Introduction

Why do organisms reproduce? Why do birds have wings? Why do neither snakes nor stars have feet? And why do most of the hoofed life-bearing animals have horns (but not all of them)?

For Aristotle, questions such as these go to the heart of natural philosophy, which is the study of the coming to be and presence of beings that have their own internal principle of change and rest. Throughout his lifetime, Aristotle was deeply committed to investigating and explaining natural phenomena, which is reflected all through the surviving treatises on natural philosophy. Among these, Aristotle's *Physica* is most fundamental. In this treatise, Aristotle lays out the general theoretical framework for his natural philosophy, defining notions such as nature, motion, causation, place, and time. In the other treatises, Aristotle explores more specific problems related to the study of natural beings, such as coming to be and passing away (in *De Generatione et Corruptione*), the nature and motion of the elements (in *De Generatione et Corruptione* and the second part of the *De Caelo*), the motions and features of the heavenly bodies (in the first part of the *De Caelo*), atmospheric causes and changes (in the *Meteorologica*), the notion of soul and its dependence on natural bodies (in *De Anima*), and finally, the causes of the coming to be and presence of living beings and of their parts and motions (in the biological works).

What unites the questions explored in these natural treatises, exemplified by the questions above, is that they are predominantly questions asking for the purpose of things, or, as Aristotle puts it, questions asking for "that for the sake of which." By posing this specific kind of why question, Aristotle is inquiring after the *function* served by the presence, absence, or material and structural differentiation of a certain natural feature, or after the *goal* for the sake of which some natural process or animal motion takes place. According to Aristotle's understanding of scientific knowledge, the answers to these specific why questions constitute teleological explanations, because they pick out the final cause (in the form of a function or goal) for the sake

of which something has come to be or is present (or absent, etc.). These teleological explanations are a central feature of Aristotle's investigation of nature and reflect the importance he attributes to final causality in the coming to be and presence of regular natural phenomena. In Aristotle's view of the world, everything that exists or comes to be "by nature" comes to be or changes, unless prevented, for a purpose and towards an end, and is present for the sake of that purpose or end. This goal-directedness is an internal tendency possessed by all natural things, which means that teleology operates among all of nature, from the level of the inanimate elements, through that of living beings, and on to the eternal realm of the heavenly bodies.

Although the importance of teleology for Aristotle (and in the ancient world in general)[1] has been acknowledged widely,[2] its nature and scope have consistently been the focus of much debate.[3] These debates have progressively led to a better understanding of Aristotle's theory of natural teleology, and especially of its (meta-)physical underpinnings and its contrasts with Aristotle's notions of chance and necessity.[4] What is lacking in the literature, however, is a precise and comprehensive understanding of the role Aristotle attributes to teleology in *explaining* natural phenomena throughout Aristotle's natural scientific works. Setting aside the other issues that remain concerning the causal nature and scope of teleology, the question that this book sets out to resolve is how – granted that Aristotle has established final causality as a cause of natural phenomena – he then *uses* (e.g., refers to, draws inferences from, builds premises upon, rejects other possible explanations on the basis of) this theory of teleology in his explanations of such phenomena.

The present book, then, provides a new perspective on Aristotle's teleology by exploring and evaluating its *scientific role* in generating

[1] Hankinson (1998, 6).

[2] E.g., Caston (2006, 341); Gotthelf and Lennox (1987, 199); Gotthelf (1997b, 82); and Johnson (2005, 1–2).

[3] Cf. Quarantotto (2005, 17). For a historical overview of the trends and circumstances that shaped the earlier interpretations of Aristotle, see Johnson (2005, 15–39). On the nature of Aristotle's teleology, see in particular Bradie and Miller (1999); Cameron (2002); Charles (1988); Cooper (1982; 1985; 1987); Gotthelf (1987); Irwin (1988); Johnson (2005); Lennox (2001a); Nussbaum (1978); Sauvé Meyer (1992); Scharle (2008); Sorabji (1980); and Wieland (1975). On the metaphysics of Aristotle's teleology, see in particular Charles (1994); Mirus (2004); Pavloupoulos (2003); and Witt (1998). On the scope of Aristotle's teleology, see in particular Cooper (1982); Furley (1985); Matthen (2001; 2009); Owens (1968); Sedley (1991); and Wardy (1993).

