CHAPTER 1

Aristotle and After

Beginning with Aristotle

It is no longer possible to begin an account of modern philosophy of physics in modernity itself; one must go back at least to the Middle Ages. In the case of philosophical thought about living things, however, or what has recently come to be called philosophy of biology, one must go back even further – to the figure of Aristotle, who lived in the fourth century B.C.E. (384–323). For one thing, Aristotle is the only major philosopher in our tradition who is also a major biologist. One cannot read him for any length of time without seeing that his central philosophical concerns were closely related to his biological interests. Moreover, Aristotle first raised the questions that have preoccupied philosophers of biology ever since: arbitrary imposition versus "cutting nature at the joints" when it comes to naming traits and classifying kinds of organisms; purposive function versus haphazardness and accident in the distribution of traits to various kinds; mechanistic reduction versus teleology or goal-orientation in the process of embryogenesis. These topics are all explicitly formulated in Aristotle's biological treatises, which comprise no less than a quarter of the corpus of his writings that have come down to us.

We must begin with Aristotle, however, not only because we find him raising issues that recur, but because Aristotle's biological way of thought forms the background of subsequent philosophy of biology. For its part, modern physics, as is well known, began by rejecting not just scholastic Aristotelianism, but the fundamental principles of Aristotle's physics itself. We can say, generalizing rather crudely, that the late Scholastics, or "Aristotelians," had forgotten Aristotle's biology, and the way it concretely informed and was informed by his metaphysics,

in favor of Christianized versions of his physics and metaphysics. We shall look at this problem in the next chapter, since modern mechanists, beginning with Descartes, took off from there. It is important to recognize, however, that the development of modern biology did *not* follow this pattern. Indeed, biologists who worked after Descartes made increasingly systematic use of the concepts of end and form in their explanations of living things, and the name of Aristotle was often spoken reverently among them. Modern biologists have, in fact, returned again and again to Aristotle as their master.[1]

In this chapter, we explicate the conceptual structure of Aristotle's program for biological research, and the ways in which that program informed and was informed by his logical, methodological, and metaphysical doctrines. Aristotle wanted this program to be completed by the Lyceum, which he founded. Very early on, however, perhaps as soon as his immediate disciple Theophrastus of Eresus ceased working, the sharp edges of Aristotle's philosophy of biology became blurred. This did not keep Aristotle's biological works from inspiring much creative thought about living things, especially after his texts were republished in the Italian Renaissance. Clearly, however, even the best of this work, such as William Harvey's, was almost never carried out under Aristotle's precise conception of what a philosophically informed biology should look like. Much had been transformed throughout the long tradition.

Hippocratic Medicine and Aristotelian Biology

Aristotle was not the first Greek to have left written reflections on living things. As the son of a doctor – his father was physician to the Macedonian court – he was clearly familiar with those literate practitioners of the medical art, the Hippocratics. The Hippocratics held that the two basic opposites – hot-cold and wet-dry – can be combined in four ways, producing the elements of earth (dry-cold), air (hot-wet), fire (hot-dry), and water (wet-cold). According to a view developed by some of them, these elements give rise to the four bodily humors – black bile (earth, located in the spleen), blood (fire, located in the heart, thought to be the source of life and hence hotter than the rest of the body), yellow bile (air, located in the gall bladder), and phlegm (water, located in the

[1] We refer here to figures as diverse as William Harvey, George-Louis Leclerq Comte de Buffon, Georges Cuvier, John Hunter, and Richard Owen, many of whom will be discussed in later chapters.

lungs) (Hippocrates, "The Nature of Man," section 4, in Hippocrates 1978, p. 262). The point of medical practice was to maintain, and whenever necessary restore, the right blending among these sometimes competing humors. In the most highly articulated versions of Hippocratic thought, the humors were in turn believed to correspond to four temperaments – melancholic, sanguine, choleric, and phlegmatic – which also corresponded to the four seasons. Unsurprisingly, in view of this picture, the Hippocratics were sensitive to the effect of diet and environment on health and of climate on the character of populations. In the Hippocratic treatise on *Airs, Waters, and Places*, for example, we learn that on the mainland of Asia Minor, "the people are milder and less passionate" than in Europe because Asia "lies equally distant from the rising of the sun in the summer and winter," and "luxuriance and ease of cultivation are to be found most often where there are no violent extremes, but when a temperate climate prevails" (Hippocrates, "Airs, Waters, and Places," section 12, in Hippocrates 1978, p. 159).

