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Aristotle and Crossing the Boundaries between the Sciences

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Abstract: On the basis of what Aristotle says in the *Posterior Analytics* about how sciences are differentiated and about the impermissibility (save in some exceptional cases) of 'kind-crossing', many commentators suppose that when it comes to his scientific practice, Aristotle treats the boundaries of the sciences as *impermeable*, so that if subject-matter *X* is the business of one science, it simply cannot (save for the exceptional cases) be the business of another. I call this the *impermeable boundary theory* of the sciences: knowledge is divided into watertight compartments, determined by their distinct genera, and what goes on in one compartment cannot turn up in another. I argue that, even if this is a correct account of Aristotle's position in the *Analytics*, the view that he accepts the impermeable boundary theory when it comes to his scientific and philosophical work outside the *Analytics* is simply untenable.

1 Introduction

I begin with a famous passage from the *Republic* about dialectic:

> It does not treat these hypotheses as *first principles* but as true hypotheses, i. e. as steps and starting-off points, so that it can go on until it reaches the unhypothetical first principle of everything, and when it has grasped this, it turns round and, following the things which follow from it, comes down to the end-point without making use of anything perceptible but only of forms themselves, through forms to forms, and ending in forms (*Republic* 511b2–c2).

Few would disagree that Aristotle rejects the picture of the sciences which is implied by – or at least is often taken to be implied by – this passage. The philosopher cannot, sadly, be afforded a grand, synoptic vision of all wisdom: different sciences, for Aristotle, have different starting points, different axioms. There are places in the *Analytics* where Aristotle appears to go further, and this is where trouble begins: different sciences, he says, are differentiated by their subject-mat-

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ter, or genus, and cannot *share* either their subject-matter or their axioms.[1] There are some axioms common to all the sciences, of course,[2] but the axioms peculiar to science *A*, and indeed their consequences, cannot figure in science *B*. I shall call this the 'no-crossing rule':

> [T1] Thus it is not possible to prove something by crossing from another genus – for example something geometrical by way of arithmetic. For there are three things involved in demonstrations: one is what is demonstrated, namely the conclusion (and this is what holds of some genus in itself); another is the axioms (and the axioms are those things from which the demonstration comes about); and the third is the underlying kind whose properties and in-itself attributes the demonstration makes clear. So the things from which the demonstration comes about can be the same; but when the genus is different, as in the case of arithmetic and geometry, it is not possible to make an arithmetical demonstration apply to the attributes of magnitudes, unless the magnitudes are numbers. How this *can* be done, in certain cases, however, will be described later.[3]

The apparent *volte-face* in Aristotle's final remark that genus-crossing *can* be done involves two types of exception.[4] The first is that in which one science is subordinate to another, in the ways in which (on the one hand) optics is subordinate to geometry, or mechanics to solid geometry, and (on the other) the 'science of the rainbow' (i. e., the study of certain forms of meteorological optics) is itself subordinate to optics.[5] The second type of exception is, notoriously, the one exemplified, according to Aristotle, by the sciences of geometry and medicine in dealing with the fact that circular wounds heal more slowly than non-circu-

1 It turns out that for these purposes Aristotle allows that subject-matter/genus can (sometimes) be distinguished intensionally. Both the mathematician and the physicist, in a sense, study the same things – natural substances – but Aristotle is happy to allow that the science which studies *X*(s) *qua Y* may have a different subject-matter from the one which studies *X*(s) *qua Z*. See, e. g., [T10] below, *Met*. E.1 and M.3, and Section 3 below.

2 See *An. Post*. A.6–10, 28; cf. *An. Pr*. A.30, 46a17–24.

3 *An. Post*. A.7, 75a38–b6 (trans. Barnes [1994] with modifications): οὐκ ἄρα ἔστιν ἐξ ἄλλου γένους μεταβάντα δεῖξαι, οἷον τὸ γεωμετρικὸν ἀριθμητικῇ. τρία γάρ ἐστι τὰ ἐν ταῖς ἀποδείξεσιν, ἓν μὲν τὸ ἀποδεικνύμενον, τὸ συμπέρασμα (τοῦτο δ' ἐστὶ τὸ ὑπάρχον γένει τινὶ καθ' αὐτό), ἓν δὲ τὰ ἀξιώματα (ἀξιώματα δ' ἐστὶν ἐξ ὧν)· τρίτον τὸ γένος τὸ ὑποκείμενον, οὗ τὰ πάθη καὶ τὰ καθ' αὐτὰ συμβεβηκότα δηλοῖ ἡ ἀπόδειξις. ἐξ ὧν μὲν οὖν ἡ ἀπόδειξις, ἐνδέχεται τὰ αὐτὰ εἶναι· ὧν δὲ τὸ γένος ἕτερον, ὥσπερ ἀριθμητικῆς καὶ γεωμετρίας, οὐκ ἔστι τὴν ἀριθμητικὴν ἀπόδειξιν ἐφαρμόσαι ἐπὶ τὰ τοῖς μεγέθεσι συμβεβηκότα, εἰ μὴ τὰ μεγέθη ἀριθμοί εἰσι· τοῦτο δ' ὡς ἐνδέχεται ἐπί τινων, ὕστερον λεχθήσεται.

4 I shall not discuss whether Aristotle's argument for the impossibility (or impermissibility) of kind-crossing is consistent with the existence of these exceptions: see Lennox 1986; Barnes 1994, *ad loc*.; Hankinson 2005, Steinkrüger 2018.

5 See *An Post*. A. 13, with Barnes's commentary (1994); McKirahan 1978; Lennox 1986.

lar ones.[6] I shall return to this case below ([T9], 21 f.). What I wish to focus on for most of my article, however, is an implication that many commentators have drawn from Aristotle's general approach here: the claim that the boundaries of Aristotelian sciences are *impermeable*, so that if *X* is part of the subject-matter of one science, it simply cannot (save for the exceptional cases noted above) be part of the subject-matter of another. I shall call this the *impermeable boundary theory* of the sciences: knowledge is divided into watertight compartments, determined by their distinct *genera*, and what goes on in one compartment cannot (except in the types of case noted above)[7] turn up in another. I shall not dispute that this is the theory of the *Posterior Analytics*, though I am actually somewhat agnostic on this point: my aim is to argue against the widely held view that Aristotle regards himself as committed to this theory in his scientific and philosophical work *outside* the *Analytics*: I shall call this the *impermeable boundary view*, or *IBV* for short. I shall argue that the *IBV* is false: while Aristotle does think that the sciences have boundaries, he is very happy in a wide variety of cases to cross them, and does not treat them as impermeable.[8]

It is important to see what the impermeable boundary theory involves. One might suppose that what it prohibits is something quite modest – that it only rules out the use of the principles of one science as axioms or premises in demonstrations in another science – and that this still allows one science to borrow or rely on the results of another, or for their subject-matter to overlap in some other way. Accepting this modest reading would not undermine my principal argument, since my main target is the difficulty which many commentators feel at *any* form of (apparent) sharing between sciences – though I shall also argue that not all the cases of boundary-crossing on Aristotle's part are of this 'modest' sort. In any case, I am not convinced that the modest reading of the prohibition is satisfactory. On the *Posterior Analytics* account, all that a science does is to provide (or encapsulate) explanations by means of demonstrations: these demonstrations yield (or encapsulate) full scientific knowledge only through the derivation of their premises from the axioms of the science. So – according to the theory of the *Analytics* – results borrowed from another science cannot be isolated from the axioms from which they are derived without losing their ability to figure in the borrowing science. The same applies to other sorts of overlap. As [T1]

6 Although this appears to exemplify the same, or a very similar, structure, this counts as a distinct type of exception because medicine as a whole is not one of the sciences subordinate to geometry; see below, 191 f.

7 From now on I shall take this qualification as read.

8 Of course, anyone who thinks that Aristotle did not hold the impermeable boundary theory in the *Analytics* will find it all the easier to maintain that he did not apply it elsewhere.

implies at 75a39–b2, there are really only four ingredients in an *Analytics*-style science: the subject-matter or kind (the subject of the definitions and postulates), the common axioms, the conclusions about the attributes which belong to the (members of the) kind, and the demonstrations which yield these conclusions.[9] If some of the ultimate or interim conclusions about the subject-matter of one science (S_1) derive from the axioms of another (S_2), then either they will not figure in S_1 – so there is no overlap after all – or we will have results in S_1 proved from the axioms of S_2, which the *Analytics* forbids. If the overlap does not take the form of conclusions about the subject-matter, it will not figure in the science at all.[10] The exceptions which the *Analytics* allows to the no-crossing rule allow the possibility that one science can provide facts (the 'that') for another science to explain, and this might seem to provide a way out for the modest reading. I shall discuss this, and the related question of how restrictive the principle is that sciences are differentiated by their subject-matter, in Section 2.

At this point some may object that outside the *Analytics* Aristotle does not view the structure of a science so restrictively, as including nothing beyond a tightly knit set of demonstrations satisfying certain conditions and the axioms from which they derive. This is a highly controversial matter on which I shall not take a view here. For present purposes, however, the point is that if one accepts this objection, then one has no reason to take Aristotle to be against boundary crossing. As we have seen, Aristotle's prohibition in the *Analytics* is based on technical considerations entirely internal to the *Analytics* picture of science; if, when he comes to do cosmology or biology or metaphysics, he does not think that that picture holds, then he has no reason to think this prohibition holds either – and as we shall see, he frequently ignores it.[11]

As I have said, the *IBV* is widespread. Here are some examples of commentators who accept it, arranged in the traditional Aristotelian order – that is to say, starting with those who are writing about logic and/or physics, then those who are writing about metaphysics, and finally those who are concerned with ethics and/or politics.

