Genes and the Agents of Life: The Individual in the Fragile Sciences: Biology

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Genes and the Agents of Life

The Individual in the Fragile Sciences
Biology

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1. INDIVIDUALS AND THE LIVING WORLD

What are the agents of life? This book is a partial answer to this simple-sounding, yet puzzling, question. In this first chapter, I shall unpack what is built into this question and introduce some of the issues that answering it will lead us to explore.

The living world not only surrounds us physically, but its denizens also occupy much of the content of human thought and action. These agents of life range from the plants and animals that fill our homes and domestic lives, to those we consume as part of our ecological regime, to organisms of all types: blue whales, dolphins, chimpanzees, dogs, fungi, flowering plants, rainforests, bacteria, viruses, sponges, tapeworms, and so on.

The living world and the agents of life that constitute it excite the full range of our passions – love, wonder, joy, fear, and disgust. Our interactions with them have inspired human artistic expression from the earliest cave drawings to late-twentieth century experiments in bio-art.

Part of what impresses us, what leaves a mental mark, is the fact that we are not simply immersed in the living world but part of it. We are each subject to its vicissitudes, such as disease and death, and each of us owes our own existence to the activities of members of the living world most like us: other human beings. Human beings are the agents of life that preoccupy most of us, most of the time, and it is more than naive anthropomorphism that places us and our own peculiar qualities at the heart of many of our representations of the living world.

But there is more to what catches our eye about the living world. It is rich, complex, and diverse. Both its particularity and its lawfulness are

the basis for at least a minor kind of awe, one that can stem from our everyday interactions with the rest of the living world. If you have ever carefully observed large mammals in their natural environments, played with a young kitten or puppy, watched a flower bloom or a bee work its way across the stamens in the flower, or learned how rapidly viruses and bacteria can multiply and change their structure, then you might have experienced the little "Wow" that I am trying to evoke.

There is a simplicity to our common-sense thinking about the richness, diversity, and complexity to the living world that is taken for granted in both common sense and the biological sciences. The living world is made up of living things, and living things are agents. We think about the dimensions of the living world, and the vague and contentious boundaries to it, in terms of the individual agents that the living world contains. These individuals range in size from single-celled organisms that can only be viewed through moderately powerful microscopes to giant sequoias that reach hundreds of meters into the sky and whose full physical scale, both above and below the ground, cannot be observed in any single, direct way. The living world includes individuals that vary massively in their longevity, with lifespans of minutes to those of hundreds of years; in their general strategies for living (for example, plants versus animals); in their internal complexity; and in their relationship to one another and their environments.

In short, when we think of the living world we think of the individual agents in it, the properties those individuals have, and the relationships they enter into, both with other living things and with the nonliving world. We think of life as we think of the mind – as tied to and delimited by agents. Neither life nor mind float free of agents, but are, in some sense, features that individuals either have or lack.

There is a flip side to this tie between life and agency. Life, like mind, does not simply belong to agents, but is more intimately woven into their fabric. Life and mind determine what it is to be an agent. Life and mind are, in some sense, *inside* individuals. They are deep features that make an important difference to the kind of individuals that have them, and they cannot be removed from any individual without changing their status as agents.

2. LIFE AND MIND

This raises the question of just how closely life and mind are related. Ancient and modern theories of both life and mind imply an intimate

relationship between the two, an intimacy reflected in the etymology of classical and modern languages. For example, Aristotle distinguished between three kinds of soul that living things can possess – vegetative, animal, and rational. Herbert Spencer, the great integrator of nineteenth-century philosophy and science, viewed life and mind as being of a piece, and took a treatment of one to be incomplete without a treatment of the other. The words usually translated as "soul" from Sanskrit, Greek, and Latin – *atman, psyche*, and *anima* – all have the connotation of breath, something that fills a living thing and is necessary for its survival. The contemporary physicist and popular science writer Fritjof Capra says "[d]escribing cognition as the breath of life seems to be a perfect metaphor," and identifies life and mind.[1]

Today these views of life and mind are likely to be seen as antiquated or quaint, and met with corresponding bemusement or the impatience that leads to contempt. We treat life and mind as independent features that an individual either has or lacks. The study of life and mind has been compartmentalized into, respectively, the biological and the cognitive sciences. This sort of disciplining of the domains of life and mind, however, was contingent rather than inevitable. While it has created the opportunity for deep insights into both life and mind, it has also produced its own blind spots. One of these concerns the role and conception of agents in thinking about life and mind. Let us begin comparatively and consider two ways in which these roles differ.