[4] See especially Johnson (2005), who brings together many of the recent new insights concerning Aristotle's teleology in his monograph, and explicitly addresses and eliminates some of its most persistent "popular misconceptions." See also Cooper (1982, 1985; 1987) and Lennox (2001a, 225 and 251).

causal explanations of natural phenomena, both in the actual explanations recorded in Aristotle's natural treatises and more abstractly in his philosophy of science.

The core of my book, consisting of Chapters 1 to 5, investigates the function, structure, and explanatory power of Aristotle's actual teleological explanations of natural phenomena. This involves a close reading of selected texts in four of Aristotle's treatises on natural science, that is, in the *Physica* (book II), *De Anima, De Partibus Animalium* (including the practice in books II–IV), and *De Caelo* (book II). These are the treatises that are most relevant to the present investigation in that they cover the main areas of Aristotle's natural science,[5] and include texts that have often been ignored in previous studies of Aristotle's teleology.[6]

In the final chapter, which is Chapter 6, I juxtapose these findings concerning Aristotle's practice in the treatises on natural science with the theoretical picture of the structure of teleological explanations gained from Aristotle's theory of scientific demonstration.[7] For this purpose I present a new interpretation of *Analytica Posteriora* II.11, a notoriously difficult chapter in which Aristotle introduces his theory of four causes into the syllogistic framework of scientific demonstration. This study thereby contributes to recent scholarship on the interplay between Aristotle's philosophy of science and philosophy of nature,[8] while at the same time adding to our knowledge of Aristotle's theory of teleology in terms of its explanatory merits and limits.

[5] Note that although this book explores Aristotle's theory and practice of providing teleological explanations as comprehensively as possible, due to the limits of space and time I have narrowed down this study to Aristotle's *science of living nature*. On a few occasions, I have something to say about the (non-natural) teleology of deliberate action as well, but the ethical and political works of Aristotle mostly fall outside the scope of this book. My central hypothesis is that Aristotle developed his notion of "that for the sake of which" primarily in the context of his investigations of living nature and that this is where he applied the notion most successfully; a further study of the use of teleology in generating explanations in, among others, his ethics or politics, would have to start from and build upon the more "basic" uses in the natural treatises.

[6] Cf. Quarantotto (2005, 27). Quarantotto points to *Ph* II.8–9 and *PA* I.1 as the key texts on which most scholars have based their interpretation of Aristotle's notion of teleology; in her own work, she studies teleology from a more comprehensive perspective, including the whole of *Physica* book II, the whole of *De Partibus Animalium*, a few passages from *De Anima*, and *Meta* I.3–10.

[7] Although there have been quite a few studies on the nature of Aristotle's (teleological) explanations within the context of the first book of the *PA* and the second book of the *Physica*: see especially Balme (1987b); Bolton (1987; 1997); Charles (1997; 1999); Detel (1997; 1999); Gotthelf (1987; 1997a); Lennox (2001a) and Pellegrin (1986), with a few exceptions (i.e., Bolton 1997; Detel 1997; and Johnson 2005), Aristotle's theoretical remarks on the structure of teleological explanations in *APo* II.11 have been ignored.

[8] For this research program, see in particular Lennox (2001a, 1–6; 1997a; 2004a; 2006), and Lloyd (1990; 1996, 7–37).

In the course of these six chapters, I defend three main theses: first, that Aristotle postulates not one, but *two types of teleological causation* as underlying the coming into being and presence of regular beneficial outcomes in nature; second, that he uses teleological principles as *heuristic tools* for the discovery of causally relevant features to be picked out in causal explanations, where the causes that are being discovered, including the final causes, are real causes and not mere epistemic reasons why;[9] and, finally, that Aristotle never attributes *causal primacy* to final causes in his explanations (even though he believes they are "prior in nature"), but only *explanatory primacy*. This means, among other things, that his teleology resists the – in itself already anachronistic – charge of backward causation. Let me say more about these three theses in turn and indicate in which chapters I defend them.

First, I argue that a more thorough understanding of Aristotle's use of teleology in the explanation of natural phenomena requires that we distinguish between two types of teleological causation, a primary and a secondary type, which are both represented in Aristotle's explanations.

The primary type of teleology involves the realization of a preexisting, internal potential (or perhaps "potentials") for form[10] through stages shaped by conditional necessity. This is the "standard" form of teleology, according to which the form of the natural being specifies the functional features that are to be realized through the goal-directed actions of the formal nature; what is picked out as causally primary in the explanations of such features is the natural being's form. For instance, birds have wings for the sake of flying, but the need to perform this activity derives from the essential nature of birds, which is being a flyer. Wings, then, are exhibited to be the necessary prerequisites for the realization of the bird's form as flyer. Explanations of phenomena that have come to be and are present as the result of primary teleology (such as wings) thus typically include references both to the ends that constitute final causes (e.g., functions such as "flying") and to the definition of the substantial being of the organism in question (e.g., definitions such as "being a flyer"), which constitutes its formal cause.

