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Technical Knowledge as Scientific Knowledge in Aristotle

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Abstract

Doctors heal people, and architects build houses. Their expertise guides them in their performance. Aristotle calls this expertise a *technē*. He often tells us that *technē* comes with a productive form of knowledge (*poiētikē epistēmē*). But what kind of knowledge does he associate with *technē*? We argue that for Aristotle technical knowledge is scientific knowledge—knowledge that can be modeled in terms of demonstrations. The view we develop enjoys several explanatory advantages over alternative interpretations and shows how Aristotle's conception of technical knowledge is consistent throughout his metaphysics, philosophy of science, and ethics.

Keywords

Aristotle – *technē* – *epistēmē* – scientific knowledge – craft – art

1 Introduction[1]

Artisans produce objects based on their expertise. Their expertise guides them in their production. Aristotle calls this sort of expertise *technē*—usually translated as art, or craft. Paradigmatic examples of *technai* include medicine and the art of building (cf. *EN* 1.1 1094a8–9 and *Metaph.* E.2 1026b10, *inter alia*).[2] Sometimes, Aristotle emphasizes that this type of expertise is associated with a specific sort of knowledge, which we will call '*technical knowledge*'. For instance, *Metaph*. Θ.2 equates *technē* with knowledge (*epistēmē*) and describes it as a productive form of knowledge (*poiētikē epistēmē*, *Metaph*. Θ.2 1046b2–3; cf. E.1 1025b25, E.2 1026b4–5, *Cael.* 3.7 306a16, *Top.* 6.6 145a15–17, *inter alia*). Yet at other times, Aristotle contrasts *technē* with knowledge. For instance, *EN* 6.1–6 appears to locate *technē* and *epistēmē* within mutually exclusive parts of the soul, thereby suggesting that *technē* does not come with *epistēmē* (see esp. *EN* 6.2 1139a5–17 and 6.3–4). This apparent tension raises the question of what type of knowledge he associates with *technē*. What is the epistemic status of technical knowledge for Aristotle?

The received view in the literature is that for Aristotle technical knowledge is *not* scientific, where 'scientific' tracks the strict way in which knowledge (*epistēmē*) is characterized in the *Posterior Analytics*. There are two main

1 A first version of this paper was presented (and made available online) at the *Classical Philosophy Colloquium* at Princeton University, on 1 December 2018. Further versions of the paper were presented at Campinas University, Columbia University, Cornell University, the Harvard Center for Hellenic Studies, the Human Abilities Centre for Advanced Studies in the Humanities, and Oxford University. We would like to thank the audiences for very helpful discussions, especially Jonathan Beere, Ted Brennan, Verity Harte, Rachana Kamtekar, Anastasia Kopylova, Hendrik Lorenz, Scott MacDonald, Wolfgang Mann, Ben Morison, Dominik Perler, Emilio Rosamilia, Mark Schiefsky, and Barbara Vetter. Moreover, we thank Jacob Rosen and David Charles for acting as invaluable respondents at Princeton and Oxford, respectively. For in-depth comments that led to considerable improvements, we are most grateful to Fabio Acerbi, Lucas Angioni, Sarah Broadie, Ursula Coope, Sara Magrin, Stephen Menn, Jessica Moss, the editors, and an anonymous referee for *Phronesis*. Thank you also to Susanne Bobzien and Mark Kalderon for discussions of parts of the penultimate draft. Finally, thank you to the Humboldt Foundation, the Harvard Center for Hellenic Studies, the Human Abilities Centre for Advanced Studies in the Humanities, and the Deutsche Forschungsgemeinschaft (grant number 409272951) for their financial support.

2 Following *Liddell-Scott-Jones*, we use these abbreviated titles of Aristotle's works*: Analytica Posteriora* [*APo.*], *Analytica Priora* [*APr.*], *de Caelo* [*Cael.*], *Ethica Eudemia* [*EE*], *Ethica Nicomachea* [*EN*], *Fragmenta* ed. V. Rose 1886 [*Fr.*], *de Generatione Animalium* [*GA*], *de Generatione et Corruptione* [*GC*], *Historia Animalium* [*HA*], *de Interpretatione* [*Int.*], *de Memoria* [*Mem.*], *Metaphysica* [*Metaph.*], *Meteorologica* [*Mete.*], *de Partibus Animalium* [*PA*], *Physica* [*Ph.*], *de Respiratione* [*Resp.*], *Rhetorica* [*Rh.*], *de Sensu* [*Sens.*], *Sophistici Elenchi* [*SE*], *Topica* [*Top.*].

reasons for this conclusion. First, technical knowledge concerns the contingency realm. Aristotle contrasts *technē* with this notion of *epistēmē* in Book 6 of the *Nicomachean Ethics*, when he states that *epistēmē* concerns what is necessarily the case (*EN* 6.1 1139a6–12, 6.3 1039b19–24, 6.5 1140a33–35, 6.6 1140b31–32), whereas *technē* concerns what can be otherwise (*EN* 6.4, esp. 1040a1–2, 10–15, 20–23; 6.6 1140b34–35). The association of *epistēmē* with necessity is confirmed in the initial part of the *Posterior Analytics*, where Aristotle tells us that one has knowledge of X only if one can draw demonstrations (*apodeixeis*) of X from claims that are true of necessity (*APo.* 1.2 71b9–19, 1.4 73a21–24, 1.6 75a12–14; cf. *EN* 6.3 1139b31–33, 6.6 1140b31–33). Based on these passages, some scholars have inferred that technical and scientific knowledge fall into mutually exclusive categories.[3]

A second and related motivation for thinking that technical knowledge cannot be scientific is that *technē* aims at producing particulars (*EN* 1.6 1097a11–13, *Metaph.* A.1 981a15–20, cf. *EN* 6.7 1141b18–21). If so, technical knowledge cannot merely consist of scientific demonstrations of universals (cf. Moss 2014a and 2014b, Johansen 2017). Moreover, some maintain that the specific circumstances within which artisans work play a key role in production and cannot be countenanced by a finite set of generalizations (Coope 2021).[4] However, for

3 For an explicit statement of this position, see Lorenz and Morison (2019, 432, 439–47, 453). These authors argue that *technai* are based on doxastic knowledge, whereas disciplines such as mathematics and the sciences of nature qualify as scientific knowledge; the relevant notion of scientific knowledge concerns what holds of necessity and involves grasping logical relations among the given claims. On their view, technical knowledge involves particulars, is not demonstrative and involves no grasp of logical relations among propositions. Chappell (2012) takes Aristotle to treat technical knowledge as non-propositional knowledge-how. Nussbaum (1986, 290) takes technical knowledge to be non-scientific and stochastic. Schatzberg (2018, ch. 2 esp. 20–4) claims that Aristotle completely separates *technē* from *epistēmē*. See also Evans (1977, 75–7), McKirahan (1992, 142–3), Moss (2014b), Parry (2020), and Cohoe (2022) for endorsements of the received view. Several further authors implicitly assume a contrast between *technē* and a scientific (in the sense of demonstrative) body of knowledge. Less recently, Burnet (1900, 257), Stewart (1982, 35) and Greenwood (1909, 150–2) took *technai* to be forms of knowledge only in a looser, non-scientific sense of the term 'knowledge', again because of the remarks of *APo*. 1.2–6 and *EN* 6.1–6. This received view is already explicitly stated in Zabarella (1608, esp. 3c–f, 4f–5a, 17e; see also 2a–b, 2d, 3c–f, 4a–b, 4f–5a, 17f–18a, 40c–d)—cf. Mikkeli (1992). Coope (2021) describes *technē* as a 'productive science' but denies that it is demonstrative. Bolton (2021) claims that *some technai* have a theoretical component and at times appears to state that some *technai* come with demonstrations (*ibid.*, 152), but without argument.

4 Coope (2021) proposes that the peculiar feature of technical knowledge is that it is indefinitely extensible, since its explanations have to cover an infinite range of circumstances. See §7 for our discussion of this view.

Aristotle scientific knowledge comprises only a finite set of explanations. From this, it is tempting to conclude that technical knowledge is not scientific.

The arguments supporting the received view are undoubtedly strong. However, several passages in the corpus put pressure on the claim that technical knowledge is not scientific. In a number of places, Aristotle calls *both* technical and theoretical forms of knowledge *epistēmai*—a term often translated as 'sciences'. Moreover, he often treats technical knowledge on a par with disciplines that, for him, clearly qualify as sciences, such as geometry, astronomy, and natural sciences.[5] Furthermore, when Aristotle exposes his theory of science in the *Posterior Analytics*, he mentions *technē* as well as specific *technai*, such as the art of medicine.[6] He also puts forward examples of scientific demonstrations that *prima facie* concern the art of war-making (*APo*. 2.11 94a36–b8) and the art of house-building (*APo*. 2.12 95b31–37; cf. 2.11 94b9–11).[7] On the face of it, these are reasons to pursue the view that technical knowledge is demonstrative—contrary to what the received view says.

This paper develops an interpretative line on which the sort of knowledge that Aristotle associates with *technē* does qualify as scientific, in the sense that it can be systematized in terms of demonstrations. We argue that this view is directly motivated by the *Posterior Analytics* and fits best with the passages in which Aristotle treats *technai* and sciences on a par. Although in the initial chapters of the *Posterior Analytics* Aristotle states that demonstrations only involve claims that are true of necessity, with *APo.* 1.30 he broadens his notion of demonstrative knowledge further. We claim that in *APo.* 1.30 Aristotle makes room for demonstrations containing claims that are true either of necessity *or for the most part*. We also show that later in the *Posterior Analytics* one can find clear examples of technical demonstrations, namely demonstrations that pertain to technical knowledge. These demonstrations are parallel to those of the natural sciences in that they include premises concerning what holds for the most part. We conclude that the *Posterior Analytics* (together with other passages) gives us good grounds for concluding that Aristotle treats technical knowledge as demonstrative, and in this sense scientific.

5 Cf. *EE* 1.5 1216b8–19, *EN* 6.10 1143a2–4, *Metaph.* E.1 1025b4–7 and 25–28, E.2 1026b4–12, K.7 1063b36–1064a1 and 1064a10–18, K.8 1064b17–23, Λ.9 1075a1–3, *Cael.* 3.7 306a16–17, *Top*. 6.6 145a15–18, *APr.* 1.30 46a3–4 and 46a17–27, *APo.* 1.13 79a13–16, *inter alia*.

6 Medicine is mentioned several times: *APo.* 1.12 77a41, 1.13 79a14–16, 1.32 88b12, 2.13 97b27. For explicit references to *technē*, see *APo.* 1.1 71a4, 2.11 95a8 (in the same context, Aristotle talks about products and uses a house and a statue as examples), and 2.19 100a8.

7 See also *APo.* 1.13 78b14–16 for a quick reference to a demonstration pertaining to medicine. *APo*. 2.11 94b8–23 contains a demonstration concerning health (specifically, good digestion), plausibly pertaining to medicine.

Besides being textually motivated, the view that technical knowledge is demonstrative offers important explanatory advantages. As we will argue, this view makes good on the claim that technical knowledge is production-guiding. Moreover, it does better than alternative views in explaining why, for Aristotle, technical knowledge guides one towards the production of *contrary outcomes*—e.g., medical knowledge puts one both in a position to heal and in a position to harm the patient (cf. *Metaph.* Θ.2 1046b4–7). Thus, the claim that technical knowledge is demonstrative is both textually and philosophically motivated. We will conclude by showing that *prima facie* recalcitrant passages—passages in which Aristotle seems to contrast technical and scientific knowledge (such as *EN* 6.1–6)—are in fact compatible with the view that technical knowledge is demonstrative.

Before we begin, a point on terminology is in order. Just like the English term 'knowledge', the corresponding Greek term *epistēmē* is ambiguous in a number of ways. One dimension of its ambiguity is that *epistēmē* can be used with more or less strict epistemic force. Thus, the sense in which the authors of this essay know (or have *epistēmē* of) mathematics is weaker than the sense in which mathematicians know mathematics. Another dimension of ambiguity for both the terms 'knowledge' and *epistēmē* is that they can be used to refer either to one's cognitive state of having knowledge (as in, 'Gödel has knowledge of mathematics'), or to the content of that cognitive state (as in, 'mathematics is a branch of knowledge').[8] The term *technē* is similarly ambiguous. It can refer either to one's cognitive state (cf. *EN* 6.4, esp. 1140a6–10 and 20–23) or to the associated content—a given body of knowledge (cf. *Metaph.* Z.7, esp. 1032a32–b14). The main focus of this paper is the nature of technical knowledge understood as a content of the cognitive state—the sort of content one grasps when possessing *technē*. As we shall see, Aristotle's claim that technical knowledge is scientific is best aligned with the view that an artisan not *only* possesses technical knowledge but also possesses experience (*empeiria*).[9] We

8 For a passage in which *epistēmē* refers to the state of knowing a certain content, see *EN* 6.3; for passages in which *epistēmē* refers to the content of cognitive states, see *Metaph.* Θ.2 1046b6–13, as well as E.2 1026b24–27 and 1027a19–21, *inter alia*. Given our focus on the content notion of *epistēmē*, we shall bracket the controversy about whether at times one should translate *epistēmē* with 'understanding' rather than 'knowledge' (but see Burnyeat 1981 and 2011; and Salmieri 2014, *inter alia*).

9 For a reading of *technē* as composed of both knowledge (*logos, epistēmē*) and experience (*empeiria*), see Angier (2010, e.g. 11 and 39), Cambiano (2012, esp. 22–3), Moss (2014b), Johansen (2017, 103 and 112–16), and Bolton (2021, 152). On the basis of *SE* 11 172a39–b1, Bolton (2018; 2021, 160) adds that *empeiria* is one type of *technē*—yet the passage alone does not seem to mandate this conclusion. Devereux (1986, 493 and 496–7) takes *technē* to be merely

leave open whether *empeiria* should be understood as a component of *technē* (along with technical knowledge) or simply as a necessary precondition for its possession or exercise.

The plan for the paper is as follows. Section 1 reconstructs textual grounds for the claim that technical knowledge is scientific. Section 2 discusses how for Aristotle having a *technē* involves having an account of the relevant product: an account that concerns universals and is explanatory. Section 3 argues that *APo.* 1.30 expands the notion of scientific demonstrations to allow for demonstrations involving premises that concern what holds for the most part. Consequently, Aristotle makes room for sciences that include claims that hold for the most part—we shall call these sciences '*non-strict sciences*'. Section 4 argues that natural and technical bodies of knowledge meet the requirements for non-strict sciences and offers examples of demonstrations from both disciplines. Section 5 distinguishes technical sciences from natural sciences and discusses the implications of our interpretation for Aristotle's taxonomy of sciences.

We then look at the explanatory benefits of interpreting technical knowledge as scientific. Section 6 discusses the sense in which technical knowledge qualifies as productive and proposes an explanation of Aristotle's claim that *technē* is productive of contraries. Section 7 argues that the flexibility of artisans does not conflict with the scientific status of technical knowledge and is in fact partly explained by it.

Finally, we consider some potential challenges for our account. Section 8 argues that Aristotle's contrast between *technē* and *epistēmē* in *EN* 6.1–6 is in fact a contrast between *technai* and the strict theoretical sciences. Section 9 addresses two further potential objections: the objection from relevance (technical demonstrations are relevant to, but not constitutive of, technical knowledge) and the objection from contingent kinds (technical knowledge is contingent on the artisan's choices). We argue that these objections fail. Section 10 concludes.

2 Three Explanatory Challenges

In *Metaph.* Θ.2, Aristotle tells us that *technē* is a rational power of a given sort. He makes three points that are important for our purposes: (i) *technē* is

composed of knowledge but distinguishes it from technical skills, which in turn are composed of both knowledge and experience. For an argument for the claim that *technē* entirely consists of *logos*, see Beere (2009, 88–9).

associated with *epistēmē*; (ii) artisans grasp accounts of their products; and (iii) technical knowledge is knowledge of contraries. This section expands on each point and looks at the challenges they set for an account of technical knowledge. The remainder of the paper addresses these challenges.

Let us begin with (i). *Metaph.* Θ.2 contains the most explicit associations of *technē* with *epistēmē* in the corpus. In the chapter, Aristotle uses *technē* and technical knowledge interchangeably and refers to *technai* as productive forms of knowledge (*poiētikai epistēmai*):[10]

> (T1) Since some principles of this sort are present in the things that lack a soul, and others in things that have a soul, and in a soul and in the part of the soul that has reason, clearly some powers will be without *logos* and some will be with *logos*. Hence, all *technai*, i.e. all productive forms of knowledge (*kai hai poiētikai epistēmai*), are powers; for they are principles of change in another thing or [in the thing itself] *qua* other.[11]
>
> Ἐπεὶ δ᾽ αἱ μὲν ἐν τοῖς ἀψύχοις ἐνυπάρχουσιν ἀρχαὶ τοιαῦται, αἱ δ᾽ ἐν τοῖς ἐμψύχοις καὶ ἐν ψυχῇ καὶ τῆς ψυχῆς ἐν τῷ λόγον ἔχοντι, δῆλον ὅτι καὶ τῶν δυνάμεων αἱ μὲν ἔσονται ἄλογοι αἱ δὲ μετὰ λόγου. διὸ πᾶσαι αἱ τέχναι καὶ αἱ ποιητικαὶ ἐπιστῆμαι δυνάμεις εἰσίν· ἀρχαὶ γὰρ μεταβλητικαί εἰσιν ἐν ἄλλῳ ἢ ᾗ ἄλλο. (*Metaph.* Θ.2 1046a36–b4)

10 Aristotle treats *technē* as a productive form of knowledge (*poiētikē epistēmē*) also in *Metaph.* E.1–2 (cf. E.1 1025b21 and 25, E.2 1026b4–5) and *Top*. 6.6 145a15–18 and 8.1 157a10–11. See also *Metaph.* K.7 1063b36–1064a1, 1064a10–17, and K.8 1064b17–23—the authenticity of *Metaphysics* K remains in dispute (for a comprehensive account of the different layers of the text, see Baldini 2020), but the text remains of significance if belonging to Aristotle's circle. Aristotle further uses *epistēmē* in a way that includes *technai* at *Metaph.* Λ.9 1074b38–a2, *Cael.* 3.7 306a16, *EE* 1.5 1216b17–19 (an explicit reference to productive forms of knowledge occurs at b17 and medicine is given as an example at b18); at *Metaph*. K.3 1061a4–5, we find a reference to medical knowledge (*iatrikē epistēmē*). *APo.* 1.12 77a40–41 seems to presuppose that medicine is a form of knowledge analogous to geometry. *APo.* 1.13 79a13–16, refers to medicine in the context of discussing sciences that 'do not fall under one another' (79a13–14). *APo.* 1.32 88b10–13 treats medicine on a par with geometry within the context of discussing the principles of a science. Further passages associating *technai* with *epistēmai* include *SE* 9 170a27–30, *EE* 2.11 1227b26–31, *EN* 1.1 1094a6–15 and 6.10 1142b34–1143a4—the latter passage refers to both medicine and geometry as *kata meros epistēmai* (1143a3), namely forms of knowledge that investigate a particular aspect of reality (geometry being concerned with magnitudes and medicine with health).

11 Translations are by Simona Aimar, unless otherwise stated.

The passage distinguishes between powers that in some important sense come with *logos* (*meta logou dunameis*) and powers that, by contrast, are without *logos* (*alogoi dunameis*) (1046a36–b2). Here we take *logos* to refer to a rational account (cf. 1046b7–8).[12] We call the powers that Aristotle describes as coming with a rational account '*rational powers*'—we return below to the meaning of 'rational account', and the role this account plays in rational powers. We call the powers that Aristotle describes as being without a rational account '*non-rational powers*'. Given this terminology, (T1) states that all *technai* are rational powers.

At 1046b3, Aristotle uses an epexegetic *kai* to identify *technai* with productive forms of knowledge (*poiētikai epistēmai*).[13] The association of *technē* with *epistēmē* raises the main question of this paper, which is also our first explanatory challenge:

> (*First Explanatory Challenge*) What notion of *epistēmē* does Aristotle associate with *technē*?

12 At 1046b1, *logon* refers to the faculty of reason. From then onwards, Aristotle uses *logos* to refer to an account. Accordingly, in the chapter *logoi* are accounts that one possesses in virtue of having the faculty of reason. See Moss (2014a) for a helpful reconstruction of these senses of *logos* in Aristotle.

13 The London Group (Burnyeat, n.d.), Ross (1924, 242), Tricot (1953, 486), and Coope (2021, 109 n. 1) agree with this reading. Makin (2006, 2) opts for translating καί as 'and'. Ross' apparatus (1924, *ad loc.*) states that Pseudo-Alexander (presumably, Michael of Ephesus; cf. Goulet 1989) cites 1046b3 by inserting καὶ αἱ after ποιητικαί. Pseudo-Alexander says: 'Because of that, all *technai* are powers: both the productive ones, like the art of house-building and the art of ship-making, and the sciences (he has called the sciences '*technai*' in a broader sense).' (Διὸ πᾶσαι αἱ τέχναι αἵ τε ποιητικαί, ἥ τε οἰκοδομικὴ καὶ ἡ ναυπηγική, καὶ αἱ ἐπιστῆμαι (κοινότερον δὲ τέχνας εἶπε τὰς ἐπιστήμας) δυνάμεις εἰσίν, *in Aristotelis Metaphysica commentaria* 569.3–6). Here, Pseudo-Alexander might (over)interpret, rather than cite, Aristotle, and read 1046b3 as containing only one καί. Aquinas in his commentary glosses 1046b3 by saying that for Aristotle there are two kinds of *technai*: those that involve acting on matter, such as architecture and the art of a blacksmith, and those that do not, such as the moral and logical sciences (*In Duodecim Libros Metaphysicorum Aristotelis Expositio*, p. 428, section 1788). Yet the Latin translation Aquinas worked with—Moerbeke's—does not contain an additional *et*. So his gloss also seems to be the result of an (over)interpretative choice. All the *recentiores* have καὶ αἱ after ποιητικαί (*pace* Ross' apparatus, which misreports them as only containing an additional καί). If one were to adopt this version of the text, Aristotle would say that all the productive disciplines and all the sciences (*epistēmai*) are powers. But the addition of καὶ αἱ is not attested by any of the ancient manuscripts of Harlfinger's stemma (E, J, and A^b), nor by any of the available Latin translations; moreover, adopting this variant makes the sentence syntactically problematic. So the insertion is probably either the result of copyists' mistakes (this would indeed be an easy type of mistake to make) or an interpolation related to a reluctance to think of *technai* as *epistēmai* (a reluctance that this paper hopes to weaken).

