, 306–12; Ferejohn, 291–318; Gill, 114–16.

[46] The *aporia* is clearly stated at *Metaph. Z* 5, 1030^{b}14–28.

cannot, in the nature of his investigation, do that.[47] Snubness is a good model for concepts that refer to unities of shape in material; but if the unity one aims to capture is that of capacity and activity, or of body and soul, it leaves much to be desired.

This explains an initially puzzling feature of this second part of *Physics* 2. 2, that an *aporia* about which of the two natures the natural scientist should study is raised *after* the snubness model has been endorsed. The fact that you are to investigate the matter but not restrict yourself to it does not settle the question of whether it is also up to the same science to study form; that will all depend on the nature of the relationship between matter and form. As he goes on to say, even if you are convinced that the objects studied by the natural scientist are matter/form composites, it remains an open question whether the natural scientist is to investigate both *components*. That will depend on the precise nature of their relationship. After all, the problem that drove the discussion up to this point was that the mathematician and the natural scientist begin their investigations with the same composites, and the very existence of mathematics proves that you need not study a composite *qua* composite.

This *aporia* is still on the table, then, because no positive account of how to investigate objects with both formal and material natures has been offered, and the option of conceiving it as some sort of amalgam of a mathematical and a natural study has been ruled out. The 'two sciences' option is still a possibility. Aristotle seeks to overcome it by focusing on the way in which natural form and natural matter are related.[48]

[47] $193^{b}33$–5 claims that what the mathematician does is separate by thought from change (*χωριστὰ . . . τῇ νοήσει κινήσεως*), and that this makes no difference from the standpoint of truth and falsehood; $194^{a}1$–7 contrasts the definitions given by mathematicians and natural scientists in the same terms, the former stating definitions without reference to change, the latter with reference to change; cf. *Metaph. E* 1, $1026^{a}3$.

[48] An interesting question, raised in comments on an earlier draft by Devin Henry, is what sort of investigator it might be, if not a mathematician. Pellegrin, 124 n. 4, following Philoponus, thinks the issue is whether it is one natural science or two. This, I think, cannot be right. Aristotle nowhere suggests that there is more than one science of nature. But the *De anima* offers a clear alternative, during a discussion of the very same issue in the context of the investigation of the affections common to body and soul, and the other science considered there is referred to as dialectic. The suggestion he is countering is that the natural scientist studies the bodily side and the dialectician the formal side. Since it is clear that Aristotle's central concern in articulating an account of natural science is to ensure that it can provide a full understanding of living things, it is reasonable to see these two discussions as closely related.

Confirmation for this reading comes from the very first thing he says after raising the *aporia*:

> Now if we turn to our predecessors, it would seem that the natural scientist should study the matter (for Empedocles and Democritus touched only to a tiny extent on the form and the essence) . . . (*Phys*. 2. 2, 194^{a}21–3)

That he chooses these predecessors, and mentions that they touch slightly on form and essence, is revealing when seen in the light of his expansion of this thought in *De partibus animalium* 1. 1. Regarding Democritus, we are there told:

> If it were by virtue of configuration [*σχῆμα*] that each of the animals and their parts is what it is, Democritus might be speaking correctly. . . . Yet though the configuration of a corpse has the same shape [*μορφή*] [as a human being], it is nevertheless *not* a human being. (640^{b}29–35)

When Democritus does nod in the direction of form, he takes his cue from mathematics and discusses configuration. Aristotle, on the other hand, insists that Democritus fails to speak correctly because in order to give an account of the essence of an animal or its parts, you must identify its (or their) capacities to function (641^{a}1–6).

Empedocles makes precisely the same mistake:

> For [formal] nature is a starting-point more than matter. Even Empedocles occasionally stumbles on this, led by the truth itself, and is forced to say that the being [*οὐσία*] and the nature [*φύσις*] is the ratio [*λόγος*], e.g. when he says what bone is. He does not say it is some one of the elements, or two or three, or all of them, but rather that it is a ratio of their mixture. (642^{a}17–21)

Logos can refer to various things in Aristotle, of course, but I think it is pretty clear what he has in mind here. Even if one translates it as 'account', the account that Aristotle has in mind here is one that specifies a precise quantitative ratio, a *harmonia*, among the elements.[49] Thus Empedocles too, in his stumbling attempts to move beyond a purely material account of nature, stumbles towards mathematics.

