CHAPTER 5

Aristotle on Productive Understanding and Completeness

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In *Metaphysics* IX.2, Aristotle describes craft (*technê*) as a special kind of understanding (*epistêmê*): productive understanding.[1] Elsewhere, he classes certain particular crafts as forms of understanding (medicine and gymnastics at *Metaph.* XI.7, 1063b36–64a1, the craft of building at *Metaph.* VI.2, 1026b4–10). My topic in this chapter is this notion of productive understanding. Aristotle himself sometimes simply identifies understanding (*epistêmê*) with theoretical understanding.[2] In what follows, I shall ask in what sense productive understanding is a genuine kind of understanding, and how exactly it differs from the kind of understanding that is theoretical.[3]

I shall argue that both kinds of understanding essentially involve grasping explanations, but that they differ in the following way. Someone who fully possesses a certain theoretical science (and hence, has full theoretical understanding within a certain domain) has explanations for everything

[1] I take the '*kai*' at IX.2.1046b3 to be epexegetic: 'all crafts, that is all productive forms of understanding, are powers' (following Ross 1924, ad loc). One reason for taking the '*kai*' in this way is that the subsequent argument seems to depend on identifying *technê* with productive understanding. Aristotle justifies the claim that *technê* is of opposites by arguing that productive understanding is of opposites. However, as we shall see below (Section III), there are some grounds for doubting whether a *technê* can be strictly identical with productive understanding. Arguably, the ability of the craftsman, qua craftsman, also includes a specific kind of perceptual ability: an ability he needs if he is to apply his productive understanding to particular circumstances and hence to act successfully on the basis that understanding.

[2] For example, at *EN* VI.3.

[3] There are several passages in which Aristotle divides *epistêmê* into three kinds: theoretical, practical and productive (*Metaph.* VI.2.1026b2ff, VI.1, 1026a21, *Metaph.*1064a10ff – where the *epistêmê* of nature is contrasted with productive and practical kinds of *epistêmê*, *Top.* 145a16 and 157a10–11.) At *Metaph.* I.1, Aristotle says that theoretical *epistêmê* is closer to being a kind of wisdom than is productive *epistêmê*. In this chapter, I focus on the differences between theoretical and productive understanding. I leave aside the more difficult, though obviously interesting, question of the relation between theoretical and practical understanding, though I hope that my discussion here will serve as a useful preliminary to tackling that further question.

within the scope of that science.[4] There is, by contrast, nothing analogous that would count as fully possessing a certain productive science: the content of productive understanding is indefinitely extendable. I shall use the label 'completeness' to characterise this difference: a science is potentially *complete* (as I am using the term) if and only if *having explanations for everything that is explicable within its scope* is in principle possible. Thus, I shall be arguing that theoretical science is in this sense potentially complete, whereas productive science is not. A consequence of this is that productive understanding requires a special kind of creativity. The ability to work out new explanations is essential to productive understanding in a way that it is not essential to theoretical understanding. In what follows, I first look at the ways in which Aristotle's account of productive understanding is similar to his account of theoretical understanding, and then look at the crucial respect in which the two kinds of understanding differ from each other.

I Explanations in Theoretical and Productive Science

Understanding, whether theoretical or productive, involves grasping explanations. Aristotle says that craft is like theoretical understanding in that it involves knowing 'the why and the cause' (*to dioti kai tên aitian*, *Metaph.* I.1 918a30). This concern with explanations is a feature of any kind of understanding:

> Every science [*epistêmê*] seeks certain principles and causes for each of its objects – e.g. medicine and gymnastics and each of the other sciences, whether productive or mathematical. For each of these marks off a certain class of things for itself and concerns itself with this. (*Metaph.* XI.7 1064a1ff)

As Aristotle says in this passage, a science will concern itself with explanations *within a certain specified domain*.

Theoretical understanding is exercised in actively thinking explanations. Its goal is contemplation. For instance, each of astronomy, physics and geometry aims at 'knowing and contemplating the nature of the things' within its domain. Productive understanding is exercised in acts of

[4] Aristotle uses the same word, '*epistêmê*', both for the content understood (a branch of theoretical or productive science, e.g., the organised body of knowledge that makes up the science of geometry or of medicine) and also for the cognitive state of the person who has that understanding. In what follows, I shall use the English word 'science', where what is meant is clearly the content understood and 'understanding' where what is meant is the cognitive state of the person who grasps that content in the right way.

production that are guided by the grasp of explanations. Its goal is a certain product. For instance, health is the goal of medical understanding, good governance of political understanding.[5]

Theoretical explanations take the form of demonstrations. A demonstration is a kind of syllogism in which the premises are explanatory of the conclusion. All the theorems that fall within the scope of a given science can be derived by demonstration from the first principles of that science, these first principles being themselves indemonstrable.[6] Aristotle claims that the principles of a theoretical science must be finite in number, since otherwise the science as a whole would be unknowable. This is the reason he gives in *Physics* I.4 for rejecting Anaxagoras' view that there are infinitely many first principles. The infinite is unknowable, so if there were infinitely many first principles, it would be 'impossible to know the things that are from them'.[7] Aristotle's syllogistic implies that if the first principles are finite, then only finitely many theorems can be deduced from them.[8] Thus, within any science there will be finitely many first principles and also finitely many demonstrations and demonstrated theorems. In other words, the fact that there are only finitely many principles implies that the theoretical science as a whole is finite: it is in principle possible to have demonstrative understanding of *all* the theorems of a given theoretical science.

The explanations that guide exercises of productive understanding are different in structure.[9] Aristotle says that in a productive science, the starting point is the goal to be achieved. This goal plays a role that is analogous to the role of a hypothesis in a theoretical science:

[5] *EE* I.5 1216b11–19.

[6] Aristotle allows that there is also an extended sense of 'science' in which one science can be subordinate to another. For instance, the science of optics falls under that of geometry. In such cases, the explanations are given by the higher science (*Post An* I.13 78b35ff).

[7] *Ph.* I.4, 187b10–11. See also *DC* 302b10ff on figures.