First, in the case of the mind, we have a clear paradigm for the sort of agent that minds belong to. They belong to rational beings, and, for better or worse, we view human agents as rational beings. This is not to deny that we often think of other kinds of agents as having minds. For example, intelligent robots or computers, such as HAL in *2001: A Space Odyssey*, God (on at least most conceptions), and nonhuman animals all have minds of some kind. But human beings are the gold standard in that the minds of these other agents are typically conceptualized as being somewhat like those of human agents but diminished or enhanced in some or all of their characteristics. The focal role that human rational agency plays in our common-sense thinking about minds survives in the sciences of the mind – from artificial and computational intelligence to comparative psychology – where minds are conceptualized in terms of categories, such as perception, learning, decision, and memory. Although these straddle the divide between human and nonhuman cognition, again they have their paradigm existence in human agents.

In the case of life, we also have a paradigm conception of what sort of agent has it, one that encompasses human agency but is somewhat broader. Our paradigm examples of living things are organisms. We are organisms, true enough, but it is also true that we are simply one kind, perhaps one very special kind, of organism. Our place in the living world is not as central as it is in the domain of cognition, a point reflected in the diminished role that human agency has within the biological sciences relative to that in the cognitive sciences.

A second difference between the role and conception of agents in thinking about life and mind concerns the physicality of individuals. By this I mean their boundedness in space and time, their material composition, and the role of dimensions of physical continuity in the survival of individual entities. Living agents have a high level of physicality. They are born (come into existence) and die (pass out of existence), they have a particular material structure important to what they can and cannot do, and their identity over time as the very same living thing – and not just the same kind of living thing – depends heavily on their physical continuity during that time. Cognitive agents, by contrast, have a low level of physicality. They are often thought of as having an essence that can be separated from their physical embodiment. This is so, not only in religious thought that embraces the survival of the soul after the death of the body, but also in the familiar fantasies of science fiction in which minds can be stored as information and beamed from one physical medium to another. The minimal physicality of cognitive agents is also manifest in the traditional view within artificial intelligence, which takes physical embodiment to be an add-on to a cognitive agent, something into which the artificial intelligence is injected after an agent has been created or established. It is part of what philosophers often think of as a Cartesian tradition that sees minds and bodies as operating in two different worlds, the mental and the physical.[2]

3. AGENTS: BIOLOGICAL, LIVING, AND OTHER

So far I have moved freely between talking of organisms as paradigms of living things, as individuals in the biological sciences, and as agents. It is time now to sharpen our focus and introduce some terminology. The central notions here will be those of a *living agent* and a *biological agent*.

I intend to characterize an agent in quite a general way: an agent is an individual entity that is a locus of causation or action. It is a source of

differential action, a thing from which and through which causes operate. Consider some concrete examples of agents that are physical, biological, and social in nature.

Agents in the physical world, or physical agents, include very small things, such as elementary particles and atomic elements; ordinary physical objects of the sort that you can see with the naked eye or manipulate with your body, such as balls, tables, and rocks; and larger and more distant objects, such as tectonic plates and stars. Agents in the biological world, or biological agents, include proteins, genes, cells, organisms, demes, species, and clades. Social agents include individual people, but also groups of people, institutions, networks, and larger systems that consist of these other agents organized in particular ways.

The notion of an agent is linked, but not identical, to that of a cause. Agents are individuals, and causes often are not. I would be content to contrast individuals with other kinds of things that we might invoke as "the cause" in a given instance, such as forces and fields, processes and events, and properties and states. But I do not want to be legislative about this, and there are certainly ways in which we can and do think about, for example, certain winds or a particular magnetic field as an individual. Giving them a proper name, such as the North Wind or Hurricane Eliza, or personifying them more generally, are two ways of treating forces and fields, for example, as individual agents.

Crucial to being an agent, in the broad sense I intend, is having a boundary, such that there are things that fall on either side of that boundary. This notion of an agent should both make it clear why organisms are paradigmatic agents and why bodily *systems*, such as the digestive system, and biochemical *pathways*, such as the integrin signaling pathway that mediates cell adhesion, might be considered biological agents. As these examples suggest, agents sometimes operate as biological mechanisms: they have functions to perform in the context of some larger agent, and in turn contain further agents (such as the stomach and cadherins, in the two above examples) that perform contributory functions.

