CHAPTER ONE

Philosophy and Biology

In working out how philosophy and biology are related, and what the philosophy *of* biology might be, much depends on general questions about the nature of philosophy and what it aims to achieve. The best one-sentence summary of what philosophy is up to was given by Wilfrid Sellars in 1962: philosophy is concerned with "how things in the broadest possible sense of the term hang together in the broadest possible sense of the term." Philosophy aims at an overall picture of what the world is like and how we fit into it.

Science, too, tries to work out how things "hang together." Philosophy does this in an especially broad way, but breadth comes in degrees. As a result, some philosophical work shades off into science; there is not a sharp border between them. Philosophy also shades off into fields like politics, law, and mathematics. In its relation to science, philosophy has often also functioned as an "incubator" of theoretical ideas, a place where they can be developed in a speculative way while they are in a form that cannot be tested empirically. Many theories seen now in psychology and linguistics, for example, have their origins in philosophy. I think of this incubator role as secondary, though, and as separate from the role that the Sellars quote expresses.

1.1. What is the philosophy of biology?

Given this picture of philosophy, what relation does philosophy have to biology? One part of the totality that "hangs together" somehow, as Sellars put it, is the world of living things, like ourselves, other animals, plants, and bacteria. Another part of the totality is human *investigation* of the living world, including the practice of science. Here are some examples of philosophical issues that arise in and around biology, in roughly the order in which they appear in this book.

Although modern biology seems to have given us a good understanding of the living world, it seems to have done so without, for the most part, describing that world in terms of *laws*, as many sciences do. Is this because the subject matter of biology is special, because the science is less advanced, or because there are plenty of laws of biology but we are not calling them by that name? That is one of the topics of the second chapter, which also looks at the role of "mechanistic" explanations in biology and at the role of theoretical models that seem to roam far from actuality, even though they aim to help us understand the empirical world.

The book then turns to evolution, and the third chapter focuses on the most controversial part of evolutionary theory, Darwin's idea of *natural selection*. Many puzzles arise around what exactly can be explained in terms of selection, and in terms of the associated idea of biological "fitness." The last part of the chapter looks at the application of evolutionary ideas outside the usual borders of biology; Darwinian ideas have been applied to change in practices within a culture, for example, and to ideas jostling around in a person's head. Are these applications of Darwinian thinking just loose metaphors, or is change by natural selection a universal feature of biological, social, and psychological systems?

One of the most historically influential and psychologically powerful ways of thinking about living things is in terms of their *purposes* and *functions*. Modern biology, with its combination of a mechanistic, bottom-up treatment of biological processes and an evolutionary account of how living things come to be, has an uneasy relationship with that way of thinking. Does this package of views dissolve the appearance of purpose in the biological world, or explain where purposes come from? This is one topic of the fourth chapter, which also looks at some elusive questions about the relationships organisms have to their circumstances of life: to what extent do organisms *adapt* to their environments, and to what extent do they *construct* them? The fifth chapter is about organisms themselves, and other "individuals" in biology. It looks at what sort of things these are, how they are bounded, and how they come to exist. The sixth is about genetics. It begins by looking at the changing role of genes as objects, as hidden factors that explain what organisms are like. I then turn to their role in evolution, especially the idea that all of evolution can be seen as a long-term struggle between rival genes.

The seventh chapter discusses species and other biological kinds. Are species real units, objective aspects of the living world's structure, perhaps with "essences" that mark off one kind of organism from another? Chapter 8 is about social behavior, and it looks closely at *cooperation* and related phenomena. I outline a general theory of the evolution of cooperative behaviors, a theory that takes a very abstract form, and then turn to the special case of cooperation in human societies. How much similarity is there between cooperation as a human, psychologically complex phenomenon and cooperation or coordination between the unthinking parts of living systems? After this discussion of social behavior I look at how the discussions of species in chapter 7 and social behavior in chapter 8 fit together to tell us something about "human nature," if such a thing exists at all.

The last chapter looks at another social phenomenon that has deep roots running through living systems: communication. This topic connects to a larger debate about the role of *information* in biology. Some biologists think that evolutionary processes, perhaps life itself, are in some sense *made* of information. I discuss those ideas fairly critically, but then look at recent work on the ways that signaling and communication pervade living systems, and at models of the evolution of these special forms of interaction. How does information transmission of the sort that we are engaged in now, reading and writing, relate to what goes on inside our bodies, between genes and cells?

These are some of the themes the book will look at. With this list laid out, it is possible to see a further way of organizing things, and thinking about the role of philosophy in relation to biology. In some of the areas described above the goal of the philosopher is to understand something about *science*—how a particular part of science works. In other cases, the goal is to understand something about the natural world itself, the world that science is studying.