The secondary type of teleology involves a formal nature of a natural being *using* materials that happen to be available (usually residues

[9] Note that I take Aristotle to be a realist about (final) causation – it is only his *use* of teleological *principles* such as "nature does nothing in vain" that I argue serves heuristic purposes. I do not believe that his theory of teleology as a whole is heuristic.

[10] My characterization of "primary teleology" builds on the understanding of teleological causation in the case of animal generation provided in Gotthelf (1987).

that have come to be of material necessity and that are not conditionally necessitated) for the production of parts that serve the animal's well-being. The presence of these parts is not a necessary prerequisite for the realization of the animal's form; instead, their presence is said to be "for the better." For instance, large land animals often have a surplus of earthen material, which – because of its hard potential – nature then uses for the production of horns in males, which serve the (non-necessary) function of defense. In these cases, functional features emerge as it were from the potentials of the materials that happen to be available, and the operation of the formal nature is secondary to the operation of material necessity that produced the materials. Explanations of phenomena that are the result of secondary teleology (such as horns) thus typically distinguish between the presence and the coming to be of those phenomena, where the presence is explained teleologically by reference to an end that constitutes the final cause (e.g., the function of "defense" served by the part) and the coming to be by reference to material necessity.[11]

Scholars usually try to reconstruct the causal nature of Aristotle's teleology by contrasting it to material necessity and chance, and therefore tend to reduce Aristotle's own references to material causation in teleological explanations to expressions of conditional necessity. By distinguishing primary from secondary teleology, however, it is possible to give an account of the role of necessity in teleological explanation that does not involve a reduction of material necessity to conditional necessity in all cases.[12] This interpretation also counteracts another unfortunate tendency among scholars, which is to treat all teleological explanations found in Aristotle's treatises as one homogeneous category, unified simply by the fact that the explanations all refer in some way or another to the goal-directedness of

[11] My distinction between primary and secondary teleology does not rely upon Aristotle's own distinction between two types of final causes, which are "that for the sake of which" and "that for the benefit of which" (he makes this distinction in, for instance, *Ph* II.2, 194a34–b1; *DA* II.4, 415b2–3; *DA* II.4, 415b20–21; *Meta* XII.7, 1072b1–3; and *EE* VII.15, 1249b15), and differs in that way from the interpretations of Kullmann, Bodnár, and Johnson. Kullmann (1985, 173) uses the term "secondary teleology" to indicate that an end is the beneficiary of something, but not a "that for the sake of which" in a strict sense. Bodnár (2005; 24–25) also builds upon Aristotle's own distinction: in "straightforward" teleology, the goals are not also the beneficiary of the teleological structure, while in inter-species teleology the goals are the beneficiary of the teleological structure. Finally, Johnson (2005) uses the distinction between the "that for the sake of which" and the beneficiary as one of his central tools for making sense of Aristotle's explanations. None differentiate between "primary" and "secondary" teleology in the way that I propose.

[12] My interpretation is aimed mostly against scholars who have either explained away the role of material necessity in teleological explanations (Balme, 1987c); reduced it to conditional necessity (Cooper, 1987; Johnson, 2005); or assigned to it primarily a "negative" role in constraining the realizations of function (Lennox, 2001a).

nature.[13] This tendency not only obscures the diversity and versatility of Aristotle's modes of explanation, but also leads to an impoverished understanding of the explanatory power of teleology.

I introduce the distinction between primary and secondary teleology in Chapters 1 and 2. More specifically, Chapter 1 shows how this distinction operates in Aristotle's defense of natural teleology in the famous rainfall example in *Physica* II.8. Chapter 2 demonstrates how it underlies Aristotle's conceptions of "living" versus "living well" in *De Anima*, which in their turn are used to ground the specific sets of capacities different kinds of living beings have. The causal patterns underlying the distinction between primary and secondary teleology are developed most fully in Chapter 3, which examines Aristotle's scientific theory of explanation in biology as introduced in *De Partibus Animalium* I.