One can find plenty of claims in Aristotle that sound Hippocratic enough. Aristotle's theory of elements, for example, is very much like theirs; the elements are not hard, entity-like substances, but phases of a self-perpetuating cyclical process in which the opposites – hot-cold and wet-dry – necessarily and predictably give way to one another (*On Generation and Corruption* 337 a 1–15). Aristotle was also conscious of how diet and climate affect character, as when he characterizes "Asians" as lacking in aggression due to the heat of their climate, and says that northern barbarians, coping as they must with extreme cold, are excessively aggressive (*Politics* 1327 b 19–32). In his *Ethics*, too, Aristotle's stress on finding a virtuous mean between opposing passions, and on finding it in a way that is uniquely appropriate to the individual, fits in with the Hippocratic approach to medicine.

Yet in spite of many stray remarks suggesting off-hand familiarity, if not complete agreement, with Hippocratic views, the spirit of Aristotle's approach to living things differs entirely from those of the Hippocratics. Although it may be said that, in a general way, the Hippocratics projected a certain theoretical framework, they did so in a pragmatic rather than a dogmatic spirit. The dominant tone of the best of their writings is one of suspicion about applying reasoning from theoretical postulates to particular cases, after the fashion of the pre-Socratic natural philosophers. "I am utterly at a loss," writes the author of the fifth-century treatise, "to know how those who prefer hypothetical arguments and reduce the science of medicine to a simple matter of 'postulates' (*hypotheses*)

could ever cure anyone" (Hippocrates, "Tradition in Medicine" [also known as "On Ancient Medicine"], in Hippocrates 1978, p. 7. The Hippocratics, in sum, were proud practitioners of the *art* of medicine, not devotees of a theoretical *science*. The focus of their writings, which were collected over a period of several centuries, was on urging their would-be adepts to cultivate skills that would enable doctors to remain true to the internal norms governing their art. That is the thrust of the famous Hippocratic Oath.

Now it is certainly true that Aristotle recognized medicine as an art, which if practiced skillfully would both require and exhibit judgment (of a sort different from the deliberative wisdom of the citizen-politician [*phronēsis*], but no less focused on how to deal with the contingencies of particular cases) (*Nicomachean Ethics* 1140 a 1–24). Indeed, Aristotle regarded medicine as the very paradigm of a craft or *technē*; and, like both Plato and the Hippocratics, he was at pains to distinguish genuine crafts such as medicine from mere empirical knacks. In the work of Aristotle and his school, however, we find for the first time a sustained effort to pursue biological inquiry (collection, description, explanation) for its own sake rather than for practical benefit. *Aristotle was the first theoretical biologist*. This drive toward theory means that in Aristotle, problems we now recognize as scientific were penetrated at every point by questions that he recognized as philosophical – and that we should, too. Theory (literally "vision" or observation) *means* philosophical insight.

Aristotle's orientation to theory leads him to judge that reasoning from hypotheses, the very process eschewed by the Hippocratics, can be helpful in searching for the indemonstrable, but certain, first principles from which the propositions constituting a science follow (*Posterior Analytics* 92 a 7–32). Presumably, the Hippocratics should not object to that. For unlike both the craft-knowledge they prized and the political-ethical activity of citizens, science is not concerned with particular cases, as doctors and politicians are, with all the uncertainty that attends these cases. It is concerned instead with what happens "always or for the most part." Aristotle divides the work of theoretical inquiry into an inductive procedure (*epagōgē*), which leads to the establishment of explanatory first principles, and a demonstrative procedure, which solves the problems encountered on the way toward principles by deducing their correct answers from these principles once they are found (*apodeixis*). Having said this, it is important for us to note that, as Aristotle understands scientific knowledge, the principles governing

what happens always, and even for the most part, are not arrived at by simple enumerative induction, as in proverbial nose-counting exercises like that about white swans. Instead, the upward path involves properly dividing the subject matter until its proper elements and its essential definition are identified, often by sorting through what is plausible and implausible in the views of predecessors. Properly conducted, inquiry of this sort will arrive at principles that are true, primary, immediate, better known than, prior to, and causative of the conclusions drawn from them (*Posterior Analytics* 71 b 16–20). Although these principles are as certain as certain can be, only the second, downward leg of the process of inquiry constitutes demonstrative scientific knowledge (*epistēmē*) as such. The sciences of nature, including what is now called biology, are for Aristotle demonstrative sciences in just this sense. They are presumed to have their own first principles, from which universally valid and sound conclusions about living things necessarily follow.