As we are about to see, *Metaph.* Θ.2's argument for the view that *technai* are for contraries requires the assumption that productive knowledge is of contraries. Thus interpreting *kai* as epexegetic at 1046b3 enables us to support Aristotle's later argument that rational *technai* are for contraries. We will argue that this conclusion follows only if *technai* are productive forms of knowledge (cf. Coope 2021, 109 n. 1). The argument that *technai* are for contraries is best understood by assuming that *technai* are productive forms of knowledge. Accordingly, we will investigate how strong a notion of *epistēmē* Aristotle has in mind when discussing productive forms of knowledge.

Let us now consider point (ii), the claim that artisans grasp accounts of their products. Shortly after (T1), Aristotle states that technical knowledge is an account (*logos*, 1046b7–8). The context suggests that the account in question is an account of the product of the relevant *technē*: Aristotle explains that technical knowledge concerns contraries—e.g., for medicine, both health and sickness (1046b18–20). *Metaph.* Z.7 further confirms that a technical *logos* is an account of what the product is, namely its essence (*to ti ēn einai*, 1032b1–2; cf. *Ph.* 2.1 193a30–31).[14] To have some *technē* is to have a form of the product in the soul, where the form is what something is. That is, artisans in some sense grasp the essence of their products.[15] Doctors know what health is, and builders know what a house is.

The claim that artisans grasp an account of the product raises the question of what technical accounts look like. We know from *Metaph.* A.1 that technical accounts concern universals (981a3–24) and are explanatory (981a24–981b6). Here Aristotle contrasts people with *technē* with people who merely have experience (*empeiria*). A merely experienced person can tell that a particular person will benefit from a certain cure. This is because experience is concerned with particulars (981a15–16).[16] However, doctors can also tell, for instance, what kind of cure benefits a given class of people—say, that such a cure benefits phlegmatic people with fevers (981a7–12).[17] In the *Rhetoric*,

14 Aristotle endorses both the claim that to have a *technē* is to have *logos* and the claim that to have a *technē* is to have the form of the product in one's soul. Strictly speaking, to have the form of X in the soul is to possess an account of X, namely an account that states what X is. Aristotle identifies *technē* with a form in the soul in several other passages, including *GA* 2.1 735a2–3, *Metaph.* Z.7 1032a32–b6 and b13–30, Z.9 1034a30–1034b1, Λ.4 1070b33.

15 Here 'form' and 'essence' are used broadly, as applying to items from any category, and not in the narrower sense that only applies to items in the category of substance. We bracket the question of how this notion relates to Aristotle's notion(s) of formal causation.

16 We leave open whether Aristotle also allows experience to include (non-causal) generalizations (for a positive answer, see Gregorić and Grgić 2006, as well as Hasper and Jurdin 2014).

17 Cambiano (2012), Broadie (2012), Moss (2014a), Moss (2014b), Johansen (2017), Coope (2021), Bolton (2021).

Aristotle goes as far as to claim that 'no *technē* looks into the particular' (οὐδεμία δὲ τέχνη σκοπεῖ τὸ καθ᾽ ἕκαστον, *Rh*. 1.2 1356b30).[18] We take this claim at face value, stating that *technē* does not consider particulars. Thus, there is a case to be made for the view that technical knowledge is exclusively at the level of universals.

However, Aristotle also emphasizes that artisans in an important sense attend to particulars (cf. *Metaph*. A.1 981a16–20). After all, they produce particular instances of their products. One can reconcile the apparent clash between the claim that artisans attend to particulars and the claim that *technē* concerns merely universals in the following way. In (T1), *technē* denotes the technical body of knowledge associated with a given art. For instance, medicine is neither knowledge of what is healthy for Socrates nor knowledge of what is healthy for Callias. Rather, it is knowledge of what brings about health in a *given type* of patient—say, someone who has a fever. This reading also fits well with Aristotle's further claim, in the *Rhetoric*, that *technē* does not concern the particular because, in the relevant sense, there is no knowledge (*epistēmē*) of the particular (*Rh*. 1.2 1356b32–33). The idea is that *technē* is associated with knowledge which consists of generalizations that exclusively belong to the level of universals.[19] We shall return later to how this type of knowledge enables artisans to attend to particulars (§§7–8).

Aristotle also thinks that technical *logoi* are in some sense causally explanatory. *Metaph*. A.1 tells us that people with mere experience are able to bring about the product in certain circumstances, despite lacking the relevant *technē*. For instance, one might be a healer without being a doctor, and one might be able to build a house despite not having mastered the art of building. People with mere experience only know that something is the case—say, that giving a certain medicine cures fever. But those who have the relevant

18 Here is the full passage: '[N]o *technē* looks into the particular. For instance, medicine does not look into what is healthy for Socrates or for Callias, but rather what is healthy for someone of a given sort, or the ones of a given sort: for this is a matter of *technē*, whereas the particular is indefinite and not knowable' (*Rh*. 1.2 1356b30–33).

19 This is not to say that *technē* has no bearing at the level of particulars. A medical explanation that accounts for why a certain treatment can heal a certain kind of patient has bearing on whether Socrates, as an individual that belongs to that kind, can be healed by that type of treatment (cf. *APo*. 2.13 97b26–28, *Metaph*. A.1 981a10–20 and Z.7 1032a32–b6, *EN* 1.6 1097a11–13 and 10.9 1180b13–16). For emphasis on the universal character of productive accounts, cf. Anagnostopoulos (1994, 376), Angier (2010, 39), Cambiano (2012, 20–25), Coope (2021, 116), Devereux (1986, 493), and Gregorić and Grgić (2006, 18–29). For readings that take technical knowledge to be concerned *not only* with particulars, see Moss (2014b), Johansen (2017), and in part Bolton (2021, 165). We further discuss the way in which artisans engage with particulars in §§7–8.

technē can explain *why* a given medicine is the right cure for fever (*Metaph.* A.1 981a24–27), because they 'know the cause' (981a28–30). Here to know the answer to 'Why X?' is tantamount to knowing the cause of X, where 'the cause' picks one of the four causes (cf. *Ph.* 2.3 194b18–20, *inter alia*). So technical accounts are *causal accounts*, in that they individuate the cause(s) of a given type of product.[20]

We can now see how point (ii) raises a second explanatory challenge for an account of Aristotle's view of technical knowledge. Artisans are not the only ones to have some knowledge of the product. This leads to the following challenge:

> (*Second Explanatory Challenge*) Can Aristotle tell apart an artisan's knowledge of the product from a layman's knowledge of the product?

One can grasp a causal and general account of health without being a doctor. In fact, one could grasp a definition of health—say, the claim that health is a balance of hot and cold in the body (cf. *Top.* 6.2 139b20–21 and *APo.* 1.13, 78b18–20, *inter alia*). However, merely knowing that health is a balance of hot and cold should *not* be sufficient to make one a doctor. Can Aristotle's account of technical knowledge set artisans apart from people who grasp some definition of the essence of these products, but are nonetheless not knowledgeable enough to bring the product about?

In addition to stating that technical knowledge is *epistēmē* and that it is an account of the product, *Metaph.* Θ.2 informs us that such knowledge is of contraries—point (iii). The claim that technical knowledge is an account

20 In *Metaph.* A.1, technical knowledge is described as knowledge 'of the things that are done' (*tōn poioumenōn*, 981b1). This fits with the view that technical knowledge is knowledge of the product (cf. *Metaph.* Z.7 1032b5–6, *inter alia*). The expression *tōn poioumenōn* may refer either to the steps that an artisan has to follow to bring about a product, or to things that are produced by artisans in general (if so, one could translate it as 'the things that are made'). In the context, we have a mild preference for the former option, but nothing major hinges upon this choice. The term 'master' (*architektōn*, 981a30) refers to whoever has the relevant *technē*. The term 'manual-worker' (*cheirotechnēs*, 981a31–b1) refers either to (a) whoever can perform the actions prescribed by a *technē* but lacks the *technē* itself, or (b) to someone who has a subordinate (*hupēretikē*) *technē*. If the former, the manual-worker merely has experience. If the latter, her *technē* is subordinate to (or falls under) the *architektonikē technē* and she uses her *technē* to do what the *architektōn* tells her to do (e.g. build a door of these dimensions here), without knowing the explanation of the higher *technē*—cf. Plato's *Laws* (720a2–d2, 857c7–d1), where doctors' assistants only rely on experience and fail to give an account (*logos*).

(*logos*) is precisely meant to support the view that powers in accordance with *logos* (and therefore *technai*) are of contraries.[21]

> (T2) For each of the ones in accordance with an account (*logos*), the same [powers] are of their contraries (*enantiōn*), but for those that are not in accordance with an account (*alogoi*), one [power is] of one [outcome]—say, the hot only of heating, but medicine both of sickness and health. This is because knowledge is an account (*logos*) and the same account reveals both a thing and its lack.
>
> Καὶ αἱ μὲν μετὰ λόγου πᾶσαι τῶν ἐναντίων αἱ αὐταί, αἱ δὲ ἄλογοι μία ἑνός, οἷον τὸ θερμὸν τοῦ θερμαίνειν μόνον ἡ δὲ ἰατρικὴ νόσου καὶ ὑγιείας. αἴτιον δὲ ὅτι λόγος ἐστὶν ἡ ἐπιστήμη, ὁ δὲ λόγος ὁ αὐτὸς δηλοῖ τὸ πρᾶγμα καὶ τὴν στέρησιν. (*Metaph.* Θ.2 1046b4–9)

To be a power of contraries is to be a power by virtue of which one can bring about contrary outcomes. If *technē* were not treated here as a productive form of knowledge, then from the mere fact that technical knowledge is of contraries it would not follow that *technē* is for contraries.[22]

The relevant contraries are *not* 'doing X' and 'not doing X'. Rather, a power is a power to either bring about feature F or to remove feature F. For instance, medicine enables doctors to bring about not only health but also the lack of health—i.e. sickness—in patients (cf. *Metaph.* Z.7 1032a32–b6, *inter alia*). The reason why a doctor can bring about both health and sickness is that medicine is, in some sense, an account of both health (the presence of health) and sickness (the lack of health). Similarly, the art of building enables the builder not only to bring about a house but also to skillfully dismantle it (cf. Beere 2009,

21 Aristotle shares Plato's assumption that *technai* come with possessing a *logos* (cf. *Gorgias* 465a2–6, *inter alia*), as well as the assumption that powers in accordance with *logos* are for contraries (cf. *Charmides* 166e7–9, *Hippias Minor* 366d3–367a7 and 3674–5, *Phaedo* 97d1–5, *Republic* 1 333e–334a), although Plato might not always understand the relevant contraries as Aristotle does here (but see *Phaedo* 71b). Aristotle refers to this claim while describing Academic views at *Metaph.* M.5 1078b26–27. For a comprehensive picture of the use of *technē* in Plato, see Balansard (2001). It is important for Aristotle to show that his picture delivers a distinctive feature of *technai*: their being for contraries. We leave open whether or not for Aristotle there are powers that are of contraries but are not *technai*. Beere (2009, 78–89) assumes that for Aristotle all powers in accordance with *logos* are *technai*. For the opposite view, cf. Menn (n.d., section III1a2).

22 The argument would also fail if one were to read καί as conjunctive and the second conjunct as a subclass of the first conjunct. From the assumption that some *technai* are productive forms of knowledge, Aristotle could not show that *all technai* are for contraries.

82–85; see also *Metaph.* Θ.2 1046b12–13 and 19–20, as well as §6 in this paper). Thus, the contraries in question are products of *technai*. Point (iii) sets up our third explanatory challenge:

> (*Third Explanatory Challenge*) In what sense does technical knowledge concern contraries?

Metaph. Θ.2 does not tell us why, if one knows what a product X is, then one is also in position to know what the relevant lack of X is. Yet the claim is essential for motivating an overall picture of *technai* as enabling artisans to bring about contraries. Addressing this third explanatory challenge and explaining how Aristotle can vindicate the claim that such knowledge is of contraries is a desideratum for any complete reconstruction of his views on technical knowledge.

Our goal in this paper is to provide an account of technical knowledge that meets all three of these explanatory challenges.

3 Technical Knowledge in the *Posterior Analytics*

A major concern about the view that technical knowledge is scientific is its apparent failure to satisfy the requirements for technical knowledge that Aristotle lays out in the *Posterior Analytics*. This section reconstructs these requirements and argues that in fact they are compatible with the claim that technical knowledge is scientific.

From what we have seen thus far, technical knowledge is general, explanatory, and concerned with what something is. Aristotle ascribes these features to scientific knowledge as well. In the *Posterior Analytics*, he tells us that one has scientific knowledge (*epistēmē*) of X just in case one grasps demonstrations (*apodeixeis*) of X (cf. *APo.* 1.2 71b9–19). As for any canonical syllogism, the premises and conclusions of a demonstration are predicative claims whose terms denote universals (cf. *APo.* 1.11 77a5–9, 1.12 77b36–37, 2.13 97b25–28; see also *Metaph.* B.6 1003a14–17 and M.10 1086b33–36, *inter alia*). The premises of a demonstration also need to satisfy further requirements, such as being true (*APo.* 1.2 71b20–21, 25–26), prior to and explanatory of the conclusion (*APo.* 1.2 71b21–22).[23] The reason why demonstrations provide an explanatory account

23 Premises of demonstrations also have to be immediate and more familiar than the conclusion (*APo.* 1.2 71b21–22 and 29–33). For accounts of all the requisites that the premises of demonstrations need to satisfy, see Angioni (2012) and Bronstein (2016), *inter alia*.

is that their middle term (the term repeated in both premises) denotes the cause of the fact described by the conclusion (cf. *APo*. 2.2 90a5–14). Aristotle is also adamant that grasping demonstrations of X amounts to grasping an account of what X is. In this sense, he takes the knowledge that comes with demonstrations to concern the essence of things.[24] Accordingly, both technical and scientific knowledge are general, explanatory, and concerned with what something is. In this and the next section, we argue that technical and scientific knowledge share these features precisely because technical knowledge is scientific knowledge.

To see that Aristotle's technical knowledge aligns with scientific knowledge, it is helpful to start from key requirements Aristotle is usually taken to assume for scientific bodies of knowledge. First, his science is axiomatic. All the claims of a given body of scientific knowledge can be derived from an initial set of indemonstrable assumptions, which constitute the 'principles' (*archai*) of the science (*APo*. 1.2 71b19–23, 72a5–8). Each claim of a given science is either a *principle* or a claim that is derived from principles, namely a *theorem*. The derivation has to be done via a chain of demonstration(s), where the conclusions of two demonstrations are premises for a further demonstration. Therefore, a science is a body of knowledge whose claims can be systematized through chains of demonstrations that go back to the principles of that science. Call this requirement on scientific knowledge the '*demonstrability-requirement*' and call a body of knowledge that satisfies this requirement '*demonstrative knowledge*'.

In the initial part of the *Posterior Analytics*, Aristotle tells us that the premises of demonstrations are true of necessity (cf. *APo.* 1.4, 73a21–25). If both premises are true of necessity, the conclusion is guaranteed to be true of necessity as well (cf. *APo*. 1.6 74b5–18 and 75a1–11). Accordingly, what one knows through demonstrations is true of necessity: *epistēmē* can only be of necessary truths.[25]

24 This notion of essence is the broad one of what something is, which can apply to any of the categories, as opposed to only the category of substance. In the *Posterior Analytics*, Aristotle refers to essences mainly by means of the expressions *to ti ēn einai* (e.g. *APo.* 2.4 91a25, 2.5 91ab8 and b26, 2.6 92a13, 2.8 93a12–13, 2.11 94a21), *to ti esti* (e.g. 2.2 90a15 and 90a31, 2.3 90a36 and 90b3, 2.7 92a34–35), and *ousia* (e.g. 1.4 73a36 and 73b7, 2.3 90b30–31, 2.4 91b9 and 91b27, 2.13 96a34). A complete demonstrative account of X is one which spells out a full causal account of what X is. See Goldin (1996), Charles (2000, esp. 64–7, 198–213), and Angioni (2014, esp. 104; 2016) for further discussion of Aristotle's essence-talk in the *Posterior Analytics*.

25 See also *APo*. 1.2 71b9–16, 1.6 75a12–14, and *EN* 6.3 1139b19–24 (where we find an explicit reference to the *Analytics*).

Call this requirement for scientific knowledge the '*necessity-requirement*'.[26] A body of knowledge seems to be scientific only if it satisfies both the demonstrability and necessity requirements.

Disciplines such as arithmetic and geometry meet both the demonstrability and the necessity requirements. Aristotle clearly takes these disciplines to satisfy the demonstrability-requirement.[27] Moreover, he assumes that these disciplines only encompass claims that, if true, are true of necessity (e.g. 'the sum of internal angles of a triangle is equal to two right angles', cf. *APo.* 1.4 73b30–32, *inter alia*). So, both mathematics and astronomy qualify as sciences. By contrast, it is far from clear that technical branches of knowledge can be scientific. For they fail to meet the necessity-requirement. The examples of technical generalizations that we find in the corpus include claims such as the following:

(1) Honey-water is beneficial to the feverish.

For Aristotle, (1) is true and concerns universals. But it is not true of necessity, since it is not always the case that a given medicine heals a patient. Rather, (1) concerns what holds for the most part (*hōs epi to polu*) (*Metaph.* E.2 1027a230–28, cf. 1026b27–31). Medical knowledge—and in fact technical knowledge in general—tolerates exceptions. It contains generalizations about facts that hold not always but only for the most part. So technical knowledge fails to meet the necessity-requirement.

Do technical bodies of knowledge at least meet the demonstrability-requirement? The initial part of the *Posterior Analytics* seems to suggest that the necessity-requirement has to be met by all demonstrations. If a syllogism qualifies as a demonstration only if it meets the necessity-requirement, then failure of the necessity-requirement also implies failure of the demonstrability-requirement. This is one prominent reason why several scholars reach the conclusion that technical knowledge is not scientific (cf. Lorenz and Morison 2019). Given that technical knowledge concerns things that hold

26 In *APo.* 1.6, Aristotle clarifies that a claim is true of necessity in virtue of being a *per se* claim, namely a claim that tracks connections that are in the relevant sense(s) non-accidental (cf. esp. 74b5–12 and 75a28–37).

27 This is confirmed by the fact that in the initial part of the *Posterior Analytics*, he uses several examples from these disciplines while exposing his account of scientific demonstrations. We find several references to mathematics in the initial part of the *Posterior Analytics*; e.g. *APo.* 1.1 71a3, 1.2 72a22, 1.4 73a34–b3, 1.5 74a13–32, 1.7. For astronomy, see for instance 1.8 75b33–36, where we find a reference to the demonstration of the eclipse of the moon; and 1.13 78a30–b4 for a demonstration about the planets. Aristotle refers to astronomy as one of the mathematical sciences at *Metaph.* E.1 1026a25–27, *inter alia*.

for the most part, rather than things that hold of necessity, many conclude that it fails to reach the level of scientific knowledge.

The line of argument that leads many to deny that technical knowledge is scientific has further implications. For one, it also leads to the conclusion that since there cannot be demonstrations about things that only hold for the most part, artisans cannot grasp the essence of the product in quite the same way as someone who has scientific knowledge does. Lorenz and Morison (2019, 452–4) suggest that artisans do not grasp essences in the way scientists do (that is, *qua* essences). However, more would need to be said to establish that for Aristotle one can grasp an essence in a way that is not *qua* essence. It is not at all obvious that Aristotle thinks that there is such a way of grasping essences. Nor is it clear that, if there were such a way of grasping essences, artisans would grasp essences in that way. In this paper, we take Aristotle's talk of artisans' grasping essences at face value. We aim to show that this alternative reading is not problematic and in fact is independently motivated. If we are correct, Aristotle's technical knowledge is demonstrative and artisans grasp essences of their products in a scientific way.