In a broad sense, all philosophy of biology is part of the "philosophy of science." But with an eye to the distinction just made, we can also distinguish *philosophy of science*, in a narrower sense, from *philosophy of nature*. Philosophy of science in this narrower sense is an attempt to understand the activity and the products of science itself. When doing philosophy of nature, we are trying to understand the universe and our place in it. The science of biology becomes an instrument—a lens—through which we look at the natural world. Science is then a resource for philosophy rather than a subject matter.

Though science is a resource for the philosopher trying to understand life, philosophy has its own perspective and its own questions. It is foolish for philosophy to place itself *above* science, but it can certainly step back from science and gain an outsider's viewpoint. This is necessary, in fact, for philosophy to be able to pursue the task of seeing how *everything* hangs together. A philosopher will look at how the message of one part of science relates to that of another, and how the scientific view of nature relates to ideas we get from other sources. The philosopher's vantage point makes it natural to question things that might be taken for granted, perhaps for practical reasons, within scientific work. So the project I call "philosophy of nature" is not giving a philosophical *report* of what is going on in science, but working out what the raw science is really telling us, and using it to put together an overall picture of the world.

This is not something that only philosophers can do. Scientists often have their own views about the philosophical significance of their work, and we'll encounter these views often in this book. But distilling the philosophical upshot of scientific work is a different activity from doing science itself.

The activity of science is itself part of nature; it is an activity undertaken by human agents. These two kinds of philosophical work interact; what you think science is *telling* us about the world will depend on how you think that part of science *works*. But being interested in the activity of science and being interested in what science is telling us about the world are somewhat different things, both of them part of the view of philosophy expressed by Sellars in the quote at the start of this chapter.

1.2. Biology and its history

This section gives a brief historical sketch of some parts of biology, emphasizing the development of evolutionary ideas and general views of the living world. The aim is to introduce some of the biological theories that are important in the book, including both current ideas and older ones that provide context and contrasts. A later chapter includes a separate historical survey of genetics.

Many early theories about the living world included evolutionary speculations of some kind—ideas about how familiar living things might have their origins in other kinds of life, or in nonliving matter. Among the ancient Greeks, Empedocles (ca. 490–430 BC) is an interesting example. He held that the earth had given birth to living creatures, but these first creatures had been disembodied *parts* of familiar organisms: "arms wandered without shoulders, and eyes strayed in need of foreheads."[1] These parts joined into combinations, with some surviving and others, unfit for life, disappearing. So the organisms we see now are results of a simple kind of "selection" process. Variations appeared and some were kept while others were lost.

Plato and Aristotle, the most influential ancient philosophers, did not endorse an evolutionary picture. In Aristotle's work a different kind of change, the orderly progression within each lifetime from egg to adult, was observed carefully and seen as a paradigm of "natural" and goal-directed change. He also saw movement towards goals as central to understanding change in areas far from biology, including physical phenomena. Living things for Aristotle are connected by gradations, with a scale from lower to higher forms that connects plants, animals, and man, though this scale does not reflect a historical sequence. The idea of a scale between higher and lower, a *scala naturae*, was immensely influential in the centuries to follow, forming an important part of the fusion of Aristotle's philosophy with Christianity that guided thinking through the Middle Ages. These scales typically began in inanimate things, extended through plants to simple and complex animals, then to man, the angels, and God.

[1] This is from Aristotle's account of Empedocles in *On Nature*.

As knowledge of plants and animals improved, scales from higher to lower came to seem less and less adequate. Some writers began to represent the organization of life with branching trees, along with other more complicated shapes (O'Hara 1991). They generally did not think of these trees and other shapes as representing patterns of ancestry. They were thought to represent "affinities"—similarities in underlying form—which have a basis in the "plan of the Creator." In the mid-18th century Carl Linnaeus developed the system of classification that is still used—in modified form and with some controversy—today (Linnaeus 1758). This is a system of groups within groups. Linnaeus categorized organisms initially in terms of their *kingdom*, *class*, *order*, *genus*, and *species*. (Other categories, such as *phylum* and *family*, were added later.)

Evolutionary speculation continued to crop up. The 18th-century French naturalist Buffon wondered about the common ancestry of some species. Darwin's grandfather Erasmus proposed in *Zoonomia* (1794) that all life diverged from a primordial "filament." The suggestion that new forms might appear by chance, some flourishing and others dying off, was sketched in vague form by various writers. The French enlightenment philosopher Denis Diderot included the idea in an anonymously published antireligious pamphlet that was so controversial that when Diderot was found to be the author he was thrown in jail ("Letter on the Blind," 1749).