9 Compare *An. Post.* A.10 76b11–22: 'Every demonstrative science is concerned with three things: what it posits to exist (these items constitute the kind whose in-itself attributes it studies); the so-called common axioms, i. e. the primary things from which its demonstrations proceed; and thirdly the attributes [...] that about which the science conducts its proofs, the things it proves, and the items from which it proves' (Barnes [1994] translation, with modifications).

10 Compare Bolton's statement of the no-crossing rule in the passage quoted on page 182 below.

11 An analogous point holds if we deny that the exceptions allowed in the *Analytics* account are tightly constrained: if they are not, so that an indefinitely wide range of boundary crossing is legitimate, then any residual prohibition will have little bite.

Richard McKirahan writes:

> Each science treats one genus (I.28, 87a38) [...] [D]ifferent genera are treated by different sciences [...] Subject genera thus serve as principles of identity and individuation for sciences. A science always deals with its own genus (I.7, 75b7–8), and no science can prove the conclusions of another (I.7, 75b12–14). Two sciences are different if and only if they treat different subject genera.[12]

McKirahan is, of course, engaged in exegesis of the *Posterior Analytics*; but if he thinks that this view does not apply outside that work, he certainly does not say so. Owen likewise speaks, in a section of his paper entitled 'The Academy: the Autonomy of the Sciences', of Aristotle's "drive for autonomy":

> The domestic economy of one field of knowledge was to be settled by fixing its frontiers. The premisses of the science were to determine what questions fell within the mathematician's competence and, no less importantly, what questions did not [...] He allows that sometimes one science may take over and apply the arguments of another, but these are the exceptions.[13]

Owen principally has in his sights the influence of, and the Aristotelian consequences for, *mathematics*: but, again, if he wishes to exclude from his talk of frontiers and of the autonomy of the sciences the other fields of knowledge which Aristotle discusses in the *Posterior Analytics*, he does not say so. In a similar vein, but with no special focus on mathematics, Monte Johnson writes: "In general, Aristotle prohibits or at least resists explaining the phenomena in one domain by reference to the principles appropriate to another domain" (the caveat "in general" only picks up the exceptions noted in *An. Post.* A.7).[14] And in his paper 'Aristotle's Natural Science', James Lennox writes as if the *Posterior Analytics* account should be taken to apply quite generally in Aristotle – the issues are how to square the *Analytics* account of what makes a unitary science *one* science with Aristotle's approach to natural science, and, as we shall see later, how far the kinds of exceptions to the autonomy of each science which are allowed in the *Analytics* might occur in cases not involving mathematics.[15]

12 McKirahan 1992, 50. McKirahan notes, of course, that "The rule has two exceptions": the common axioms "which apply to a plurality of subject genera", and the case of subordinate sciences (A.7, 75b15), in which the principles of a higher science in the group are used to prove (at least some of) the conclusions in a lower one (1992, 50 f.).

13 Owen 1966/1986, 141/213.

14 Johnson 2009, 335.

15 Lennox 2010, see especially 5 f. and 10–12. I return to his account of medicine in Section 2.

Turning to First Philosophy, Werner Jaeger writes about 'the growth of metaphysics' in the context of *Met*. E.1 and Γ:

> Each of these sciences marks off systematically a definite sphere of reality (ὄν τι) and a definite genus (γένος τι) and studies the resulting limited complex of facts [...] Their demonstrations [...] deal *solely* with the properties and functions following from [their particular] definitions or from facts evident to sense.[16]

A few pages later, the *IBV* can be seen at work once more in Jaeger's account of the structure of *Met*. Λ.[17] Despite Aristotle's explicit introduction of Λ as a single enquiry into substance, Jaeger writes: "the three original kinds of beings are clearly apportioned between physics and metaphysics" (1948, 221). I shall return to the case of Λ later; we shall see that, despite his distance from Jaeger, Myles Burnyeat shares his assumption that (for Aristotle) if *X* is the business of one science, it cannot also be the business of another.[18] Robert Bolton states the position trenchantly, citing *An. Post*. A.10, 76b11–22. (quoted in note 9 above) and *Met*. E.1:

> [...] biology is a proper part of physics or natural science (*phusikē*), which is itself wholly autonomous and separate from other theoretical sciences. This means not only that biology is autonomous and separate from each of the mathematical sciences such as geometry or astronomy or optics. It is also autonomous and separate from the *primary* theoretical science, namely theology [which, Bolton claims, is either identical with or belongs to the same science as general metaphysics] [...] there is no room at all for overlap in content or subject matter, for Aristotle, between metaphysics and biology or physics.[19]

And so to ethics and politics, where the *IBV* can be found in Terence Irwin's work on the principles of ethics:

> Aristotle's ethics, then, is not wholly autonomous; it relies on principles that are justified by non-ethical beliefs. This conclusion might seem to conflict with one of Aristotle's own doctrines about method. For he insists that each science has its own 'special principles' (ἀρχαὶ οἰκεῖαι) which are supposed to explain the appropriate "appearances" – observations or common beliefs or both.[20]

16 Jaeger 1948, 215; my italics.
17 Jaeger 1948, 220–2.
18 Jaeger's view of how the subject-matter of ZHΘ relates to physics is harder to pin down; Burnyeat's view (discussed in Section 2), can, in effect, be seen as an attempt to rehabilitate the main part of Jaeger's vision of the central books in a way which conforms to the *IBV*.
19 Bolton 2010, 30–32.
20 Irwin 1981, 222.

He cites *An. Post*. A.2, 72a5–7 and 6, 74b24–6.[21] Irwin subscribes at least to a nuanced version of the *IBV*. He thinks that the no-crossing rule does apply outside the *Analytics* – which is one thing which I wish to deny.[22] He invokes a narrower understanding of the rule, however, according to which it does not apply to the case of metaphysics and ethics. He arrives at this narrower understanding by considering what, on reflection, Aristotle *ought* to say about the autonomy of the sciences. Irwin argues that Aristotle *ought not* to accept the autonomy claim, or at least ought to restrict it to the 'demonstrative sciences' such as arithmetic and geometry. Is this what Aristotle actually does in the *Analytics*? Of course, it is true that the *Posterior Analytics* is, in a sense, entirely concerned with demonstrative science: but, as Irwin rightly concedes, the *Analytics* counts natural science and even sciences such as medicine as 'demonstrative' (after all, medicine figures as Aristotle's star example in the second type of exception to the no-crossing rule). In the *Analytics*, *all* explanatory sciences[23] qualify as demonstrative.[24]

Irwin's claim that Aristotle's ethical principles are grounded in his metaphysics and psychology has generated some debate predicated on the *IBV*. Thus Timothy Roche argues in response to Irwin that these ethical principles cannot be so grounded, in part because this would violate "Aristotle's well-known doctrine of the autonomy of distinct branches of philosophical knowledge [...] a doctrine which he espouses throughout the corpus".[25] Dominic Scott also picks up Irwin's

21 Irwin also cites *GC* I.2, 316a5–13: but this passage does not seem to concern the autonomy of the sciences, but rather the distinction between arguments and approaches which are too abstract, or 'logical' (λογικῶς: the example is Platonic atomism), and those which are appropriate to their subject because they are better connected with the data (the example is Democritean atomism). Cf. *Cael*. II.13, 293a23–30, III.7, 306a1–17, *Met*. Λ.1, 1069a25–30 (and perhaps *GA* II.8, 748a8–12).

22 In other words, Irwin agrees that his interpretation of Aristotle's ethics conflicts with the no-crossing rule on a certain interpretation of it – namely the standard interpretation – and thinks that it is important to avoid the conflict.

23 I say 'explanatory sciences' because the *Analytics may* allow that there are some subordinate, 'fact-gathering' sciences which are non-explanatory, such as 'star-gazing' or 'nautical astronomy': see *An. Post*. A.13, 78b32–79a16 (discussed on page 13 below and in McKirahan 1978; Barnes 1994, 158–62; Lennox 1986; Johnson 2009, 335–7).

24 I return to this point in discussing Scott's view below. One could suppose, alternatively but less plausibly, that the *Analytics* does not regard these sciences as demonstrative; but then one would have to think that the no-crossing rule does *not* depend (in Aristotle's view) on features unique to 'properly' demonstrative sciences. I discuss the case of medicine below, in discussing [T2]–[T3] and [T9].

25 Roche 1988, 53 f. Deborah Achtenberg, citing Roche, characterises what she calls "Aristotle's rule that different sciences are autonomous" in such a way that any use by one science of material which belongs to another science to which it is not subordinate "violates" the rule (Achtenberg 2002, 93).

argument, in relation to the principles of political science.[26] Unlike Irwin, he tries to *reconcile* the view that these principles are established by other sciences with what he calls the "autonomy principle" as standardly understood: "briefly stated, this holds that each science has its own principles, which are not susceptible of being derived from another science" (2015, 155). I shall return to this when I discuss [T7] and [T8].