For our purposes, a key point is that although the initial chapters of the *Posterior Analytics* state that premises and conclusions of demonstrations must be about facts that hold of necessity, in *APo.* 1.30 Aristotle explicitly makes room for claims about facts that hold for the most part (henceforth, FMP-claims):

> (T3) There is no knowledge (*epistēmē*) through demonstration of what holds by chance (*apo tuchēs*). For what holds by chance is neither necessary nor for the most part, but [it is] what comes to be contrary to these; and demonstration is of one or other of these. For every syllogism is either through necessary or through for the most part (*hōs epi to polu*) premises. And if the premises are necessary, the conclusion is necessary too; and if for the most part, the conclusion is of this sort too. Hence if what happens by chance is neither for the most part nor necessary, there will not be demonstration of it.
>
> Τοῦ δ' ἀπὸ τύχης οὐκ ἔστιν ἐπιστήμη δι' ἀποδείξεως. οὔτε γὰρ ὡς ἀναγκαῖον οὔθ' ὡς ἐπὶ τὸ πολὺ τὸ ἀπὸ τύχης ἐστίν, ἀλλὰ τὸ παρὰ ταῦτα γινόμενον· ἡ δ' ἀπόδειξις θατέρου τούτων. πᾶς γὰρ συλλογισμὸς ἢ δι'ἀναγκαίων ἢ διὰ τῶν ὡς ἐπὶ τὸ πολὺ προτάσεων· καὶ εἰ μὲν αἱ προτάσεις ἀναγκαῖαι, καὶ τὸ συμπέρασμα ἀναγκαῖον, εἰ δ' ὡς ἐπὶ τὸ πολύ, καὶ τὸ συμπέρασμα τοιοῦτον. ὥστ' εἰ τὸ ἀπὸ τύχης μήθ' ὡς ἐπὶ τὸ πολὺ μήτ' ἀναγκαῖον, οὐκ ἂν εἴη αὐτοῦ ἀπόδειξις. (*APo.* 1.30 87b19–27; cf. 2.12 96a8–19, *EN* 1.3 1094b21–22)

In contrast with what was stated in *APo*. 1.2–6, in (T3) Aristotle claims that demonstrations are either of what holds of necessity, or of what holds for the most part. Thus (T3) broadens the notion of a demonstration. Here the conclusion of a demonstration no longer needs to be true of necessity: it is *either* a claim about facts that hold of necessity *or* about facts that hold for the most part. When a demonstration only contains premises that concern things that hold of necessity, the conclusion is guaranteed to be about things that also hold of necessity (henceforth, NEC-demonstrations). By contrast, when a demonstration contains premises about what holds for the most part, the conclusion is only guaranteed to be about what also holds for the most part (henceforth, FMP-demonstrations). The language of demonstrations and syllogisms suggests that Aristotle thinks of both NEC-demonstrations and FMP-demonstrations as valid deductions.[28]

(T3) seems to contrast holding of necessity and holding for the most part. This fits well with a passage of *APr*. 1.13, where Aristotle classifies FMP-claims as one type of contingent claims:

> (T4) Having made these distinctions, let us next explain that 'to be contingent' is said in two ways. In one way of what happens for the most part and falls short of necessity, such as that a man turns gray or grows or ages, or in general that which happens by nature (for this does not have continuous necessity because a man does not always exist; however, when there is a man, it is either of necessity or for the most part). In the other way of what is indefinite [...] in general, what comes about by chance (for it is no more natural for this to happen in one way than in the opposite way).
>
> Διωρισμένων δὲ τούτων πάλιν λέγωμεν ὅτι τὸ ἐνδέχεσθαι κατὰ δύο λέγεται τρόπους, ἕνα μὲν τὸ ὡς ἐπὶ τὸ πολὺ γίνεσθαι καὶ διαλείπειν τὸ ἀναγκαῖον, οἷον τὸ πολιοῦσθαι ἄνθρωπον ἢ τὸ αὐξάνεσθαι ἢ φθίνειν, ἢ ὅλως τὸ πεφυκὸς ὑπάρχειν (τοῦτο γὰρ οὐ συνεχὲς μὲν ἔχει τὸ ἀναγκαῖον διὰ τὸ μὴ ἀεὶ εἶναι ἄνθρωπον, ὄντος μέντοι ἀνθρώπου ἢ ἐξ ἀνάγκης ἢ ὡς ἐπὶ τὸ πολύ ἐστιν), ἄλλον δὲ τὸ ἀόριστον [...] ὅλως τὸ ἀπὸ τύχης γινόμενον· οὐδὲν γὰρ μᾶλλον οὕτως πέφυκεν ἢ ἐναντίως. (*APr*. 1.13 32b4–13; cf. *APr*. 1.3 25b14–15, *Int*. 9 19a18–22)

28 For extensive defense of this claim, see Striker (2022, ch. 2). See *APo*. 2.12 96a8–19 for the claim that there are scientific principles holding for the most part and that at least one premise of an FMP-demonstration is an FMP-claim. This further supports the hypothesis that Aristotle takes FMP-demonstrations to be valid syllogisms. For a reading of FMP-demonstrations as not logically valid, see for instance Coope (2021, 113).

There are two types of cases that fall under the heading of what is contingent: what happens for the most part, and what happens by chance. For example, that a man's hair turns gray over time happens for the most part and not of necessity (32b6–7). Here Aristotle explicitly denies that what holds for the most part holds of necessity. The context confirms that he is considering the modal status of claims that can be premises of a syllogism. In light of (T4), it is plausible to assume that in (T3) Aristotle takes FMP-claims to fall short of necessity.[29]

By introducing the new class of FMP-premises and contrasting it with necessary premises, Aristotle expands his notion of scientific knowledge so as to make room for bodies of knowledge containing claims that can fall short of necessity, as long as they hold for the most part. On this broader notion of knowledge, the necessity-requirement gets replaced with the weaker requirement that each premise of a science must hold either of necessity *or* for the most part (henceforth, necessity-or-fmp-requirement). We shall call a science that satisfies at most the necessity-or-fmp-requirement and the demonstrability-requirement a '*non-strict science*'. By contrast, we shall call a science that satisfies both the demonstrability-requirement and the stronger necessity-requirement a '*strict science*'. The distinctive feature of strict sciences is thus that they only contain claims about what holds of necessity. The distinctive feature of non-strict sciences is that they include claims about what holds for the most part.[30]

One might concede that with (T3) Aristotle extends his notion of scientific knowledge to cover things that happen for the most part and yet still question whether this broader account of scientific knowledge covers technical knowledge as well. (T3) does not explicitly mention *technē*, nor does it come with any other example. So why think of technical knowledge as a non-strict science? This is the question we turn to next.

29 The assumption that the FMP-claims are contingently true does *not* rule out that the corresponding claim that includes the expression 'for the most part' in its logical form might hold true of necessity.

30 Denyer (1991) also states that *APo.* 1.30 expands the notion of demonstration Aristotle has in mind but takes this point to merely aim at making room for the study of nature. Reeve (1992, ch. 1, esp. 8–22) draws a distinction between what he calls 'unconditional scientific-knowledge' (for us, knowledge of strict sciences) and 'plain scientific-knowledge' (for us, knowledge of non-strict sciences). Anagnostopoulos (1994) and Irwin (2000) talk of inexact *vs* exact sciences, in order to support the claim that for Aristotle practical knowledge is scientific. In the next section, we focus on how (T3) is relevant to technical knowledge.

4 Technical and Natural Sciences as Non-strict Sciences

In the *Analytics*, Aristotle treats *technai* on a par with other sciences several times. *APr.* 1.30 discusses astronomy together with 'any *technē* or science whatsoever' (46a22). *APo.* 1.12 presupposes that medicine is a science, together with geometry (77a40–41). *APo.* 1.13 has a reference to medicine (79a14), within the context of discussing sciences that 'do not fall under one another' (79a13–14). *APo.* 1.32 refers again to medicine together with other sciences such as geometry, within the context of discussing the principles of a science (88b10–3). Later in the same work, there are examples of causal reasoning that belong to the art of war (2.11 94a36–94b8) and the art of house-building (2.12 95b31–37). Overall, this is a *prima facie* reason to think that Aristotle's theory of science applies to technical knowledge.[31] We shall now argue that indeed the sciences of nature and the technical sciences both have a claim to being non-strict sciences, for they both meet the necessity-or-fmp-requirement (§4.1) and the demonstrability-requirement (§4.2).

4.1 *The Necessity-or-fmp Requirement*

In *Metaph.* E.2, Aristotle clarifies that there is only *epistēmē* of what is not accidental:

> (T5) [T]hat there is no knowledge (*epistēmē*) of the accidental is clear; for all knowledge is either of that which is always or of that which is for the most part (*hōs epi to polu*). For how else is one to learn or to teach another? For one must characterize [things] either as holding always or as holding for the most part, e.g. that honey-water is beneficial to a feverish person holds for the most part. But what is contrary to that cannot be stated when that does not happen, such as on the day of the new moon; for what holds on the day of the new moon also [holds] either always or for the most part; but the accidental is contrary to this.
>
> [Ὅ]τι δ' ἐπιστήμη οὐκ ἔστι τοῦ συμβεβηκότος φανερόν· ἐπιστήμη μὲν γὰρ πᾶσα ἢ τοῦ ἀεὶ ἢ τοῦ ὡς ἐπὶ τὸ πολύ. πῶς γὰρ ἢ μαθήσεται ἢ διδάξει ἄλλον;

31 Bolton (2021, 152) takes the fact that (in his view) some technical accounts are causal and general to be enough to infer that they are demonstrative. But the claim that a house is for the sake of sheltering people is general and causal but not demonstrative. This is also the sort of claim that a layman may have, and therefore the requirements it meets cannot alone suffice to characterize technical knowledge.

> δεῖ γὰρ ὡρίσθαι ἢ τῷ ἀεὶ ἢ τῷ ὡς ἐπὶ τὸ πολύ, οἷον ὅτι ὠφέλιμον τὸ μελίκρατον τῷ πυρέττοντι ὡς ἐπὶ τὸ πολύ. τὸ δὲ παρὰ τοῦτο οὐχ ἕξει λέγειν, πότε οὔ, οἷον νουμηνίᾳ· ἢ γὰρ ἀεὶ ἢ ὡς ἐπὶ τὸ πολὺ καὶ τὸ τῇ νουμηνίᾳ· τὸ δὲ συμβεβηκός ἐστι παρὰ ταῦτα. (*Metaph.* E.2 1027a19–1027a26; cf. K.8 1065a30–35)

Here 'always' (*aei*, 1027a21–22, 25) is a proxy for 'necessary'.[32] The idea is that for something to be the object of *epistēmē*, it must hold either of necessity, or for the most part. Aristotle uses *epistēmē* to refer to theoretical knowledge, productive knowledge, and practical knowledge (cf. 1026b4–5).[33] (T5)'s example of an FMP-claim comes from medicine: the claim that honey-water is beneficial to the feverish (cf. claim (1) above and 1027a23–24) concerns what holds for the most part.

There are important parallels between (T3) and (T5). In both passages, we are told that *epistēmē* concerns what is *not* accidental and that what is not accidental is the case *either* of necessity *or* for the most part. This suggests that the expression 'for the most part' is used in the same way in (T3) and (T5).[34] Shortly after (T5), Aristotle gives us the examples of the art of house-building and geometry (1026b6–12) as cases of *epistēmai* that do not look at the accidental. Here geometry is an example of a science concerning what holds of necessity.

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32 For further passages that explicitly contrast what holds for the most part with what is necessary, see *APr.* 1.13 32b4–10 and *Top.* 2.6 112b1–20. In *EN* 3.6, among other places, Aristotle also points out that what is necessary is eternal, i.e. it always holds (1139b23–4). Sometimes he directly introduces what holds for the most part by contrasting it with what always holds (cf. *APo.* 2.12 96a8–16; *Top.* 5.1 129a6–16; *Ph.* 2.5 196b10–13) and with what holds in every case (*HA* 5.14 545a14–20; *PA* 3.2 663b28–29). It is however worth keeping in mind that sometimes within these contrasts Aristotle may be using 'for the most part' in the mere sense of frequency. For the distinction between uses that track natural or causal regularities and uses that track mere frequency, see Irwin (2000) and Henry (2015, 179–85).

33 We leave open whether Aristotle also countenances the practical forms of knowledge as sciences that are concerned with what holds for the most part. For the view that he does, see Anagnostopoulos (1994), Winter (1997), Irwin (2000b), Allen (2015, 62), and Nielsen (2015, 35–44); for concerns, cf. Henry (2015, 189), as well as Lorenz and Morison (2019). Pacius (1597, 318–19) takes (T3) to make room for ethical demonstrations but adds that these are somehow less proper.

34 It follows that in (T3) Aristotle also weakens his claim from *APo.* 1.6 (74b6–10, 75a28–31) that what holds *per se* (and therefore not accidentally) holds of necessity: now what holds *per se* holds either of necessity, or for the most part. Given this broader notion of holding *per se*, the premises and conclusions of FMP-demonstrations remain *per se* claims (for emphasis on the claim that science is not concerned with the accidental, cf. *Metaph.* E.2 and K.8 1064b17–1065a, *inter alia*).

Plausibly, the art of building is an example of a science concerning what holds for the most part. As we have just seen, (T5) also assumes that another art, that of medicine, contains FMP-claims. So in these passages Aristotle treats *technai* as *epistēmai* that include FMP-claims.

A further reference to FMP-claims relates to the sciences of nature. Aristotle often describes these sciences as including FMP-claims.[35] Later in *Metaph*. E.2, at 1026b33–35, he raises the question of whether the claim that in the dog-days one has storms and cold temperatures holds for the most part. This suggests that in (T5) knowledge of what holds for the most part includes knowledge possessed by artisans as well as natural scientists. Similarly, in *Ph.* 2.8 Aristotle says that what happens for the most part is not due to accident nor chance (here 'accidental' is narrower than in (T3)–(T5)).[36] He also equates what holds for the most part with what holds if nothing prevents it (*Ph.* 2.8 199b24–26; cf. 199b17–18). The thought seems to be that A belongs to B for the most part just in case it is true that A belongs to B if nothing prevents it.[37]

Aristotle often draws a parallel between *technai* and sciences of nature, most notably in *Ph*. 2.8 (esp. 199a12–20, 199a33–b4, 199b26–32; cf. *Mete*. 4.3 381b4–7, *PA* 1.1 639b15–640a33). Nature is like *technē* in several important respects.[38] Both art and nature can be prevented from reaching their goals and, therefore, only reach them for the most part: 'As in action, thus in nature; and as in nature, thus in each action, if nothing prevents it' (οὐκοῦν ὡς πράττεται, οὕτω πέφυκε, καὶ ὡς πέφυκεν, οὕτω πράττεται ἕκαστον, ἂν μή τι ἐμποδίζῃ, *Ph*. 2.8 199a9–11). This sustained parallel between *technai* and the sciences of nature suggests that Aristotle's gloss of holding for the most part in terms of holding if nothing prevents is meant to extend as much to *technai* as to the sciences of nature.[39] Both

35 *Metaph*. E.1–2 esp. 1026b27–1027a1; *GA* 1.19 727b29–30, 4.4 770b9–17, 4.8 777a20–21; *HA* 4.3 527b6–7; *GC* 2.6 333b3–9; *PA* 3.2 663b27–29; *Ph*. 2.7 198b4–9 and 2.8 199b24–26.

36 'These and all other natural things come about in a given way either always or for the most part, but not so for what happens by chance or spontaneously' (*Ph*. 2.8 198b34–36; cf. *GC* 2.6 333b4–7, *inter alia*).

37 Cf. *Ph*. 2.8 199b25–26, 8.4 255a34–b12 and b19–21, *inter alia*. The only author who explicitly makes this claim is Striker (2022, 29). Striker however goes on to equate what happens for the most part with what happens 'with normal conditions' (*ibid*., 32). We do not take this further equation for granted.

38 For accounts, see Sedley (2007, 173–81) and Broadie (1990, 392–6).

39 The claim that both the sciences of nature and *technai* are concerned with what holds for the most part is compatible with Aristotle's claim that art completes what nature fails to finish (*Ph*. 2.8 199a15–17), as exemplified by a doctor healing a patient who could not recover without intervention. This is because the range of what is accidental by nature is different from the range of what is accidental for an artisan. One might also think that in

technai and the sciences of nature study what holds for the most part, where something holds for the most part just in case it holds *if nothing prevents*.[40]

4.2 *The Demonstrability-Requirement*

We have seen that technical bodies of knowledge, like the sciences of nature, include FMP-claims. This does not yet suffice to establish the stronger claim that technical knowledge and the sciences of nature are analogous in that they can be systematized in terms of demonstrations. To make a case for the stronger claim, we shall show that the *Posterior Analytics* features examples of FMP-demonstrations concerning both subject matters of the sciences of nature and subject matters of *technai* (§§4.2.1–4); this suggests that Aristotle thinks of these disciplines as scientific. Further, we argue, Aristotle thinks that demonstrations about natural and technical subject matters can be derived from first principles—i.e., that these bodies of knowledge are axiomatizable (§4.3). So both display the structure of non-strict sciences.

We shall now single out two examples of demonstrations belonging to natural sciences and two examples of demonstrations belonging to *technai*.[41]

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nature things always happen unless something interferes, whereas artifacts only come to be *if* something interferes, namely the artisan. *Metaph.* Θ.7 might be taken to support this line of thinking. There Aristotle clarifies that a house is potentially if nothing in the relevant matter needs to be changed, or added to it, or subtracted from it (see esp. 1049a9–11; we thank an anonymous reviewer for encouraging us to expand on this point). However, the changes aimed at making matter ready for production come *before* the start of the production itself (the activity of house-building, say, only begins once there is material that qualifies as being potentially a house). Preparatory changes to the matter do not count as interferences to the change of production. What counts as an interference with the course of nature (say, the action of an artisan) is usually not the same as what counts as an interference with the performance of an artisan (say, particularly extreme weather). In *Metaph.* Θ.7 itself, Aristotle does not treat the action of the agent of a given change of production as interferences. Rather, he draws a distinction between external interferences and the actions of the artisan (*qua* artisan): 'when it [i.e. a change of production] is wanted [by an agent], it comes about as long as nothing external prevents it' (*Metaph.* Θ.7 1049a6–7; cf. also Θ.5 1048a11–25).

40 Aristotle refers to what holds in the absence of preventing conditions in several passages, mostly in connection with *technai* (*Ph.* 2.8 199a10–11, *Metaph.* Θ.5 1048a16–21 and Θ.7 1049a5–11 taken together, *inter alia*) and nature (*Ph.* 2.8 199a10–11, 8.4 255b6–12 and 17–23, *GA* 4.10 778a4–9, *HA* 4.3 527b6–7, *inter alia*).

41 A number of scholars have made the case for the claim that Aristotle applies his scientific method in his discussion of the natural sciences—cf. Leunissen (2010) for an example, with a direct focus on the *Posterior Analytics*. On the similarities between demonstrations in the natural sciences and geometric demonstrations, see Gotthelf (1987, 197–8; 1997; 2011) and Lennox (2001b). For the claim that there are overall methodological similarities between strict sciences and natural sciences, see Balme (1987), Bolton (2017; 1997), Charles (1997; 1999; 2000), and Detel (1997; 1999), *inter alia*.

They corroborate our claim that Aristotle takes these disciplines to be demonstrative, namely to satisfy his demonstrability-requirement on scientific knowledge.

4.2.1 River Demonstration

APo. 2.15 alludes to demonstrations concerning rivers:

> (T6) Why does the Nile flow more abundantly at the end of the month? Because the end of the month is stormier.
>
> Διὰ τί ὁ Νεῖλος φθίνοντος τοῦ μηνὸς μᾶλλον ῥεῖ; διότι χειμεριώτερος φθίνων ὁ μείς. (*APo*. 2.15 98a31–32; cf. *Fr*. 246 Rose[3])

Earlier in the *Posterior Analytics*, Aristotle established that a demonstration can be rearranged in terms of a why-question and its answer (cf. *APo*. 2.2 90a5–9, 2.8 93b7–12, 2.10 94a3–7; see also 2.11). There is an associated demonstration where the cause is picked up by the middle term (the term repeated in both premises) and the effect is described by the conclusion. In (T6), he quickly alludes to demonstrations by stating a why-question and its answer.

Plausibly, the canonical demonstration to be associated with (T6) is one about rivers of a certain kind.[42] The middle term of this demonstration has to pick up the cause mentioned in the answer to the why-question—namely, the fact that the relevant period is stormier. We therefore obtain the following demonstration about rivers:

Terms	**River Demonstration**
A: Such-and-such rivers flowing more abundantly. B: Stormier periods. C: The end of the month.	Such-and-such rivers flowing more abundantly belong to stormier periods. Stormier periods belong to the end of the month. So, Such-and-such rivers flowing more abundantly belong to the end of the month.

42 We assume that one can extrapolate the canonical demonstration by replacing the term denoting the Nile with the relevant universal which the Nile instantiates—presumably, being a river of a certain sort. Aimar (n.d.) provides a sustained defense of this assumption.

The *River Demonstration* belongs to the science of nature—more specifically, to the science of rivers. Its second premise describes a fact that only holds for the most part, as opposed to holding of necessity. For it is not necessarily the case that there are more storms at the end of the month than at any other time of the month. Given (T3), this entails that the conclusion of the *River Demonstration* is also an FMP-claim. We have here an example of FMP-demonstration that belongs to the study of nature.

4.2.2 Tree Demonstration

Here is a second example of demonstration from natural sciences, from *APo.* 2.16:

> (T7) [W]hy do trees shed leaves? If it is because of the solidification of their moisture, then if a tree sheds its leaves, solidification must be the case, and if solidification is the case—not for anything whatsoever but for a tree—[the tree] sheds leaves.
>
> [Δ]ιὰ τί τὰ δένδρα φυλλορροεῖ; εἰ δὴ διὰ πῆξιν τοῦ ὑγροῦ, εἴτε φυλλορροεῖ δένδρον, δεῖ ὑπάρχειν πῆξιν, εἴτε πῆξις ὑπάρχει, μὴ ὁτῳοῦν ἀλλὰ δένδρῳ, φυλλορροεῖν. (*APo*. 2.16 98b36–38)

The conclusion is the claim that trees shed their leaves. Earlier on in the chapter, Aristotle clarifies that he has in mind a specific type of tree—broad-leaved trees (cf. 98b4). The cause of leaf-shedding is solidification of moisture. So the relevant demonstration seems to go like this:

Terms	**Tree Demonstration**
A: Leaf-shedding. B: Solidification of moisture. C: Broad-leaved trees.	Leaf-shedding belongs to solidification of moisture. Solidification of moisture belongs to broad-leaved trees. So, Leaf-shedding belongs to broad-leaved trees.