[8] As Smith 2009: 54 emphasises, this is a way in which the syllogistic differs from modern propositional logic: in modern logic 'if we start with just a single proposition p, its logical consequences include not only all the infinitely many tautologies, but also all the infinitely many propositions equivalent to it: p & p, p & (q v -q), p v p etc'.

[9] For a contrasting view of the relation between the explanations of theoretical science and the explanations that constitute the content of productive understanding, see Bolton's discussion of *Metaphysics* I.1 (Chapter 6). Of course, even on my interpretation, it will often in fact turn out that having the relevant productive explanations will only be possible for someone who also has a certain amount of theoretical understanding. For instance, it may turn out that a certain level of understanding of the science of trees is needed in order to be a good gardener. My claim is only that the explanations that directly guide what the craftsman does are explanations that are differently structured from the explanations that are grasped as part of a theoretical science. That is compatible with the view that, in certain cases, a level of theoretical understanding is required in order to possess the relevant productive explanations.

> as in the theoretical sciences the hypotheses are the starting points, so in the productive the end is the starting point and hypothesis. Since this body is to be made healthy, it is necessary for this thing to be if that is to come about, just as there [in geometry], if the angles of the triangle are equal to two right angles, necessarily this is the case. (*EE* III.1227b28ff)[10]

In this passage, Aristotle is comparing the kind of demonstrative syllogism that is grasped by a geometrician to the productive syllogism that might be grasped by a doctor attempting to cure someone. This suggests that there is an analogy between demonstrations in theoretical science and productive explanations in productive science. The geometrician grasps certain first principles (e.g., that the angles of the triangle are equal to two right angles) and demonstrates certain theorems from these first principles. In grasping these demonstrations, he grasps why the theorems hold. The first principle grasped by the doctor is the goal to be achieved (e.g., that health is to be brought about in this body). The doctor reasons about what should be done in the light of this first principle. In so doing, she arrives at a productive explanation of why such and such should be done.

How exactly is the productive explanation the doctor arrives at *explanatory*? In theoretical demonstrations, the explanatory work is done by the middle term.[11] For example, 'sap-solidifiers' is the middle term in the demonstrative syllogism: 'all broad-leaved trees are sap-solidifiers, all sap-solidifiers lose their leaves, so all broad-leaved trees lose their leaves'. This shows that the explanation of why broad-leaved trees shed their leaves is that they are sap-solidifiers.[12] Is there anything analogous to this in the case of productive explanation?

[10] My discussion here and in what follows is especially indebted to Moss 2014. The parallel between theoretical and practical/productive explanation is also helpfully discussed in Allen 2015. Moss 2014: 214 n. 41 suggests that Aristotle's point would have been clearer had he used as his example of a theoretical first principle a claim about the essence of triangles (since elsewhere, he is quite clear that 'the angles of a triangle add up to two right angles' is itself demonstrable, rather than an ultimate first principle, *Metaph.* V. 30 1025a30–34; *Pr An*, I.35 48a36–37). However, there is perhaps a reason for Aristotle not to use an ultimate first principle as his example here. The first principles of a *technê* are not, strictly, analogous to *indemonstrable* first principles within a theoretical science. Rather, they are first principles that are explicable, but not explicable *within the technê*. There is an explanation of why this patient should be made healthy, but knowing that explanation is no part of the doctor's craft. Thus, for Aristotle's purpose here (of comparing theoretical and productive understanding), a better example of a theoretical hypothesis would have been something that is assumed, and hence not demonstrated, within a subordinate theoretical science, but that might be demonstrated within a higher science. (For Aristotle's account of subordinate theoretical sciences, see *Post An* I.13.)

[11] See *Post An* II.2 (90a6–7) and II.11.

[12] For the example, see *Post An* II.16–17.

Consider the following chain of productive reasoning:

> Starting point or goal: To make a chilled patient healthy.
> The way to make a chilled patient healthy is to heat her.
> The way to heat the patient is to rub her.
> CONCLUSION: The way to make a chilled patient healthy is to rub her.

We can think of this as analogous to a demonstrative explanation. The middle term is 'heating', and this connects in an explanatory way the two terms mentioned in the conclusion ('producing health in a chilled patient' and 'rubbing'). The doctor who knows this productive explanation knows why rubbing is the way to make a chilled patient healthy. The explanation is that rubbing her is a good way of heating her and heating her is a good way of making her healthy. Thus, the doctor who knows the whole productive explanation knows the explanation that connects *rubbing* to *producing health*, just as the natural scientist who knows the demonstrative syllogism about trees knows the explanation that connects *being a broad-leaved* tree and *losing leaves*.[13]

Thus, productive explanations are in certain respects analogous to the demonstrative explanations of theoretical science. Nevertheless, we can already see that there are two important differences between theoretical and productive explanations. First, the conclusion of a productive explanation is, in a certain sense, essentially comparative. If I know that rubbing is generally a good way to produce health in a chilled patient, then I know that rubbing is good *in comparison to other possible ways of producing health in chilled patients*. I either know that rubbing is the best possible method of producing health in such patients, or at least that it is among the better methods. This already suggests that productive understanding is *in a certain sense* unlimited in its range: grasping a single productive explanation requires knowing indefinitely many facts about other things not mentioned in the explanation (e.g., about alternative possible methods of producing health). By contrast, the conclusion of a theoretical demonstration is not, in the same way, essentially comparative.