2 Crossing Boundaries

I shall explore five sets of cases in which Aristotle permits – indeed encourages – the sharing of material across distinct sciences in various ways which are not included in the exceptions specified in the *Analytics*. As we shall see, some of these are consciously methodological. Most are matters of his actual practice: but even if some of these might seem to be easy to dispense with – so that his practice could readily be 'sanitised' to conform to the requirements of the impermeable boundary theory – others seem very firmly, and some quite inextricably, embedded in Aristotle's method. I shall not discuss every such case – others which spring to mind include the *De Motu*, the *De Anima*, and the account of the emotions in the *Rhetoric*,[27] each of which raises very complex issues which are beyond the compass of this article.

(1) I shall begin with an example from the outer reaches of the physical works – the closing words of *De Iuventute et Senectute*, *De Vita et Morte*, *De Respiratione*:

> [T2] This study of life and death and kindred things is now almost complete. But as to health and disease, it is not only for the doctor but also for the natural scientist, up to a point,[28] to state their causes. How these two differ and how they investigate different things must not escape us, since what happens testifies that the inquiry is, up to a point at any rate, co-terminous. For those doctors who are refined and curious say something about nature, and claim to derive their principles from it, while the most accomplished of those who make inquiries about nature generally conclude with the principles of medicine.[29]

26 Scott 2015, 155–7.

27 Wider questions relating to the general status of the *Rhetoric* are raised in Adams 2015.

28 This is the same expression which he uses about the natural scientist and matter in *Phys*. II.2, 194a21–7: 'but if art imitates nature, and it is for the same body of knowledge to know the form and, up to a point, the matter (e. g., it is for the doctor to know about health, and also about bile and phlegm, in which health is to be found; and similarly it is for the builder to know both the form of the house and the matter – that it is bricks and timbers – and in the same way too in the case of the other arts), then it would be for natural science to know both sorts of nature.'

29 *De Iuv*. 27, 480b21-30: περὶ μὲν οὖν ζωῆς καὶ θανάτου καὶ τῶν συγγενῶν ταύτης τῆς σκέψεως

This point has already been made in the course of the programmatic remarks at the start of the *De Sensu*:

> [T3] It is for the natural scientist to see also the first principles of health and disease; for neither health nor disease can exist in things which are deprived of life. For this reason it can be said of most of those who inquire into nature, and of those physicians who pursue their art more philosophically, that while the former conclude their works with the things about medicine, the latter start from the things about nature.[30]

Lennox writes of these passages, and of a related one in *PA*:[31]

> There is also, in these three passages, more than a hint that Aristotle is thinking of the relationship between medicine and the theoretical investigation of nature by analogy with the relationship between optics and geometry, or harmonics and arithmetic.[32]

He puts the point a little more strongly in a later article, where, referring back to this one, he writes "Elsewhere I have argued that [these three passages] suggest that [Aristotle] did see the relationship between medicine (a productive science) and the science of nature on the subordinate science model."[33] This is, clearly, what Aristotle, if he subscribes to the prohibition on boundary crossing, *ought* to think. But it seems equally clear that in these passages he does not think this. One of the key features of the subordinate science model in the *Analytics* is that it is the business of only *one* science to give the causes: if *B* is subordinate to *A* as optics is to geometry, then apparently, since *B* gets (some of) its principles from *A*, it is for *A*, not *B*, to give the reason why. Likewise if *B* itself is superordinate to

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σχεδὸν εἴρηται περὶ πάντων. περὶ δὲ ὑγιείας καὶ νόσου οὐ μόνον ἐστὶν ἰατροῦ ἀλλὰ καὶ τοῦ φυσικοῦ μέχρι του τὰς αἰτίας εἰπεῖν. ᾗ δὲ διαφέρουσι καὶ ᾗ διαφέροντα θεωροῦσιν, οὐ δεῖ λανθάνειν, ἐπεὶ ὅτι γε σύνορος ἡ πραγματεία μέχρι τινός ἐστι, μαρτυρεῖ τὸ γινόμενον· τῶν τε γὰρ ἰατρῶν ὅσοι κομψοὶ καὶ περίεργοι λέγουσί τι περὶ φύσεως καὶ τὰς ἀρχὰς ἐκεῖθεν ἀξιοῦσι λαμβάνειν, καὶ τῶν περὶ φύσεως πραγματευθέντων οἱ χαριέστατοι σχεδὸν τελευτῶσιν εἰς τὰς ἀρχὰς τὰς ἰατρικάς.

30 *De Sensu* 1, 436a17-b1: φυσικοῦ δὲ καὶ περὶ ὑγιείας καὶ νόσου τὰς πρώτας ἰδεῖν ἀρχάς· οὔτε γὰρ ὑγίειαν οὔτε νόσον οἷόν τε γίγνεσθαι τοῖς ἐστερημένοις ζωῆς. διὸ σχεδὸν τῶν περὶ φύσεως οἱ πλεῖστοι καὶ τῶν ἰατρῶν οἱ φιλοσοφωτέρως τὴν τέχνην μετιόντες, οἱ μὲν τελευτῶσιν εἰς τὰ περὶ ἰατρικῆς, οἱ δ' ἐκ τῶν περὶ φύσεως ἄρχονται.

31 *PA* II.7, 653a1–10: "For when the nourishment vaporises up through the blood vessels, the residue that undergoes cooling because of the potential of this region produces fluxes of phlegm and serum [...] However, the appropriate place to speak about these things – to the extent that it is up to the natural philosopher to speak about them – is in the discussion of the origin of disease" (trans. Lennox [2005]).

32 Lennox 2005, 67; he discusses these passages on pages 66–8.

33 Lennox 2010, 12 n25.

a 'fact-gathering' science, *C* – as perhaps astronomy is to nautical astronomy – again only one of them (in this case *B*) gives the reason why.[34] For this reason the cases of natural science and medicine in these passages are, precisely, *not* presented as analogous to the subordinate science model. Aristotle says here that it is for *both* sciences to state the causes, and (hence) that, up to a point, they *share* this topic – this is what is behind his remark that they are co-terminous (σύνορος).[35] This disanalogy is also implicit in the idea that the natural scientist should know about the causes of health and disease *up to a point*: it is not the job of the geometer (in the strict sense) to know about the causes of optical phenomena up to *any* point. Aristotle does not unequivocally say here whether the shared subject-matter is just that – something simply common to both sciences. It is very plausible, however, that physics is the more authoritative of the two in establishing the relevant first principles;[36] and so we might suppose that this subject-matter belongs primarily to physics. At the same time, it is striking that it is the natural scientist, not the doctor, whose concern with the first principles of health is said to extend "up to a point".[37] This does not alter the significance of how Aristotle presents the situation in these passages, however: if he does think this, he must take it to be quite compatible with these principles being a genuine, if borrowed, part of medicine as well.

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34 This why Aristotle can treat the case of circular wounds as a localised example of the same structure, and why he says that the doctor knows the 'that', while the geometer knows the 'why'. Aristotle's division of labour account of superordinate and subordinate sciences involves a number of difficulties which I cannot fully pursue here. In particular, one might suppose that the paradigm subordinate sciences such as optics are explanatory sciences in their own right (a point which one of the anonymous *Archiv* readers pressed). If this is Aristotle's view, then what he says in *An. Post*. A.13 must mean that the superordinate science provides a key part of the explanation (e. g., a geometrical property of lines) which the subordinate science turns into the explanation proper by showing how this applies to natural phenomena (e. g., optical rays). This still seems to commit Aristotle to the claim that it is only for one science to know the proper explanation of the phenomena, since it will not be for geometry as such to know about optical rays.

35 Aristotle's point is that the final part of natural science – the explanation of health and disease – is the starting point of medicine. Lennox translates σύνορος ἡ πραγματεία simply as "the subject is a shared one" (2005, 66).

36 Lennox argues that the remark at 480b27–8 that the more philosophical doctors "claim to derive their principles from [nature]" actually means this (2005, 67). I am not sure that it need mean this, since Aristotle has just said that this part of (the study of) nature is shared by physicists and doctors.

37 So Aristotle is not (as Paolo Fait suggested to me) thinking merely that the doctor needs to know a smattering of natural science.

(2) My second example is more famous – the discussion of the existence of plurality and change in *Phys*. I.2:

> [T4] To investigate, then, whether what is is one and unchangeable does not belong to the investigation of nature. Just as the geometer no longer has anything to say to the one who does away with the principles <of geometry> – but it is either for another science, or for one which is common to all – neither does the one who is inquiring into principles. For there will no longer be a principle if there is one thing only, and one in this way; for a principle is a principle of some thing or things. Hence inquiring whether it is one in this way is like discussing any other thesis advanced for the sake of argument, [...] or like exposing a disputatious argument, such as both their arguments contain – both that of Melissus and that of Parmenides [...] For ourselves, let it be assumed that the things that are by nature are, all or some of them, subject to change; and this is clear from a survey of cases. At the same time it is not fitting to show what is wrong in all cases, but only those reached by false reasoning from the principles, and not those which are not; for example it is for the geometer to refute the quadrature by means of segments, but not for the geometer to refute Antiphon's. Nevertheless, since, though they say nothing about nature, they happen to raise difficulties about nature, we would perhaps do well to say a little about them; for the enquiry contains philosophy.[38]

A number of things emerge from this passage. First, the question whether what is is one and unchangeable does *not* belong, in Aristotle's view, to the discussion of nature, but to another science.[39] Here the sort of possibility which I floated in relation to [T2] and [T3] is explicitly endorsed. Another example is [T5]:

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38 *Phys*. I.2, 184b25–185a20: τὸ μὲν οὖν εἰ ἓν καὶ ἀκίνητον τὸ ὂν σκοπεῖν οὐ περὶ φύσεώς ἐστι σκοπεῖν· ὥσπερ γὰρ καὶ τῷ γεωμέτρῃ οὐκέτι λόγος ἔστι πρὸς τὸν ἀνελόντα τὰς ἀρχάς, ἀλλ' ἤτοι ἑτέρας ἐπιστήμης ἢ πασῶν κοινῆς, οὕτως οὐδὲ τῷ περὶ ἀρχῶν· οὐ γὰρ ἔτι ἀρχὴ ἔστιν, εἰ ἓν μόνον καὶ οὕτως ἓν ἔστιν. ἡ γὰρ ἀρχὴ τινὸς ἢ τινῶν. ὅμοιον δὴ τὸ σκοπεῖν εἰ οὕτως ἓν καὶ πρὸς ἄλλην θέσιν ὁποιανοῦν διαλέγεσθαι τῶν λόγου ἕνεκα λεγομένων [...], ἢ λύειν λόγον ἐριστικόν, ὅπερ ἀμφότεροι μὲν ἔχουσιν οἱ λόγοι, καὶ ὁ Μελίσσου καὶ ὁ Παρμενίδου· [...] ἡμῖν δ' ὑποκείσθω τὰ φύσει ἢ πάντα ἢ ἔνια κινούμενα εἶναι· δῆλον δ' ἐκ τῆς ἐπαγωγῆς. ἅμα δ' οὐδὲ λύειν ἅπαντα προσήκει, ἀλλ' ἢ ὅσα ἐκ τῶν ἀρχῶν τις ἐπιδεικνὺς ψεύδεται, ὅσα δὲ μή, οὔ, οἷον τὸν τετραγωνισμὸν τὸν μὲν διὰ τῶν τμημάτων γεωμετρικοῦ διαλῦσαι, τὸν δὲ Ἀντιφῶντος οὐ γεωμετρικοῦ· οὐ μὴν ἀλλ' ἐπειδὴ περὶ φύσεως μὲν οὔ, φυσικὰς δὲ ἀπορίας συμβαίνει λέγειν αὐτοῖς, ἴσως ἔχει καλῶς ἐπὶ μικρὸν διαλεχθῆναι περὶ αὐτῶν· ἔχει γὰρ φιλοσοφίαν ἡ σκέψις.

39 I take this to be First Philosophy (so Ross, 1936, 461); for the view that it is dialectic, see Irwin 1988, 67; Bolton 1991, 14 f.; Falcon 2005, 28; Clarke 2017. While conceding that the discussion relies on various metaphysical claims (e. g., that being and one are said in many ways) Clarke appeals to Aristotle's language: '[investigating the Eleatic position] is like arguing dialectically [διαλέγεσθαι] against any other thesis put forward for the sake of argument [...] or like solving a disputacious argument' (185a5–8; cf. διαλεχθῆναι at 185a19–20). This use of διαλέγεσθαι does not, however, require that Aristotle is engaging in dialectic in the technical sense. Clarke also argues that, since Aristotle says that it does not fall to the person investigating principles to answer an opponent

> [T5] How it is with what is separable, and what it is, it is the work of first philosophy to determine.[40]

It is very much *not* part of my argument to deny that Aristotle thinks that some subjects belong to, or are the work of, one science rather than another, and I shall say what it is for something to belong to one science rather than another in Section 3. But, as I have said, I do not think that from the fact that *X* belongs to science *A* it follows that *X* cannot be a part of – or properly used, or borrowed by, and hence figure in – science *B*. Indeed, the second thing which [T4] makes very clear is that Aristotle is going to discuss the Eleatic question *here*, even though engaged in physics. The defender of the *IBV* seems committed to thinking that Aristotle is a *digression-acratic*: he knows that it is not the business of natural science to discuss this topic, but he just cannot help discussing it anyway – for another 128 lines![41] Now I am happy to suppose that Aristotle does, occasionally, simply digress into the territory of another science: a good example is his brief discussion of some supposed difficulties for Empedocles' account of the soul in *GC* II.6 (334a10–14), which is followed by the remark at the start of II.7:

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who denies the existence of principles (185a1–3), this must eliminate the first philosopher too, since she also studies principles (the principles of being *qua* being). But Aristotle need only mean that it does not fall to the person who studies the principles of *X* to answer an opponent who denies the existence of *X*'s principles. On the other side are the points (i) that the discussion uses a variety of claims which are not dialectically agreed but which are highly distinctive elements of Aristotle's own First Philosophy; and (ii) that Aristotle describes the discussion of the Eleatic position as the business not of physics but of *another science* (ἑτέρας ἐπιστήμης). At least as far as the *Analytics* is concerned, dialectic is not a science because it has no specific subject-matter and is not demonstrative (*An. Post.* A.11, 77a26–35). Bolton translates ἐπιστήμη in the passage as '(type of) knowledge'; and while Irwin translates it as 'science', he glosses it in our sentence as 'a discipline'. But in the context set by ch. 1's programme for seeking scientific knowledge (τὸ εἰδέναι καὶ τὸ ἐπίστασθαι: 184a10), ἐπιστήμη naturally means 'science'; this is confirmed by Aristotle's use of '*another* science (sc. than physics)' – and the other example in play is geometry.

40 *Phys.* II.2, 194b14–15: πῶς δ' ἔχει τὸ χωριστὸν καὶ τί ἐστι, φιλοσοφίας ἔργον διορίσαι τῆς πρώτης. For a brief discussion, see Lennox 2008, 164 and n. 27. Cf. the account of the sciences in *Met.* E.1, and, e. g., *An. Post.* A.33, 89b7–9: some questions to do with διάνοια, νοῦς, ἐπιστήμη, τέχνη, etc., "are rather for natural science and in part for ethics"; *EN* VIII.1, 1155b8–9 (the *physical* problems of the idea that like attracts are not οἰκεῖα τῆς παρούσης σκέψεως); *De An.* I. 3, 407b12: the discussion of Plato's account of how God causes the motions of the heavens belongs more to another work.

41 Intuitively, [T4] does seem very relevant to the concerns of *Phys.* I, and so, one might claim, the discussion it introduces is not a digression (Terence Irwin and an anonymous reader made this point to me). I entirely agree – indeed, I shall argue that it is not one. But if the *IBV* were correct, that would simply push the question back a stage, to the question of how it *can* be relevant, given that it belongs to a distinct science.

> [T6] But to consider these things is the work of another study [viz. the *De Anima*].[42]

But this digression lasts a mere five lines. It is not merely the length of the discussion which counts against the digression view of the *Physics* passage, moreover: the Eleatic position is firmly embedded in the taxonomy of earlier views which Aristotle outlines in I.2. A more satisfactory explanation is that Aristotle thinks that the question's *belonging* to First Philosophy is compatible with it being *used in*, or *borrowed by*, Second Philosophy.

A third thing emerges from [T4], and in particular from Aristotle's remark at 183a2–3 that dealing with those who do away with the principles of science *A* 'is either for another science, or for one which is common to all.' The point of the disjunction is, as Ross says, that:

> (1) the science in question may be a subaltern science (as optics is subaltern to geometry [...]), and if so, the discussion of its ἀρχαί belongs to the superior science. Or (2) it may be a science which has no special science superior to it. In this case its ἀρχαί can be reached only by a science which is πασῶν κοινή.[43]

Clearly Aristotle thinks that this latter possibility is the one exemplified in the case of the first principles of natural science. Now the very idea that some science *B* establishes or defuses the objections to the first principles of a non-subordinate science *A* seems to violate the requirements of the impermeable boundary theory in a different way: these first principles will concern the genus of *A*; but how could *B* even discuss, let alone establish them, unless they belong to the genus of *B* as well? It will not do for the defender of the *IBV* to say that the genera are distinct because they comprise sets with only partly overlapping membership. The idea behind the 'one genus – one science' principle is that the genus forms at least some kind of natural unity which explains, or helps to explain, the unity of the science in question:[44] if the genera in question are purely extensional, the principle would rule out too little – it would only rule out the existence of two distinct sciences concerned with exactly the same items.[45]

42 *GC* II.7 334a15: ἀλλὰ περὶ μὲν τούτων ἑτέρας ἔργον ἐστὶ θεωρίας.

43 Ross 1936, 461.

44 See, e. g., McKirahan quoted above, 6, and Barnes 1994, 131.

45 The issues here are, admittedly, complex, and deserve fuller discussion than I can give them here; I will return to some of them below in relation to [T10]–[T12].

(3) My next two examples, [T7] and [T8], are from the other end of the spectrum, so to speak – the discussions of the Form of the Good in *Nicomachean Ethics* I.6 and *Eudemian Ethics* I.8. *EN* proceeds without any comment on the question of whose business it is to discuss this; *EE* says:

> [T7] To examine this opinion [that the good-itself is the Form of the Good, and that this is separate from the things that share in it] thoroughly is for a different investigation, and one which is, of necessity, in many ways more abstract; for arguments that are at the same time destructive and common belong to no other science. If we ought to speak about them in summary fashion, however, let us say [...]. [46]

[T8] is a more general methodological remark at the beginning of *EE* I which I think has this discussion (among other things) in its sights:

> [T8] There are many inquiries which pose problems and require investigation about each object and each nature; of these some contribute only to the attainment of knowledge, while others have also to do with acquirings and actions in relation to the object.[47] In respect of those things that have only theoretical philosophy, we must say, when the occasion arises, whatever is appropriate to the investigation.[48]

Whether one agrees or disagrees with the views of Irwin and Scott about the general reliance of Aristotelian ethics on his metaphysics and psychology, [T7] is a clear case in which ethics puts metaphysical considerations to use; and it does the same, without methodological comment, in *EN* I.6. I have already discussed Irwin's attempt to avoid conflict with the *IBV* in relation to ethics. Scott too

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46 *EE* I.8, 1217b16-20: ἔστι μὲν οὖν τὸ διασκοπεῖν περὶ ταύτης τῆς δόξης ἑτέρας τε διατριβῆς καὶ τὰ πολλὰ λογικωτέρας ἐξ ἀνάγκης (οἱ γὰρ ἅμα ἀναιρετικοί τε καὶ κοινοὶ λόγοι κατ' οὐδεμίαν εἰσὶν ἄλλην ἐπιστήμην)· εἰ δὲ δεῖ συντόμως εἰπεῖν περὶ αὐτῶν, λέγωμεν ὅτι [...]