Within the *Tree Demonstration*, the premise that solidification of moisture belongs to broad-leaved trees seems to be an FMP-claim. One may imagine broad-leaved trees that for some reason fail to shed their leaves. If this premise

holds for the most part, so does the conclusion.[43] Here we have another example of FMP-demonstration that belongs to the science of nature.

4.2.3 War Demonstration

Aristotle also gives us examples of demonstrations that belong to *technai* within the *Posterior Analytics*. We offer two such examples. The first concerns the art of war:

> (T8) Why did the Persian war come upon the Athenians? What is the cause of the Athenians' being warred upon? That they attacked Sardis with the Eretrians—for this moved first. War A, being first to attack B, Athenians C. B holds of C (being first to attack holds of the Athenians), and A holds of B (men make war on those who have first wronged them). Therefore, A holds of B (being warred upon holds of those who first began), and this—B—of the Athenians (they first began it). Therefore, here too the cause, what initiated a change, is a middle term.
>
> Τὸ δὲ διὰ τί ὁ Μηδικὸς πόλεμος ἐγένετο Ἀθηναίοις; τίς αἰτία τοῦ πολεμεῖσθαι Ἀθηναίους; ὅτι εἰς Σάρδεις μετ' Ἐρετριέων ἐνέβαλον· τοῦτο γὰρ ἐκίνησε πρῶτον. πόλεμος ἐφ'οὗ Α, προτέρους εἰσβαλεῖν Β, Ἀθηναῖοι τὸ Γ. ὑπάρχει δὴ τὸ Β τῷ Γ, (τὸ προτέροις ἐμβαλεῖν τοῖς Ἀθηναίοις), τὸ δὲ Α τῷ Β· (πολεμοῦσι γὰρ τοῖς πρότερον ἀδικήσασιν). ὑπάρχει ἄρα τῷ μὲν Β τὸ Α (τὸ πολεμεῖσθαι τοῖς προτέροις ἄρξασι)· τοῦτο δὲ τὸ Β τοῖς Ἀθηναίοις· (πρότεροι γὰρ ἦρξαν). μέσον ἄρα καὶ ἐνταῦθα τὸ αἴτιον, τὸ πρῶτον κινῆσαν. (*APo.* 2.11 94a36–94b8)

Aristotle starts off *APo.* 2.11 by stating that the middle term of a demonstration can pick up any of the four causes (94a20–24). The chapter then gives examples from each of the causes. (T8) is meant to support the claim that a middle term can pick up an efficient cause.

The passage slightly rephrases the terms of the syllogism along the way. At first, term A is 'war' (*polemos*, 94b2) but shortly afterwards Aristotle takes term A to be 'being warred upon' (*to polemeisthai*, 94b5–6). The rephrase might be an attempt at precision on Aristotle's part. We will use 'being warred upon' in the reconstruction below. On the face of it, the syllogism that Aristotle has in mind seems to contain at least one term referring to particulars—'the

43 Charles (2000, 204–7) takes Aristotle to aim at showing that, in all broad-leaved trees, leaf-loss will always and only occur because of the solidification of moisture. It is unclear whether the minor premise qualifies as being true of necessity, however.

Athenians' (*Athēnaioi*, 94b2–3). So at first pass the demonstration seems to be: war belongs to being the first to attack, attacking belongs to the Athenians, so war belongs to the Athenians. The only issue is that we have again a term that denotes particulars—'the Athenians'. Since the chapter's goal is to establish that the middle terms of demonstrations can pick up any of the four causes, and (T8) covers the case of efficient causation, the passage would not be fully philosophically successful if one could not extrapolate a canonical demonstration with such a middle term. Just as in the case of the Nile example above, a term that denotes particulars goes proxy for a term denoting a universal, which is in turn the term that appears in the canonical version of the demonstration.

In order to reconstruct the canonical demonstration associated with (T8), we need to supply a term denoting the plausible universal that the Athenians might be instantiating. We know that the raid of Sardis (498 BC) was an act of Ionian rebellion against the Persians, in support of which Athens sent twenty ships. Accordingly, we will suppose that the feature the Athenians instantiate is that of promoting revolt, and thus that Athenians are revolt-promoters:

Terms	**War Demonstration**
A: Being warred upon.	Being warred upon belongs to attacking first.
B: Attacking first.	Attacking first belongs to revolt-promoters.
C: Revolt-promoters.	So,
	Being warred upon belongs to revolt-promoters.

The *War Demonstration* accounts for the fact that those who try to expand get warred upon—this is because they first attack their enemy. The premise 'being warred upon belongs to attacking first' seems to describe something that holds only for the most part. It might well be that in some circumstances those who do not attack first get warred upon.[44] If the *War Demonstration* belongs to the *technē* of war, we have a technical demonstration that involves FMP-claims.

44 We take the demonstration contained in (T8) to belong to the art of war for the following reasons. There are in Greek at least two possible ways of referring to the art of war: *strategikē* and *polemikē*. Aristotle refers to *strategikē* as a *technē* many times. In *EE* 7.14 1247a5–7, *strategikē* is an example of *technē*, together with the art of navigation (*kubernētikē*). At *EN* 1.1 1094a9 and 1.7 1097a17–20, *strategikē* is described as a *technē* whose aim and product is victory; it is listed together with *technai* such as ship-building, medicine, and architecture (see also 1.1 1094b3). At 1.6 1096a32–33, in the context of discussing forms of knowledge (*epistēmai*), Aristotle points out that *strategikē* studies

4.2.4 House Demonstration

APo. 2.12 refers to a demonstration concerning house-building:

> (T9) And it is in this way with regard to tasks (*epi tōn ergōn*): if a house has come to be, it is necessary that stones have been cut and have come to be. Why is this? Because necessarily a foundation has come to be, if also a house has come to be. If a foundation, then necessarily stones have come to be earlier. Again, if there will be a house, in the same way there will have to be stones earlier. And it is shown through the middle term in this way: for there will be a foundation earlier.
>
> Ἔχει δὲ οὕτως ἐπὶ τῶν ἔργων· εἰ γέγονεν οἰκία, ἀνάγκη τετμῆσθαι λίθους καὶ γεγονέναι. τοῦτο διὰ τί; ὅτι ἀνάγκη θεμέλιον γεγονέναι, εἴπερ καὶ οἰκία γέγονεν· εἰ δὲ θεμέλιον, πρότερον λίθους γεγονέναι ἀνάγκη. πάλιν εἰ ἔσται οἰκία, ὡσαύτως πρότερον ἔσονται λίθοι. δείκνυται δὲ διὰ τοῦ μέσου ὁμοίως· ἔσται γὰρ θεμέλιος πρότερον. (*APo.* 2.12 95b31–37)

The chapter as a whole introduces and accounts for tensed syllogisms, namely syllogisms with copulas that indicate past, present or future times. Why does Aristotle bring in the notion of a tensed syllogisms in the *Posterior Analytics*? In *APo.* 2.12, he considers how to apply scientific knowledge to the temporal

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opportunity in *war*, whereas medicine studies disease. At *EE* 1.8 1217b39–40, again within the context of discussing forms of knowledge, *strategikē* is described as concerned with war-related practices (*ta polemika praxeis*). Plato treats *strategikē* as a *technē* as well (cf. *Philebus* 56b2). Thus, although Aristotle does not explicitly state in (T8) that he has in mind the art of strategy, and given his descriptions of this art elsewhere, this looks to us as the most plausible candidate. If on the other hand one thinks that the discipline described by *strategikē* is narrower than *polemikē* (e.g. more concerned with soldiers' formation), it remains open to read the *War Demonstration* as an instance of *polemikē*. In the *Republic* (456a1 and 522c10) and *Statesman* (*Politicus* 304a, 304e, and 305a), Plato refers to *polemikē* in contexts in which it is treated as a *technē*.

A further alternative hypothesis about (T8) might be that Aristotle there has in mind claims from history, or human behavior in general, rather than the art of war. But it is implausible that he would think of history as a science, since it is a collection of particular facts. Aristotle would not consider belligerent matters as pertaining to the study of nature either. Moreover, there is no question that in ancient times war techniques were studied and made the subject matter of several technical treatises; see for instance Aeneas Tacticus' *Poliorkētika,* the surviving portion of a treatise on the art of war, most likely written in the 4th century BC (Bettalli 1990). Thus, at the time there were systematic studies about belligerent matters, containing causal generalizations. Both Plato and Aristotle endorsed generalizations about the goal of war—this being victory (*EN* 1.7 1097a17–20) or acquiring wealth (*Phaedo* 66c6–d2). So there are strong grounds for thinking that in (T8) we are dealing with a *technē* concerning war.

realm. He gives us two further examples of explanatory tensed syllogisms: one concerning the eclipse (95a14–16) and one concerning ice (95a16–20). The tensed syllogism of the eclipse is reminiscent of the well-known eclipse demonstration (cf. *APo.* 2.8 93a37–b7) but involves tensed copulas. We suggest that for each of the syllogisms with tensed copulas there is a corresponding canonical demonstration. Thus, there is a canonical ice demonstration and a corresponding canonical house demonstration. The corresponding tensed syllogisms derive from canonical demonstrations and are applied to temporally situated events.

The methodology we suggest is in play in *APo.* 2.12 implies that given a temporal demonstration, one can reconstruct the corresponding canonical demonstration. Accordingly, given (T9)'s temporal syllogism, we can extrapolate a canonical demonstration concerning houses with untensed premises.[45] The corresponding canonical demonstration goes like this:[46]

Terms	**House Demonstration**
A: Stones.	Stones belong to foundation.
B: Foundation.	Foundation belongs to house.
C: House.	So,
	Stones belong to house.

45 One might object that productive reasoning *requires* tensed premises because it starts from the goal and infers what needs to be the case for the goal to come about. Lloyd (1996, 29–37) and others connect this diachronic reasoning with hypothetical necessity and suggest that the syllogisms of the sciences of nature and of *technai* are not really scientific demonstrations in a strict sense because of their being diachronic. We agree that tensed syllogisms for Aristotle cannot be demonstrations in a canonical sense, and that the term *apodeixis* can be used more or less loosely, both in Aristotle and in Greek more generally. However, it does not follow from this that there are no scientific demonstrations with untensed premises for the sciences of nature and *technai* (cf. Gotthelf 1987, 197–8). In the main text, we provide precisely examples of scientific demonstrations that include FMP-premises and are not tensed. Striker (2022, ch. 2) shows that FMP-premises can be linked to Aristotle's notion of conditional necessity in a way that is not temporal, as long as one assumes that an FMP-claim concerns what holds of necessity, *if nothing prevents* it. Cooper (2004, chs. 5–6) and Rosen (n.d.) argue that the notion of conditional necessity is not always connected with diachronic reasoning in Aristotle.

46 Charles (1999) further motivates the claim that one can extrapolate a demonstration concerning houses from (T9). Leunissen (2010, 45) takes this example to illustrate 'the mode of inference that is appropriate with regard to consecutive causal chains and not necessarily a demonstration itself'. Yet she also claims that the chapter offers a blueprint for applying demonstrations to natural sciences (*ibid.*). Note that the blueprint that Leunissen (2010) has in mind is also satisfied by Aristotle's house example.

Are the premises of the *House Demonstration* true of necessity or for the most part? On the basis of (T9), one cannot say with full certainty whether Aristotle thinks that, say, necessarily the foundations of a house are made of stones, or whether he thinks that this holds merely for the most part.[47] Similarly for the other premise. However, we shall now show that either option works for our account.

Here is why the uncertain modal status of the premises of the *House Demonstration* does not affect our overall point that this is an example of a technical demonstration. For all that *APo.* 1.30 says about non-strict sciences, Aristotle allows that non-strict sciences include claims that hold of necessity *simpliciter*, as opposed to only containing claims that concern what merely holds for the most part. If so, some of the demonstrations of a non-strict science can be NEC-demonstrations. Either way, the *House Demonstration* is a key example of a technical demonstration. It systematizes knowledge that belongs to the science of house-building. This further corroborates the claim that in the *Posterior Analytics* Aristotle takes technical bodies of knowledge as meeting the demonstrability-requirement.[48]

We are now in position to understand (T3) a bit better. We suggest that when Aristotle introduces the notion of FMP-demonstration in (T3), he makes room for a type of science that can be systematized by means of demonstrations that involve premises and conclusions about what holds merely for the most part. Although (T3) contains no examples, we have reconstructed examples of FMP-demonstrations on the basis of further passages from the *Posterior Analytics*. These examples pertain to the sciences of nature and also to technical subject matters. We have also seen that elsewhere in the corpus both

47 *If* the premise is an FMP-claim, Aristotle allows that one may build foundations out of a material other than stones, such as wood. Even if that will result in a less durable house, the resulting construction would still count as a house. By contrast, *if* the relevant premise is a claim that is true of necessity, then for Aristotle a shelter with foundations made of wood could not be a house—it might be a mere hut. Either option is compatible with our picture. Note that (T9) contains the expression 'necessarily' (*anagkē*) before the statement of each premise (95b32–33). This can either be a reference to logical implication, or it can clarify the modal status of each premise. The fact that the expression occurs twice gives one some reason to favor the latter option. Thus, it is more likely that the premises of the *House Demonstration* are in fact both true of necessity. We return to the question of contingency of artifact-kinds in §9.2.

48 Coope (2021, 113) denies that the conclusion of a productive explanation is logically entailed by its premises and adds that 'Aristotle never suggests that the steps in a productive explanation are logically entailed by the first principles of the art, as the steps in a chain of demonstrations are entailed by the first principles of the relevant theoretical science' (*ibid.*, 114). But see *APo.* 2.12 96a16–18 for the claim that principles of a science can be FMP-claims; see also n. 29.

natural sciences and technical knowledge are presented as concerned with what holds for the most part. These considerations support an interpretation on which (T3) applies to both the natural sciences and to technical subject matters. If so, both bodies of knowledge are associated with sets of demonstrations that include FMP-demonstrations.

4.3 *The Principles of Technical Knowledge*

The presence of FMP-demonstrations is not enough to establish that technical knowledge is scientific. As we have seen, for Aristotle a body of knowledge is demonstrative just in case one can derive all the remaining claims of the science from a set of indemonstrable principles—principles that today we would describe as the axioms of a science (cf. §3). Several scholars have defended the claim that there are principles of natural sciences.[49] But is it equally plausible to think that there are principles of technical knowledge from which all the technical theorems can be demonstrated? This section argues for a positive answer to this question. According to Aristotle, technical knowledge can be axiomatized in such a way that all its theorems derive from principles.

Let us begin from *APr.* 1.27–30. Aristotle discusses here how one finds the deductions that establish a thesis from appropriate premises (1.27 43a20–24). The relevant deductions include demonstrations (cf. 43b9–11). Along the way, he touches on FMP-claims:

> (T10) Those claims which follow from and are followed by for the most part claims must also be assumed. For syllogisms of problems which are for the most part are also from for the most part premises (either all or some of them); for the conclusion of each syllogism is like the starting points (*tais archais*).
>
> ληπτέον δὲ καὶ τὰ ὡς ἐπὶ τὸ πολὺ ἑπόμενα καὶ οἷς ἕπεται· τῶν γὰρ ὡς ἐπὶ τὸ πολὺ προβλημάτων καὶ ὁ συλλογισμὸς ἐκ τῶν ὡς ἐπὶ τὸ πολὺ προτάσεων, ἢ πασῶν ἢ τινῶν· ὅμοιον γὰρ ἑκάστου τὸ συμπέρασμα ταῖς ἀρχαῖς. (*APr.* 1.27 43b32–36; cf. 1.24 41b27–31, *APo.* 1.30, 2.12 96a8–19)

The passage points out that FMP-claims only derive from syllogisms that involve at least one FMP-premise.[50] The final clause states that this is because

49 Lennox (2001a; 2001b; 2011; 2021), Gotthelf (1987; 1997; 2010), Leunissen (2010), and Henry (2021), *inter alia*. For skepticism, see Barnes (1975, 77 and 84), Lloyd (1991; 1996), and to an extent Charles (2000).

50 As we have seen in §3, (T3) contains a similar point, namely that one can demonstrate FMP-claims only by means of demonstrations that contain FMP-premises.

the conclusion of a syllogism has to be of the same sort as its starting points—*archai*.

Aristotle at times uses *archai* to refer to the principles of a science. Yet other times he uses the term to refer to the starting points of a syllogism, namely its premises. In (T10), the expression *tais archais* denotes the premises of a syllogism (cf. Smith 1989, 43; Striker 2009, 44 and 194).[51] So Aristotle's claim is similar to the one we encountered in (T3)—see §3—except for the fact that it is extended to *all* syllogisms. Whenever the conclusion of a syllogism is an FMP-claim, at least one premise is an FMP-claim. Now the fact that FMP-claims can only be derived from other FMP-claims entails that if a scientific body of knowledge contains FMP-claims, then some of its principles are FMP-claims. Aristotle confirms that he takes this to hold for some sciences at *APo.* 1.32, where he tells us that some principles concern what holds of necessity and others concern what holds contingently: 'some principles are necessary and others contingent' (αἱ ἀρχαὶ αἱ μὲν ἐξ ἀνάγκης αἱ δ' ἐνδεχόμεναι, 88b7–8). As seen in §3, FMP-claims concern what holds contingently (cf. (T4), in §3). Accordingly, we suggest that when Aristotle claims that some principles are contingent he has in mind FMP-claims. His point at 88b7–8 is that some scientific principles are FMP-claims.

Aristotle discusses how his method for finding deductions applies to sciences towards the end of *APr*. 1.30. After clarifying that the method as a whole applies both to science and dialectic (46a3–10), he takes a closer look at those deductions which are demonstrations:

> (T11) In each science most of the principles are peculiar to it. This is why providing us with the principles of each is the business of experience. I mean for example that astronomical experience [provides us with the principles] of astronomical science (*tēs astrologikēs epistēmēs*). For once the phenomena had been adequately apprehended, the astronomical demonstrations (*apodeixeis*) were therefore discovered. Similarly, with any other sort of *technē* or science (*kai peri allēn hopoioanoun technēn te kai epistēmēn*). So that, if the things belonging to each are grasped, we will

51 Whether Aristotle has in mind all sciences or only sciences that study what one can perceive depends on whether μάθημα at 46a4 refers to: (i) applied mathematical sciences like optics, harmonics and astronomy; (ii) mathematical sciences; or (iii) any discipline or body of knowledge that involves learning. Striker (2009, 206) favors (i), following Bonitz's suggestion that the term μάθημα in the plural always denotes mathematical sciences distinct from geometry and arithmetic. We are inclined to follow Philoponus and other ancient commentators in favoring (iii)—so is Smith (1989, 206). Either way, the chapter goes on to include *technai* among the relevant sciences under discussion. As Striker (*ibid.*) points out, here Aristotle has in mind productive sciences.

> then be prepared to readily bring the demonstrations (*tas apodeixeis*) to light. For if nothing that truly belongs to the things has been omitted in the collection of facts, we will be in a position to find the demonstration of each thing of which there is a demonstration and demonstrate it, and to make clear of which things there is no natural demonstration.[52]

> ἴδιαι δὲ καθ' ἑκάστην αἱ πλεῖσται. διὸ τὰς μὲν ἀρχὰς τὰς περὶ ἕκαστον ἐμπειρίας ἐστὶ παραδοῦναι, λέγω δ' οἷον τὴν ἀστρολογικὴν μὲν ἐμπειρίαν τῆς ἀστρολογικῆς ἐπιστήμης (ληφθέντων γὰρ ἱκανῶς τῶν φαινομένων οὕτως εὑρέθησαν αἱ ἀστρολογικαὶ ἀποδείξεις), ὁμοίως δὲ καὶ περὶ ἄλλην ὁποιανοῦν ἔχει τέχνην τε καὶ ἐπιστήμην· ὥστ'ἐὰν ληφθῇ τὰ ὑπάρχοντα περὶ ἕκαστον, ἡμέτερον ἤδη τὰς ἀποδείξεις ἑτοίμως ἐμφανίζειν. εἰ γὰρ μηδὲν κατὰ τὴν ἱστορίαν παραλειφθείη τῶν ἀληθῶς ὑπαρχόντων τοῖς πράγμασιν, ἕξομεν περὶ ἅπαντος οὗ μὲν ἔστιν ἀπόδειξις, ταύτην εὑρεῖν καὶ ἀποδεικνύναι, οὗ δὲ μὴ πέφυκεν ἀπόδειξις, τοῦτο ποιεῖν φανερόν. (*APr.* 1.30 46a17–27)

In this passage, *archai* refers to the principles of a science and *apodeixes* denotes scientific demonstrations.[53] Aristotle points out that the principles peculiar to sciences like astronomy in some sense derive from experience (17–18). In astronomy, one spells out demonstrations (*apodeixeis*) on the basis of principles (*tas archas*) (46a17–21; cf. *Metaph.* A.1 981b20–982a1, *APo.* 1.10 76b3–76b16, *PA* 1.1 639a12–16 and 639b7–11). Just as in astronomy, he continues, 'in any sort of *technē* and science' (*APr.* 1.30 46a21–22) we must start from principles and infer demonstrations from these.[54] (T11) continues to explain that

52 Aristotle takes the principles of a science to be natural predications (*APr.* 1.30 46a27; cf. *APo.* 1.19–22), where the subject term must denote an underlying subject, and these features are to be preserved in the chain of deductive inferences one draws from principles. For a reconstruction of this point, see Malink (2022) and Bronstein (2019).