Second, the conclusion of a demonstration, unlike the conclusion of a productive explanation, is entailed by its premises. Of course, Aristotle

[13] This suggestion is confirmed by the way in which Aristotle applies his theory to final cause explanations in *Post An* II.11 94b12–21: the way to make yourself healthy is to walk after dinner, because walking after dinner makes the food not remain at the mouth of the stomach, and this produces health. (The explanatory middle term is *the food not remaining at the mouth of the stomach*.) An experienced person might know that the way to keep yourself healthy is to walk after dinner without knowing the reason why this is so (that is, without knowing the relevant middle term), and hence without having the relevant craft knowledge.

thinks that it is because the craftsperson grasps the goal that she is able to come up with productive explanations, just as it is because the theoretical scientist grasps the principles of the science that she is able to come up with demonstrations.[14] But Aristotle never suggests that the steps in a productive explanation are *logically entailed by* the first principles of the craft, as the steps in a chain of demonstrations are entailed by the first principles of the relevant theoretical science. This difference bears on our question about completeness. As we saw earlier, Aristotelian syllogistic ensures the finitude of theoretical science: if there are finitely many first principles, then only finitely many theorems can be deduced from them. Since productive explanations are not constrained in the same way by Aristotelian logic, there is no analogous reason to insist that productive understanding must be finite (that is, that there must be finitely many explanations within the scope of any given productive science).

However, although Aristotle does not have this formal reason for insisting on the finitude of productive understanding, in spelling out his account of productive understanding, he is clearly concerned to limit its scope. As we shall see, he claims that productive understanding is limited in three key ways, each corresponding to a limitation on the scope of theoretical understanding. If we can get clearer about these ways in which productive and theoretical understanding are analogous, this will help to bring into focus the important respects in which they differ.

II Limitations on Scope: Productive and Theoretical Understanding

I shall argue that there are three limitations on the scope of theoretical understanding, each of which has a parallel in a limitation on the scope of productive understanding. The first is that understanding is of general truths. The second is that there is no understanding of the accidental. And the third is that chains of explanation are finite.

II.A Understanding Is of General Truths

Aristotle says that 'every science [*epistêmê*] is of what holds either always or for the most part' (*Metaph.* VI. 1027a20–21). His account of theoretical understanding places constraints on what can count as a theorem of a

[14] It is because the doctor has a full grasp of what health is that she is able to explain how to cure; it is because the housebuilder has a grasp of what a house is that she is able to explain how to build.

science (and hence, what can be explained within a science). A theorem must be the kind of thing that can be the conclusion of a demonstration. Aristotle sometimes says that only necessary truths can be demonstrated and hence only such truths can be the theorems of a science: 'if something is understood demonstratively, it must hold from necessity'.[15] However, this constraint on demonstration would rule out the possibility of natural science. A complete natural science could not consist simply of explanations of necessary truths about the things in its domain: the behaviour of natural things is too irregular to be explained in this way. To accommodate the possibility of natural science, Aristotle in some texts allows that there can be demonstrations, and hence scientific knowledge, of what holds for the most part (i.e., as a rule, *hôs epi to polu*).[16]

Our understanding of general truths gives us a *kind* of derivative understanding of the infinitely many particulars to which they apply (though this derivative, applied kind of understanding does not fall within the scope of theoretical understanding itself). For instance, if I understand on the basis of demonstration why vines as a rule lose their leaves in autumn, then provided that this particular vine lost its leaves in virtue of a natural causal regularity, I thereby understand why *it* lost its leaves in autumn. Similarly, if I understand why all triangles have angles adding up to two right angles, then I thereby also understand why any particular perceptible triangle has angles adding up to two right angles.[17]

Elsewhere, Aristotle says that productive understanding too is of general truths. In the *Posterior Analytics*, he gives an example from medicine: 'the doctor does not say what is healthy in the case of some individual eye, but either in the case of every eye, or determining some species of eye' (*Post An* 97b25–28). In the *Rhetoric* he appeals to his view that the particular is 'not knowable' in support of his claim that craft is, strictly speaking, of the universal:

[15] *Post An* I.6 75a12–13. See also *EN* VI.3.1139b19–21 for the claim that *epistêmê* can only be of necessary truths.

[16] For instance, at *Post An* I.30 87b21–23, he says that demonstrations are of either what happens of necessity or what happens as a rule, since 'every syllogism is either through necessary premises or those that hold as a rule'. If the relevant syllogisms are to be valid, then holding 'as a rule' (*hôs epi to polu*) here must mean holding in virtue of some natural causal regularity, not merely something that holds as a matter of statistical frequency (although Aristotle is elsewhere prepared to use the expression '*hôs epi to polu*' for mere statistical regularity). For some discussion of this point, see Henry 2015: 179–85.

[17] This point is nicely made in a paper by Callard (unpublished). At *Pr An* II.21 67a12–16, Aristotle implies that someone who knows that every triangle contains angles equal to two right angles, in a sense already knows (universally) of any particular triangle, that it contains angles equal to two right angles.

> No craft [*technê*] looks to the particular [*to kath' hekaston*]. For instance, medicine does not look to what is healthy for Socrates or for Callias, but rather what is healthy for someone of this type, or people of these types: for this is a matter of skill [*entechnon*], but the particular is unlimited and not knowable [*apeiron kai ouk epistêton*]. Similarly, neither will rhetoric study what seems plausible [*endoxon*] to this or that particular person e.g. to Socrates or to Hippias, but rather what seems plausible to people of a certain type. (*Rhet.* I.2 1356b30–35)

Technical explanations might tell us why a certain type of treatment heals a certain kind of patient, or why a certain type of rhetorical technique is effective in persuading a certain type of listener; they do not refer to particular patients or particular listeners.

As with theoretical understanding, this leaves open the possibility of understanding *certain* facts about particulars, provided these facts are instances of explicable general truths. Just as my understanding of why vines as a rule lose their leaves gives me a kind of derivative understanding of why this vine lost its leaves, so also the doctor's understanding of why honey water should be given to patients with bilious fever enables her to have a kind of derivative understanding of why honey water should be given to *this* patient with bilious fever. Thus, Aristotle can still allow that a productive syllogism ends in a particular action (an action of treating *this* patient in *these* circumstances). His point is that the explanation of why this particular action is the right one for producing health must be general. What gets explained is, in the first instance, why an action *of this sort* will produce health; that this particular action is health-producing is just an instance of this more general explanandum.