47 The idea that "some [inquiries] contribute only to the attainment of knowledge; some have also to do with acquirings and actions" reflects Aristotle's standard distinction between theoretical and practical knowledge (see, e. g., *Met*. E.1 1025b18–28); he also, of course, distinguishes both of these from productive knowledge, such as medicine.

48 *EE* I.1, 1214a8–14: πολλῶν δ' ὄντων θεωρημάτων ἃ περὶ ἕκαστον πρᾶγμα καὶ περὶ ἑκάστην φύσιν ἀπορίαν ἔχει καὶ δεῖται σκέψεως, τὰ μὲν αὐτῶν συντείνει πρὸς τὸ γνῶναι μόνον, τὰ δὲ καὶ περὶ τὰς κτήσεις καὶ περὶ τὰς πράξεις τοῦ πράγματος. ὅσα μὲν οὖν ἔχει φιλοσοφίαν μόνον θεωρητικήν, λεκτέον κατὰ τὸν ἐπιβάλλοντα καιρόν, ὅ τι περ οἰκεῖον ἦν τῇ μεθόδῳ [...]. Cf. *EN* I.6, 1096b30–1 (how goods form some sort of unity): ἀλλ' ἴσως ταῦτα μὲν ἀφετέον τὸ νῦν· ἐξακριβοῦν γὰρ ὑπὲρ αὐτῶν ἄλλης ἂν εἴη φιλοσοφίας οἰκειότερον. *EN* I.13, 1102a23-32 (the politician must study the soul, but (only) as far as he needs to for his purpose; he need not make a more exact inquiry): θεωρητέον δὴ καὶ τῷ πολιτικῷ περὶ ψυχῆς, θεωρητέον δὲ τούτων χάριν, καὶ ἐφ' ὅσον ἱκανῶς ἔχει πρὸς τὰ ζητούμενα· τὸ γὰρ ἐπὶ πλεῖον ἐξακριβοῦν ἐργωδέστερον ἴσως ἐστὶ τῶν προκειμένων. *EN* X.8, 1178a22-3 (the separateness of νοῦς): ἡ δὲ τοῦ νοῦ κεχωρισμένη· τοσοῦτον γὰρ περὶ αὐτῆς εἰρήσθω· διακριβῶσαι γὰρ μεῖζον τοῦ προκειμένου ἐστίν.

thinks that Aristotle uses metaphysics and psychology to establish the principles of ethics and politics: he tries to save the *IBV* as standardly interpreted[49] by focusing on the exceptions which Aristotle allows to his no-crossing rule in *An. Post*. A.13, 78b32–79a16. The first type of exception leaves open the possibility that the principles of science *B* might be derived from science *A* if *B* is subordinate to *A*. Scott agrees that this will not help with the case in hand, so he appeals to the second type of exception, exemplified by the case of circular wounds:

> [T9] Many sciences which do not fall under one another are in fact related in this way [i. e. the way exemplified by the cases of subordinate sciences just mentioned] – e. g. medicine to geometry: it is for the doctor to know the fact that curved wounds heal more slowly, and for the geometer to know the reason why.[50]

Scott claims that this case "shows [...] that, even though [Aristotle] held some sort of autonomy principle, he still allows for the possibility of demonstrative sciences capable of explaining facts assumed by certain forms of practical expertise."[51] This sort of very general characterisation of permissible kind-crossing can, of course, be generated by abstraction from the example of circular wounds. But as exegesis of the *Posterior Analytics* it seems inadequate: the wounds case is clearly meant to be a special type of case – albeit one which can occur in "many sciences" – and it cannot be a coincidence that it exhibits just the same sort of 'mixed' mathematics that characterises the mixed subordinate sciences which constitute the first type of exception.[52] Aristotle is not here opening a general floodgate, but rather adverting to the existence of cases in which there is what we might call *localised* mixed mathematics of the same general type as that found in a subordinate mixed mathematical science. Medicine is not subordinate to geometry, since most explanations of medical facts do not rest on the geometrical attributes of the things in question; but the way in which geometry combines with medical facts in this localised case is just the same as the way it combines

49 Though he also repeats Irwin's argument that this is a case of a non-demonstrative science, and so outside the ambit of the no-crossing rule (2015, 156).

50 *An. Post*. A.13, 79a13–16 (trans. Barnes [1994] with modifications): πολλαὶ δὲ καὶ τῶν μὴ ὑπ' ἀλλήλας ἐπιστημῶν ἔχουσιν οὕτως, οἷον ἰατρικὴ πρὸς γεωμετρίαν· ὅτι μὲν γὰρ τὰ ἕλκη τὰ περιφερῆ βραδύτερον ὑγιάζεται, τοῦ ἰατροῦ εἰδέναι, διότι δὲ τοῦ γεωμέτρου.

51 Scott 2015, 157.

52 And we should note that *An. Post*. A.9 in effect inveighs against generalising too far from the kind-crossing exceptions (Lennox makes this point in relation to Aristotle's remark at A.9, 76a9–15. that "otherwise it will be like proving something in harmonics by arithmetic" [2010, 11–12]).

with optical facts in the subordinate science of optics.[53] Another example of such localised mixed mathematics, this time in the case of ethics, might be the use to which Aristotle puts arithmetic at various points in his account of particular justice.[54]

(4) It might be possible to suppose that, while [T4] and [T7] reveal Aristotle as happy to borrow material from one science while engaged in another, they are compatible with the idea that this borrowing is peripheral, or easily dispensed with: perhaps a defender of the *IBV* might hold that *Phys*. I could have proceeded well enough without the discussion of the Eleatics, or perhaps even the Ethics without the attack on the Form of the Good.[55] Is this always the case? Let's consider the example of astronomy and natural science, as described in *Phys*. II.2:

> [T10] Since we have distinguished the various ways in which nature is spoken of, we must next consider how the mathematician differs from the natural scientist; for natural bodies have planes, solids, lengths and points, which the mathematician investigates. Again <we must consider whether> astronomy is different from, or a part of, the science of nature. For it is absurd if it is for the natural scientist to know what the sun or moon is, but none of their *per se* attributes, especially as those who discuss nature plainly also discuss the shape of the moon and the sun, and indeed whether the earth and the cosmos are spherical or not. The mathematician deals with these things too, but not, each of them, as a limit of a natural body; nor does he deal with their attributes as attributes of things which are of such a sort [...] the mathematical sciences which are more like natural science, such as optics, harmonics, and astronomy, are in a way the reverse of geometry. For geometry inquires about natural lines, but not as natural, whereas optics concerns mathematical lines, but not as mathematical but as natural.[56]

53 Cf. A.9, 76a22–5: "Demonstration does not apply to another kind – except, as I have said, geometrical demonstrations to mechanical and optical ones, and arithmetical demonstrations to ones in harmonics."

54 For some discussion of this, see Judson 1997. Laura Castelli has suggested to me that it might be illuminating to think of cases such as these in terms of 'localised relevance' rather than localised mixing: this brings out the point that they are cases in which mathematical features occasionally acquire some relevance for sciences which do not study their objects *qua* characterized by those features. I think that this is a helpful way to look at the matter, but it does not offer any comfort to the defender of the *IBV*, since she is equally committed to the unacceptability of explanatory scientific relevance which crosses boundaries.

55 This would not be my view.

56 *Phys*. II.2, 193b22–194a12: ἐπεὶ δὲ διώρισται ποσαχῶς ἡ φύσις, μετὰ τοῦτο θεωρητέον τίνι διαφέρει ὁ μαθηματικὸς τοῦ φυσικοῦ (καὶ γὰρ ἐπίπεδα καὶ στερεὰ ἔχει τὰ φυσικὰ σώματα καὶ μήκη καὶ στιγμάς, περὶ ὧν σκοπεῖ ὁ μαθηματικός)· ἔτι ἡ ἀστρολογία ἑτέρα ἢ μέρος τῆς φυσικῆς· εἰ γὰρ τοῦ φυσικοῦ τὸ τί ἐστιν ἥλιος ἢ σελήνη εἰδέναι, τῶν δὲ συμβεβηκότων καθ' αὑτὰ μηδέν, ἄτοπον, ἄλλως τε καὶ ὅτι φαίνονται λέγοντες οἱ περὶ φύσεως καὶ περὶ σχήματος σελήνης καὶ ἡλίου, καὶ δὴ καὶ πότερον σφαιροειδὴς ἡ γῆ καὶ ὁ κόσμος ἢ οὔ. περὶ τούτων μὲν οὖν πραγματεύεται καὶ

This is a complex and far from straightforward passage;[57] I wish to focus on just one aspect of it, to do with astronomy and natural science. Astronomy, in Aristotle's view, is a *mathematical* science: it is, as I said earlier, one of the mixed sciences, like optics and harmonics, which in the *Analytics* he claims are subordinate to arithmetic or to geometry.[58] He repeats his view that astronomy is a mathematical science in a number of places, including [T10].[59] His answer to the question whether astronomy is different from, or a part of, the science of nature, therefore, is that it is a different science. This indeed is Aristotle's standard view of the subordinate, mixed sciences.[60] Two points emerge from this which are difficult for the *IBV*.