Aristotle looks for inspiration in another direction. Earlier, I in-

[49] Cf. Simpl. *In Phys*. 300. 21 Diels (=Empedocles 31 B 96 DK): 'And kindly earth received in its broad melting-pots two parts of the glitter of Nestis out of eight, and four of Hephaestus; and they became white bones, marvellously joined by the gluing of Harmonia.'

terrupted him in mid-sentence in order to pause over his comment about Democritus and Empedocles; the sentence continues:

> . . . however, if art imitates nature, and it is the task of the same science to know both the form and the matter up to a certain point (e.g. of the doctor to know health and also bile and phlegm, in which health resides; and likewise of the builder to know the form of the house and the matter, that it is bricks and timber; and in the same way too in the other cases), it would also be the task of natural science to know both natures. (*Phys*. 2. 2, 194[a]21–7)

This passage harbours a number of puzzles; the first is rarely commented on, but unless dealt with renders the argument one large *petitio*. The goal, specified conditionally, is to defend the thesis that it is up to natural science to know both the formal and material nature. But the protasis of the conditional seems to assume from the start that it is the task of the same science to know the form and the matter, from which one could infer directly that it is the job of one science of nature to study the formal and material nature. It would seem, then, that the reference of *ἐπιστήμη* at 194[a]22 must initially be restricted to the realm of *τέχνη*, as indeed is implied by the examples that are used to defend his claim—that medicine studies both health and bodily humours and that housebuilding studies the form of a house as well as bricks and wood. With that restriction, we can take the argument to be: if art imitates nature, and the student of the arts investigates and seeks to know both the form and the matter of his art, then the student of nature must seek to know both the form and the matter of natural things.

So spelt out, however, a second puzzling aspect of this conditional argument reveals itself. There is indeed a parallel that Aristotle often notes between art and nature, understood as the sources and causes of artistic and natural objects respectively—indeed this was a key feature of his development of the concept of nature as an internal source of change in chapter 1 (cf. 192[b]13–33). Art is a source of coming to be of its product, but the source is in the artist, not in the product; nature is a source of change within the natural thing itself. In the current passage, however, the focus is not on art as a *cause* of health or a house, but on art as *a kind of knowledge* possessed by the artist. But here the parallel, on which the adage 'art imitates nature' depends, breaks down. The sense in which art imitates nature is that the artist imposes formal structure on mate-

rials in a goal-directed manner, just as the nature of a natural thing does. But while the artist is at once the repository of the requisite artistic knowledge and the agent of artistic production, the natural scientist is only a knower of natural change, not its causal source. That is why, as we know from *Metaphysics E* 1, natural science is theoretical, while arts such as medicine and housebuilding are practical. Thus while the supposed major premiss of this argument is that art imitates nature, the feature of the arts to which he draws our attention—that the craftsman knows both form and matter up to a point—is *not* an imitation of nature (which does not know anything) but an imitation of, if anything, the natural scientist.[50]

Now it is possible that this is a highly compressed argument that, if expanded, might go something like this. 'I have made the case that there are two natures, and the issue now on the table is whether there is a single science of nature that studies them both. Since art imitates nature, perhaps we can gain insight into this question by looking at the arts. Now in the arts we can see that, as in nature, there is both a formal and a material aspect to its objects. But that does not lead to two distinct areas of knowledge, one of the formal aspect and one of the material aspect. Rather it appears that, for the doctor to do his job, he needs to have knowledge of both. If that is correct, then it will be for the natural scientist to know both natures as well.' However, it must be conceded that the argument Aristotle actually gives us trades critically on an unmentioned ambiguity in the notion that art imitates nature.[51]

With that in mind, I would like to suggest that this conditional argument is not intended to convince us of its conclusion so much as to point us towards the domain of artistic production for insight into how it might be that there could be a unified understanding of a composite of matter and form. That is, I see this somewhat puzzling, conditional argument as setting up the immediately following argument, one that is not conditional and that depends heavily on some detailed discussion of craft knowledge. It is in that discussion

[50] However, one of the crafts used as an example is medicine, which brings us quite close to natural science: the doctor, that is, both enquires what health—a capacity of the organism to function properly—is and what bile and phlegm are since health depends on them.