I find it compelling to think of these agent-marking boundaries as spatial and temporal, and so view agents as having both spatial and temporal beginnings and endings, as well as spatio-temporal continuity throughout their existence. Yet some of the agents most commonly invoked across cultures in explanations and accounts of our personal experiences are thought to be nonmaterial: from God, to angels, to ghosts, to ancestral spirits. Any view of agency needs to say something about such putatively nonmaterial agents, but we need not do so in this introductory chapter.

Consider then (and for now) just physical agents, agents that have spatial and temporal boundaries, a material composition, and continued existence in space and time. Biological agents are one kind of physical agent. What of *living* agents? Put simply, these are biological agents that are living. Living things are often characterized in terms of one or more of the following properties: they have a metabolism, grow, contain adaptations, evolve, or have heterogeneous, specialized parts. The relationship between the concepts of organism, agency, and life is the topic for several chapters in Part Two. For now, I simply appeal to these properties as a way to provide a fix on what a living agent is, and note that, with the exception of organisms, we might reasonably question whether *any* of the examples of biological agents that I provided previously – proteins, genes, cells, demes, species, and clades – are living agents in and of themselves.

There are two important features of the way in which we think about biological agents, including living agents, particularly in the contemporary biological sciences.

First, biological agents are often conceived as forming a hierarchy of increasingly inclusive entities, starting with very small biological agents and ending with larger entities comprised of the agents with which we began. As the philosopher Todd Grantham says,

> Life on earth is hierarchically organized. The biotic world consists of many 'levels' with the entities at each higher level composed of lower-level entities. Groups of cells form the tissues and organs out of which organisms are constructed, and organisms form various kinds of groups such as kin groups, populations, and species.[3]

This hierarchical thinking is ubiquitous in the biological sciences, and it extends to include not just agents (in my sense) but processes, events, properties, and states. In all of these cases, our default view is a sort of realism about these hierarchies. They and the individuals they contain are a part of the fabric of the world, rather than simply a product of our ways of thinking about the world, something we discover rather than invent.

Second, it is common to distinguish kinds of biological agents from one another. For example, some are physiological (cells), others are genetic (segments of DNA), some are ecological (predators), others evolutionary (species). These specific kinds of biological agents are also thought to be organized hierarchically. Together with the fact that the resulting more specific lists of biological agents are almost always distinct, this suggests that there is no single listing of "the" biological agents there are in the world.

TABLE 1.1. *The genealogical hierarchy and two versions of the ecological hierarchy*

Genealogical	Ecological (1)	Ecological (2)
Monophyletic taxa	Regional biotas	Biosphere
Species	Communities	Ecosystems
Demes	Populations	Populations
Organisms	Organisms	Organisms
Chromosomes	Cells	Cells
Genes	Molecules	Molecules

Source: Redrawn from Table 6.3 of Niles Eldredge, *Unfinished Synthesis* (New York: Oxford University Press, 1985).

Consider a version of the distinction between genealogical and ecological hierarchies initially introduced by the paleontologists Niles Eldredge and Stanley Salthe (Table 1.1).[4]

The genealogical hierarchy contains entities that form historical lineages and give rise to patterns of ancestry and descent. The ecological hierarchy, by contrast, orders entities that play some sort of economic or functional role in the activities of life. As the distinction between two possible ecological hierarchies suggests, there are different ways to individuate the entities in these hierarchies, here turning on whether, as in the middle column, we restrict our ecological hierarchy to living things, or whether we take it to also include the abiotic environment, as in the right-most column.

Both the role and nature of hierarchical thinking within the biological sciences, and the idea of pluralism about biological agents, are topics that will occupy us further throughout *Genes and the Agents of Life*. As a way of illustrating how both topics are engaged by alternative conceptions of the individual in the biological sciences, I turn next to consider the long shadow cast by the Aristotelian view of the natural world and challenges to it in relatively recent biological thinking.