The first is about Aristotle's *practice*: he is very happy, as a natural scientist, to use, rely on, and generally to *borrow* arguments and results from astronomy. This is perhaps only implicit in [T10], but is explicit in the *De Caelo*, as we can see from [T11] and [T12]:

> [T11] Our view of the order of the planets, the way in which they move through being some nearer, some further away, and their distances from each other, should be studied on the basis of the works on astronomy [or: on the basis of the *On Astronomy*]; for they are adequately discussed <there>.[61]

ὁ μαθηματικός, ἀλλ' οὐχ ᾗ φυσικοῦ σώματος πέρας ἕκαστον· οὐδὲ τὰ συμβεβηκότα θεωρεῖ ᾗ τοιούτοις οὖσι συμβέβηκεν [...]. δηλοῖ δὲ καὶ τὰ φυσικώτερα τῶν μαθημάτων, οἷον ὀπτικὴ καὶ ἁρμονικὴ καὶ ἀστρολογία· ἀνάπαλιν γὰρ τρόπον τιν' ἔχουσιν τῇ γεωμετρίᾳ. ἡ μὲν γὰρ γεωμετρία περὶ γραμμῆς φυσικῆς σκοπεῖ, ἀλλ' οὐχ ᾗ φυσική, ἡ δ' ὀπτικὴ μαθηματικὴν μὲν γραμμήν, ἀλλ' οὐχ ᾗ μαθηματικὴ ἀλλ' ᾗ φυσική.

At 193b25 I read ἔτι ἡ, with the MSS and Mueller 2006, 175–80, rather than Ross's ἔτι εἰ ἡ. I still treat the sentence as an indirect question, however (*pace* Mueller).

57 For discussion see Lennox 1986 and 2008, 164–71; Mueller 2006; Peramatzis 2011, 55–77.

58 *An. Post*. A.13.

59 *An. Post*. A.14, 79a18–20; *Met*. A.8, 989b32–3, Λ.8, 1073b3–8; cf. *PA* I.1, 639b5–10, *Met*. M.3, 1078a9–14. This reflects a classification which goes back at least to Plato; but Plato himself went on to distinguish 'ideal', mathematical astronomy, which turns its back on the observational fine print to describe the ideal motions of perfect astronomical bodies, from the imperfect empirical kind (*Republic* VII 528e4–530c4); in calling astronomy a branch of mathematics Aristotle is certainly not siding with Plato's preference for the former over the latter (he would be the first to insist that the mathematical analysis must answer to observational data: see Λ.8, 1073b35–8 and b38–1074a5).

60 See McKirahan 1978; Lennox 1986; Mueller 2006; Distelzweig 2013.

61 *Cael*. II.10, 291a29–32: περὶ δὲ τῆς τάξεως αὐτῶν, ὃν μὲν τρόπον ἕκαστα κινεῖται τῷ τὰ μὲν εἶναι πρότερα τὰ δ' ὕστερα, καὶ πῶς ἔχει πρὸς ἄλληλα τοῖς ἀποστήμασιν, ἐκ τῶν περὶ ἀστρολογίαν θεωρείσθω· λέγεται γὰρ ἱκανῶς. I follow Allan in reading κινεῖται rather than κεῖται.

The chapter simply summarises these results. In *Cael*. II.14 Aristotle presents a series of arguments to show that the earth is immobile at the centre of the cosmos, and concludes:

> [T12] What is said by the mathematicians concerned with astronomy also testifies to these things.[62]

Note that in [T11] Aristotle explicitly says that the natural scientist *should* use the results of astronomy (θεωρείσθω): this material is not peripheral to the work of the natural scientist, or easily dispensable.

Such borrowing may not seem to be obviously the same as using the principles of one science as premises in demonstrations in another science. To some extent this depends on how we suppose Aristotle would have structured his cosmology as a fully finished part of natural science. If we suppose that what we have in the *De Caelo* is already close to that, then it is far removed from the *Analytics* picture of a finished science, and we have no grounds for ascribing any prohibition on boundary crossing to Aristotle outside that work.[63] If we suppose that Aristotle envisages a regimentation of the work in *De Caelo* into stricter demonstrative form, then we have to ask how these astronomical findings would figure. As I have said, Aristotle is emphatic that astronomy and natural science are distinct sciences: he does not embrace the idea of a 'mixed' science of astronomical cosmology. And it simply will not do to construe these findings as like the case of circular wounds, for at least three reasons. (i) The exception allowing for cases such as the slower healing of circular wounds is clearly understood as itself exceptional: medicine and geometry hardly ever intersect in this way. The use of astronomy in Aristotelian cosmology, by contrast, is systematic and pervasive. (ii) Astronomy does not (or does not always) provide the explanation for the fact provided by cosmology in the way that geometry, according to Aristotle, provides

62 *Cael*. II.14, 297a3–4: μαρτυρεῖ δὲ τούτοις καὶ τὰ παρὰ τῶν μαθηματικῶν λεγόμενα περὶ τὴν ἀστρολογίαν. We see the same type of borrowing at *Meteor*. I.3, 339b7–8: the relative size of the earth to the cosmos is clear; "for it has been made evident through the astronomical investigations that [...]" (ἤδη γὰρ ὤπται διὰ τῶν ἀστρολογικῶν θεωρημάτων [...]). We also find it at I.8, 345b1–2: the sun must shine on *all* the stars (and so a certain theory about the nature of the Milky Way is false), "if things are as has now been proved in the investigations concerning astronomy [about the relative sizes and distances of the sun, earth and stars]" (εἰ καθάπερ δείκνυται νῦν ἐν τοῖς περὶ ἀστρολογίαν θεωρήμασιν). Later we shall see that First Philosophy also borrows the results of astronomy.

63 See pages 179 f. above.

the explanation of the slow healing of wounds.[64] (iii) Some of the things which astronomy is concerned to establish are *the very same things* that the cosmologist is concerned to establish.

This is the second main point to emerge from [T10] – a point that is also reflected in [T12]. It is methodological rather than a matter of Aristotle's practice. Although the astronomer and the natural scientist are practitioners of different sciences, and although natural science as a whole is not subordinate to mathematics, Aristotle insists here (193b25–30) that the natural scientist – the cosmologist – will sometimes consider *the very same issues* as the mathematical astronomer. Some of what they study – some of what they *prove* – is exactly the same: it does not differ in genus. But that sciences are individuated by their genera is, as we have seen, a key part of the 'no crossing' account in the *Analytics*.

Lennox gives a good account of how the natural scientist and the astronomer will differ in their approach to, say, the sphericity of the earth, with reference to Aristotle's actual practice in *Cael*. II.14:[65]

> [*Cael*. II.14] 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' (297a3–4) in support of his argument, stressing that he is borrowing from another science. So our *Physics* passage [i. e. [T10]] should not be thought to argue that the *physikos* cannot provide explanations of attributes such as the spherical shape of the earth. What 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.

This is a good statement of part of the difference between the *physikos* and the mathematical astronomer, but it does nothing to undercut the point that they can and do both prove the same thing – the sphericity or location of the earth: it only insists that they do so in different ways. Someone might, in the spirit of the final sentence of the quotation, argue that the astronomer and the physicist think of the *earth's sphericity* (say) in different ways: one *qua* property of a natural body – the earth – and one simply *qua* geometrical property.[66] But this would be to deny the difference, as Aristotle sees it, between astronomy and *geometry*: it is for the

64 See Distelzweig 2013, 102 f.

65 Lennox, 2008, 167 f. (He speaks as if [T12] is part of the arguments for the sphericity of the earth, rather than part of the arguments for its immobility; but this does not affect his basic point.).

66 This appears to be Mariska Leunissen's view (2010, 155 f.).

pure geometer to think about the sphericity of the earth simply *qua* geometrical property – i. e. about *sphericity* – and not the astronomer.[67]

(5) If the *IBV* must be discarded, perhaps this is so only for rather specific types of case – those in which the borrowed material is ancillary, or used merely in raising objections to other theories, or which involve the use by natural philosophy of material from the mixed mathematical sciences such as astronomy. Such a view would ignore the case of medicine and natural science in [T2] and [T3], but in any event my final three examples will all involve the use of material from other enquiries by First Philosophy. What is more, in most of these examples the use of this material seems absolutely integral to the positive work of First Philosophy: it is not ancillary, digressive, or used to attack other theories.