[51] There are also puzzles regarding the phrase *εἰδέναι τὸ εἶδος καὶ τὴν ὕλην μέχρι του*. Is it only matter that is to be known 'up to a point', as Ross (508, ad $194^{a}23$) claims, or both matter and form? And in either case, does Aristotle anywhere tell us up to *what* point? The answer to the second question is yes, he apparently does at $194^{b}9$–10, and I shall return to the first question when I consider his answer.

that Aristotle begins to present the case for a revolutionary concept of the unity of natural science, a case that it will take the rest of book 2 to complete:

> Further, it is the task of the same [science?] to know that for the sake of which and the end as well as what is for the sake of these; and nature is an end and for the sake of which (for among those things of which there is some end of continuous change, this final thing is also that for the sake of which [the change occurred]) . . . (*Phys*. 2. 2, 194^{a}27–30)

After a comical aside, Aristotle goes into some detail about the various sorts of knowledge that are involved in craftsmanship, using an example familiar to readers of Plato's *Cratylus*.[52] The 'art imitates nature' adage has guided Aristotle's audience to the idea that we might gain insight by looking at art as to how form and matter are unified in such a way that they can be known by one science. He then asserts, but does not argue for, the claim that if the objects of study are teleologically organized, that is, if the objects of study undergo changes that proceed continuously to a goal, then it will be for the same science to study both the goal and what is 'for the sake of' that goal. He also asserts without argument that the nature of a natural object is a goal, a 'that for the sake of which'. It follows, then, that if natural science studies *that* nature, it must *also* study what is for the sake of that nature.[53]

Aristotle does not at this point provide an argument to convince his audience that nature is a domain that is teleologically organized; that is the explicitly stated aim of *Physics* 2. 8. With that in mind, Aristotle's next move is reasonable. He is going to lay out a familiar, teleological picture of craft production and the knowledge involved in it, and by way of two disanalogies between art and nature, sketch the radical idea that matter and form are unified in natural substances in a way that allows them to be studied by one

[52] See *Crat*. 390 B 11–C 1: 'SOCR. And who will direct the shipwright? HERM. The pilot'; 390 D 1–3: 'SOCR. Then the work of the carpenter is to make a rudder, and the pilot has to direct him, if the rudder is to be well made. HERM. True.' This example is one of many used to drive home the point that it is the user of a craft product who knows the appropriate form and materials (cf. 390 B 1–11) for producing his instrument and therefore must direct the craftsman. Compare *Phys*. 2. 2, 194^{b}5–7: 'The pilot knows and prescribes what the form for a rudder is, and the carpenter knows out of what sort of wood and by what changes it will be made.'

[53] Cf. D. Quarantotto, *Causa finale, sostanza, essenza in Aristotele* (Naples, 2005). Quarantotto's discussion of *Phys*. 2. 2 (165–77) is the only one I have encountered that sees a connection between the two sections of the chapter, and indeed her discussion is complementary to the argument I am presenting here.

science—unified by virtue of the form being that for the sake of which the matter comes to be and is. I say 'sketch', because this core idea of Aristotle's *Physics* is nowhere in chapter 2 stated with the clarity and elegance of its expression in this summary statement of chapter 8:

> And since the nature [of a thing] is twofold, on the one hand as matter and on the other as form, and the nature as form is an end, while other things are for the sake of the end, this [nature as form] would be the cause for-the-sake-of-which. ($199^{a}30$–2; cf. $200^{a}7$–15, $^{a}32$–$^{b}8$)[54]

The craft model will aid his audience in taking a first step towards understanding the teleological unity of natural science; but it is only in chapters 7–9 that the full picture is presented clearly.

It would take us too far afield to explore the discussion of craft production here in detail. I want to extract only two points from it, both points about the greater unity of natural objects compared with craft objects. First, craftsmen not only make their objects by informing matter in a goal-directed way—they also make their matter.[55] While he does not elaborate, Aristotle insists this is not the case with nature, where the matter is already present. Second, the objects of craft, at least in one obvious sense, are produced for the sake of the beneficiary, which, Aristotle reminds us, is only one of two ways in which the expression *τὸ οὗ ἕνεκα* is used.[56] This passage implies that it is in the other sense, as *the goal for which* of a change rather than as its beneficiary, that nature is *τὸ οὗ ἕνεκα*.