II.B There Is No Understanding of the Accidental

Aristotle tells us that the accidental 'is not the concern of any science, whether practical, productive or theoretical' (*Metaph.* VI.2, 1026b2ff). It is relatively easy to see why the accidental is excluded from theoretical science. Something counts as accidental from the point of view of a natural science if it is not explained by the natures of the things that fall under that natural science. Since natural things do not always behave in accordance with their nature, there will be truths about particular natural things that are not instances of either universal or as-a-rule (*hôs epi to polu*) generalisations, and hence that cannot be explained by appeal to a demonstrative syllogism. Aristotle says that such truths fall outside the scope of natural science and are, in that sense, accidental. For example, the science of trees

will not explain why this particular broad-leaved tree lost its leaves unnaturally in the spring rather than in the autumn. Of course, we might be able to tell a story about why the tree lost its leaves then: it was diseased, it was hit by lightning, some children came and picked all the leaves. But this kind of explanation is not a part of any natural science. Any particular tree will presumably have many such accidental features that are not explained by the science of trees.[18]

It is less clear what counts as being accidental to productive understanding. After all, productive understanding is not confined to explaining *how things are by nature* as natural scientific understanding is. In *Metaphysics* VI.2, Aristotle goes some way towards clarifying the relation of craft to the accidental. He says that there will be features of any particular craft-product that are accidental to its being a product of that craft. For example, the house that the builder produces may be pleasing to some people and unpleasing to others, but these features of the house are accidental to its being a product of the building craft. The building craft aims at making a house stable and weatherproof, and the builder should be able to explain how his actions further these aims, but the builder is not, as such, expected to know how to make the house pleasing to any particular group of people. For instance, it is not part of the craft of building to know what type of house will please stockbrokers.

Although Aristotle does not himself spell this out, it is plausible to suppose that there are also other ways of being accidental in relation to a craft. Many things can prevent even the right medical prescription from producing health: the patient may be struck by lightning before the treatment takes effect or the medicine may be stolen before the patient has a chance to take it. Presumably, it is not the job of the medical craft to guard against failures of this kind. Moreover, because of interference,[19] it can sometimes happen that though the patient recovers after treatment,

[18] Aristotle's point is not merely that such accidental facts about the tree are inexplicable *given our current state of knowledge*. Of course, *sometimes* what might appear to be an exception to an explanatory generalisation is in fact evidence that one has picked the wrong generalisation. For example, the fact that fir-trees keep their leaves shows that the relevant general *explanandum* should be *broad leaved trees lose their leaves in autumn*, rather than simply *trees lose their leaves in autumn*. Aristotle's view, however, is that there will be exceptions even to the maximally refined generalisations of a fully developed natural science. Particular natural things do not always behave in accordance with their natures, and hence there will be exceptions to any generalisations that describe the behaviour of natural things as the behaviour they engage in when acting in accord with their natures. Such exceptions will be accidental to the science: even a complete science will not include explanations of them.

[19] On whether the absence of interfering factors enters into the specification of the *technê*'s capacity, see also Nawar in this volume (Chapter 2).

the treatment is not the *cause* of the recovery. Perhaps the doctor gave the wrong medication, but something else intervened with the result that the patient recovered anyway. In this case, the medical craft does not explain the recovery: there is no general medical-craft-explanation of why giving the wrong medication results in recovery. Perhaps the doctor gave the right medication, but the patient accidentally took an antidote and then went on to recover without medical help. In this case too, the medical craft does not explain the recovery: though there *is* a general explanation that connects giving the right medication to recovery, what happens in this case (where the patient accidentally takes an antidote) is not an instance of that general explanation.

These are some respects in which Aristotelian productive understanding, like theoretical understanding, is not concerned with the accidental. Nevertheless, as we shall see, what counts as accidental to a craft is importantly different from what counts as accidental to natural science. In Section IV, I shall argue that, because of the way in which productive understanding is oriented towards particulars, productive understanding differs from natural science in being essentially concerned with certain types of exceptional circumstance. Something can be an exception to one of the generalisations explained by a branch of productive understanding without thereby being accidental to that branch of productive understanding.

II.C Finite Explanatory Chains

In his account of theoretical understanding, Aristotle emphasises that chains of demonstration are finite. They start from indemonstrable first principles[20] and they arrive, after finitely many steps, at a conclusion from which nothing further can be demonstrated (*Post An* I.19–22).[21] I shall

[20] Or, in the case of a subordinate science, principles that are indemonstrable *within that science*.

[21] This claim might seem to be threatened by the unlimited possibilities for classifying things into more and more specific types. One problem arises from the natural variations that Aristotle describes as differences of more and less. (For some discussion of how these phenomena relate to demonstrations, see Henry 2015: 184–85.) Suppose, for instance, we have a demonstration that explains why male dogs lift their leg to urinate when they develop appropriate strength. Aristotle says that this happens at around the age of six months, but that there is a range of natural variation (*HA* VI.20). If we need a separate demonstration for each *precise* time of developing strength, then there will be infinitely many demonstrations and infinitely many relevant subspecies (dogs that develop the appropriate strength in their fifth month, those that develop it in the first week of their fifth month, those that develop it on the first day of the first week of their fifth month and so on). To counter this, Aristotle needs to be able to allow that there are some levels of natural variation that fall below the level of detail that is explained by the relevant science. The science of dogs need

argue that some remarks Aristotle makes about the finitude of deliberation imply that productive explanations are also finite in length.

When we deliberate, we inquire into how to bring about some end; in doing so, we work out both how to act and also why acting in that way is a successful means to bringing about the end. Thus, deliberation is a way of coming up with productive explanations.[22] Aristotle makes two points about the finitude of deliberation. First, it is no part of a craft to deliberate about whether to produce the craft's end. For instance, the doctor (qua doctor) does not deliberate about whether to produce health (*EN* III.3 1112b13). Aristotle's point here is about the scope of the medical craft, not about the practice of actual doctors. As we have seen, he compares the end aimed at by a craft to the first principles of a theoretical science. Just as a science does not demonstrate its first principles, so also 'no craft asks questions about the end' (*EE* III.11 1227b27). A medical productive syllogism will explain how to produce health, but it will not go further and explain how health is itself a means to producing some further good.