Biology Within the Bounds of Physics

In describing Aristotle's program of theoretical biology, we must first recognize that he had no word for "biology." That term was coined toward the end of the eighteenth century (see Chapter 4). For Aristotle, on the contrary, what *we* recognize as biology was part, indeed a central part, of the science of natural philosophy or physics. Clearly, Aristotle had a wider notion of the study of "physics" (nature) than has become conventional in modern times.

For Aristotle, physics, which in Greek means "things that grow or develop" (*phuomena*), is the study of any and all beings that have within themselves a non-incidental source of motion and of rest (*Physics* 192 b 12–15; 20–23; 199 b 15). All such beings are substances, the individuated entities that collectively make up the world (*Physics* 192 b 32–34). Some of these substances – the ones physics studies – come into being and pass away. This process constitutes substantial change. Moreover, almost all substances – at least all of the perishable ones – are able, while they exist, to remain themselves by means of various processes of change – qualitative, quantitative, locomotive – in which they acquire or lose properties. These are non-substantial, or in Aristotle's terminology, "incidental," changes; they are less fundamental than the generation or extinction ("corruption") of a substantial unity itself. That there are many (relatively) independently existing entities or substances, whose natures our minds are suited to understand, is absolutely basic to Aristotle's view

of things. These are the everyday things we see around us: plants, animals, and, among animals, ourselves. Substances that remain the same things through incidental changes are said to have a nature (*phusis*) and to change by nature (*phusei*) (*Physics* 192 b 33–193 a 1).

To understand more precisely what Aristotle means by "nature," it helps to see that what happens naturally is contrasted in various places in his works with three other sorts of things:

1. Natural philosophy (physics) is contrasted in the first instance with the study of substances that do not move at all, even if they move other things (*Metaphysics* 1026 a 10–20). What Aristotle has in mind here is the outermost sphere of the *kosmos*, which for him is also the divine self-understanding of the eternal world-order itself, to which finite things are both oriented and subordinated. This substance is the ultimate subject of "first philosophy," or what Aristotle calls "theology" (of a highly rationalized sort by typical Greek standards) (*Metaphysics* 1026 a 19–20). The sphere of physics, by contrast, is "second philosophy."

2. What happens by nature is also contrasted with what happens by art or craft (*technē*). What happens by art comes into being not naturally, but by way of a source external to itself – namely, the thought in the mind and the artfulness in the hands of an artificer or practitioner. In contrast to the materials from which they are made, for example, "a bedstead or a coat or anything else of that sort . . . has within itself no internal impulse to change" (*Physics* 192 b 16–18, revised Oxford translation, amended). We can see from this example what Aristotle means by a non-incidental source of change. A bedstead can change incidentally when the wood from which it is made grows brittle and needs to be glued, or when, like Antiphon's bed, it rots and sprouts branches (*Physics* 193 a 12–16). But this does not happen insofar as it is a *bed*. It happens insofar as it is *wooden* (*Physics* 193 b 8–11). In part because of their external source of motion, products of art are not sufficiently integrated to count as substances. In artefacts, as the example of the bed shows, matter (the stuff of which something is composed) and the form (the kind of thing it is) do not fully fuse. In natural entities, matter and form are not so separate.

Granted, there is an important analogy for Aristotle between what comes to be by art and what comes to be by nature (*Physics* 199 a 9–19). In both processes, as in both kinds of entities, Aristotle distinguishes four "causes" – one might say four reasons why a thing is as it is. Its matter and form are two of these, which are always distinguishable when we look at a substance (or an artefact) in cross-section, so to speak, at

a given period of its existence. When we consider its life-history over time, however, we find two more correlative explanatory factors: the efficient or moving cause, which names the agency by which a thing comes into existence, and the final cause, which refers to the end for which it comes into existence or its terminal point of development. In the case of natural substances, as we will see, form, end, and efficient cause are often identified. Matter, which for Aristotle is the potentiality for assuming form, is decidedly subordinate to the other three. This four-fold categorization of causes provides an indispensable framework for analyzing the fundamental structure of natural substances – as well as of metaphysical ("theological"), or eternal, substances and, indeed, artefacts.