53 Alexander (*in Aristotelis Analyticorum Priorum librum I commentarium* 330.31–332.4), Pacius (1597, 180–1), Lennox (1991, 268–9), Ferejohn (1991, 142 n. 12), Angioni (2019, 172), Bronstein (2016, 125–7), and Malink (2022). Alternatively, one might suggest that 'demonstration' in (T11) has a broader meaning, as it can often have in ordinary Greek (Lloyd 1996 argues that this broader reading of 'demonstration' is required in other passages of the corpus), so to denote proof in a less technical sense. We take the overall context and the philosophical points Aristotle makes to support our preferred reading. Alternatively, one might suggest that 'principle' picks up the universals denoted by the terms proper to a given science. The fact that Aristotle here says that one starts from principles and infers demonstrations does not favor this suggestion.

54 Cf. *PA* 1.1 639b7–21 and *EE* 2.11 1227b28–32 for further methodological analogies between *technai* and other sciences of nature. Lloyd (1996, 29–37) excludes that Aristotle has in mind the principles of an axiomatic science. For compelling criticism of Lloyd's overall reading of *PA* 1.1, see Lennox (2001b, 140–2). We follow Lennox (2001a, 129–31; 2001b; 2021,

from a complete collection of observed facts, the scientist is in a position to lay out all the demonstrations of the science. They can derive all the theorems of the science from its first principles (22–27). Aristotle here treats technical bodies of knowledge as structurally similar to sciences like astronomy, precisely on the ground that they involve demonstrations from principles.

The second part of (T11) clarifies that once all the facts about astronomy are discovered (it is simply assumed that this goal is achievable), one can demonstrate all there is to demonstrate on the subject matter. Additionally, one can identify what cannot be demonstrated. The claims that are not susceptible of demonstration are the first principles of a science.[55] The generalization to 'any other sort of *technai* and science' (21–22) suggests that here Aristotle treats technical bodies of knowledge as systematizable in terms of demonstrations.

The corpus contains further direct references to the principles of *technai*. In the *Eudemian Ethics* Aristotle says that 'just as in the theoretical sciences the hypotheses are principles, so in the productive sciences the end is a principle and hypothesis' (*EE* 2.11 1227b28–31). As Malink (2017, 171) argues, here '*hypothesis*' refers to the principles of a scientific demonstration.[56] The end is the final cause of production, namely the form of the product. When Aristotle says that the end is a principle, he means that a definition of the product is among the principles of the science. For instance, the claim that health is a balance of

ch. 6), Gotthelf (1987, 170–2), and Anagnostopoulos (1994, 280), *inter alia*, and assume that the most natural reading of *archē* at *PA* 1.1 640a4 is that of the principle of a science. In the context, Aristotle considers what types of demonstrations apply to the sciences of nature—cf. also *GA* 2.6 742b23–35 and *HA* 1.6 491a7–14. He also treats the natural sciences and *technai* on a par: both the products of *technē* and the goals of natural processes are things that one must define (*PA* 1.1 639b15–19 and 640a32–33). What one must define is the form (e.g. for house-building the form of a house). The scientist draws demonstrations from principles (*PA* 1.1 639b30–640a9, *inter alia*; cf. *Ph.* 2.9 200a15–b8). *EE* 1.8 1218b16–22 also emphasizes that teachers start off defining the goal and draw demonstrations from there, while giving the example of defining health. *APo.* 1.8 75b31–32 adds that one of the roles definitions can play is that of being the principles of a science (see also 2.3 90b24–27). At 2.12 95a36–40 we find the claim that a principle gives us an account of what comes about, shortly before giving us the example of the *House Demonstration* (§4.2.4). It is a short step to conclude that in the case of a productive science there is a set of undemonstrated definitions of the goal (the product) and its parts which is included among the principles of the science—cf. Lennox (2001a, 130–1), *inter alia*.

55 Cf. Malink (2022), Rodriguez (2020, 460–1), Angioni (2019, 172–5), Smith (1991, 51–2). See also McKirahan (1992, 264), Striker (1998, 222; 2009, 208), Crubellier (2008, esp. 140), *inter alia*.

56 Crivelli (2011, 123) provides evidence that the use of '*hypothesis*' to mean principle is the most prominent in Aristotle.

heat and cold is plausibly one of the principles of medicine. Aristotle refers to these principles in *De Respiratione*, a work which closes with the following point: when it comes to health and sickness, medicine starts where the science of nature ends (*Resp.* 21 480b21–30; cf. *Sens.* 1 436a18–b2). While the most advanced and inquisitive doctors grasp principles of the sciences of nature, the most accomplished natural scientists in their inquiry arrive at 'the principles of medicine' (*tas archas tas iatrikas*, *Resp.* 21 480b30).[57] We find another reference to the principles of medicine at *APo*. 1.32 88b10–13, just after the claim that some principles of a science concern what falls short of necessity. This textual evidence further supports the view that Aristotle treats technical bodies of knowledge, together with the sciences of nature and mathematical sciences, as derivable from first principles.

We conclude that for Aristotle technical bodies of knowledge meet the requirements for being a non-strict science: (i) the necessity-or-fmp-requirement and (ii) the demonstrability-requirement. In this respect, they are just like natural sciences. That is to say, both the natural science and technical bodies of knowledge are non-strict sciences. The fact that technical knowledge is demonstrative in the same way that natural sciences are also implies that artisans grasp their subject matter just as natural scientists do. They know what the product and its parts are, as well as what features these products bear in virtue of their essence and what the causes of these features are. They grasp the essence of their product in a complex and articulate manner. In short, artisans have scientific knowledge.

5 Differences between Technical and Natural Sciences

We have seen that natural sciences and technical knowledge are structurally analogous, in that they can both be modeled in terms of FMP-demonstrations. In this section, we show that the demonstrations involved in natural sciences are nonetheless importantly different from technical demonstrations. If we are correct, the way in which they are different casts light on the distinctively productive aim of technical knowledge.

One respect in which natural sciences and technical sciences come apart is that they concern different types of things. Natural sciences study natural things, whereas technical sciences study artificial things, namely the products

57 See also *Metaph*. K.7 1063b35–1064a1 for a reference to the principles of medicine and gymnastics, as well as the principles of mathematical sciences.

of arts. Aristotle does have a way of distinguishing natural things from artifacts. Although both undergo change and come and go out of existence, only natural things have a nature, an inner source of change and stability (*Ph.* 2.1 192b13–33; cf. *Metaph.* E.1 1025b19–21). When an acorn grows, it does so because of its internal nature, rather than because of an external agent.[58] By contrast, since a bed does not have a nature, it always requires an external agent, such as an artisan, to modify it—e.g. to extend a bed or paint it a different color (*Ph.* 2.1 192b16–19; cf. *GA* 2.1 735a2–4). Thus, natural sciences look at things that have an inner principle of change, whereas technical sciences look at things that can only change by virtue of external agents (cf. *EN* 6.4 1140a14–15).

However, there are cases in which different sciences concern the *same* subject matter. Consider medicine. Aristotle treats it often as a unified discipline concerned with health (cf. *Metaph.* Z.7 1032b13, *inter alia*).[59] Yet, health is also studied by biology (cf. *Sens.* 1 436a18–b2, *Resp.* 21 480b21–30): after all, one can be naturally healthy. This is a case where a branch of natural science and a branch of technical science cannot be set apart in terms of their subject matter.[60] How can one tell them apart?

In the *Physics*, Aristotle distinguishes between considering a bed (or any other artifact) *qua* artifact or considering it *qua* wooden item (*Ph.* 2.1 192b16–192b23).[61] An artifact is natural to the extent to which its materials are natural—namely they have an internal principle of change. Although *qua* artifact, a bed lacks an internal principle of change (192b18–19), it has a nature *qua* wooden (192b19–23). Similarly, health can come about either by nature or by *technē*. A person can be naturally healthy or become healthy because of a doctor. When health comes about naturally, it is not an artifact. Hence, health can be considered in different respects: *qua* natural or *qua* produced by

58 For a helpful account of the notion of nature in Aristotle, see Kelsey (2003).

59 One may wonder whether medicine can at all be treated as a unified body of knowledge: on the one hand, Aristotle often treats it as a kind of science; on the other hand, at times he uses medicine as a paradigmatic example of a *technē* which requires its explanations to adapt to a variety of circumstances. See Anagnastopoulos (1994, 85–8) for reasons to think that Aristotle took medicine to be a unified discipline, with a scientific component. We discuss how scientific knowledge can account for the flexibility of *technai* in §7.

60 Coope (2021) argues that an important difference between natural sciences and technical knowledge is that whereas the former are potentially complete bodies of explanations, the latter are indefinitely extendable. See §7 for discussion of this view.

61 For the claim that *qua*-clauses do not pick up different things altogether, see Netz (2005) and Martini (2022).

medicine.[62] This distinction gives us resources to characterize the difference between medicine and the branch of biology that concerns health—biology$_h$, for short. Aristotle can distinguish biology$_h$ from medicine in the following way. Biology$_h$ studies health insofar as it is due to nature (health-*qua*-natural). Medicine studies health insofar as it is due to *technē* (health-*qua*-artifact).

The difference in subject matter between medicine and biology$_h$ directly translates into a difference at the level of demonstrations. Since the middle term of each demonstration picks up the cause of the fact described by the conclusion (see §3), chains of demonstrations model causal chains. Medicine and biology$_h$ are concerned with different sorts of causal paths leading to health. In general, natural sciences look at *natural causal paths*—namely causal paths that depend on something's nature. By contrast, technical sciences look at *artificial causal paths*—namely paths that include steps that involve the artisan's agency, like rubbing (*Metaph*. Z.7 1032b26) or giving honey-water (E.2 1027a23).[63] Accordingly, technical and natural sciences are structurally alike but differ in terms of the type of causal chains that the respective sets of demonstrations track.

Interestingly, the picture we have just given also comports well with Aristotle's classifications of productive and theoretical sciences. Book Epsilon of the *Metaphysics* tells us that the natural sciences are theoretical and the technical sciences are productive (E.1 1025b18–28; cf. K.7 1064b1–3). A theoretical science is ultimately for the sake of contemplation, whereas a technical science is ultimately for the sake of production (*ibid*.; cf. *Top*. 6.6 145a15–18). The class of theoretical sciences includes natural science, theology, and mathematics (*Metaph*. E.1 1026a18–19; cf. K.7 1064b1–3). Our account of productive knowledge fits well with this taxonomy, because we take productive sciences to be technical bodies of knowledge. Given our reading, a science being theoretical does not entail its being strict: the sciences of nature are theoretical but

62 See *Ph*. 2.8 199a8–20, *inter alia*, for the claim that art completes what nature cannot finish (cf. Plato's *Laws* 889a4–e1). There are of course also the interesting cases of living beings that exist (either at all or in their current form) because of technical knowledge—say, some human-bred animals, such as cows. It seems that insofar as things exist because of human knowledge, they are artifacts—just as health brought about by doctors is, to this extent, an artifact. Plausibly, having a nature (rather than just being entailed by a given nature) does not imply being due to nature.

63 Gracia (1978, 34–5) suggests that the scientific knowledge on which doctors rely is simply that of biology. However, Aristotle only grants the weaker claim that medicine relies on claims from biology$_h$ (as well as some claims from other sciences)—cf. *APo.* 1.13 79a14–16, where there is reference to a demonstration of circular wounds which has one premise that is borrowed from geometry. The best doctors also have some knowledge of biology$_h$ (*Sens*. 1 436a19–22, *Resp*. 21 4b0b22–30).

non-strict.[64] A science being demonstrative does not entail its being theoretical: the technical sciences are neither strict nor theoretical.[65]

6 The Productivity of Technical Knowledge

The claim that medical theory is needed for doctors to operate was questioned in ancient times. The author of *On Ancient Medicine* argues, most likely in the late fifth century BC, that medical knowledge requires observation and experience rather than principles (*hypotheseis*; cf. Schiefsky 2005, 113)—*On Ancient Medicine* 1.1–3, 9.3, 15.1, and 20.1–2. Diocles of Carystus, a distinguished physician of the fourth century, claims that causal accounts in relation to nutrition and health can be useless (fr. 176 in Eijk 2000, 283–6, esp. 284–5; cf. Frede 1986, 223). By the third century, Empiricists go as far as to claim that doctors need no theories but merely experience (cf. Celsus' *De Medicina, prooemium*, in Spencer 1935, vol. 1, 6–19; cf. Frede 1986, 224–5), presumably on the ground that it is unclear how theories by themselves could be productive.

Interpreters such as Lorenz and Morison (2009) have suggested that Aristotle is sympathetic to the Empiricist's skepticism about the productive value of technical theories.[66] They argue that, for this reason, Aristotle understood

64 Sometimes Aristotle uses 'theoretical' (θεωρητική) more narrowly, to denote the narrower subclass of theoretical sciences that are concerned with what holds of necessity, and thereby excluding the natural sciences (cf. *PA* 1.1 639b30–a9). Menn (2020, 117) claims that in *PA* 1.1 639b30–640a9 Aristotle treats the science of nature as a productive science: we disagree—see n. 96. In the main text, we rely on his broader and common use of 'theoretical' as referring to a science that is ultimately for the sake of contemplation. Note that, in our reading, the category of demonstrative bodies of knowledge includes both theoretical sciences (in the broader sense that includes the sciences of nature) and productive ones. One might worry that this picture undermines the assumption that Aristotle treats the division between theoretical, practical, and productive as his basic scientific taxonomy. However, the tripartition between theoretical, productive, and practical sciences appears in contexts where Aristotle is interested in distinguishing the *goals* of these disciplines. By contrast, the bipartition between demonstrative and non-demonstrative knowledge occurs in contexts where he is interested in demarcating the *form* of bodies of knowledge, i.e. distinguishing more rigorous bodies of knowledge from less rigorous ones. Moreover, although Aristotle does commit to the view that theoretical implies demonstrative (cf. *EN* 6.4), he does not state the reverse claim that demonstrative implies theoretical—precisely because, we suggest, he does not endorse it.

65 Bolton (2021, 152 and 155) suggests that *technai* like medicine involves a 'theoretical scientific component' (*ibid.*, 155). If we are right, there is no need to go this far: for Aristotle, the presence of a demonstrative (i.e. scientific) component does *not* entail being theoretical.

66 Lorenz and Morison (2019, 435) go as far as to claim that 'the medical Empiricist provides a useful way of thinking about Aristotle's conception of doxastic knowledge [i.e., in their

technical knowledge as doxastic—that is, as non-scientific. In this section, we argue that things are the other way round. Not only does Aristotle not anticipate the Empiricists' skepticism about the productive value of scientific theories: he even *relies* on the scientific status of technical knowledge to shed light on the sense in which such knowledge enables artisans to bring about contraries. We first raise two objections to existing accounts of Aristotle's claim that technical knowledge is productive (§6.1). Then we show how our reading solves both problems (§6.2).

6.1 *The Recipe Analogy and Its Problems*

How do current non-scientific accounts of technical knowledge elucidate Aristotle's claim that this knowledge is productive? In the literature, we find the following suggestion: when Aristotle characterizes technical knowledge as productive, he means that it is akin to a recipe, or a list of instructions (Johansen 2017, 125; Fernandez and Mittelmann 2017, 138 and 150 n. 26; Menn 2002, 13–15; Gill 1994, 23). For instance, the technical knowledge associated with the art of building is akin to a set of instructions for building a house. Accordingly, the suggestion continues, technical knowledge is productive because recipes are production-guiding.

We are sympathetic to the claim that technical knowledge is productive in the sense that it guides an artisan's production. But we do not think that Aristotle would accept that such knowledge is recipe-like. There are two main problems with this analogy. A first issue is that the recipe analogy does not preserve Aristotle's claim that technical knowledge is causal-explanatory (cf. §2). Recipes do not guarantee that the artisan appreciates the causal connections that underlie production. Consider the comparison between the master worker and the manual workers in *Metaph.* A.1. Aristotle points out that master workers know the causes of the steps to bring about a product and have an account of the latter, whereas the manual workers that they instruct do not (*Metaph.* A.1 981a31–b6). However, upon being told how to build the house by the master workers, manual workers might learn a recipe for building a house. Their grasp of a recipe need not provide them with an appreciation of the causal account of the product. This is because one might know *that* a given set of instructions yields a house—'lay the foundations and then make the walls, and the

view, technical knowledge]'. We have already given arguments for a scientific (as opposed to doxastic) understanding of technical knowledge in Aristotle §§3–4. See §6 for how this relates to productivity. See also §9.1 for a reply to a related lingering objection.

roof …'—without knowing *why* these are the right instructions for bringing about a house.[67]

A second issue for the recipe analogy is that it does not account for the claim that technical knowledge is of contraries (*Metaph.* Θ.2 1046b8–24; cf. §2 and §6.3). Aristotle states that technical knowledge is precisely what makes *technē* productive of *contraries*. This is because an artisan has the *logos* of the product X as well as, in some sense, the *logos* of the lack of such product in an entity of the same sort—call this lack 'X_{lack}'. For instance, the technical knowledge of health must in some sense be knowledge of lack of health—sickness—as well. Yet it is unclear how understanding technical knowledge in terms of recipes may account for its being productive of contraries. Consider having the instructions for bringing about health. This does not necessarily amount to having the instructions for bringing about sickness. Similarly, one might grasp the instructions for building a house without having the instructions for *destroying* the house. Therefore, understanding of technical knowledge in terms of recipes does not suffice to capture the sense in which it is knowledge of contraries.

Now, when discussing the claim that technical knowledge concerns contraries, Aristotle adds an important qualification. He states: 'the account (*logos*) is of the one [i.e. X] in respect of itself, and of the other [i.e. X_{lack}], in a sense (*tropon tina*) accidentally (*kata sumbebēkos*)' (1046b12–13). The thought is that knowledge of X also implies, indirectly, knowledge of X_{lack}. But why exactly? We suggest that when knowing X one can also grasp X_{lack} through further inferential steps. While first and foremost medical knowledge concerns health, such knowledge also allows one to derivatively infer facts pertaining to lack of health. In this sense, medical knowledge concerns sickness too.

67 In the contemporary rule-following literature, one finds the claim that rule-following and understanding can come apart, so that behaving in such a way to follow a rule does not entail understanding the rule or its relevance in the context of that behavior—cf. Boghossian (1989). Analogously, Johansen (2017, 120–1) understands the epistemic difference between master workers and manual workers by distinguishing between working in accordance to (*kata*) *logos* and working with (*meta*) *logos*—a distinction that Aristotle draws in *EN* 6.13 (at 1144b21–30). Whereas manual workers only work in accordance with *logos*, master workers work with *logos*. We agree that the distinction between working in accordance with *logos* and working with *logos* can be helpful. Yet since technical *logoi* are causal and technical recipes are not, we resist modeling technical *logoi* as recipes. If a manual worker has a recipe (which falls under knowledge-that) they can act *kata logos* but not *meta logos* (where *kata logos* and *meta logos* are understood as in *EN* 6.13 1144b21–30).

Given this account of the sense in which technical knowledge is of contraries, however, proponents of the recipe analogy might argue that our second objection to their reading is too quick. Our objection was that the recipe analogy cannot account for the claim that technical knowledge is of contraries. Yet one might contend that this claim relies on a narrow definition of 'recipe'. If one knows that adding flour thickens besciamella sauce, one might also understand that not adding it will make the sauce too thin. It seems reasonable to assume that this is an implication of knowing the recipe. This suggests that Aristotle's claim that technical accounts concern contraries may simply mean the following: if one knows that X is required for, say, health, then one can infer that removing X will cause lack of health. But then, proponents of the recipe analogy may have a way of accounting for the claim that technical knowledge concerns contraries after all.[68]

We agree with part of this reply. Specifically, we concur that if one knows that X is required for bringing about health, one can infer that removing X will cause sickness (assuming they understand that sickness is the absence of health). But firstly, note that this response brings the recipe account significantly closer to our own, as it presupposes an understanding of technical knowledge as involving the grasp of causal connections and engaging in causal reasoning. Secondly, even with this advancement, it is not obvious how the recipe analogy can explain *why* the artisan knows that removing X will lead to X_{lack}. Thirdly, and importantly, in some cases merely removing X might not be sufficient to bring about X_{lack}. For instance, making someone sick could involve producing poisons that disrupt the body's balance (rather than simply withholding a necessary medicine). It is unclear how the recipe account can explain this production of sickness without adopting a more complex notion of recipe, one that risks collapsing into our account of technical knowledge.[69]

6.2 *Technical Knowledge as Production-Guiding*

An alternative way of thinking about technical knowledge is as a causal account that, while not identical to a recipe, can *generate* a recipe. We will now argue that a demonstrative account of technical knowledge yields precisely this picture. We will then show that on the resulting account Aristotle has the tools to explain his own claim that technical knowledge concerns contraries (§6.3). Given our account, technical knowledge does put artisans both in the position

68 We thank an anonymous reviewer for pointing out this potential reply.

69 In §6.3 we further expand on how our account explains the claim that technical knowledge is of contraries.

to extrapolate instructions for production and to know why these are the right instructions for production.

Not every causal account can be turned into a set of instructions for an artisan. For example, Aristotle tells us that thunder is the quenching of fire in the clouds (*APo*. 2.8 93b8–12, *inter alia*). This is a causal account of thunder that includes reference to the efficient cause of thunder, namely the quenching of fire. However, this account does not yield instructions to artisans. This is because it is not in the power of artisans to start a causal chain that leads to the quenching of fire in the clouds.[70] By contrast, technical accounts specify *particular* kinds of causal paths—artificial causal paths (cf. §5)—which are ultimately within the power of an artisan to initiate. On the basis of her knowledge of these paths, the artisan can extrapolate the relevant instructions for production.