To this point, then, most of the lessons we are to draw from examining craftsmanship are by way of contrasts. Because there is a craft involved in making the matter, there may in fact be a distinction between the knowledge involved in making the matter

[54] The compression of Aristotle's Greek is impossible to capture in English: *καὶ ἐπεὶ ἡ φύσις διττή, ἡ μέν ὡς ὕλη ἡ δ ὡς μορφή, τέλος δ αὕτη, τοῦ τέλους δὲ ἕνεκα τἆλλα, αὕτη ἂν εἴη ἡ αἰτία, ἡ οὗ ἕνεκα.*

[55] We need not go into the details, but Aristotle rightly distinguishes between crafts where the material used is made from scratch (for example, bronze is a manufactured alloy of copper and tin) and those where it is rendered workable (as when timber is hewn into lumber). Ross's note on the passage (509–10) is quite helpful.

[56] Without explaining what these two ways are he refers readers to *On Philosophy* ($194^{a}35$–6), a lost work widely attested in the doxographical tradition. The distinction is very briefly elaborated on at *DA* 2. 4, $415^{b}2$–3, and *Metaph. Λ* 7, $1072^{b}2$–4; it is discussed in detail in W. Kullmann, 'Different Conceptions of the Final Cause in Aristotle', in A. Gotthelf (ed.), *Aristotle on Nature and Living Things* (Pittsburgh and Bristol, 1985), 169–75.

and the knowledge of the form required for directing production—though nothing Aristotle says suggests there is more than one craft involved in, say, building a ship. Moreover, because the crafts aim at bringing about results for human benefit, there is at least one way of answering the question 'what is it for?' of a craft product that does not identify the form to be produced.

Which brings us to the final question to be faced in this chapter—up to *what* point is it for the natural scientist to know the form and 'what-it-is' of things ($194^{b}9$–10)?[57] Recall that the entire discussion of whether there could be a unified understanding of both the formal and material nature was framed as a conditional of precisely this form: 'But if art imitates nature, and it is for the same science *to know the form and the matter up to a point* . . .' ($194^{a}21$–3). When we last visited those lines, I postponed the question of whether the scope of 'up to a point' ranged over knowledge of the matter alone or over both the form and the matter, except to note that Ross was inclined towards the first option. One reason for his inclination could well be that at first sight the passage we are about to look at appears to be about a third question different from either of those, namely: 'Up to what point should the natural philosopher study *the form*?' There would then, on Ross's suggested reading of the first passage, be a pleasing balance: the first conditionally endorses studying matter up to a point, the second equally conditionally endorses studying form up to a point. It is now time to explain why this apparently reasonable reading cannot be correct.

The clue to the correct understanding of both passages lies in the apparent non sequitur formed by the question posed and the answer given:

> Up to what point, then, should the student of nature know the form and the what-it-is? Perhaps just as a doctor knows sinew and a sculptor bronze, up to the point of knowing what each is for, and about that which is separable in form but in matter. ($194^{b}10$–13)

The question that is posed concerns the extent of the natural scientist's knowledge of *form*, but initially it looks as if the answer concerns the extent to which the natural scientist should know things analogous to a craftsman's knowledge of his *matter*. But notice Aristotle's full answer: the craftsman and the natural scientist

[57] The text is disputed. For a good discussion of the issues and some of the options see Ross, 510–11, ad $194^{b}10$–13.

need to know what the relevant matter is *for*. And what is the matter for? It is for its goal, *τὸ οὗ ἕνεκα*. That, however, is a certain sort of knowledge of the formal nature. It is, indeed, knowledge of the form, up to a point; but also of the matter, as present and organized for the sake of the form.

Aristotle's answer, then, takes us directly back to the teleological model of unity—'it is for the same science to know that for the sake of which and the end as well as what is for the sake of these'. It is up to the natural scientist to investigate form in so far as form is identified with *the goal of certain materials* (and again we are told to look to crafts such as medicine or carpentry for a model of how this works).[58] By framing the answer in the way that he does, Aristotle underscores the way in which the teleological unity of matter and form leads to an *epistemological* unity—one enquires into natural form by asking, about things like flesh and bone, 'What are they for?' Such teleological unification is characterized clearly at *PA* 2. 1, 646^{b}14–25:

> And since the actions and movements present both in animals as a whole and their non-uniform parts are complex, it is necessary for their components to have distinct potentials; for softness is useful for some things, hardness for others; certain things must have elasticity, others flexibility. Thus while in the uniform parts such potentials are distributed part by part (one of them is soft while another is hard, one moist, another dry, one pliant, another brittle), in the non-uniform parts they are distributed to many and are conjoined with each other; for a different potential is useful to the hand for pressing and for grasping.[59]

What makes it necessary that a hand is composed of flesh, bone, and muscle distributed in a certain way is the complex activity for which hands are constructed.