The first detailed evolutionary theory was developed by Jean-Baptiste Lamarck, working in the early 19th century in France. Lamarck is famous now for the idea that evolution can occur by the "inheritance of acquired characteristics," something often referred to as "Lamarckian" evolution. The idea is that if an organism acquires a new physical characteristic during its lifetime, as a consequence of its habits of life, there is some tendency for that characteristic to be passed to its offspring. A hypothesis that Lamarck put more emphasis on, however, involved the actions of fluids, visible and invisible, flowing through living bodies. As they flow, they carve out new channels and make each organism more complex, in a way inherited across generations (Lamarck 1809). Life for Lamarck is also continually produced from inanimate matter by "spontaneous generation," forming independent lineages. A mammal alive now, for Lamarck, is a member of an older evolutionary lineage than a jellyfish around now; the jellyfish lineage has had less time to travel the road toward increased complexity. The present mammal and jellyfish do not have a common ancestor, though the mammal has a long-dead jellyfish ancestor. Lamarck did use a tree-like drawing to represent the relations between groups of organisms. There is some debate about how it should be interpreted, but it was not a tree representing a total pattern of common ancestry.[2]

Charles Darwin worked out his central ideas in the 1830s and published *On the Origin of Species* in 1859, publishing then because another English biologist, Alfred Russell Wallace, had come to similar conclusions. Darwin's theory had two main parts. One was a hypothesis of *common ancestry* of living species, which Darwin presented in terms of a "tree of life." As noted above, tree metaphors had been used to represent the organization of life before this. Darwin's move was to give the tree a historical, genealogical interpretation. Through evolutionary time, new species are formed by the splitting or fragmentation of existing ones. This gives rise to a network of relatedness among species themselves, forming the shape of a tree.

The other part of Darwin's view was a theory of how change occurs within species—on twigs or segments of the tree. In any species, new variations appear from time to time by accident. Individuals appear with quirks in their structure or behavior that other members of the species do not have. These variations arise in a haphazard way (perhaps, according to Darwin, due to shocks to the reproductive system). Most new variations are harmful, but a few help organisms to survive and reproduce. Many of these characteristics also tend to be passed on in reproduction. When a new characteristic appears that both is useful *and* tends to be inherited, it is likely to proliferate through the species. Small

[2] A comment Lamarck made in defense of this view has considerable evolutionary irony. He noted that a version of his view exists as a proverb, "*Habits form a second nature*." Then, "if the habits and nature of each animal could never vary, the proverb would have been false and would not have come into existence, nor been preserved in the event of anyone suggesting it" (1809/2011, p. 114).

changes of this kind accumulate, and slowly give rise to whole new forms of life.

Darwin's thinking was influenced by three sets of ideas in other fields. "Natural theology" was a tradition of writing about nature emphasizing the perfection of God's creation, especially the complex design of organisms and the match between organism and environment (Paley 1802/2006). A second influence was Thomas Malthus's *Essay on the Principle of Population* (1798), a pessimistic work that argued that the natural growth of the human population must inevitably lead to famine, as the food supply could never grow fast enough to keep up. This led Darwin to the idea of a "struggle for life." The third was Charles Lyell's work in geology (1830), which argued that dramatic transformations of the earth could result from the operation of undramatic, everyday causes operating over vast periods of time.

Darwin was cautious on many points. He was unsure whether life formed a single tree or several. He accepted that factors beside natural selection affect the evolutionary process. He did not tie his view to speculations about matters about which little was known, such as the physical nature of life—he avoided the "fluids" and "filaments" of earlier writers. Instead he linked his evolutionary hypotheses to familiar and readily observed phenomena, especially the results of animal and plant breeding.[3]

Most biologists were fairly quickly convinced that evolution (as we now call it) had occurred, and that common ancestry connects much or all of life on earth. There was more controversy about *how* the process had happened, especially about natural selection and Darwin's insistence on gradual change. One of the weaker points in Darwin's work was his understanding of reproduction and inheritance. Gregor Mendel, a monk working in what is now the Czech Republic, had worked out some crucial ideas in this area around 1860, but his work was largely ignored. Mendel suggested that inheritance is due to "factors" (later called

[3] A remark in a letter by William James in 1883 captures, in James's unique style, an aspect of Darwin's mind that made his work so powerful: Darwin's tendency was to avoid abstractions and consider "concrete things in the plenitude of their peculiarities & with all the consequences thereof" (Skrupskelis 2007, p. 747).