3. Finally, what changes by a natural internal impulse is also contrasted with what happens spontaneously ("automatically," in Greek), by chance or coincidence, and by force. Aristotle thinks that just because natural substances have an internal principle of change and rest, their behavior is, to one degree or another, predictable and regular (*Physics* 198 b 35). What happens spontaneously or by coincidence does not conform to this pattern. Nor does what happens by external force, which makes a natural process deviate from its built-in pattern of motion. In other words, Aristotle denies that what happens spontaneously, coincidentally, or by force can be regular and lawlike. He also denies that what happens spontaneously, by chance, or by force can be the object of scientific knowledge. For scientific knowledge depends on logically necessitated demonstrations from secure first principles, as we have already noted, and Aristotle thinks that only non-incidental changes in the objects of a science can be necessitated in this way. For Aristotle, what is spontaneous, chancy, or forced cannot be scientifically known (*Physics* 199 a 1–6).

It is precisely in these areas that Aristotle's thought differs most fundamentally from modern science. Modern science is founded on the notion that regular behavior can be explained by equilibria arising among entities governed by external forces, or that emerge from the spontaneous statistical sorting of chancy events. This tenor in scientific thinking has been made possible by explicit denials of Aristotle's claim that what happens by force, spontaneously, or by coincidence cannot be studied scientifically. Aristotle certainly does not deny that the world is full of loose change, as it were, or of irregular, violent motions. He simply denies that appeals to what happens spontaneously, coincidentally, or by the exertion of force can figure in systematic, cognitively worthwhile

explanations of natural processes. Spontaneity, chance, and force do not count for him as causes in the same way that the four causes do. When they are appealed to, it is as excuses for mere oddities, not as basic explanations.

Thus marked off from unmoved movers, externally moved artefacts, and irregular occurrences, Aristotle's physics includes, in the first instance, the study of the four elements, and especially of their natural process of conversion into one another in regularly necessitated cycles. These processes are explained in terms of the various inherent, natural tendencies of the elements that figure in them – fire goes up by nature, earth down. But Aristotle's notion of physics also includes the study of substances whose internal source of motion and rest is soul (*psuchē*). For Aristotle, soul means primarily "organizing principle." It is not a separate substance that ingresses into the body, as it is for Descartes and various Christian theologians.[2] Soul is instead a principle of life. It integrates beings composed of differentiated parts, or organs, into substantial unities – that is, organisms. This integration-by-differentiation enables ensouled substances to *do* various things – sometimes very clever things – rather than, like elemental cycles, merely undergoing predictable changes. Organized beings – beings with organs – have distinctive "works" or functions (*erga*) that make them capable of distinctive sorts of activities (*On the Soul* 412 a 27-b5). Plants, for example, have souls that initiate and guide reproductive, metabolic, and growth functions. Animals have, in addition, sensory and locomotive capacities, as well as affections. For, unlike plants, they must move over space to find food and mates, and so must have not only means of locomotion, but desires to drive them toward some things and away from others, as well as senses to guide them in doing so. Human animals, finally, have rational soul functions, as well as those characteristic of animals and plants (*On the Soul* 414 a 29-b1).

For Aristotle, organisms have a natural life-cycle; they are not only born and grow, but also age and die ("of natural causes"). From this fact, in conjunction with his view that organisms are paradigmatically

[2] The intellectual soul of human beings is, Aristotle concedes, separable from the body. The centuries' long effort by Christian theologians to give the intellectual soul a personal identity led to Descartes's understanding of the intellect as a separate *substance*, an inference that departs from the connection to Aristotle's conception of soul as the form of the body to which Thomas Aquinas, for example, still clung. Of great importance in this transformation was Descartes's denial that plants and animals have souls at all. For him, they are just machines (see Chapter 2).

natural substances, we can see why Aristotle says that what is natural has an internal principle of rest as well as of motion (*Physics* 192 b 14–15). We can see, too, why for Aristotle the study of organisms, and by extension of all natural substances, calls for the use of all four causes. There is an end-oriented temporal dimension in Aristotle's natural substances (growth), as well as an integration of matter and form at each point (metabolism). By contrast, modern physics, restricted as it is to the study of local motion under external forces, involves only material and efficient causation.