(i) In *Met*. Λ.6–7 Aristotle uses a series of arguments relating to the Prime Mover taken from *Phys*. VIII. *Met*. Λ's argument for the need for a Prime Mover owes much to *Phys*. VIII, obviously, though Λ's version is highly abbreviated and somewhat revised; he follows this, in [T13], with the 'infinite *dunamis*' argument for the Prime Mover's partlessness, lifted straight from the *Physics*, and an argument for its impassivity which takes the priority of locomotion straight from that work too:

> [T13] And it has been proved in addition that this same substance can have no magnitude, but is partless and indivisible. For it causes motion for an infinite time, and nothing finite can have an infinite power. Now every magnitude is either infinite or finite; but it could not have a finite magnitude for this reason, nor an infinite one because there is no infinite magnitude of any sort. But also that it is impassive and not subject to alteration; for the other changes are posterior to that in respect of place.[68]

67 As Lennox puts it, "The terms optics, harmonics, mechanics, and astronomy, when used *simpliciter*, cover both the knowledge of the facts to be demonstrated and the knowledge of the principles of demonstration. The principles of such demonstrations, however, when viewed outside the context of explanation in the mixed sciences, *just are* mathematical propositions. What makes mathematical optics or astronomy something other than pure geometry is that the geometry is restricted in its range of application to explaining why a certain restricted [and *physically demarcated*: 1986, 42] class of *natural* phenomena possesses the *geometrical* properties it does" (Lennox 1986, 43).

68 *Met*. Λ.7, 1073a5–12: δέδεικται δὲ καὶ ὅτι μέγεθος οὐδὲν ἔχειν ἐνδέχεται ταύτην τὴν οὐσίαν ἀλλ' ἀμερὴς καὶ ἀδιαίρετός ἐστιν (κινεῖ γὰρ τὸν ἄπειρον χρόνον, οὐδὲν δ' ἔχει δύναμιν ἄπειρον πεπερασμένον· ἐπεὶ δὲ πᾶν μέγεθος ἢ ἄπειρον ἢ πεπερασμένον, πεπερασμένον μὲν διὰ τοῦτο οὐκ ἂν ἔχοι μέγεθος, ἄπειρον δ' ὅτι ὅλως οὐκ ἔστιν οὐδὲν ἄπειρον μέγεθος)· ἀλλὰ μὴν καὶ ὅτι ἀπαθὲς καὶ ἀναλλοίωτον· πᾶσαι γὰρ αἱ ἄλλαι κινήσεις ὕστεραι τῆς κατὰ τόπον. Compare VIII.10, 266a10–b27, 267b17–26 (infinite *dunamis*), and VIII.7, 260a26–261a26 (primacy of locomotion).

(ii) Whatever else it does, it is the job of First Philosophy to investigate immaterial, unchangeable substance. So the question, 'how many substances of this sort are there?', is a First-Philosophical question if ever there was one, and the proof that there are such-and-such a number of them is a proof in First Philosophy. But it turns out that we need to use mathematical astronomy to answer it: there are as many immaterial substances as there are perfect motions in the heavens, and

> [T14] As for the number of the motions, this is straightaway something which must be investigated on the basis of the mathematical science which is most akin to philosophy, astronomy. For this one studies substance which is perceptible but eternal, while the others – e. g. the one concerned with numbers, and geometry – do not study any substances.[69]

It turns out, moreover, that we cannot do without physics either: we need cosmology (in the shape of the theory of the back-winding spheres[70]) to supplement astronomy so as to arrive at the full number of motions required, and we need natural teleology to secure the result that there are no *more* heavenly motions than are thus required.[71] The proof that there are 56, or 50, or 48 immaterial substances requires an indissoluble collaboration between three distinct sciences.

(iii) Examples (i) and (ii) are peculiar – in the old-fashioned sense – to Λ; but that is because they concern the Prime Mover, and it is only in Λ that First Philosophy succeeds in getting to this.[72] My final example is at its clearest in Λ too, but, as we shall see, it really involves Aristotle's whole approach to First Philosophy.

> [T15] Perceptible substance is subject to change. If change is from things which are set against each other or from what is between, and not from all things which are set against each other (for voice is not pale), but from the *opposite*, it is necessary for there to be something underlying, which is what changes into the opposite condition; for it is not the opposites that change. Further, while something remains, the opposite does not remain. There is therefore a third thing besides the opposites – the matter [...] There are, therefore, three causes and three principles: two are the pair of opposites – of which one is the formula and form, one the privation – and the third is the matter.[73]

69 *Met*. Λ.8, 1073b3–8: τὸ δὲ πλῆθος ἤδη τῶν φορῶν ἐκ τῆς οἰκειοτάτης φιλοσοφίᾳ τῶν μαθηματικῶν ἐπιστημῶν δεῖ σκοπεῖν, ἐκ τῆς ἀστρολογίας· αὕτη γὰρ περὶ οὐσίας αἰσθητῆς μὲν ἀϊδίου δὲ ποιεῖται τὴν θεωρίαν, αἱ δ' ἄλλαι περὶ οὐδεμιᾶς οὐσίας, οἷον ἥ τε περὶ τοὺς ἀριθμοὺς καὶ τὴν γεωμετρίαν.

70 These are not an astronomical device, but a cosmological one.

71 For discussion see Judson 2015, Section 6, and 2019, commentary on 1074a17–24.

72 Though of course there are references to this advance in Z (2, 1028b13–15 and 27–32, 3, 1029a33–b12, 11, 1037a10–17: the last of these is [T17] below).

73 *Met*. Λ.1–2, 1069b3–34: ἡ δ' αἰσθητὴ οὐσία μεταβλητή. εἰ δ' ἡ μεταβολὴ ἐκ τῶν ἀντικειμένων ἢ τῶν μεταξύ, ἀντικειμένων δὲ μὴ πάντων (οὐ λευκὸν γὰρ ἡ φωνή) ἀλλ' ἐκ τοῦ ἐναντίου, ἀνάγκη

What Aristotle does here is, I think, quite simple: he is summarising the results and arguments of *Phys*. I; and he does this because he thinks that the principles arrived at there *just are* the metaphysical principles of substance.[74] First Philosophy proceeds by way of natural science.

How might defenders of the *IBV* avoid this conclusion? One attempted – but I think unsuccessful – way out is Jaeger's assumption that, since Λ.1–5 is about sensible substances, it must be a part of physics, not of First Philosophy. One might try to gain some support for this from a passage in Λ.1:

> [T16] The former kinds of substance, then, are the subject of natural science (for they involve motion), but the latter of another science, if there is no principle common to them all.[75]

Jaeger takes this to mean that *any* enquiry into natural substance belongs to physics.[76] But we should not read the passage this way. The first point to note is that this reading would be devastating for our understanding of Z and H: they too would be physics, not metaphysics, as [T17] shows:

> [T17] Whether there is any other matter than that of substances of this kind, and whether we should seek some other kind of substance, for instance numbers or something of this kind, must be considered later. For it is for the sake of this that we are attempting to analyse perceptible substances too, since the study of perceptible substances is in a way the task of natural science, i. e. Second Philosophy.[77]

ὑπεῖναί τι τὸ μεταβάλλον εἰς τὴν ἐναντίωσιν· οὐ γὰρ τὰ ἐναντία μεταβάλλει. ἔτι τὸ μὲν ὑπομένει, τὸ δ' ἐναντίον οὐχ ὑπομένει· ἔστιν ἄρα τι τρίτον παρὰ τὰ ἐναντία, ἡ ὕλη [...]. τρία δὴ τὰ αἴτια καὶ τρεῖς αἱ ἀρχαί, δύο μὲν ἡ ἐναντίωσις, ἧς τὸ μὲν λόγος καὶ εἶδος τὸ δὲ στέρησις, τὸ δὲ τρίτον ἡ ὕλη.

74 David Charles has argued that Aristotle's treatment of matter in Λ.2 is actually quite different from that in *Phys*. I (2000, 84–106; for discussion see Judson 2019, Prologue to ch. 2); but the difference he detects is one of doctrine, about how matter is to be conceived of, not one of First-Philosophical vs Second-Philosophical approaches to the same thing.

75 *Met*. Λ.1, 1069a36–b2: ἐκεῖναι μὲν δὴ φυσικῆς (μετὰ κινήσεως γάρ), αὕτη δὲ ἑτέρας, εἰ μηδεμία αὐτοῖς ἀρχὴ κοινή. I retain the reading of the majority of MSS at b2, εἰ μηδεμία αὐτοῖς ἀρχὴ κοινή, rather than the variant found in some MSS (most notably C and M), εἰ μηδεμία αὐτοῖς ἀρχὴ κινήσεως: for discussion see Frede 2000, 74.

76 Jaeger 1948, 221.

77 Z.11, 1037a10–16 (trans. Bostock [1974], with modifications): πότερον δὲ ἔστι παρὰ τὴν ὕλην τῶν τοιούτων οὐσιῶν τις ἄλλη, καὶ δεῖ ζητεῖν οὐσίαν ἑτέραν τινὰ οἷον ἀριθμοὺς ἤ τι τοιοῦτον, σκεπτέον ὕστερον. τούτου γὰρ χάριν καὶ περὶ τῶν αἰσθητῶν οὐσιῶν πειρώμεθα διορίζειν, ἐπεὶ τρόπον τινὰ τῆς φυσικῆς καὶ δευτέρας φιλοσοφίας ἔργον ἡ περὶ τὰς αἰσθητὰς οὐσίας θεωρία. Jaeger's comment on this is an instructive application of the *IBV*. He contrasts the "in a way" remark here with the claim at Λ.6, 1071b3–4, "Since there were three kinds of substance, two of them physical and one unmovable [...]": "Whereas later [i. e. in Z.11] Aristotle describes the two kinds of sensible reality as 'in a sense' the concern of physics, he here calls them physical without qualification" (1948, 220).