In *Metaph*. Z.7, Aristotle considers the reasoning that a doctor undertakes in order to make a patient healthy:

> (T12) The healthy [patient] comes to be when one thinks (*noēsantos*) in this way. Since health is this (*todi*), necessarily if [the patient] is to be healthy, this must be present—say, a uniform state—and if that, heat. And one keeps thinking in this way, until one gets to a final thing which one can make. Then, from this point onward, the process is called 'making'—the one towards being healthy.
>
> Γίγνεται δὲ τὸ ὑγιὲς νοήσαντος οὕτως· ἐπειδὴ τοδὶ ὑγίεια, ἀνάγκη εἰ ὑγιὲς ἔσται τοδὶ ὑπάρξαι, οἷον ὁμαλότητα, εἰ δὲ τοῦτο, θερμότητα· καὶ οὕτως ἀεὶ νοεῖ, ἕως ἂν ἀγάγῃ εἰς τοῦτο ὃ αὐτὸς δύναται ἔσχατον ποιεῖν, εἶτα ἤδη ἡ ἀπὸ τούτου κίνησις ποίησις καλεῖται, ἡ ἐπὶ τὸ ὑγιαίνειν. (*Metaph*. Z.7 1032b6–10)

According to (T12), there are two stages to the doctor's performance. Stage 1 is at the level of thinking: the doctor thinks through what they need to do to restore the patient's health. In Stage 1, one starts off with thinking about what kind of thing health is and then reasons backwards. Stage 2 is the actual action, or set of actions, that the doctor performs.[71]

70 If Aristotle thought this was in the power of an artisan, the causal account of thunder could be part of a broader causal story that does yield instructions for artificially bringing thunder about.

71 We take the reference to 'this' (*todi*) at 1032b6 and 1032b7 to refer to kinds, rather than particulars.

We assume that the level of deliberations and the level of demonstrations are importantly distinct. A productive deliberation is an activity one undertakes in a particular circumstance that can be associated with a syllogism which specifies what particular action one is to perform in the circumstances, with an aim of bringing about the product (cf. *EN* 3.3 1112a33–b31). Demonstrations, we have argued, model technical knowledge. Technical knowledge is only at the level of universals (cf. §§2–3), whereas the level of deliberation concerns particulars.

For example, a doctor engages in deliberation in order to decide what to do to heal a *particular* patient. Production is about bringing about *particular* products (cf. *Metaph.* A.1 981a16–17).[72] However, productive deliberation cannot be all there is to productive reasoning. Any account of productive reasonings has to secure the claim that it can concern contraries. But a productive deliberation always starts with a particular goal. It is not clear how one can account for the claim that artisans are in a position to produce contraries if all there is to productive reasoning is productive deliberation. The artisan *relies* on knowledge while deliberating. That is, it is partly in virtue of the doctor's knowledge of health that the doctor can deliberate competently about how to cure a particular patient. Similarly, the master worker needs to have general knowledge of houses in order to deliberate well about how to build a particular house.

Technical knowledge is the general knowledge of the product, whereas in deliberation technical knowledge is applied to particular circumstances in order to bring about a particular product. Although deliberations are not the same as demonstrations, the artisan deliberates in particular circumstances *on the basis of* their technical knowledge. Moreover, technical knowledge is exercised in production in particular situations thanks to the deliberative activity of the artisan. While technical knowledge and deliberation are distinct, they are each in need of the other for a *technē* to be exercised in production. Accordingly, we take (T12) to describe the process of deliberation that the doctor undertakes on the basis of their technical knowledge of health (cf. A.1 981a7–20).[73] The doctor's train of thought is deliberative, rather than

72 The importance of deliberation for production has been emphasized by many scholars, including: Moss 2014b; Lorenz and Morison 2019, 444–57; and Coope 2021, 113–14.

73 We will not discuss here exactly how the deliberator moves from technical knowledge to deliberating. We can think of at least two ways in which one may move from the level of demonstration (concerning universals) to the level of deliberation (concerning particulars). As Aimar (n.d.) suggests, Aristotle has the tools for moving from demonstrations at the level of universals to syllogisms at the level of particular by replacing a given term with one denoting a particular that instantiates the relevant universal (one passage

demonstrative. But his deliberative process relies on technical knowledge. One can in fact extrapolate what technical knowledge the doctor relies on in (T12) while deliberating. The relevant piece of technical knowledge can be modeled by means of a demonstration:

Terms	**Health-1 Demonstration**
A: Healthy.	Healthy belongs to uniform state.
B: Uniform state.	Uniform state belongs to hot.
C: Hot.	So,
	Healthy belongs to hot.[74]

A doctor can deliberate that making the patient hot will make them healthy on the basis of their grasp of the technical knowledge modeled by the *Health-1 Demonstration*.

(T12) further suggests that the doctor's deliberation can go on further (1032b8–10). Aristotle goes back to this point soon after:

> (T13) That which makes (*to poioun*) and that whence the process of becoming healthy begins (*archetai*), if it happens by *technē*, is the form that is in the soul: but if it happens spontaneously, then it is from whatever starts the making of the maker from *technē*, just as in healing presumably the starting point [of the process of becoming healthy] is from heating (and this one makes by rubbing).
>
> Τὸ δὴ ποιοῦν καὶ ὅθεν ἄρχεται ἡ κίνησις τοῦ ὑγιαίνειν, ἂν μὲν ἀπὸ τέχνης, τὸ εἶδός ἐστι τὸ ἐν τῇ ψυχῇ, ἐὰν δ'ἀπὸ ταὐτομάτου, ἀπὸ τούτου ὅ ποτε τοῦ ποιεῖν

that supports this view is *APo.* 1.8). One may think that the resulting syllogism with terms denoting particulars is the one resulting from productive deliberation. Alternatively, one might think that deliberation is one more step removed from demonstrations at the level of universals, in that it relies on the corresponding syllogisms with particulars. For an account of deliberation that takes it to culminate in the grasp of a syllogism, see *Mem.* 2 453a16 (cf. Moss 2014a, 212); see also Allen (2015, 53 and 56–8), Price (2011, 200–5), and Broadie (1991, esp. 225–42), *inter alia*. For skepticism, see Cooper (1975).

74 In (T12), Aristotle individuates terms rather sloppily. The demonstration we can extrapolate is however no less precise than others one finds in the *Posterior Analytics* (cf. *APo.* 2.11 94b8–21 for a demonstration of what walking leads to health).

> ἄρχει τῷ ποιοῦντι ἀπὸ τέχνης, ὥσπερ καὶ ἐν τῷ ἰατρεύειν ἴσως ἀπὸ τοῦ θερμαίνειν ἡ ἀρχή (τοῦτο δὲ ποιεῖ τῇ τρίψει). (*Metaph.* Z.7, 1032b21–26)[75]

One may heal either spontaneously or thanks to medicine. As far as healing by medicine goes, this occurs when the doctor produces heat in the patient—say, by rubbing.

The reference to rubbing adds another layer to the thinking that the doctors entertain and allows us to extrapolate a further demonstration which models the sort of knowledge on which the doctor's deliberation relies:

Terms	**Rubbing Demonstration**
A: Healthy.	Healthy belongs to hot.
B: Hot.	Hot belongs to rubbing.
C: Rubbing.	So,
	Healthy belongs to rubbing.

The *Rubbing Demonstration* starts off by assuming that certain kinds of bodies that are sufficiently hot are healthy. It also assumes that these bodies get hot when undergoing a rubbing treatment. From these two premises, it follows that rubbing leads to health in a given type of body.

Note that the *Rubbing Demonstration* has as one of its premises the conclusion of the *Health-1 Demonstration* reconstructed above, namely the claim that 'healthy belongs to hot'. Taken together, the two demonstrations give us a short chain of technical demonstrations, illustrated below.

Healthy belongs to uniform state. Uniform state belongs to hot.

Healthy belongs to hot. Hot belongs to rubbing.

Healthy belongs to rubbing.

75 Primavesi's edition currently reads τὸ instead of τοῦ at 1032b22, following A^b and an Arabic translation and against his edition's tendency to favor E and J. The τοῦ-reading remains supported by α which in turn depends on E and J. We are inclined to prefer it, following Ross (1924, *ad loc.*).

The chain denotes steps in the process of restoring health: rubbing brings about heat, which in turn brings about a uniform state in the body, namely health. This two-step chain of demonstrations tracks an artificial causal path to health. It specifies an artificial cause that the doctor is in a position to bring about—i.e. rubbing—as well as the consequences it gives rise to. This knowledge allows a deliberating doctor to develop prescriptions for bringing about the desired outcome.[76] In this sense, medical knowledge ultimately aims at production. This is what Aristotle has in mind when he describes technical knowledge as productive.

6.3 *Technical Knowledge as Concerning Contraries*

So far, we have seen how technical knowledge guides the production of a given sort of product. We have also seen that Aristotle claims that *technē* is productive of contraries: in virtue of possessing, say, the art of medicine, a doctor can bring about either health or sickness. Since in some sense technical knowledge concerns contraries, it can guide the production of contraries. We have also established that the recipe-view cannot fully account for the claim that technical knowledge is of contraries (§2 and §6.1). The technical knowledge of X must in some sense also be knowledge of the absence of X in something that can be a bearer of X—namely, knowledge of what we called 'X_{lack}' in §6.1. For example, medicine is knowledge of medicine and must also be knowledge of sickness. We are now in a position to address the following question: how exactly can Aristotle vindicate his claim that technical knowledge is of contraries?

This section argues that our demonstrative account of technical knowledge meets this explanatory challenge. In a nutshell, our proposal is the following. *Technai* are for contraries because possessing technical knowledge of a product X entails possessing technical knowledge of the contrary of X, where the contrary is to be understood as the absence of X. More specifically, given that technical knowledge is demonstrative, one is in a position to grasp demonstrations about the contrary X *in virtue of knowing what X is*. Thus here if one knows (in the relevant sense) what X is, and knows that a given Y is the contrary of X (namely, one knows that Y just is X_{lack}, i.e. the absence of X in a given

76 Aristotle models chains of demonstrations for each of the four causes (cf. *APo.* 2.11; see also §5). An account of a house can be modeled in terms of a *formal* chain of demonstrations (on which the middle terms pick up formal causes), a *material* chain of demonstrations, and so on. When producing, the artisan takes into account all the four causes. For instance, they consider which materials to use, what structure to build out of them, that the house is functional enough for its future inhabitants, and what steps to perform.

type of entity), then one is in a position to draw demonstrations not only about X, but also about Y. For instance, if one knows what health is and that sickness is the contrary of health, then one can draw a demonstration about sickness (namely, the absence of health in a patient) as well.

Aristotle points out that technical knowledge concerns contraries in *Metaph.* Θ.2. At 1046b21–22, he tells us that the soul of an artisan 'will change [things] in both ways from the same source, having connected things to the same' (ἄμφω ἀπὸ τῆς αὐτῆς ἀρχῆς κινήσει πρὸς ταὐτὸ συνάψασα). Here we translate ἄμφω with 'in both ways': it refers to the two types of production that the artisan can engage with in virtue of her art: bringing about feature X in what can have X, or removing feature X in what has X. The reference to 'the same thing' (*tauto*) is either a reference to the same account (say, the account of health) or a reference to the type of thing that can acquire or lose X (say, a human being). The line is too quick for us to be able to fully disambiguate it with certainty. But in the *Analytics*, the verb *sunaptō* appears to express how one links certain terms to one another (cf. *APr.* 1.23 41a1 and 19), or how the result of an inference is connected to terms and premises of that inference (cf. *APr.* 2.17 65b33, 2.24 69a19). Elsewhere, it is again used to express how one connects different terms in thought so as to make assertions (cf. *Int.* 12 22a10, *Metaph.* E.4 1027b32). This suggests that the sense in which technical knowledge is for contraries has to do with the fact that in virtue of possessing this knowledge the artisan can make assertions and reason about both of the possible outcomes of production.

We get more details in an overlooked passage of *APo.* 1.13:

> (T14) If the denial is explanatory of something's not holding, then the affirmation is explanatory of its holding (thus if an imbalance of the hot and cold elements explains not being healthy, their balance explains their being healthy); and similarly, if the affirmation explains something's holding, then the denial explains its not holding.
>
> εἰ ἡ ἀπόφασις αἰτία τοῦ μὴ ὑπάρχειν, ἡ κατάφασις τοῦ ὑπάρχειν, ὥσπερ εἰ τὸ ἀσύμμετρα εἶναι τὰ θερμὰ καὶ τὰ ψυχρὰ τοῦ μὴ ὑγιαίνειν, τὸ σύμμετρα εἶναι τοῦ ὑγιαίνειν,—ὁμοίως δὲ καὶ εἰ ἡ κατάφασις τοῦ ὑπάρχειν, ἡ ἀπόφασις τοῦ μὴ ὑπάρχειν. (*APo.* 1.13 78b17–21)

A denial (*apophasis*) is a predicative claim involving a negative copula (as in, 'A does not belong to B'), and an affirmation (*kataphasis*) is a claim with a positive copula (as in, 'A does belong to B'). (T14) presupposes that if 'A holds of B' is true, then 'the lack of A does not hold of B' is also true—and vice versa. Assume that health is a balance of hot and cold elements in the body. If the lack of balance of heat and cold explains why health *does not* belong to a

body, then the balance of heat and cold explains why health *does* belong to a body—and vice versa.

In (T14), Aristotle's example alludes to the following demonstration:

Terms	**Sickness Demonstration**
A: Healthy.	Healthy belongs to balance.
B: Balance (of hot and cold elements).	Balance does not belong to body.
C: Body.	So,
	Healthy does not belong to body.

This is an example of cases in which 'the negation is explanatory of something's not holding' (78b17–18), for the minor premise of this demonstration has a copula involving negation. Now if this demonstration holds, (T14) says, the following demonstration (with the same terms) also holds:

Terms	**Health-2 Demonstration**
A: Healthy.	Healthy belongs to balance.
B: Balance (of hot and cold elements).	Balance belongs to body.
C: Body.	So,
	Healthy belongs to body.

This second demonstration, which we call '*Health-2 Demonstration*', is an example of cases in which the affirmation is explanatory of something holding (78b18). The minor premise of *Health-2 Demonstration* corresponds to the affirmation of the minor premise of the previous *Sickness Demonstration* (i.e., what we obtain by turning the negative copula of that premise into a positive copula). Aristotle says that if one has an explanation (and thus the corresponding demonstration(s)) of why something is not healthy, one can figure out the corresponding positive explanation (and demonstration(s)) of why something is healthy; and vice versa.[77] By negating the major premise of a demonstration of X, one gets a demonstration of the contrary of X.

77 One can also build corresponding demonstrations with the terms 'sick' and 'imbalance'. On the assumption that imbalance is lack of balance and sickness is lack of health, the following principles hold: that 'balance belongs to body just in case imbalance does

We can now see how a doctor who knows how to heal a patient is in a position to figure out how to sicken a patient. Once a doctor grasps the explanation of health captured by the *Health-2 Demonstration* and knows that sickness is the absence of health in a body, she is also in a position to grasp the explanation of sickness that is systematized by the *Sickness Demonstration*. The doctor will also be in a position to know how to either worsen or improve the health condition of a given sort of patient.

Let us illustrate this point with an example. Consider again the case of rubbing discussed above (§6.2). Given the *Rubbing Demonstration*, in order to restore health in a given sort of patient, the doctor needs to bring about heat via rubbing. But suppose our doctor is evil and wants to make the patient sicker. Since being sick is to lack balance of heat and cold, the doctor will be able to figure out that what they need to do to sicken the patient is to make the patient colder. A process that leads to cooling a given type of patient (say, putting the patient under ice) makes that type of patient sicker. It is not difficult to systematize this reasoning by means of demonstrations.[78]

Thus, the underpinning demonstrative structure of explanations clarifies why Aristotle thought that if one knows the cause of X and that Y is the absence of X—X_{lack}—, then one is in a position to reason to the cause of Y as well. The contrary nature of the two products an artisan can bring about, together with the inferential patterns that result from it within a demonstrative structure, entails that an artisan who grasps what a product X is will also grasp what its contrary is. We conclude that understanding technical knowledge as demonstrative puts Aristotle in a position to elucidate his own claim that such knowledge concerns contraries.

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not belong to body', and that 'healthy belongs to body just in case sick does not belong to body'.

78 Since the type of patient to which the *Rubbing Demonstration* (see §6.2) applies is unwell (too cold), one can assume that a warmer condition in the body comes with better health. Here are the *Rubbing Demonstration* and a corresponding demonstration of how to sicken the patient further:

Rubbing Demonstration	*Under-Ice Demonstration.*
Healthy belongs to hot.	Healthy belongs to hot.
Hot belongs to rubbing.	Hot does not belong to putting-under-ice.
So, healthy belongs to rubbing.	So, healthy does not belong to putting-under-ice.

One can also use the terms 'sick' (contrary of 'healthy') and 'cold' (contrary of 'hot'):

Sick-by-Ice Demonstration
Sick belongs to cold.
Cold belongs to putting-under-ice.
So, sick belongs to putting-under-ice.

7 The Flexibility of Artisans

There is a further aspect of *technai* that a theory of technical knowledge should account for. Artisans are *flexible*. That is to say, artisans can adapt their performances to the specific occasion. In order to do so, they must take into account the specifics of the situation they are in: 'Those who act must always consider the circumstances relating to the occasion [*ta pros ton kairon skopein*], as is the case in medicine too and in navigation' (*EN* 2.2 1104a8–10). In fact, artisans can make the finest product depending on the materials at their disposal, even if these materials are unusual or relatively novel: '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; in the same way also for all the other kinds of artisans' (1.10 1101a3–6; cf. *Rh.* 1.1 1355b12–14, *GA* 2.6 743a25). Thanks to their *technē*, artisans are flexible in that they can produce by adapting themselves to different, and possibly novel, contingencies.

We assume that technical accounts must play a key role in explaining the flexibility of artisans.[79] The richness of the demonstrative knowledge of a *technē* partly accounts for this flexibility (cf. *Rh.* 1.1 1355b12–14, *GA* 2.6 744b16–17). This type of knowledge is general, systematic, and causally organized. In virtue of this sort of knowledge, the technician is in a position to subsume novel circumstances under the same sort of causal generalizations. An artisan will know what makes not previously used materials also suitable for building if she appreciates what features of these materials normally used for house-building are conducive to building—say, the fact that they have a certain rigidity and solidity.[80] So for Aristotle there is a sense in which having technical knowledge makes the artisan better at producing than merely having experience: thanks to her technical knowledge, she can bring about the product in a wider range of circumstances.[81]

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79 Johansen (2017, 130–3) and Coope (2021) already point out that technical *logoi* must help to explain the flexibility of artisans. We discuss aspects of Coope's view later in this section.

80 In cognitive psychology, the *Novel Tool Test* studies how subjects expert in performing a task by using a certain tool (e.g. unscrewing a screw using a screwdriver or eating a yogurt with a spoon) can succeed at performing the same sort of task with a novel tool (e.g. unscrewing a screw using a coin or a blade instead of a screwdriver; eating a yogurt using a fork) (cf. Goldenberg 2013). According to many prominent theories, subjects that pass the *Novel Tool Test* do so by generalizing from their knowledge of general causal-functional properties of familiar tools. In this way, one might conclude that any object providing a blade with the same properties as the screwdriver might replace the screwdriver, and that therefore, if necessary, one can also unscrew a screw with a coin or a knife.

81 Alexander of Aphrodisias is incorrect when he says: '*technē* is more honorable than experience, despite the fact that the latter is in no way inferior to *technē* with respect to action

Admittedly, at this point one might still wonder whether the flexibility of *technē* can be *fully* accounted for by a view of technical knowledge as demonstrative. We can think of two main challenges for our account. The first challenge is that flexibility requires taking into account the specifics of the circumstances of production, and will involve taking into account *particulars*. How can technical knowledge explain this ability to take into account particulars if, insofar as it is scientific knowledge, it merely concerns universals? The second challenge was recently raised by Coope (2021). Coope points out that demonstrative knowledge is finite but the flexibility of artisans depends on technical knowledge being indefinitely extendable. If so, technical knowledge cannot be demonstrative after all. In the remainder of this section we discuss this second challenge. (We postpone a discussion of the first challenge to §8.2.)

Coope (2021) emphasizes that artisans need to be able to deal with 'non-ideal' circumstances—circumstances that are exceptions to the rule (*ibid.*, 118 and 123–4). She believes that this is a potential difference from natural sciences, since in the case of natural sciences exceptions to the rule fall outside the scope of scientific explanations (*ibid.*, 123–4). Hence, Coope concludes that while theoretical sciences for Aristotle are finite bodies of knowledge, technical knowledge ought to be indefinitely extendable, if it has to account for the remarkable flexibility of the artisans in the face of non-ideal and exceptional circumstances. It is a short step from here to object to our view. Demonstrative bodies of knowledge are finite. But if technical knowledge is infinitely extendable, it cannot consist of a finite set of demonstrations. Therefore, technical knowledge cannot be demonstrative knowledge.

To set up our response, let us distinguish between two types of cases that are contrary to the rule, i.e. contrary to what happens for the most part (cf. *ibid.*, 122). First, there are *accidental* cases—namely cases that are in fact contrary to *any* true generalization about what holds always or for the most part. Since any explanation is a generalization about what holds always or for the most part, there is no explanation of the accidental (*Metaph.* E.2 1027a19–26; *Ph.* 2.5 197a19–21; cf. *Metaph.* K.8 1065a4–21). Aristotle contends that there are phenomena for which no explanation is to be found and which thereby fall beyond the scope of scientific explanation. Second, there are *exceptional cases*—namely exceptions to *some* for the most part generalization(s). Although exceptions

and may in fact occasionally prove more effective than *technē*; but experience is inferior with respect to knowledge' (*in Aristotelis Metaphysica commentaria* 5.16–24; Dooley's translation, with minor revisions)—*pace* Bolton (2021, 160–2). The explanations afforded by technical knowledge make it in some respect superior to experience, since they put artisans in the position to deal with a greater variety of circumstances.

to one generalization, exceptional cases can at least in principle be subsumed under another generalization.