[58] Thus we return to Ross's note suggesting that the *μέχρι του* at 194^{a}23 'is probably meant to qualify only the knowledge of the matter, since any science should know completely the form or essence of the things studied by it' (Ross, 508). In the light of Aristotle's remarks at the end of book 1, about a 'source according to form' that needs to be considered by first philosophy, and the claim there that the discussion to follow immediately will be restricted to 'forms of natural and perishable things', it is reasonable to take Aristotle to be restricting the knowledge of form here to what a natural scientist can say about it. Moreover, the second use of *μέχρι του* is clearly suggesting a limitation on the natural scientist's knowledge of form (contrary to Ross's note), but one which implies as well a limitation on his knowledge of matter. So I think we must read the first passage as I have suggested earlier, with *μέχρι του* ranging over both form and matter.

[59] J. G. Lennox (trans. and comm.), *Aristotle:* On the Parts of Animals *I–IV* [*PA*] (Oxford, 2001), ad loc.

That may or may not be all there is to say about form, however. In the last lines of this sketch of how a science of two natures might be unified, Aristotle returns to the question of separability. After saying that the *physikos* should study form just as a doctor studies the form of sinews by asking what they are for, he adds: 'and about things which are separable in form, yet are in matter' ($194^{b}12–13$). This expression is *prima facie* odd. For the things he appears to be discussing are natural forms, and it is odd to say that forms are separable in form. However, the immediate focus is on the idea that the natural scientist is to know what natural things are in the way that the doctor is to know that for the sake of which a bodily part is as it is. The thought, then, is that one can think of the biological function formally, but it is always the function of some material body.[60] The thought goes back to the idea that the Aristotelian conception of natural science is that it studies things that are 'not without matter, but not in accordance with matter'. 'Separable in form but in matter', in other words, is the positive way of saying 'not without matter, but not in accordance with matter'. The nature of this 'separability in form' or 'in account', however, and how it differs from the 'separability in thought from change' that Aristotle grants to mathematical attributes, is not explored here. There is much more to be said about this issue, and much more that *is* said in *Metaphysics Z–H*.[61] That, I take it, is why this is knowledge of form (and matter) only up to a point, and why, however one reads them, the last lines of *Physics* 2. 2 point to issues concerning separability that are to be taken up by first philosophy.

Aristotle does not justify his focus on the crafts in these initial steps towards a teleologically unified science of nature, but I can provide a conjecture that has some initial plausibility. He wants to move us away from the idea that natural form is to be thought

[60] Ross, 510, ad $194^{b}10–13$, glosses over the problem but reaches the same interpretation. The parallels between this closing section of *Physics* 2. 2 and *DA* 1. 1, $403^{a}25–^{b}19$, are extensive and worth exploring in depth. Both take seriously the question of whether the formal and material components of a composite are to be studied by a single science or not; and both discussions revolve around questions about the nature of the separability of the objects to be investigated by the natural scientist, the mathematician, and the first philosopher (cf. $403^{b}9–19$), as if trying to ensure a place for a distinctive, and unified, theoretical science of nature.

[61] Moreover, it is instructive to consider the differences between the discussion of living functions in the *De anima* in comparison with works such as *De partibus animalium*, *De incessu animalium*, or *De respiratione*. There are ways of discussing living form that, while acknowledging its material basis, abstract significantly from it.

of as mathematical structure, so easily separable in thought from material embodiments, towards the idea that natural form is to be thought of as the functional capacity that is the source of unity of the natural thing's materials—to identify their proper function is to explain why certain materials are present rather than others, and why they are organized in the way they are. The shift takes place, as many commentators have noted, within a comfortably Platonic environment, reminiscent of *Gorgias* or *Cratylus*;[62] and yet by the end of *Physics* 2 that environment has been transformed into something utterly alien to a Platonic investigator of nature.[63]

6. Conclusion

In *Phaedo* Socrates sees two values in the Anaxagorean natural science he imagined; the first is that it will be able to explain, by reference to the good, why it is that organisms are configured as they are and behave as they do, when they do. The other is that it can give a similar explanation for the configuration of the earth and the cosmos. Plato presents, in the *Timaeus*, a teleological science of the created cosmos wherein mathematical structure, in the form of harmony, proportion, and geometric figure, is the model of how to implement the good in matter, starting with the heavens and implemented all the way through to accounts of flesh and bone.[64]

Aristotle is developing a teleological science of nature as well.