Aristotle's second point about the finitude of deliberation concerns its limit in the other direction. In *Nicomachean Ethics* III.3, he says:

> So there will not be deliberation about particulars either, as e.g. about whether this is a loaf, or whether it has been cooked as it should; for these belong to the sphere of perception. And if a person deliberates at every point, he will go on *ad infinitum* [*ei de aei bouleusetai, eis apeiron hêxei*]. (1112b34–13a2, trans. based on Broadie and Rowe 2002)

Again, I think, this point must be about the scope of the craft, rather than just about the practice of actual deliberators. Aristotle is not merely saying that actual processes of deliberation eventually come to an end (when the

not explain why one dog develops the relevant strength an hour before another. That seems rather plausible. However, it is harder to see how Aristotle can justify ruling out infinite demonstrative chains in mathematics. Suppose that even numbers are a species of number and that the proper attributes of even numbers are demonstrated within arithmetic; it might seem that *numbers that are divisible by four* will be a further species of even number, with certain proper attributes of their own; and if so, then presumably *numbers that are divisible by eight* will be a further sub-species, and so on ad infinitum. (For this example, see Barnes 2003: 126–27.) This threatens to produce a potentially infinite chain of demonstrations. No finite chain would explain the proper attributes of all the sub-species: wherever the chain stopped, there would always be a further sub-species whose attributes would remain undemonstrated and hence unexplained. Aristotle needs to deny that all the kinds in the series *numbers divisible by four*, *numbers divisible by eight and so on* are genuine sub-species of the kind *even numbers*. But it is hard to see how a complete mathematical science could avoid postulating infinitely many kinds (of numbers in the case of arithmetic, or of figures in the case of geometry). Aristotle himself never attempts to explain in detail how this might work.

[22] Allen 2015: 53 emphasises that deliberation culminates in, and is aimed at, the grasp of a whole syllogism (not merely the grasp of the conclusion of a syllogism).

deliberator stops deliberating and starts acting). His claim is that deliberation must eventually come to an end because beyond a certain point there are no further explanatory accounts to be grasped. For example, suppose the final explanation in a chain is 'the way to finish the bread-making process is to take the loaf out of the oven when it has been cooked just enough'. The baker is guided by his knowledge of this explanatory chain, but his ability to act on this knowledge by taking out the loaf at the right time is not based on his grasp of some *method* for telling just when the loaf has been cooked enough, a method that might be captured by a further step in the explanatory chain: 'the way to take the loaf out when it has been cooked just enough is to . . .'. Rather, Aristotle says that at this point the baker simply acts on the basis of perception. Because the baker is experienced, he can simply see when the loaf has been cooked enough. Aristotle's more general claim here is that any such chains of explanation will eventually reach a point at which there is no further explanation to be had. At that point, the craftsman must draw upon his experience in perceiving how to act.[23]

III Craft and the Fine-Tuning Needed for Acting on One's Productive Understanding: A Difference between Craft and Theoretical Understanding

In Section II, I described three limitations on the scope of craft-explanations, each corresponding to a limitation on the scope of theoretical explanations. These parallels between craft and theoretical understanding help to justify thinking of a craft as itself a kind of understanding. In Sections III and IV, I focus instead on two important differences between craft and theoretical understanding, both of them resulting from the way in which craft and theoretical understanding differ in their goals. The goal of a craft is successful production, whereas the goal of theoretical understanding is contemplation.[24] I shall argue that because of this difference, exercising a craft requires engaging with particulars in a way that exercising theoretical understanding does not.

One reason for this is that exercising a craft requires more than simply grasping that, and why, such and such a course of action will best achieve a certain end; it requires, in addition, *acting* on this understanding. The

[23] It must be admitted that if I am right about what Aristotle is claiming here, the examples he uses are not very helpful: neither 'this is a loaf' nor 'this has been cooked enough' are claims about how to do something, so neither of them are the kinds of things that could be steps in such an explanatory chain.

[24] As Aristotle says in *EE* I.5.

craftsman must be able to apply his understanding to the particular circumstances in which he finds himself. Aristotle says that this adjustment to particular circumstances does not itself 'fall under any craft [*hupo technên*] or set of rules [*hupo paraggelian oudemian*]'; rather, 'the agents themselves have to consider the circumstances relating to the occasion [*ta pros ton kairon skopein*], as is the case in medicine too and in navigation' (*EN* II.2 1104a7–10). When Aristotle says that this adjustment to particular circumstances does not fall under any craft, I take it that he means that the craftsman's explanations (of what he should do and why) cannot capture precisely every detail of how he should adjust what he does to the circumstances. As Aristotle says in *EN* III.3, the craftsman needs to make use of perceptual powers in order to act on his explanatory knowledge. For instance, at a certain point, a craftsman must just be able to *see* whether this loaf has been cooked enough, or whether this is the right amount of medicine to give to this patient. Though not a part of the craftsman's explanatory understanding, much of this ability to see is itself acquired as part of learning the craft. Though one does not need any special craft to see *that this is a loaf*, the ability to see *when a loaf has been baked enough* is an ability that is acquired through the repeated practice of baking loaves; similarly, the ability to see that this is the precise amount of medicine to give to this patient is an ability acquired through repeated experiences of treating particular patients. That is, one acquires this perceptual ability in just the way that one acquires productive understanding: by practice.

In claiming that the craftsman must use this experience-informed perceptual ability, Aristotle is introducing a *kind* of unlimitedness into the nature of the craft. In acting on his explanatory understanding, the craftsman must respond perceptually to unlimitedly many potential features of his environment.[25] He must fine-tune his action to suit the circumstances. Achieving the goal of a craft requires not only having the ability to come up with relevant productive explanations, but also having the perceptual ability that enables one to act in just the right way on the basis of those explanations.[26] The doctor will not only understand why

[25] Of course, it is also true that in order to apply your *theoretical* understanding to the world around you, you will need to be responsive to such features of your environment. The difference is that the goal of theoretical understanding is contemplation and this does not essentially involve applying such understanding to the world around you. By contrast, the goal of productive understanding is production and producing something necessarily involves interacting with your environment.