My second thesis concerns the role of teleology in Aristotle's methods of discovery. There are a relatively small number of teleological explanations in Aristotle's natural treatises that do not refer directly to final causes, but that proceed through the use of teleological principles such as "nature does nothing in vain."[14] I argue that Aristotle uses these principles as *heuristic tools*. The principles are used to discover causal features, which then figure in teleological explanations, but the principles do not themselves play a causal role in the ultimate explanations of natural phenomena.

In the natural treatises, there are rare cases where the end that constitutes the final cause of some natural phenomenon is not immediately accessible for observation, or where the explanandum is otherwise particularly complicated. These are typically the contexts in which Aristotle posits a teleological principle and thereby generates the appropriate series of inferences that ultimately leads to the identification of the causally relevant

[13] Sorabji (1980, 155–174) offers an account of how according to him the various kinds of teleological explanations work, but I believe his distinctions are not subtle enough to cover Aristotle's actual practice of explaining natural phenomena in a teleological way. Johnson (2005, 1 and 7) introduces his investigations into Aristotle's teleology as a study of "how ends are used by Aristotle as explanations in natural philosophy" (2005, 1). However, the core of his monograph contains a discussion of the sorts of things that according to Aristotle behave in a goal-directed way, and of the reasons why these things behave that way (and are thus explainable by reference to teleology). He does not produce any analysis of the different types of teleological explanation Aristotle uses, or any reflections upon why Aristotle uses the types of teleological explanation he does, or what he thinks these explanations amount to, which is the sort of reflection I offer in this book. Charles (1991), who recognizes that there is a plurality of teleological models at work in Aristotle's *Physica*, faults Aristotle for not presenting a unified model.

[14] Although Lennox's work on the principle that nature does nothing in vain (2001a, 205–222) suggests that Aristotle uses teleological principles in very specific ways to explain their own set of explananda, some scholars still think that they are just "didactic mantras," to remind his students that he believes nature is goal-directed. See, for instance, Quarantotto (2005, 13).

feature, which is then picked out in the explanation of the phenomenon in question. An important part of the process of discovery in these cases is the identification of what type of teleology (i.e., primary or secondary teleology) is responsible for the presence of the natural phenomenon that needs to be explained; it is my contention that teleological principles help to make this identification, while they are not themselves part of the ultimate (syllogistic) explanation.

I argue for this thesis in Chapter 4, which examines Aristotle's heuristic strategies and actual (teleological) explanations as recorded in *De Partibus Animalium* II–IV, and trace its consequences for the possibility of understanding heavenly phenomena in Chapter 5.

My final thesis, which is perhaps the most important one from a contemporary perspective, is that for Aristotle the scientific value of final causes in natural science lies in their explanatory priority. Final causes, even though they certainly play a significant causal role in natural developments (they are, after all, one of the four types of causal factors Aristotle distinguishes in nature), nevertheless never receive causal priority *in the (syllogistic) explanation of those developments*.[15]

For Aristotle, scientific explanations or demonstrations ideally follow the pattern of a Barbara syllogism (i.e., AaB, BaC, ∴ AaC). In such demonstrations, some attribute (picked out by the major or predicative term) is demonstrated to hold always or for the most part of some subject (picked out by the minor or subject term) through some causally primary feature (picked out by the middle term). In addition, Aristotle argues that scientific demonstrations of natural phenomena – unlike those of mathematical states of affairs, which are timeless – ought to reflect the chronological order of causation in the world, moving from the start or origin of the natural development to its end. For the practice of demonstrating teleological natural processes, this means that final causes can never take the position of a middle term, which picks out the causally *primary* factor in a chain of development. For, although Aristotle repeatedly points out that final causes are prior in nature and in definition (and undeniably do have causal priority in those senses), in *generation* they are last, because the ends that constitute the final causes of natural phenomena are chronologically speaking the last to come about. Whereas the end that constitutes the final cause explains the *presence* of a given natural phenomenon, the *coming*

[15] This answers the question, addressed on a general level by Code (1997) and by Bolton (2004), why Aristotle assigns special explanatory power to explanations that pick out final causes and why he considers it to be the foremost (although not exclusive) task of natural philosophers to provide teleological explanations of the natural phenomena they investigate.

to be of that end must itself be explained further in terms of either the operation of formal-efficient causation or of material-efficient causation. These latter causes are *causally prior in generation* and they can therefore take the position of middle terms in scientific demonstrations of natural phenomena. In sum, because ends that constitute the final causes of natural phenomena can by definition never be prior in generation, and because it is priority in generation that is tracked by scientific demonstrations of natural phenomena, ends can never be identified as the causally primary fact in such demonstrations.