"genes") that are passed on intact across generations, forming new combinations in different individuals. In 1900 this work was rediscovered and the science of genetics emerged. Initially, many scientists thought that the new Mendelian ideas were incompatible with Darwinism, as the Mendelian view was seen as allied to a "discontinuous" or "saltationist" view of evolution in which new forms appear in sudden jumps.

In time, Darwin's ideas were united with Mendelian genetics (Fisher 1930, Wright 1932). According to this "synthesis" of the views, most characteristics of organisms are affected by many genes, each of which has small effects. Evolution occurs as selection and other factors gradually make genes more or less common in the "gene pool" of the species. New genes are introduced by the random "mutation" of old genes. So mutation produces new genes, sexual reproduction brings existing genes into new combinations, and natural selection makes genes more or less common, as a result of the overall effect each gene has on the construction of living organisms.

One thing missing from this picture was any understanding of the chemical makeup of genes, and the processes by which they affect organisms. Another problem was the absence of much connection between evolutionary theory and the biology of individual *development*; evolution, according to critics, was being presented as if comprised of a procession of adults. The first changed in 1953, with the discovery of the double-helix structure of DNA by James Watson and Francis Crick. This discovery contained immediate clues about *how* genes do what they do (Crick 1958). The years that followed saw a deluge of information from the new "molecular biology," adding a further level of detail to evolutionary theory as the rest of biology was transformed.

In the past few pages I followed evolutionary thinking from the early 19th century forward. Central ideas in other parts of biology were also established in the 19th century. These include the ideas that *cells* are the basic units in living things, and that cells arise from other cells by division and fusion. Experiments by Louis Pasteur put the idea of ongoing "spontaneous generation" of life to rest in the middle of the century. For many years the chemistry of living systems, or "organic" chemistry, had seemed so separate from the rest of chemistry that it appeared that life might involve its own special chemical principles, beyond those seen in "inorganic" matter. This also changed in the 19th century, with the first chemical synthesis of organic compounds and recognition of the special role of carbon, with its ability to form complex structures such as rings and chains. The puzzlingly separate "organic" chemistry became carbon chemistry.

Nonetheless, debate continued through the late 19th and early 20th centuries over whether all living activity has a purely physical basis. "Vitalists" thought that living processes were too purpose-driven to be merely physical (Driesch 1914). The biology of individual development, the sequence by which egg leads to adult, remained so puzzling that for some it did seem possible that a special organizing factor, something beyond ordinary physics, might be operating. Vitalism faded as the mechanistic side of biology advanced, and late in the 20th century the orderly progression that Aristotle had seen as a paradigm of natural change received a new type of explanation through the integration of developmental biology with molecular genetics, and a charting of the intricate processes by which gene action is regulated within cells. Simultaneously, the effects on evolutionary paths of the processes of individual development were explored (especially by the "evo-devo" movement), integrating explanations of change from the levels of molecules, through organisms, to the evolution of species.

Further reading

For large-scale history, see Lovejoy (1936), Bowler (2009); for Lamarck, Burkhardt (1977); for Darwin, Browne (1996, 2003) and Lewens (2006); for precursors, including those outside the Western tradition, Stott (2012); on the synthesis, Provine (1971), J. Huxley (1942); on evolution and development, Amundson (2005), Laublichler and Maienschein (2009), Wagner (forthcoming); on species, Wilkins (2009); on molecular biology, Judson (1996).

CHAPTER TWO

Laws, Mechanisms, and Models

Looking at biology from a philosophical point of view, one of the first things people notice is that there is apparently not much role for scientific *laws*. The image of science as a search for the laws governing the natural world is an old and influential one, and many philosophers have held that the investigation of laws is central to any genuine scientific field (Carnap 1966, Hempel 1966). The laws of physics may be basic, but each science tries to find its own laws—laws present in the systems it studies. Perhaps biology is just a cataloguing of the world's contents, and not a theoretical science that gives us real understanding?[1] The progress in biology over the past century has made this seem more and more unlikely. Instead, it appears that good science can be organized differently. Or perhaps laws are present in biology but we are not seeing them clearly and calling them by that name?

This chapter is about the organization of hypotheses and explanations in biology. I start with laws, and then look at two other sets of issues.

2.1. Laws

What exactly is a law of nature? There is much disagreement, and I will focus on a few features that are widely accepted. First, a statement of a law is a true generalization that is *spatiotemporally unrestricted*; it applies to all of space and time. Second, a law does not describe how things merely *happen* to be, but (in some sense) how they *have* to be. An example of a law that seems to

[1] Ernest Rutherford, who split the atom, allegedly said, "All science is either physics or stamp collecting." See also Smart (1959).