[26] As I mentioned above (n. 1), this puts some pressure on the identification of craft with productive understanding, at least if 'productive understanding' is simply an ability to come up with appropriate productive explanations.

such and such medicine is appropriate and why giving too much or too little would be harmful; he will also be able to discern *what counts as just the right amount* for *this* patient. To discern this is to be responsive to details of the circumstances, beyond those that can be mentioned explicitly in a finite productive explanatory account.

The claim that successful craft-production depends on this kind of unlimited ability is quite compatible with the claim that the *explanations* that form the content of productive understanding are finitely specifiable; that is, it is quite compatible with the claim that craft-understanding is potentially complete: its explanatory content could in principle be fully grasped. However, in what follows I shall argue that there is a further respect in which a craftsman's ability is unlimited, and that this does imply the essential incompleteness of craft-understanding. Productive understanding is unlike theoretical understanding because its explanatory content cannot be finitely specified.

The source of this further kind of unlimitedness lies in the way in which productive understanding treats of exceptional circumstances. As we have seen, Aristotle holds that neither craft nor theoretical science provides explanations of accidents. However, this similarity hides an important difference. What it is to be an accident relative to a theoretical science cannot be quite the same as what it is to be an accident relative to a craft. The difference lies in the relation between accidents and exceptions to rules. In natural science, anything that is an exception to one of the generalisations explained by the science is an accident from the point of view of that science and hence is not explicable within the science. A natural science thus explains the behaviour of the things within its scope, *in so far as those things are behaving naturally*. By contrast, I shall argue, the generalisations that are explained within a craft have exceptions that are themselves also explicable within the craft. Such exceptions do not, then, count as accidents relative to the craft. I shall argue that because there is no limit to such potential exceptions, the explanatory scope of a craft is similarly unlimited.

IV Craft and Exceptional Circumstances: A Second Difference between Craft and Theoretical Understanding

The generalisations that are explained by both craft and the science of nature are generalisations that hold only for the most part, or as a rule (*hôs epi to polu*). For example, the science of tree frogs explains why male tree frogs as a rule produce sperm in summer. Of course, there will be

exceptions to this generalisation: there will be individual male tree frogs that fail to produce sperm in summer, perhaps because their organs are defective, or perhaps because they are not in their natural habitat. Similarly, the medical craft explains why, as a rule, honey water should be given to patients suffering from bilious fever (perhaps, in order to thin the blood and hence produce health). But there will be exceptions to this generalisation. For instance, honey water should *not* be given to patients who are suffering from bilious fever but are allergic to honey. The building craft explains why, as a rule, foundations in gravel should be dug to a depth of 70 cm. But there will be multiple exceptions to this generalisation. For instance, the foundations will need to be dug to a different depth if the ground is waterlogged.

My claim is that a craftsman, unlike an expert in the science of nature, needs to engage successfully with such exceptional cases. An expert in the science of tree frogs can explain how tree frogs are *in so far as they are developing and behaving in accord with their nature*; she does not concern herself with defective tree frogs or with tree frogs that are outside their natural habitat.[27] By contrast, an expert doctor will need to know what to do when the patient is allergic to the normal treatment (and why) and an expert builder will need to know what to do when the ground is waterlogged (and why). As Aristotle says, a craftsman will be able to act successfully in nonideal circumstances: 'a good general uses the available army in the most militarily effective way and a good shoemaker makes the finest shoe out of the leather provided to him, and the same also for all the other kinds of craftsmen' (*EN* I.10 1101a3–6). The craftsman will even need to be able to act well in circumstances in which fully achieving the goal of the craft is impossible: 'it is not the function of medicine simply to make man quite healthy, but to put him as far as may be on the road to health; it is possible to give excellent treatment even to those who can never enjoy full health' (*Rhet.* I.1.1355b12–14).[28] These are claims about

[27] Of course, someone who knows the science of tree frogs may in fact also be able to say something about how a tree frog will react in such exceptional circumstances, but the ability to do so is not part of understanding the science of tree frogs.

[28] Aristotle does make certain superficially similar remarks about nature. For example, at *PA* II.14 658a23–24, he says that nature makes the best arrangement *out of those that are possible*. And at *GA* II.6 744b15–16 he explains the way in which bodily residues are used for making bones, nails, etc. with the remark: 'nature, like a good householder, is not in the habit of throwing away anything from which it is possible to make anything useful'. Neither of these, however, concerns something that is an exception to one of the generalisations explained by the science of nature. Neither is a case in which the matter is defective or unsuitable for its purpose. Aristotle's point is that when things operate as they should by nature, there will be certain residues that are used for making bones, and things will be organised in the best way given the materials that nature makes available. The natural

what is involved in having a certain craft, not merely claims about what the practitioners of a craft will in fact be able to do.

The reason for this difference is that a natural thing's nature specifies both its matter and its habitat, whereas a craft does not determine in the same way the environment in which it is exercised and the matter it is exercised upon. Of course, a craft will limit the materials and environment to some extent. As Aristotle says, 'the carpenter would not make a box except out of wood' (*GA* II.6, 743a25). Moreover, it is the job of the carpenter to know what would be the best kind of wood to use. But the craft will often need to be exercised in circumstances in which the best kind of material is not available. The reason for this is that the craft itself does not determine the circumstances of its exercise. *Whether or not to exercise the craft in this case* is determined externally, by the employer (or by the craftsman himself but not qua craftsman). If the employer wants shoes made out of unsuitable leather, the shoemaker will be able to make the best possible shoes out of that leather. If the employer wants a house on earthquake-prone ground, the housebuilder will be able to produce the best house possible for that situation. Because of this, the craft-expert will need to operate successfully in unlimitedly many cases that are, in a certain sense, 'exceptional': cases in which the generalisations that explain what one should do in normal circumstances do not apply.[29]

This introduces a further respect in which a craft is unlimited, and hence a further way in which craft differs from theoretical understanding. In Section V, I shall argue that this further kind of unlimitedness suggests

scientist needs to be able to explain these facts. But the natural scientist does not need to explain the functioning of a defective animal, or how an animal might function if it were made of some material other than the material of which it is naturally made. (I am grateful to Thomas Johansen for pressing me on this point.) Of course, an understanding of natural science (that is, an understanding of why things develop as they do when acting in accord with their natures) could incidentally also shed light on what happens in defective cases. Thus, in *GA* IV.4, Aristotle himself attempts to explain the causes of certain monstrosities (where monstrosities, properly speaking, are things that occur contrary to nature and contrary to what happens as a rule, 770b9–11). My point is just that the content of natural science does not include such explanations: a natural science does not need to provide such explanations in order to be complete.