No one takes this to mean that Z's enquiry is a piece of natural science.[78] The second point is that Jaeger's reading is impossible to square with the way in which, as I said earlier, Aristotle explicitly incorporates the enquiry into the principles of natural substance into the structure of Book Λ: the book is a *single* enquiry into the causes and principles of substance: some substances are changeable, and some are not, so he will first discuss the former and then the latter.[79]

On the next page we see Jaeger struggling, not very successfully, to give an account of Λ which respects the *IBV*:

> In book Λ we can at last see clearly how this vital part of Aristotle's philosophy [i. e. the doctrine of immanent forms] was related to theology while it was still part of physics. The gradual ascent from sensible to supersensible form, which later took place within metaphysics, is effected in Λ by the primitive device of letting metaphysics, as the science of the unmoved and transcendental, simply rest externally on physics, the science of the movable and immanent. By the logical manipulation of the objects of sensible experience physics obtains the conceptions of form and entelechy, which it distinguishes from matter and potency, and the relations of which to these other conceptions it determines. It then hands them over to metaphysics.[80]

Jaeger is clearly convinced that the study of natural substances must belong exclusively to physics, but then has difficulty in expressing the idea that First Philosophy *uses* the results of physics without conceding that the same material can properly be used by both sciences.

For these reasons we should take both [T16] and [T17] to mean that the *extended* study of the specific features of these substances belongs to physics: the study of their features at the most general level also belongs here – to First Philosophy – while everything more specific belongs just to natural science.

Another possible way out for [T15] – equally unsuccessful – is Burnyeat's. He rejects Jaeger's assumption, but he does not rid himself of the *IBV*. Burnyeat thinks that there is a sharp discontinuity of approach between *Phys*. I and both Z and Λ.1–2:

78 Nor does anyone take the arguments for the 'generation by synonyms' claims in Z.7–9 – even the appeal to the case of mules – to mean this. One of the *Archiv* readers pointed out the remark at *Met*. E.1, 1026a27–32: 'if, then, there is no other substance beyond those constituted by nature, natural science would be the first science.' This is a dark saying, but it does not imply that *no* discussion of natural substance can be a part of First Philosophy in its own right (see below): for discussion see Judson 2019, commentary on 1069a36–b2.

79 For discussion see Judson 2018.

80 1948, 222.

> There is a first-philosophical way of studying sensible substantial beings as well as a second-philosophical way. Z 11 [he is referring to [T17]] is proof of that [...] Nowhere does Jaeger grasp the idea that first philosophy and second could both study sensible substantial being, each from a different perspective *and focussing on different aspects of the same subject-matter [...]*. The way to read the early chapters of Λ is a first-philosophical use of the factors invoked in *Physics* I to explain change (matter, form and privation) [...]. These now reappear as the principles that explain the substantial being of sensible, hence changeable, substantial beings.[81]

This might seem tenable were one to suppose that the principles of *Phys*. I are primarily principles of *change*, not of *changeable substances,* but Burnyeat rightly rejects this view.[82] How, then, if the principles of *Phys*. I are those of natural substances, is what Aristotle does in Λ different from what he does in *Phys*. I? Burnyeat says that "the focus of physics is on sensible substantial beings as things whose nature is a principle of stability and change, while first philosophy is interested in more abstract questions about their *being*."[83] I confess that I cannot see any such difference at work: Λ.2 rehearses exactly the same considerations as *Phys*. I about the termini of changes and the need for 'something which remains', in order to arrive at its three principles of substance: they invoke precisely the same principles of precisely the same things.[84] What is distinctly different about the two enquiries is the *subsequent* way in which physics and First Philosophy will go on to use them, but this does not make the material itself different. Rather than insist that there *must* be a difference in this material according to whether it is being used in physics or in First Philosophy, we should take Aristotle's deployment of it in both contexts to reveal it as common to both.

81 Burnyeat 2001, 129 and note 6, and 133; my italics.

82 For discussion see Judson 2017.

83 Burnyeat 2001, 129. Rapp argues 'It is one thing to ask how (and in virtue of which principles) certain sensible substances come to be and cease to exist or how (and in virtue of which principles) all sensible substances manage to undergo change and to change their position, but it might be quite another thing to ask what the principles and causes of the being of the same substances are, once it has come into being' (2016, 89). I agree that these are different questions, and that it is a puzzle why *Phys*. I, an enquiry into the principles of the things that are by nature, approaches the second by way of the first (for an attempt at an explanation, see Judson 2017); but it is clearly the province of natural science to ask both. The question then is the one which arises for Burnyeat's view: what distinctively different version of the second question could it be for metaphysics to ask?

84 Compare the question how (on the *IBV*) can it be the business of First Philosophy to establish whether there is change? Not by, or even in the course of, considering natural beings simply as *beings*; for it is not as beings *simpliciter* that they are liable to change, but as natural beings. Or if the idea is that being a natural being, or having form and matter, just *is* what it is for this sort of being to be a being, then we will have something like the programme of Λ. For discussion of some related issues in Met. Γ see Judson 2018, Section 4.

3 Conclusion

As I have said, I do not wish to deny that, in Aristotle's view (outside the *Analytics* as well as inside), it is possible for something to belong to one science rather than to another – and some of the texts we have considered explicitly make claims of this kind. What then is it for such a claim to be true if the *IBV* is false? It seems that Aristotle can differentiate the sciences in broadly the way he seems to in the *Analytics* – in terms of different subject-matter – providing that he deploys something like a majoritarian understanding of this: *X* belongs to science *A* if *X* is part of the subject-matter with which *A* is mostly concerned (or is among the *per se* attributes of that subject-matter). Note that I am neither endorsing nor rejecting the *general* adequacy of the subject-matter approach: if it turns out that this approach is insufficient to capture how Aristotle differentiates sciences outside the *Analytics*, so much the worse for the *IBV*. It is part of the rejection of the impermeable boundary theory, however, to suppose that the subject-matter with which *A* is mostly concerned can overlap with the subject-matter with which *B* is mostly concerned (the case with physics and medicine, as we have seen);[85] and, as I have repeatedly stressed, it is also part of this rejection to suppose that if *X* belongs to science *A*, it can nonetheless figure in *B* as well.

From the point of view of the impermeable boundary theory, the picture of Aristotelian science and philosophy which I have painted – or, I hope, revealed – is *messy*. That is, in my view, a very good thing: different sciences and areas of expertise – like the different branches of what we nowadays call philosophy – are not distinguished and connected in neat ways: their relations are, indeed, messy. It is also, in my view, a very Aristotelian thing: no other philosopher in the history of the subject comes close to Aristotle in the way he combines an intense drive for systematisation with an intense appreciation of the differences between things, and the need to deal with them as they are. We should just accept that Aristotle does not conform to the boundary-crossing prohibition of the *Analytics*.

What view should we take of this? Martha Nussbaum, assuming that different branches of natural science constitute different sciences, and so advancing the view that the *De Motu*'s mixing up of different branches of natural science violates the no-crossing requirement, saw Aristotle as clear-sightedly rejecting his earlier, crabbed and simply false view.[86] I have to say that I am, instead, agnostic.

85 How might these sciences be differentiated by their subject-matter? One could perhaps say that, since medicine is concerned with bringing about health, its (propositional) subject-matter is health and cures.

86 "Perhaps the *MA* does indeed represent a departure from the *Organon*'s system, but a deliberate and fruitful one [...] it is a fine example of his capacity for self-criticism [...] [Aristotle]

Perhaps what Aristotle says in the *Analytics* was intended as a stab – and it is a reasonable stab – at what can be said about *systematic* borrowing and sharing among the sciences – whereas what I have pointed to is the messy, unsystematic borrowing and sharing which is quite properly characteristic of Aristotle's scientific inquiries. Or perhaps the issue of the non-applicability of the no-crossing rule outside its source in the *Analytics* should be treated as part of a wider set of difficulties in thinking that Aristotle's practice and methodological attitudes outside the *Analytics* are consonant with the picture of science developed there. That is not my concern: all I have attempted to do is show how permeable the boundaries of Aristotelian sciences actually are.[87]

An. Post.	*Posterior Analytics*
An. Pr.	*Prior Analytics*
Cael.	*De Caelo*
De An.	*De Anima*
De Iuv.	*De Iuventute et Senectute, De Vita et Morte, De Respiratione*
De Sensu	*De Sensu et Sensibilibus*
MA	*De Motu Animalium*
EE	*Eudemian Ethics*
EN	*Nicomachean Ethics*
GC	*De Generatione et Corruptione*
Met.	*Metaphysics*
Meteor.	*Meteorologica*
PA	*De Partibus Animalium*
Phys.	*Physics*

moves [...] towards a less departmental and more flexible picture of scientific study [...] Brief and cryptic though it is, the *MA* makes a valuable contribution to our knowledge of Aristotle's mature views concerning the articulation of the universe and of man's sciences" (Nussbaum 1978, 113 f.). As I have said, her version of the problem stems from her assumption that different branches of natural science constitute different sciences (cf. Kung 1982; for criticism, see Lennox 2010, especially. 8 f.).

87 An earlier version of this paper was given at a conference in Oxford on Aristotle's science and metaphysics. I am grateful to the participants for their comments, and especially to Elena Cagnoli Fiecconi, Paolo Fait, Terence Irwin, Marko Malink, and Michael Peramatzis; I am also very grateful to Timothy Clarke for a discussion of some of the issues, and to Laura Castelli, Andrea Falcon, and two anonymous *Archiv* readers for comments on another version.

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