[62] For the parallels in the *Cratylus* see n. 53 above. Cf. *Gorg.* 503 E–504 A: 'Look, for example, if you will, at painters, builders, shipwrights, and all other craftsmen—any of them you choose—and see how each one disposes each element he contributes in a fixed order, and compels one to fit and harmonize with the other until he has combined the whole into something well ordered and regulated.'

[63] Sean Kelsey, in commenting on an early draft of this paper, urged the view that *Laws* 10 should be seen as an important background here as well (cf. S. Kelsey, 'Aristotle's Definition of Nature', *Oxford Studies in Ancient Philosophy*, 25 (2003), 59–87 at 84–6). I have no doubt that the ideas found in *Laws* 10, e.g. at 892 A–B, express a view to which Aristotle is self-consciously offering an alternative. But I believe that alternative is already explicit in the *Timaeus*, a dialogue to which Aristotle refers constantly and repeatedly in his natural works, while the *Laws* is referred to only in his political and ethical works, and to my knowledge book 10 is never explicitly referred to.

[64] On which see T. K. Johansen, *Plato's Natural Philosophy* (Cambridge, 2004), chs. 4–5; J. G. Lennox, 'Plato's Unnatural Teleology', in D. J. O'Meara (ed.), *Platonic Investigations* (Washington, 1985), 195–218; D. Sedley, 'Teleology and Myth in the *Phaedo*', in J. J. Clearly and D. C. Shartin (eds.), *Proceedings of the Boston Area Colloquium in Ancient Philosophy, Volume V (1989)* (Lanham, Md., 1991), 359–83.

But it is one that moves the study of life to centre stage. The study of form, as that for the sake of which matter is organized as it is, is not a mathematical study, but a study of function in relation to instrument. I have argued that *Physics* 2. 1 is addressed to an audience that may hear of a study of nature that distinguishes nature as matter from nature as form and imagine a natural science looking like a subordinate mathematical science of the sort described in *Posterior Analytics* 1. 13, one involving the mathematical study of form and an 'observational' study of matter. It is to subvert those expectations and convert that audience to a different idea of natural investigation that Aristotle constructs the argument of *Physics* 2. 2 as he does.

In the process, the concept of matter as a relational concept is quietly introduced. This will be of central importance to the success of this new science of nature. Aristotle's explanatory study of the parts of animals begins, as we saw, by defending layers of teleological explanation; simple bodies combined in a certain way so that the flesh will have the appropriate capacities; uniform bodies combined in certain ways so that non-uniform organs can perform their complex functions.[65] At least in the case of the living world, teleological unity goes all the way down. In practice, it leads to recommendations such as the following:

> The central reason why previous thinkers have not discussed these things [respiration] well *is their lack of experience with the internal parts and their failure to grasp that nature produces them all for the sake of something*; for had they been seeking that for the sake of which breathing belongs to animals, and had they been investigating this with respect to the parts, e.g. gills and lung, the cause would have quickly been discovered. (*Resp.* 3, $471^{b}23$–9)

Thinkers in the seventeenth century, such as Galileo and Newton, by viewing all of nature as a great, divinely designed mechanism, envisioned a future in which all of natural philosophy would take on the character of a hierarchy of subordinate mathematical sciences, with a mathematical mechanics at its core. Astronomy was already being viewed as celestial mechanics, and a similar reduction of optics and harmonics was under way. The Cartesians clearly had hopes that anatomy and physiology would rapidly fall into line, though biology to this day is unified by its interest in functional adaptation, even when those adaptations are at the molecular level. What

[65] *PA* 2. 1, $646^{a}24$–$647^{a}3$, part of which is translated and discussed above, p. 181.

is now the second chapter of the second book of Aristotle's *Physics* is, I have argued, addressed to an audience that had similar expectations, encouraged perhaps by Platonic and Pythagorean views about how a science of nature that takes form seriously should be organized, or by Aristotle's account of the subordinate mathematical sciences in the *Posterior Analytics*. That audience, as it turned out, was in for a surprise.

University of Pittsburgh

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