[29] This is consistent with Aristotle's remark, discussed in Section II above, that there is no productive understanding of the accidental. As we saw above, there are certain types of accidental feature that the craft is not concerned with. The housebuilder does not need to be able to explain how to produce a house that will increase in value. Even with this limitation on the scope of craft, there will still be unlimitedly many cases in which the craftsman will need to explain how to act in unusual circumstances. In theoretical science, anything that is an exception to one of the generalisations explained by the science counts as an accident (and hence as something that falls outside the scope of the science). My claim is that this is not true of a craft: something can be an exception to one of the as-a-rule generalisations explained by the craft without thereby being an accident (and thus something that falls outside the scope of the craft).

that productive understanding is never complete. The expert craftsman, unlike the expert in theoretical science, has a capacity for working out potentially infinitely many explanations.

V Exceptional Cases and Productive Explanations

The fact that an expert craftsman must be able to act successfully in a potentially infinite range of circumstances does not, *by itself*, show that he must be able to work out potentially infinitely many explanations. Someone might argue that the craftsman's ability to respond to exceptional cases does not depend on an ability to work out new explanations. As we saw earlier, the craftsman makes use of a kind of perception-based ability in applying an explanatory account to his particular circumstances. For instance, a kind of trained perception might enable the doctor to tell that *this* is the right amount of honey water to give to *this* patient, and thus enable him to act successfully on his explanatory account of why honey water needs to be given to this patient (and of why the patient should not be given too little or too much). In doing this, the doctor does not need a new explanation; instead, he uses his perceptual power in applying the explanation he already has to new circumstances. It might be argued, then, that the craftsman's ability to respond to exceptional cases is based in a similar way on trained perception rather than on a capacity for working out new explanatory accounts.

However, the ability to respond to exceptional cases is importantly different from the ability to fine-tune one's action to the circumstances in acting on a given explanatory account. The doctor who uses trained perception to see just how much honey water to give this patient (basing this on his sense of the patient's general health, the progress of the disease, etc.) is still acting on his understanding of why honey water should be given to patients with this kind of fever. The doctor who grasps that this patient should not be treated with honey water (because he is allergic) needs to find some alternative method of treatment. Presumably, if he is acting as a craftsman, he will need, in acting, to understand why that alternative method is successful. This requires him to grasp a new explanation.

Of course, the doctor's grasp of the original productive explanation will often help him to come up with a new one. This is, in part, because (as we saw earlier) grasping a productive explanation is grasping something comparative. If the doctor understands why administering honey water is generally a good way to cure bilious fever, then he understands why this

method of treatment would generally be better than others (or at least as good as certain others). This understanding will inform his choice of alternatives in cases in which honey water would not be suitable.

Moreover, the new productive explanation might (and often will) be closely related to the original one. For instance, if honey water cures by thinning the blood, then the doctor might look for some alternative blood-thinning substance. In judging that some alternative blood-thinning substance should be given to the patient, he is acting on a new explanatory account: 'such and such a substance should be given to patients with this kind of fever who are allergic to honey, because such and such a substance produces health by thinning the blood, and does so without causing an allergic reaction'.

In grasping, and acting on, a new explanatory account, the doctor is exercising a rational power, not simply employing trained perception. The doctor might arrive at this new account by deliberation or he might just grasp it immediately without having to spend time working it out. In either case, though, the cognitive power he is using is the same: it is a rational power for grasping explanatory accounts.[30]

VI Why Theoretical Understanding Must Be Complete but Productive Understanding Need Not Be

The arguments I have given above strongly suggest that productive understanding necessarily involves the capacity to come up with new explanations: the explanatory content of a craft cannot be encapsulated in a finite list of explanatory accounts. The craftsman's ability to use trained perception is not itself a substitute for his ability to come up with new explanatory accounts to fit exceptional circumstances.

What I have said does not, I think, provide a *conclusive* argument for the incompleteness of productive understanding. I have not demonstrated that there are, in fact, *infinitely* many different types of exceptional cases that fall within the scope of the craft. What I have shown is that there is no obvious way in which the finitude of productive understanding could be ensured by limiting the range of exceptional cases. Moreover, it might still be possible to defend the view that craft understanding was complete, by allowing a single (though relatively vacuous) explanation to account for a

[30] I take this to show that this rational power cannot simply be what Aristotle calls 'experience' (*empeiria*). For a very different view on the role of experience in Aristotle's account, see Bolton's discussion of *Metaphysics* I.1 (Chapter 6).

wide range of cases. For instance, it might be argued that the doctor acts on an account of the form 'to cure the bilious patient, thin the blood; to thin the blood, administer treatment that thins the blood', and uses trained perception to see what treatment, in the circumstances, will be best for thinning the blood. The explanation he acted on would just be 'administering treatment that thins the blood cures the bilious patient by thinning the blood'. This would allow for a very wide range of treatments to be explained by one and the same account, but it would do so at the expense of making such explanations rather vacuous.

In this last section, I want to step back from this question and ask instead why one should expect understanding (whether theoretical or productive) to be potentially complete. I shall argue that Aristotle has a good reason for wanting to maintain that theoretical understanding is potentially complete, but that this reason does not apply to productive understanding. As we have seen, Aristotle does introduce certain limitations on productive understanding, corresponding to limitations on theoretical understanding: in both, what are explained are generalities; in both the length of explanatory chains is finite; in both, there is no explanatory grasp of the accidental. These correspondences bring out certain important similarities between theoretical and productive understanding. However, there is no reason to suppose that productive understanding must be like theoretical understanding in being finite in its explanatory scope.