So far, then, it looks as though our modern concept of biology corresponds fairly well to the study of Aristotle's ensouled, or organ-ized, physical substances. However, we must be careful. For Aristotelian physics extends not only to living things in our sense, but also to the study of some substances that are "ungenerated, imperishable, and eternal" – namely, the stars and planets (*On the Heavens* 192 b 16–18). Admittedly, these immortal, and hence (by Greek usage) divine, beings do not reproduce, since they are free from the dependencies of plants and animals and from environmental wear and tear. As a result, they can maintain themselves in existence as numerically identical substances forever. In this respect, the heavenly bodies differ from plants, animals, and human beings, which are subject to "generation and decay," and so can live forever only in the sense that they regularly engage in the "highly natural" act of replacing themselves with offspring that have the same characteristics – "an animal [of a certain kind] producing an animal [of the same kind], a plant a plant," in an endless chain of species regeneration (*On the Soul* 415 a 28). (Aristotle says that in acting to replace themselves, mortal ensouled beings – organisms – strive to "partake in the eternal and divine" to the extent that is possible for them [*On the Soul* 415 a 30-b1; *Generation of Animals* 731 b 24–732 a 1][3]). None of this is to deny, however, that for Aristotle the heavenly bodies too are living beings. They are rationally ensouled natural substances whose internal principle of motion and rest is mental. Here we encounter an aspect of Aristotle's thought totally alien to our way of thinking. Although he is not as animistic or panpsychic as, say, the ancient Stoics, who maintained that the whole *kosmos*, as distinct from Aristotle's system of individuated substantial beings, is itself a single living substance,

[3] James Lennox argues that this desire or urge (*hormē*) is to be taken as applying to each individual in a species, and as aimed at the eternal persistence of one's own form (see Lennox 2001, p. 134).

Aristotle is willing to assign life and soul, even intellectual soul, to some beings that we have come to regard as decidedly inanimate.

At the end of *Parts of Animals I*, Aristotle admits that the study of "natural substances that are ungenerated, imperishable, and eternal" – that is, the stars and planets – is highly attractive (*Parts of Animals* 644 b 32). But he also says (in what reads like a pep-talk designed to induce reluctant students to study zoology) that we cannot know much about them, while "respecting perishable plants and animals we have abundant information, living as we do in their midst, and ample data may be collected concerning all their various kinds, if only we are willing to take the trouble" (*Parts of Animals* 644 b 28–32). Acknowledging that his prospective scholars may regard even thinking about "the humbler animals," let alone touching, manipulating, and even opening them up, as beneath their dignity, Aristotle suddenly waxes lyrical. He points out that "if some animals admittedly have no graces to charm the senses, nature, which fashioned them, still affords amazing pleasure" when we inspect them (*Parts of Animals* 645 a 7–11). For our attention as scholars is not to be on "blood, flesh, bones, vessels, and the like," but on the causes, particularly the formal and final causes, which reveal in perishable natural substances "absence of anything that is haphazard and conduciveness of everything to an end" (*Parts of Animals* 645 a 24). In this passage, we are afforded a rare glimpse into the motives that induced Aristotle to become the first true philosopher of biology.

Aristotle's Biological Works Surveyed

In the spirit of wonder evoked by the passage we have just summarized, Aristotle sets out to inquire systematically into a number of questions raised by the general picture of mortal ensouled substances we have sketched. The key word here is *systematically*. Each of Aristotle's treatises on natural philosophy, including what we call his biological works, marks off part of what amounts to a highly organized cycle of lecture courses. It is remarkable just how tidily related Aristotle's natural treatises actually are. This can be seen clearly at the outset of his treatise on "meteorology" (by which he means such things as comets, meteors, and the weather). Aristotle remarks here, speaking to his students, "When this inquiry has been concluded, we can consider what account we can give . . . of animals and plants . . . When this has been done, we may say that the whole of our original undertaking [into natural science] will have been carried out" (*Meteorology* 339 a 6–20).