Coope (2021, 122–4 esp. n. 29) argues that in the case of natural sciences, anything that is an exception to one of the generalizations included in the science counts as an accident (and hence falls outside the scope of the science). Consider a frog that is not fertile during the summer. This is an exception to the generalization that frogs are fertile in the summer. For Coope, these frogs fall beyond the scope of the study of frogs. By contrast, the artisans' flexibility relies on their being able to provide generalizations and explanations for exceptional cases. Thus, a doctor should be able to find a cure for the feverish patient who is allergic to honey-water. Although this patient cannot be cured with honey-water, there are other treatments that can be used to restore their health. So other generalizations of medicine apply to this sort of case. On the assumption that the list of exceptional cases for a *technē* is potentially infinite, Coope concludes that technical knowledge is bound to be indefinitely extendable, whereas scientific knowledge is not.

We agree with Coope (2021) that the flexibility of an artisan puts them in position to successfully produce in exceptional circumstances that are not accidental. But we disagree that natural sciences and *technai* come apart when it comes to explaining these cases. Let us expand on our response. Coope (2021) assumes that in the natural sciences, *if* something is an exception to a generalization, then it is thereby accidental. However, there is reason to think that Aristotle did not endorse such an assumption. In *Metaph*. E.2, in the context of explaining that something, say a spring tide, may accidentally coincide with a new moon, Aristotle says that if one were able to state *when* the thing we thought of as accidental (the spring tide) coincides with a new moon, 'then it will be so on the day of new moon either always or for the most part' (1027a25–26). He leaves open here that if one could predict when spring tides coincide with a new moon, there would be a further scientific explanation of why, under certain conditions, a spring tide coincides with a new moon. In the *Posterior Analytics*, when discussing the theoretical science of astronomy, Aristotle assumes that there is an explanation of why under certain conditions the sun does not cast light on the Earth but is eclipsed (cf. *APo*. 2.8 93a37–b7). The occurrence of an eclipse is an exception to the claim that 'for the most part the Sun casts light on the Earth'. But this claim is not accidental, since it describes a fact that is scientifically explicable. Thus, within the theoretical sciences, there can be cases that qualify as exceptions relative to one FMP-claim, but nevertheless fall within the scope of another FMP-claim. We suggest that this holds for theoretical sciences in general. In this respect, the theoretical sciences are on a par with the technical sciences.

The fact that a theoretical science explains *some* exceptional cases does *not* entail that it is indefinitely extendable. Rather, a theoretical scientist who comes up with a new explanation of a certain exceptional natural phenomenon is adding an explanation to a body of knowledge that is in principle complete, but currently incomplete. We suggest that the same holds for *technai*. An artisan who comes up with new explanations is adding explanations to a body of knowledge that is only *currently* incomplete.[82] For example, when a doctor comes up with new generalizations concerning patients allergic to honey-water, they are adding an explanation to medicine. This does not undermine the view that medicine is in principle complete.[83]

We nonetheless agree with Coope that there is an important sense in which *technē* is extendable but sciences of nature are not. Humans can always come up with new kinds of artifacts. By contrast, on a standard reading of Aristotle's biology, the same is not true of natural kinds. For example, houses can be built in ways that were not available before, as new materials and techniques and even new kinds of houses are introduced. If this is correct, there is a sense in which the art of building is extendable in virtue of the subject matter: any time a new viable type of house is conceived of, there will be new explanations concerning how to build that type of house. By contrast, if new types of natural kinds cannot be generated, the science of nature cannot be extendable in this sense. So there seems to be an important difference between the bodies of knowledge that concern these two sorts of kinds: technical knowledge is always in some sense extendable, whereas natural bodies of explanations are not.

This difference between technical knowledge and theoretical sciences does not entail that the technical bodies of knowledge are not sciences. When new artifacts or methods of production get invented, a new but complete set of explanations comes to light. Suppose one creates a new type of house with a different kind of material or with a new type of foundations. Then we have

82 As far as we are aware, Aristotle never claims that technical knowledge is infinitely extendable. The fact that he uses examples of *technai* in the *Posterior Analytics* (see §4) corroborates the view that he took a complete body of technical knowledge to be finite, just as he does for any other body of scientific knowledge. There is also reason to think that Aristotle thought that a technical body of knowledge can be incomplete at a given point in time. He talks of the recurrent redevelopment of *technai* in *De Philosophia*, in connection with the fact that civilizations are periodically destroyed by cataclysms (Chroust 1973; cf. *Metaph*. Λ.8 1074b10–13).

83 For instance, in Aristotle's time the nature of the rainbow was hotly debated. Aristotle is presumably aware of this and picks one explanation thereof in some passages; the fact that the explanation is contentious does not make him doubt that the study of the rainbow is not a finite body of knowledge; he uses it as an example of a science at *APo*. 1.13 79a11.

new causal paths to the production of houses. These can be modeled in terms of a finite set of explanations that get added to the science of house-building. In this sense, one can extend the *technē* of house-building. But the extension is an addition of a finite set of explanations to an already finite set of explanations. As a result, at any point in time the science of house-building, or any other technical science, consists of a finite set of explanations—as Aristotle's theory of science requires.[84] Even if novel kinds of products can always be generated and even if in this sense the relevant *technē* can be extended, this hardly undermines the claim that the corresponding bodies of technical knowledge qualify as Aristotelian sciences.[85]

8 *Technē* vs *epistēmē* in the *Nicomachean Ethics*

Let us take stock. We have made the case for the view that technical knowledge is demonstrative. We have also shown how this account sheds light on Aristotle's claim that technical knowledge is productive of contraries and on the flexibility of artisans. It is now time to consider how our view fits with

84 This is in line with Aristotle's notion of the infinite as merely potential: the numbers are potentially infinite in that one can always add one more number to the series; but the series is never actually infinite. Similarly, if Aristotle thinks of the set of artifacts as potentially infinite, the sciences concerning these artifacts can still be thought of as containing finite sets of explanation at any given historical point.

85 One might worry that an important disanalogy between *technai* and natural sciences still holds: while *technē* figures out different possible paths to a certain product (given the circumstances), natural sciences provide only one path to a certain outcome, for a given species. For example, rubbing is only one of the possible ways in which a doctor brings about heat in a given patient. By contrast, a given species of plants can only grow in accordance with a unique path of development. *If* this is correct, one might ask whether this difference is reflected in two quite different sorts of demonstrations, for *technē* and for the sciences respectively. However, this alleged difference might not stand closer scrutiny. There are several ways in which a plant can develop and grow, just as there are several ways in which a patient may recover. Even a given species of plant can achieve full growth in different ways: in dry weather by absorbing a lot of water at once and in more humid weather by doing so more gradually. Similarly, a given animal can reach their nest in different ways: flying or jumping from one branch to another. Which option gets utilized might depend on the circumstances (e.g. whether there are predators in the sky or not). The same goes for *technai*. The doctor reasons that for a given type of patient rubbing is the best way to achieve the goal, and for another patient (one whose skin is over-sensitive to rubbing) contact with hot stones might be a preferable option. The presence of different causal paths is allowed within a finite body of demonstrative knowledge: they can be modeled in terms of different chains of demonstrations each leading to the same type of outcome.

the discussion of *technē* in the *Nicomachean Ethics*. As is well known, Aristotle contrasts *technē* with *epistēmē* in *EN* 6.1–6. He suggests there that *technē*, unlike *epistēmē*, concerns what can be otherwise and is in this respect parallel to *phronēsis*.

This section argues that in *EN* 6.1–6 Aristotle does *not* reject the view that technical knowledge is demonstrative. The gist of our reading of *EN* 6.1–6 is as follows. In order to find common ground with his Platonist interlocutors, in *EN* 6.1–6 Aristotle uses *epistēmē* in a narrow sense, according to which only *strict sciences* count as sciences. Hence, when contrasting there *technē* with *epistēmē*, he merely rejects the claim that technical knowledge is a *strict* science, without ruling out that technical knowledge is demonstrative (§8.1). Against what is often assumed, the fact that *technai* concern what is contingent does not undermine the scientific status of technical knowledge (§8.2). Nor does it invalidate the analogies that Aristotle draws between *technē* and *phronēsis* (§8.3).

8.1 Epistēmē *as Strict Science in* Nicomachean Ethics *6.1–6*

EN 6.1–6 discusses the excellence of the intellectual virtues, namely 'practical wisdom' (*phronēsis*). Aristotle begins by reminding his audience that the soul can be divided into a rational part and a non-rational part (*EN* 6.1 1139a3–5; cf. 1.13 1102b13–1103a3 and 5.11 1138b8–9). He then goes on to further divide the rational part of the soul into a scientific part (*to epistēmonikon*, *EN* 6.1 1139a12) and a calculative part (*to logistikon*, 1139a14–15). The scientific part is responsible for reflecting on 'the sort of things whose principles cannot be otherwise' (1139a6–8). The calculative part is responsible for reflecting on things that can be otherwise (1139a8, 12–14). Later on, Aristotle adds that what holds of necessity falls under the scope of scientific knowledge (*epistēmē*, *EN* 6.3 1139b19–23). By contrast, *technē* and *phronēsis* are concerned with what is contingent (*EN* 6.4 1140a1–2, 10–13, 20–23, 6.5 1140a35–b4).

On the basis of these passages, there might seem to be an important reason to think that technical knowledge *cannot* be demonstrative. *EN* 6.3 clarifies that the notion of *epistēmē* in play here has been expounded on in the *Analytics* (1139b32–33). The chapter also explicitly associates *epistēmē* with demonstrations, which in turn are described as merely concerned with what holds of necessity (1139b31–33; cf. 6.5 1140a33–35, 6.6 1140b31–1141a1). Thus, in this context *epistēmē* is demonstrative knowledge of what holds of necessity. Since *technē* concerns what can be otherwise, here Aristotle seems to rule out that technical knowledge is demonstrative (cf. 6.4 1140a10–16). Because of this, authors generally argue that productive knowledge is not demonstrative

knowledge, nor does it involve a straightforward grasp of the essence of a product.[86] Call this the '*standard reading*' of *EN* 6.1–6.

The standard reading crucially assumes that for Aristotle scientific knowledge always has to satisfy the necessity-requirement (cf. §4). However, as we have seen, in *APo.* 1.30 Aristotle expands his notion of demonstrations so as to allow for premises about what holds for the most part. We have also seen that for Aristotle FMP-claims are a type of contingent claim (cf. *APr.* 1.13 32b4–13, cited as (T4) in §3). The expansion of the notion of demonstration and *epistēmē* so as to allow for sciences that include FMP-claims is meant to make room for demonstrative knowledge in the realm of what can be otherwise: both natural sciences and *technai* look to this domain. The expansion also allows us to make sense of Aristotle's claim that *technai* involve grasping the essence of products (cf. §2 and §4). These considerations are part of what motivates us in developing an alternative reading of *EN* 6.1–6 that is consistent with what Aristotle told us about demonstrations and technical knowledge in the *Posterior Analytics*.

Let us begin by looking at the broader philosophical context of *EN* 6. Aristotle here aims at establishing what practical wisdom is. In doing so, he refutes two Plato-inspired models of practical wisdom. The central books of Plato's *Republic* (esp. Books 5–7) are suggestive of a view according to which the peak of practical wisdom consists of contemplating the Form of the Good. We thus get a model on which practical wisdom amounts to *epistēmē* (*phronēsis*-as-*epistēmē* model). Now, Book 1 of the *Republic* can also inspire a *further* model of practical wisdom. There, starting from 332c, Socrates strives to develop a picture in which justice is due to *technē*. If justice is thought of as bound up with practical knowledge, it is a short step to suggest that practical wisdom is a *technē* (*phronēsis*-as-*technē* model).[87] In *EN* 6, Aristotle distances himself from both of these models.

Aristotle thinks that the two Platonist models fail to guarantee that *phronēsis* is *practical*. If *phronēsis* were *epistēmē*, it would be theoretical (and what is theoretical is not practical). If it were a *technē*, it would be productive (but only actions here qualify as practical and, Aristotle is assuming, they are not productions). Therefore, practical wisdom must be neither *technē* (cf. 6.5 1140b24–25) nor *epistēmē* (cf. 6.13 1144b28–30), but in fact something else altogether (cf. 6.9 1142b31–33, 6.10 1142b34–1143a10 and 6.13 1144b26–30). Given the

86 For a very clear example of this reasoning, see Lorenz and Morison (2019, 432, 439–47, 453).

87 For an account of the model, see Barney 2021.

dialectic with the Platonist, we read Aristotle as understanding *epistēmē* narrowly, in the sense of strict scientific knowledge:

> (T15) For we all presuppose that what we know scientifically cannot be otherwise. Whenever the things that can be otherwise have fallen outside our observation, it escapes us whether they are or not the case. Therefore, the object of knowledge is of necessity. Hence, it is eternal. For things that are of necessity in the unqualified sense are all eternal, and things that are eternal are ungenerated and imperishable.
>
> Πάντες γὰρ ὑπολαμβάνομεν, ὃ ἐπιστάμεθα, μηδ'ἐνδέχεσθαι ἄλλως ἔχειν· τὰ δ'ἐνδεχόμενα ἄλλως, ὅταν ἔξω τοῦ θεωρεῖν γένηται, λανθάνει εἰ ἔστιν ἢ μή. ἐξ ἀνάγκης ἄρα ἐστὶ τὸ ἐπιστητόν. ἀίδιον ἄρα· τὰ γὰρ ἐξ ἀνάγκης ὄντα ἁπλῶς πάντα ἀίδια, τὰ δ'ἀίδια ἀγένητα καὶ ἄφθαρτα. (*EN* 6.3 1139b19–24)

What is known scientifically, we are told, holds of necessity (1139b19–23). The object of scientific knowledge (*to epistēton*, 1139b23) is eternal, ungenerated, and imperishable (1139b24). Aristotle shortly afterwards refers to objects of this sort as universals (1139b29). Therefore, here, *epistēmē* exclusively concerns necessary truths about universals.

We read (T15) as setting up common ground with the Platonists, who inspired the accounts of practical wisdom that Aristotle means to reject.[88] The very opening of (T15) confirms this reading: 'For we *all* presuppose that what is known scientifically cannot be otherwise' (1139b19–21, emphasis added). We take the reference to 'all' here to pick up on a group that includes both Aristotle and his interlocutors. The group is presumably that of the Platonist interlocutors in the Academy. The use of the verb in the first-person plural (*hupolambanomen*, 'we presuppose'; 1139b20) confirms that Aristotle is including himself in this group and is therefore, in this argumentative context, willing to assume aspects of the Platonist picture of *epistēmē*.[89]

The subsequent references to necessity, eternality, and imperishability (1139b23–24) further echo Platonistic assumptions. The Platonist that Aristotle

88 Anagnostopoulos (1994, 282–3) also emphasizes the importance of reading the chapter in the light of its dialectic, but takes Aristotle's opponent to be just Plato, as opposed to a broader group of Platonists. *Ditto* for Gauthier and Jolif (1970, II.2 451).

89 Moreover, this verb in Aristotle often signals an appeal to common assumptions—cf. *Metaph.* A.1 981a26, b19, and b29 for parallel uses of this verb. See also Cambiano (2012, 23–4).

envisages is someone who takes truths about Forms to be necessary truths. The Forms are eternal in the sense that they fail to come into being or pass away. By contrast, the realm of change, or appearances, involves contingent truths whose grasp is a matter of mere belief (*doxa*), and cannot be the subject of scientific knowledge.[90] (T15)'s second sentence precisely refers to the instability of our grasp of what can be otherwise: 'Whenever the things that can be otherwise have fallen outside our observation, it escapes us whether they are or not the case' (1139b21–22). This line picks up on the Platonic theme of the instability of our grasp of what holds contingently. Overall, then, (T15) tells us that here Aristotle is assuming the view that *epistēmē* concerns the grasping of claims that are about universals and true of necessity, for the sake of setting up common ground with the Platonists.[91]

Immediately after (T15), Aristotle moves on to explain how this Platonist notion of *epistēmē* translates into his own philosophical framework. It is here that he states that *epistēmē* has further features that one can find elucidated in the *Analytics* and characterizes *epistēmē* as a 'soul's disposition to demonstrate' (*hexis apodeiktikē*, 1139b31–32). The picture is indeed one that is familiar to us from the opening moves of the *Posterior Analytics* (esp. *APo*. 1.2): *epistēmē* is a disposition to grasp necessary truths which we derive from the principles of a given science, via demonstrations. Thus, *EN* 6.3 tells us that the Platonist notion of *epistēmē* corresponds to Aristotle's notion of a demonstrative state of the soul concerned with claims that are true of necessity.

We take Aristotle to endorse the view that any type of scientific knowledge is a disposition to demonstrate. However, within *EN* 6.3, Aristotle only focuses on *strict scientific knowledge*, because as we have seen he is setting up common ground with the Platonist. We have also seen that strict scientific knowledge satisfies both the demonstrative-requirement *and* the necessity-requirement (cf. §4). The fact that Aristotle is here addressing Platonist interlocutors explains why he merely focuses on demonstrations concerned with things that hold of necessity and makes no room for the notion of demonstrations that

90 For Plato's contrast between *doxa* and *epistēmē* in his *Republic*, see 473c11–480a13. Fine (1978; 1990) argues that Plato does not explicitly confine *epistēmē* to Forms, but in fact endorses the weaker claim that a grasp of Forms is required for *epistēmē*. Either way, Aristotle interprets the Platonists as assuming that scientific knowledge only concerns what holds of necessity.

91 Later in the same book, when the dialectic with the Platonist is less salient for his immediate argumentative purposes, Aristotle broadens his notion of *epistēmē* and gives both medicine (a non-strict science) and geometry (a strict science) as examples of sciences (*epistēmai*, *EN* 6.10 1143a3–4; cf. 6.7 1141a9–16).

allows for FMP-demonstrations.[92] He thereby tells us how the Platonist notion of *epistēmē* translates into his own framework: what the Platonist considers *epistēmē*, Aristotle considers a demonstrative disposition, where the relevant demonstrations only contain claims that are true of necessity.

An implication of our reading is that in these lines the sciences of nature do *not* qualify as *epistēmai*.[93] Here is textual support for this claim:

> (T16) For *technē* is not concerned with things that either are or come to be by necessity, nor with things that are or come to be by nature, since these have their source [of change] in themselves.
>
> οὔτε γὰρ τῶν ἐξ ἀνάγκης ὄντων ἢ γινομένων ἡ τέχνη ἐστίν, οὔτε τῶν κατὰ φύσιν· ἐν αὑτοῖς γὰρ ἔχουσι ταῦτα τὴν ἀρχήν. (*EN* 6.4 1140a14–16)

After clarifying that *technē* does not concern what holds of necessity, Aristotle adds that *technē* also does not concern what is or comes about by nature.[94] We are in a context where *epistēmē* concerns what holds of necessity. So if the natural sciences were to qualify as *epistēmai*, their subject matter would have to hold of necessity. But this would mean that Aristotle's reference to what

92 For interpretations of *EN* 6.1–6 that are close to ours but mostly offered in the context of discussing whether there is a science of ethics, see Reeve (1992, 16–17; and 2013, 128–9) and Anagnostopoulos (1994, esp. 282). These authors do not expand on how *epistēmē* and *technē* interact in *EN* 6.1–6.

93 For the opposite claim, that in *EN* 6.3 Aristotle's use of *epistēmē* also denotes the sciences of nature, see Zabarella (1608, 3c–5a), Broadie and Rowe (2002, 361), Lorenz and Morison (2019, 439), and Coope (2021, 109), *inter alia*. Such a reading can countenance the sciences of nature among *epistēmai* only on the assumption that all the FMP-claims of the natural sciences are true of necessity (unlike those of the technical bodies of knowledge). The resulting asymmetry between the FMP-claims of the sciences of nature and the ones of *technai prima facie* clashes with the many passages in which Aristotle appears to treat these two classes of claims on a par (cf. §§4–5). The reading also gives rise to further difficulties: on one version of the resulting view, a claim such as 'sheep have four legs' is both true of necessity and yet allows for exceptions; yet it is not clear that Aristotle would endorse a position of this sort (see Barnes 2009 for further discussion).

94 One may wonder whether here the second οὔτε at 1140a15 specifies a subclass of the case introduced by the first οὔτε, thereby including what changes by nature under the heading of what holds by necessity (we thank a helpful editor for raising this point). Yet Aristotle predominantly uses οὔτε … οὔτε to introduce mutually exclusive classes. Moreover, he consistently treats what changes by nature as pertaining to the realm of contingency—as does his Platonist interlocutor. Note also that in (T4) Aristotle contrasts what holds of necessity with what holds contingently: there his example of a contingent claim concerning what holds for the most part is that of a natural change (the fact that a man's hair turns gray).

happens by nature in (T16) is redundant. The standard reading yields precisely this redundancy.

On our reading, (T16) is not redundant. Instead, it clarifies what type of contingent things fall under the scope of *technē*. Aristotle tells us that *technē* is not concerned with things that are by necessity because it focuses on the realm of contingency. But within such a realm, *technē* is not concerned with things that come about by nature. Even though natural things fall into the realm of contingency (like artifacts), they have their sources of change in themselves (unlike artifacts). The objects of natural sciences are entities that exist contingently and come to be and can undergo change thanks to an internal source of change, namely their nature. *Technē* concerns instead contingent objects that do *not* have an internal principle of change, namely the entities that Aristotle classifies as artifacts (cf. §5).[95] So in (T16) Aristotle excludes both what holds of necessity and what changes by nature as the subject matter of *technai*. In the content of *EN* VI, natural sciences do not fall under the strict notion of *epistēmē*. This is why there, after saying that *technē* is not (a strict) *epistēmē*, Aristotle has to add that *technē* does not concern what changes by nature. In this way he negatively carves out the subject matter of *technai*. They concern what belongs to the realm of contingency but is not due to nature.