Thus I shall argue that the syllogistic patterns of teleological explanation that Aristotle employs in the biological practice and that he describes in his theory of science never pick out final causes as being explanatory of the conclusion, but rather include functions and ends as part of the conclusion that is being demonstrated. In other words, final causes are always picked out by the major term, in the predicative position, and never by the middle term. Under this scheme, teleological explanations are explanations in which a final cause is picked out as being responsible for the *presence* of some natural feature, where the end that constitutes that final cause is demonstrated to *come to hold* of that feature through the operation of some *other* type of cause (i.e., formal-efficient causes in the case of primary teleology; material-efficient causes in the case of secondary teleology).

Final causes thus exert no "mysterious causal pull" from the future and do not cause the coming to be of their own necessitating conditions, as some – anachronistically – have suggested. Final causes are prior in nature and in definition, and function quite literally as ends and limits of developments, which is why they function as the starting points of scientific demonstrations of natural phenomena. However, in the order of generation, final causes are last, and Aristotle does not conflate these different orders of priority.

This is the central thesis of Chapter 6, in which I present my interpretation of *Analytica Posteriora* II.11 and juxtapose this with my findings concerning Aristotle's practice of providing teleological explanations especially in the biological works.

My interpretation of Aristotle's teleology as (1) incorporating (at least in some cases) material necessity rather than opposing it, (2) allowing a heuristic use of teleological principles, and (3) resisting the charge of backward causation has important ramifications not only for the way we standardly depict the place of Aristotle in the history of science, but perhaps also for contemporary debates about the notion of biological function.

The Aristotelian worldview that came to be rejected in the sixteenth and seventeenth centuries in favor of mechanistic models of the world was in fact even less Aristotle's than is often assumed. For Aristotle, the theory of natural teleology is not an a priori assumption, but a scientific hypothesis, much like contemporary etiological or propensity theories of function are. A deeper understanding of the merits (and limits) of Aristotle's use of teleology in producing explanations might put us in a better position to reconsider notions of biological function that do not rely on the postulation of mystical forces or the existence of benevolent, intelligent gods, but rather on immanent, natural principles and laws.

CHAPTER 1

Aristotle's defense of natural teleology: setting the stage for teleological explanations in the Physica

1.0 INTRODUCTION

The *Physica* forms Aristotle's most fundamental treatise in his studies of natural science. In this treatise, Aristotle investigates the principles and causes of all things that have a nature – that is, of all things that have an internal principle of change and rest – with the purpose of generating knowledge of natural phenomena (*Ph* I.1, 184a10–16). In the course of doing so, Aristotle defines a large number of key notions of his natural philosophy, such as motion and change, space and time, matter and form, causal explanation, luck and spontaneity, teleology and necessity. The conceptual apparatus and framework laid out in the *Physica* are consequently applied and reshaped for the inquiries into the more specific and more complex segments of the natural world, written down in Aristotle's other natural treatises.[1]

Final causes and natural teleology figure especially prominently in the second book of the *Physica*, where Aristotle defines his concept of nature, introduces his theory of four types of cause or causal explanation,[2] and discusses the kinds of cause operative in art and nature. In this chapter, I shall focus on Aristotle's first argument in defense of natural teleology

[1] As Aristotle makes clear in his programmatic opening of the *Meteorologica* (I.1, 338a20–339a10), the whole investigation of nature will comprise the study of change and motion in the heavens (*De Caelo*), the elements and coming to be and perishing in general (*De Caelo*, *De Generatione et Corruptione*), atmospheric causes and changes (*Meteorologica*), and finally living beings (the biological works). On the importance of the *Meteorologica* passage for the systematic connection between Aristotle's works, see Burnyeat (2001, 118–119); Falcon (2005, 2–7); and Nussbaum (1978, 107–109).

[2] Aristotle is a realist concerning both causes and explanations, which means that the four types of causal explanations he distinguishes in *Ph* II.3 and *Ph* II.7 are grounded in four types of causal relations that obtain in the world: the four *aitiai* are the kinds of answers one gives to four different why questions, and these answers will only be explanatory and hence productive of scientific knowledge if they pick out real causes (and not merely epistemic reasons why) under their causally relevant description. Cf. Freeland (1991); Hankinson (1998, 132); Johnson (2005, 41); and Moravcsik (1991, 31). Pace Van Fraassen (1980). On Aristotle's erotetic concept of inquiry, see Hintikka (1989, 73) and Lennox (1994).