Why, then, does Aristotle insist that theoretical understanding must be potentially complete, while allowing that productive understanding need not be? I want to suggest that his position on this is a consequence of his view that divine beings exercise theoretical, but not productive, understanding. Aristotle claims that the gods must be active, and that the kind of activity they engage in is contemplation, rather than either production or practical action (*EN* X.8 1178b18–22). In other words, the gods exercise theoretical, but not productive or practical, understanding.[31] Now Aristotle's views about divine perfection imply that a god could not have a kind of infinitely extendable ability to work out new explanations. On his view, gods are pure activities: they do not have abilities that might or might not be exercised.[32] In *Metaphysics* XII.8, he says that divine contemplative activity cannot be the exercise of some potential (*dunamis*),

[31] In this, of course, Aristotle departs from Plato's view in the *Timaeus*. For a discussion of Plato's account of divine craftsmanship, see Chapter 4 in this volume.

[32] At *Int.* 13 23a23–24 he says that primary substances are 'activities [*energeiai*] without potentiality'. In *Metaph.* IX.8 1050b6–22 he argues that eternal things do not have potentialities (nothing eternal is *dunamei*). For discussion of this argument, see Makin 2006: 209–15 and Beere 2009: 317–24.

since if it were, it would be the kind of activity that could become wearisome.[33] Rather, a god simply *is* contemplative activity. It follows that divine understanding must, being perfect, consist in a grasp of *all* the explanations within its scope. This does not imply that gods are *omniscient* – Aristotle says that the objects of divine understanding can only be the most divine and honourable things[34] – but it does imply that the activity of divine understanding is a grasp of *everything* that is explicable about the objects within its domain.

Aristotle's view that there is no actual infinite implies that grasping infinitely many distinct explanations is impossible.[35] This is not merely something that is impossible for finite human intellects. Thus, if divine understanding is complete, in the sense that it is a grasp of *all* the explanations within its domain, it must also be finite. Within the scope of such understanding, there must be only finitely many explanations *to be grasped*.[36]

Of course, someone could agree with Aristotle's account of the divine and still hold that human theoretical understanding is infinitely extendable. But if Aristotle were to agree with this, he would have to give up on the idea that divine activity is a model for human theoretical understanding. For Aristotle, it is important that humans, in exercising theoretical understanding are engaging, albeit imperfectly, in a divine kind of activity. A human should, by exercising such understanding, 'become like the immortals' (*athanatizein*) in so far as this is possible.[37] Aristotle needs, then, a single account of theoretical understanding that applies both to the kind of understanding exercised by the gods and to human understanding. What humans aim at in their theoretical inquiries must then, like divine understanding, be complete and finite.

There are no such constraints on Aristotle's account of craft (*technê*), since he denies that the gods exercise productive understanding. Aristotle allows that there is a sense in which one can be in complete possession of a craft: 'a doctor is complete (*teleios*) and a flute-player is complete, when in respect of the form of their proper excellence nothing is lacking' (*Metaph.* V.16 1021b16–17). But there is no reason to suppose that 'lacking nothing' with respect to a craft implies already knowing *all* the explanations needed to act on the craft. Instead, I have suggested that productive understanding essentially involves the capacity to work out new explanations, as the circumstances demand. If this is right, then a craft essentially

[33] *Metaph.* XII.9 1074b28–29. [34] *Metaph.* XII.9 1074b25–26. [35] *Ph.* III.4–8.
[36] The importance both of the fact that divine beings engage in theoretical understanding and of the view that grasping the infinite is in principle impossible are recognised by Crager 2013.
[37] See *EN* X.7 1177b26–34.

involves a kind of capacity for innovation. To 'lack nothing' with respect to a craft is to have a fully honed capacity for working out and acting on new explanations, as they are needed.

VII Conclusion

I have argued that the content of a particular theoretical science must be finite: such a science consists of finitely many explanatory demonstrations. Of course, to have understanding, one must grasp these explanations *in a particular way*. It is not enough simply to be able to recite the demonstrations; one must, in addition, grasp how the conclusion of each demonstration follows from, and is explained by, its premises. The content of any particular branch of craft-understanding is, by contrast, potentially infinite. Fully possessing a craft does not, then, involve grasping *all* of that craft's productive explanations. Instead, someone who fully possesses the craft will grasp a certain limited number of productive explanations and will have the capacity to come up with further explanations. Having a craft, like having theoretical understanding, involves grasping explanations in a particular way. Like the person of theoretical understanding, the craftsman must be able not merely to recite the relevant explanations but also to appreciate their explanatoriness. However, grasping the relevant explanations *in the way that constitutes having a craft* also involves more than this. Having productive understanding involves having the capacity to reason about what to do, and why, when faced with new circumstances. You grasp the relevant explanations *in the way that constitutes having a craft* only if your grasp of these explanations is such as to allow you to extrapolate from them so as to work out new explanations to suit new circumstances. Thus, you only count as having productive understanding if you have developed, through training and instruction, this reason-based capacity for innovation.

Aristotle's view about the difference between productive and theoretical understanding is of interest in itself. If I am right that this view is underpinned by his assumptions about the divine and the infinite, this suggests interesting avenues for further inquiry. Later philosophers differed from Aristotle on many of these assumptions. For instance, certain Christians held both that God exercises a kind of craft and also that God's knowledge (unlike human knowledge) can be infinite.[38] Are these departures from

[38] For the view that there is a divine craft, see Aquinas, *On Physics* II, Lecture 14, 268, where nature is described as 'the divine craft, impressed upon things'. For the view that God, unlike human beings, could grasp an actual infinite, see Aquinas, *Summa Contra Gentiles* I.69.

Aristotle reflected also in differing views about the completeness of productive understanding? More generally, to what extent can we explain the views these ancient and medieval philosophers adopted on the nature of craft understanding by looking at their views on the divine and the infinite?