Further support for our reading of (T16) comes from *PA* 1.1 639b30–640a9, where Aristotle also uses 'theoretical science' in a narrow sense that rules out the sciences of nature (see esp. 640a1–5).[96] The context is that of explaining the method of biology. Interestingly, there too Aristotle is in dialogue with the Platonist. He justifies the exclusion of natural sciences from the class of theoretical sciences by saying that theoretical sciences draw inferences from what is, whereas the natural sciences draw inferences from what is going to be, and what must be for it to come about (*ibid.*). What is of relevance for our purposes is that here too Aristotle assumes that the theoretical sciences do not concern

95 We discuss the relation between contingency of artifacts and technical knowledge in more depth in §9.2.

96 For a discussion of an alternative reading of 'theoretical science' in *PA* 1.1 639b30–640a9, see Anagnostopoulos (1994, 120, 289 n. 4), Lloyd (1996) and Lennox (2001a, 129–31). As these authors point out, one can either take Aristotle to contrast the science of nature with *technē* or to contrast it with sciences like mathematics. We favor the second option, together with Balme (1992, 84), Greene (1985, 9–13), Lennox (2001a, 128–31), and Menn (2020, 116–17)—*contra* Ogle (1882, 142), Düring (1961, 215), and Pellegrin (1986, 131–3). Note that given the narrow sense of the expression 'theoretical science' in play in *PA* 1.1, the fact that there Aristotle excludes the natural sciences from the domain of theoretical sciences does *not* imply that they are productive sciences (*pace* Menn 2020, 117): it only implies that they are not strict sciences.

what comes into being (or goes away). This is in line with (T16), where Aristotle describes *epistēmē* as not concerned with what comes into being. Overall, the Platonist takes all of *epistēmē* (in the sense of scientific knowledge) to be theoretical and to concern things that are eternal and unchanging. The notion of theoretical science in play in *PA* 1.1 639b30–640a9 is plausibly equivalent to the notion of *epistēmē* of *EN* 6.1–6: this is what for the Platonist counts as scientific knowledge and what, within Aristotle's framework, amounts to strict science.

We conclude that (T16) supports our reading of *epistēmē* in *EN* 6.1–6 as excluding all the bodies of knowledge that include FMP-claims. These are not only technical bodies of knowledge but also the natural sciences. As a result, the passage provides further reasons to think that in *EN* 6.1–6 Aristotle uses *epistēmē* exclusively in connection with strict sciences. And if this is correct, *EN* 6.1–6 does not imply that technical knowledge is not demonstrative—*pace* the standard reading.

8.2 Technē *Attends to Contingent Particulars*

A positive way of carving out the subject matter of *technē* is to say that it is about objects that are contingent and come to be in virtue of human agency. Just like *phronēsis*, *technai* concern the domain of actions, which depend on human deliberation. It is no surprise then that these chapters emphasize how in producing and in acting we deliberate about what to do. This connection with deliberation gives grounds to the following concern: since *EN* 6.1–6 shows that *technē* is essentially linked with deliberation, it supports the view that technical knowledge is ultimately *not* demonstrative. For deliberation and demonstration are different. This subsection addresses this challenge.

On our reading, *EN* 6.1–6 does *not* provide sufficient grounds for denying that technical demonstrations are parts of *technai*. It is important to keep in mind once again that Aristotle is here in dialogue with the Platonists. The very expression 'calculative part of the soul' (*to logistikon*) is Platonic: Plato uses it to denote the part of the soul ultimately responsible for political reasoning (cf. *Republic* 4 439c5).[97] With the claim that 'to calculate and to deliberate are the same' (*EN* 6.1 1139a11–12), Aristotle tells us how to translate Plato's terminology into his own. From his perspective, Plato called 'calculation' what he calls 'deliberation'. Secondly, as we saw in §8.1, what the Platonist calls *epistēmē* for Aristotle is strict science. The Platonist's narrow notion of *epistēmē* in play in this context leaves no room for a discussion of non-strict sciences.

97 For a thorough discussion of Plato's division of the soul, see Kamtekar (2017, ch. 4, esp. 135–8, and ch. 5), and Lorenz (2006), *inter alia*.

Our reading of *EN* 6.1–6 implies that discussing the epistemic status of technical knowledge is not one of Aristotle's goals in the chapter. In the first part of *EN* 6, he focuses on denying that *phronesis* is *epistēmē*. It is in this context that he looks at deliberation: for deliberating involves looking at particulars that hold contingently. Aristotle there makes no commitment about the status of technical knowledge other than denying that it is strict science. Instead, in *EN* 6.2, he states that 'thought by itself sets nothing in motion' (1139a35–36). He then points out how only thought that is practical (*praktikē*, 1139a36) can set things in motion, and then further extends the latter point to productive (*poiētikē*, 1139b1) thought as well. Overall, here Aristotle has in mind deliberative reasoning (cf. also 6.1 1139a12–14). But this does not rule out that technical knowledge is demonstrative. On the contrary, here Aristotle explicitly makes room for a level of thinking that qualifies as productive but is *distinct* from deliberation.[98] Our contention is that this non-deliberative level of thinking is demonstrative in the way that pertains to non-strict sciences.

But how can *technē* concern particulars, if technical knowledge is demonstrative? We know from the *Metaphysics* that a doctor 'does not cure a man, except in an incidental way, but Callias or Socrates or some other called by some such individual name, who happens to be a man' (*Metaph.* A.1 981a17–20; cf. also 981a20–24 and *EN* 6.7 1141b18–1141b21). Passages like this one seem to suggest that when it comes to production the relevance of universals is at best contingent. The manner of an artisan's production and the sort of productive deliberation that this requires will be dependent on what works best to bring about a goal in particular circumstances.[99] One might worry that our ascribing the status of non-strict science to technical knowledge still conflicts with his overall emphasis on the fact that artisans have to attend to particulars when producing.

The question of the applicability of *technai* is paramount for understanding their *modus operandi*. But it is important to note that it is a question that arises for *any* view of *technē* which takes technical knowledge to concern universals (cf. Coope 2021, Johansen 2017, Moss 2014a and 2014b), independently of whether this knowledge is thought of as demonstrative or not. As some scholars have pointed out, moreover, technical knowledge does not lead one to

98 In *Ph.* 2.8, one finds the claim that '*technē* too does not deliberate' (199b28). Aristotle is not saying that artisans do not engage in deliberation. Rather, he is identifying *technē* with the form of the product in the mind of the artisan, just as he does in *Metaph.* Z.7 1032b5–14, *inter alia* (cf. Sedley 2007, 179–81). For a different reading, see Broadie 1990; Broadie now leans towards Sedley's reading—private conversations.

99 The point that the particular is the goal of *technai* is well made by Moss (2014a, 217 n. 44).

production *alone*.[100] That is why one cannot become a good doctor from medical textbooks alone (*EN* 10.9 1181b2–6). To bring about health, a doctor additionally needs experience (*empeiria*, cf. 1181b5). The less experience the higher the chances the doctor will fail to cure the patient (*Metaph.* A.1 981a20–24). This is what enables her to apply technical knowledge to particular circumstances, subsuming the particular circumstances under more general knowledge.

Specifically, the role of experience comes into play both when the artisan acquires a *technē* through practice and when they deliberate about producing a particular product. For deliberation specifies what particular action one is to perform in the circumstances (cf. *EN* 3.3 1112b31–33, 6.7 1141b9–21). General knowledge is nonetheless relevant when deliberating. In order to best deliberate how to cure Callias, the doctor relies on general knowledge about what cures the kind of illness that Callias has. But they must also be able to recognize that illness in Callias. For that, one needs to have the experience that allows one to detect the symptoms Callias has. When deliberating, the artisan relies *both* on general knowledge *and* on her grasp of the particular situation through experience.[101] Given that artisans do not merely rely on technical knowledge when producing, they are in a position to attend to particulars even if technical knowledge concerns universals.

8.3 Technē *and* phronēsis

One possible further concern with our interpretation is that it might seem to do little with the many similarities stressed by the *Nicomachean Ethics* between *technē* and *phronēsis* (cf. Angier 2010). If *phronēsis* involves no scientific knowledge and *technē* is analogous to *phronēsis*, there may seem reason to think that technical knowledge is not scientific.

To settle this issue, what needs to be clarified are the respects in which *technē* and *phronēsis* are analogous in *EN* 6. First, *technē* and *phronēsis* both have goals that are different from contemplation: productions in one case, good actions in the other case. Second, *empeiria* plays a crucial role in acquiring both *technē* and *phronēsis*. In both cases, as we have seen, exercising *technē* and *phronēsis* requires deliberation in order to figure out what to do in particular situations.[102] Nothing about these similarities rules out that the knowledge

100 Johansen (2017, 132).

101 This point is compatible with two pictures of *technē*: (i) one on which experience is a constitutive *part* of *technē*, together with technical knowledge; and (ii) one on which experience is a necessary condition for the exercise of *technē*, namely production. In this paper, we leave open which of these two pictures Aristotle subscribes to.

102 See Angier (2010) on the analogies between *technē* and of *phronēsis*. Among other things, Angier emphasizes the parallels in the acquisition process for both *technē* and of

element of *technē* is a demonstrative one.[103] The reason is that, as we have seen in the last section, these similarities are due to the role that *empeiria* plays in relation to both *technē* and *phronēsis*. Thus, the fact that Aristotle acknowledges similarities between *technē* and *phronēsis* in *EN* 6.1–6 does not suffice to conclude that technical knowledge is not scientific.

One might further wonder whether our argument for the demonstrative nature of technical knowledge also extends to practical knowledge—the component of *phronēsis* concerned with universals. Possibly. We have not settled whether *phronēsis* might also involve a demonstrative element. Aristotle's claim that *phronēsis* is also concerned with the particular (6.7 1141b9–21) does not exclude the possibility that the component concerned with universals might also allow for a scientific structure (cf. Reeve 1992, Anagnostopoulos 1994, and Irwin 2000). We shall leave open whether a parallel version of our argument about technical knowledge can be run for practical knowledge. Our point here is that the analogies between *technē* and *phronēsis* in *EN* 6.1–6 do not detract from the scientific status of technical knowledge.

9 Objections and Replies

We conclude by considering two potential objections to our account of technical knowledge.

9.1 *The Objection from Relevance*

It is one thing to claim that scientific knowledge is relevant for a *technē*, but another to claim that technical knowledge must consist of demonstrations. For example, the knowledge from the natural science of dogs will for Aristotle consist in demonstrations, and surely be relevant to the vet, in the practice of their *technē*. One might protest that even if Aristotle allows that there are technical demonstrations, these are *merely* relevant to a given *technē*. Why think that technical knowledge ought to *consist* of demonstrations?

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phronēsis, the role of deliberation in both production and action (*ibid.*, 54–8 and 107–25), as well as the *importance* of a *technē*-shaped conception of *ergon* in Aristotle's function argument (*EN* 1.7 1097b22–1098a20). The parallels between *technē* and *phronēsis* are important, but do not invalidate a scientific conception of technical knowledge.

103 Our picture does not settle whether the knowledge-element of *technē* is the only component of *technē* or not: *empeiria* might be an extrinsic but necessary condition to the acquisition and exercise of a *technē* or might be an intrinsic component of *technē* (cf. n. 9). For further discussion, see Dunne (2021).

In addition to providing textual evidence, we have given philosophical motivations for the claim that for Aristotle technical knowledge consists of demonstrations. We have shown how this reading affords him an explanation of the claim that *technē* is of contraries (§6.2), as well as an account of the flexibility and reliability of artisans (§7). However, the objection that our view makes technical knowledge too demanding for artisans is important to consider. In the context of distinguishing *technē* from *epistēmē*, Aristotle tells us that *epistēmē* is 'a disposition to demonstrate' (*hexis apodeiktikē*, *EN* 6.3 1139b31–32; cf. §8.1). Within the same context, he also tells us that having a *technē* is a different sort of disposition, namely a disposition to produce things in accordance with a true account (*hexis meta logou alēthous poiētikē*, 6.4 1140a10, 1140a20–21). It is not clear then why artisans would *also* need to have a disposition to demonstrate. After all, the logical competence that pertains to mastering demonstrations is not obviously something that any artisan *qua* artisan needs to have.

To address this, we need to consider Aristotle's claim that science is a disposition to demonstrate (henceforth, SDD) more closely. As we have seen, in the context of *EN* 6.1–6 Aristotle uses *epistēmē* in the narrow sense of strict science (§8). Nonetheless, it seems plausible that non-strict sciences are also dispositions to demonstrate. Now what does it mean to say that a (strict or non-strict) science is a disposition to demonstrate?

On a strong reading of SDD, scientific knowledge is *a disposition to spell out the scientific demonstrations in terms of which a scientific body of knowledge can be systematized*. But as it has been pointed out in the context of discussing strict sciences, SDD cannot be taken to say that to be a scientist just is to write down demonstrations.[104] Plausibly, one could be a scientist even if one were not aware of how to axiomatize a science in the very exact way described in the *Posterior Analytics*. Thus, the most plausible reading of SDD is that a scientist *who also grasps Aristotle's theory of demonstrations* is able to spell out demonstrations. Given our account of technical knowledge, this claim can be true of artisans too. If an artisan were fluent in Aristotle's theory of demonstration, they would be able to extrapolate demonstrations out of the explanations that they possess about the product.

104 There is a parallel discussion of this point in connection with the sciences of nature. Given the worry that the natural treatises do not obviously conform to the *Posterior Analytics*, Lennox (1987, 118–19; 2001b; 2021) and Gotthelf (1987, 194–6) argue that the *Posterior Analytics* does not establish how treatises of natural science must be written or natural truths be first discovered, but rather lays out the underlying formal structure of scientific knowledge: thus the practices of natural scientists (and in fact of any scientist) may rely on argumentative expositions that are not explicit series of demonstrations.

Thus understood, SDD boils down to the claim that a scientist possesses a body of knowledge that can in principle be systematized in terms of demonstrations. So, if one possesses appropriate explanations of X, then one possesses demonstrative knowledge of X. This way of understanding SDD aligns with our view, as the artisan plausibly possesses the disposition to offer explanations that can be systematized through demonstrations. Indeed, Aristotle makes clear that it is in virtue of possessing explanations about the product that the artisan is able to teach their *technē* (*EE* 1.8 1218b17–22; *Metaph*. E.2 1027a20–22, *Top*. 6.4 141a29–30). Teaching X amounts to passing on explanations about what X is (*Metaph*. A.2 982a29–30). Moreover, as we have also seen, Aristotle thinks that technical explanations can be rearranged in terms of demonstrations. But then, an artisan does possess a body of knowledge that can in principle be systematized as a set of demonstrations.

We conclude that the concern that a demonstrative account of technical knowledge is too demanding depends on incorrect assumptions about what it takes to have demonstrative knowledge. Clarifying that to possess demonstrative knowledge is to have a body of knowledge that can in principle be systematized in terms of demonstration resolves the concern. Moreover, given the additional theoretical advantages of viewing technical knowledge as demonstrative, the burden shifts to proponents of alternative interpretations. They must provide reasons for thinking that, for Aristotle, technical knowledge could *not* be demonstrative in the way we have described.

9.2 *The Objection from Contingent Kinds*

In the case of artificial kinds, it is clear that their very existence and features depend on human creativity and conventional choices. So, for example, these kinds come into being once someone invents them, and go out of existence once nobody uses or produces them any longer. Houses came into being once we started creating them. And artifacts like the epigonion and the daguerreotype are no longer used or produced. The dependence on human creativity of artifacts seems to imply that artificial kinds are contingent in a way in which natural kinds are not. Is this dimension of contingency compatible with the scientific status of technical knowledge? There are at least two ways in which the distinctive contingency of artificial kinds might threaten the scientific status of technical knowledge. First, there is a concern that if artifacts of a given type do not always exist, then generalizations about these artifacts cannot be true. Second, there is the concern that artifact-types can change over time. Let us discuss each concern.

We start with the first concern. On a traditional view, Aristotle thinks that generalizations of the form 'all Ks are Gs' are true only if there are some Ks. If

so, the concern goes, FMP-claims and universal generalizations about artifacts cannot be guaranteed to be true if there are no Ks. Without this guarantee, there is no room for technical sciences. After all, Aristotle allows no science of claims that are not true. So by his lights scientific bodies of knowledge cannot include FMP-claims.

To address this worry, it is helpful to consider some of the remarks that Aristotle makes about generalizations concerning what holds for the most part. As we have seen, in *APr.* 1.13 Aristotle distinguishes between two types of contingent claims about universals (see (T4) in §4): claims about what holds for the most part; and claims about what holds by chance. For instance, the claim that a man's hair turns gray holds merely for the most part and, therefore, not of necessity. What is interesting for present purposes is the parenthetical remark that he makes while giving an example of a claim about what holds for the most part: 'such as that a man turns gray or grows or ages, or in general that which happens by nature (for this does not have continuous necessity because a man does not always exist; however, when there is a man, it is either of necessity or for the most part)' (*APr.* 1.13 32b6–10). Aristotle acknowledges here the possibility that at some point in time there may be no men. Interestingly, he makes the point that *when there is a man* (32b9) the claim 'a man's hair turns gray' is true, either of necessity or for the most part. This suggests that he thinks that generalizations about kinds that are not always instantiated can nonetheless be true either of necessity or for the most part, provided that one considers them relative to the assumption that they have at least one instance. The context makes clear that Aristotle's point is a general one, as opposed to being confined to some disciplines only. So it can be applied to technical knowledge. For example, the art of producing epigonia includes claims about the essence and properties of epigonia. Given the assumption that there are such instruments, these generalizations are about what holds either of necessity or for the most part.[105] Accordingly, Aristotle has the tools for treating the contingency of artifact-kinds as compatible with the scientific status of claims about those kinds.

The second concern related to the contingency of artifacts arises from the following consideration. Precisely because the existence of artifacts depends

105 The assumption that Aristotle allows for science with non-empty domains leaves open how he technically implements this relativization, as well as how he addresses in general the issue of existential import in his logic. Malink (2013, 41–4 and ch. 4) guarantees non-empty domains for Aristotle's modal logic by suggesting that for Aristotle self-predication is satisfied for terms denoting universals. For further discussion of existential import, see Mignucci (2007) and Read (2015), *inter alia*.

on human creativity, artifact-types can change. One might create a functioning chair with three legs, thereby challenging the claim that chairs have four legs. The variability of artifacts may seem to suggest that their essential features do not hold of necessity or for the most part. After all, it just takes a creative insight to make the constitutive feature of a given artifact-type a bygone.

But this concern can be addressed. Cases in which an artifact kind seems to change can be accounted for in two ways. Consider the creation of a new type of chair, namely the type 3-LEGGED CHAIR. With this invention, we discover that chairs can also serve their function with three rather than four legs. So we learn something new about their super-class, the type CHAIR. This invention shows that 'chairs have four legs' is not a fact about chairs that holds for the most part or of necessity. Another kind of case is one in which one creates an artifact that performs the function of an old artifact as well as some new functions—e.g. an espresso machine that can also make cappuccino. Here, it seems plausible that a new kind of artifact has been introduced and with it a novel technical science. In either case, the fact that artifact-types can in this sense develop over time does not show that there cannot be scientific truths about them.

10 Conclusion

This paper has provided an account of technical knowledge in Aristotle by addressing three main explanatory challenges:

- (*First Explanatory Challenge*). What notion of *epistēmē* does Aristotle associate with *technē*?
- (*Second Explanatory Challenge*). Can Aristotle tell apart an artisan's knowledge of the product from a layman's knowledge of the product?
- (*Third Explanatory Challenge*). In what sense does technical knowledge concern contraries?

We have met the first explanatory challenge by arguing that for Aristotle technical knowledge is both productive and scientific—i.e. systematizable in terms of demonstrations about the relevant products. Our argument for this claim involved both textual and philosophical considerations. Textually, we have highlighted the parallels that Aristotle draws between technical knowledge and the other sciences, especially the natural sciences, and we have reconstructed how he makes room for technical demonstrations in the *Posterior Analytics*. We have then shown that the demonstrative nature of technical knowledge has two main theoretical payoffs: it allows us to address the second and third explanatory challenges. Our view addresses the second challenge because

it accounts for Aristotle's claim that artisans grasp what the product is: they grasp the essence of the product in virtue of having demonstrative knowledge about the product. Further, our view addresses the third explanatory challenge because it makes good on Aristotle's claim that it is knowledge of contraries: in virtue of having demonstrative knowledge about X, one is also in a position to draw inferences about not-X.

Our account of technical knowledge constitutes an alternative to the received view that this knowledge neither is demonstrative nor involves scientifically grasping the essence of its product. The main motivation for the received view lies in Aristotle's contrast between *technē* and *epistēmē* in *EN* 6. We have offered an alternative interpretation of these passages. Specifically, we have argued that in *EN* 6.1–6 Aristotle uses *epistēmē* in the narrow sense of strict science—demonstrative knowledge concerned exclusively with claims that are true of necessity. The contrast between *technē* and *epistēmē* does not imply that technical knowledge cannot be demonstrative. Rather, it indicates that technical knowledge does not satisfy the criteria of strict science.

On our interpretation, Aristotle's conception of technical knowledge is consistent across his scientific, metaphysical, and ethical writings. By expanding the notion of demonstrative knowledge so to include non-strict sciences, Aristotle not only affirms the scientific standing of natural sciences but also grants technical knowledge the status of scientific knowledge. The result is an account that elevates the epistemological status of technical knowledge within the ancient philosophical scene.

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