4. SPECIES AND NATURAL KINDS: THE ARISTOTELIAN SHADOW

I have already noted the obviousness of individual organisms when one looks at or reflects on the organization of the biological world. Only slightly less perspicuous a feature of that organization is that organisms are not randomly assorted throughout nature but cluster in groups whose

members are similar to one another, or are of a kind. Plus or minus a bit, biological species – whether they are human beings, domestic dogs or cats, or robins, to take four of the species most often invoked in common-sense thought and talk – strike us as a form of organization in nature, a natural kind. As recent work in folk biological taxonomy suggests, "[h]umans everywhere classify animals and plants into specieslike groupings that are as obvious to a modern scientist as to a Maya Indian."[5]

Given the naturalness, at least to us, of this level of organization in the biological world, it should be no surprise to learn that the idea that individual organisms belong to natural kinds, species, has a long history. It is often associated with Aristotle, and some conception of biological species has remained central to the history of Western thought about the structure of the biological world since his time. The general metaphysical categories of individual, species, and genus, and the relationships between them, and between them and the rest of reality, play a central role within Aristotle's metaphysics. Many of the examples that Aristotle uses to illustrate these general categories are biological in nature. Since the general outlines of Aristotle's views have remained influential throughout a range of other, sometimes quite radical, changes in metaphysical views, it will pay to have at least that outline before us in thinking about individuals and species in the biological world.

Individual organisms are paradigmatic instances of what Aristotle calls *substances*, the true subjects in the world, the things of which everything else is predicated but which are not themselves predicated of other things. Substances are the focus of the study of metaphysics, which strives to understand their nature or essence. Throughout his writings, Aristotle recognizes some of the similarities between individuals and what he calls species of individuals. In his *Categories* he goes so far as to distinguish explicitly between *primary* substances, individuals, and *secondary* substances, of which species, including biological species, are paradigmatic instances. In so doing he underscores the importance of these similarities. An individual human is an example of primary substance, and to predicate "human" of that person is, in part, to define what sort of thing that individual is, in a way that predicating color or height of him or her does not. To say that humans are animals, that is, to predicate the genus of the species, is to do just the same thing. Thus, for Aristotle, both species and genus are secondary substances, with species being "more truly substance than the genus."[6]

Aristotle's metaphysical picture implies that the biological world is hierarchically structured, and that this structure constitutes a way in which

the biological world is unified. There is a single way in which it hangs together, represented by the taxonomic schemata of evolutionary biology. On the Aristotelian view, species are a fixed part of the order of things. Although the fixity of species was one of the central ideas challenged by Darwin's *On the Origin of Species*, a modified essentialism about species, one that viewed them as natural kinds, albeit with essences that could change over time, has largely been taken for granted throughout the history of biology and philosophy.

Biologists and philosophers of biology have, over the past thirty years, challenged this Aristotelian framework, particularly its essentialism about species and its unificationism about the order in the biological world. These challenges and the resulting alternatives to essentialism and unificationism – namely, the idea that species are individuals and species pluralism – have been so successful that they have usurped the traditional view of species in contemporary philosophy of biology. Species are not simply comprised of individuals but are themselves individuals, not natural kinds. And there is not any one order of things in the biological world, represented by "the" species concept and its place in the Linnaean hierarchy, but many such orders, represented by various species concepts.[7]

Both the thesis that species are themselves biological individuals, and the claim that we should be pluralists about species concepts, deserve more articulation than that provided by my bare summary. But it should be clear already that these views are integral to a variety of issues about the nature of the biological world and our thinking about it, and that they have been viewed as such by their proponents. For example, if species are themselves individuals, rather than natural kinds, then individual organisms are parts of, rather than members of, species, and essentialism about species membership looks something like what philosophers call a *category mistake*. And if pluralism is true, then attempts to articulate "the" species concept can never succeed, for there is no single biological reality for such a concept to map to.

5. PLURALISM, REALISM, AND SCIENCE

Pluralism has considerable vogue within contemporary philosophy of biology and biology itself. I have already mentioned pluralism about species concepts, a pluralism that can be readily extended to the various more general approaches within systematics (for example, cladistics, phenetics). But one can find pluralistic views in many other areas of biology: in

debates over the levels of selection, in disputes about the concept of the gene and the role of genes in evolution and development, and in controversies concerning adaptationism as a research strategy in evolutionary biology. For many of the topics that I shall discuss in the remainder of *Genes and the Agents of Life*, including the four just mentioned, pluralism is not simply a possible position but one defended by many of the leading figures in the field.

There are diverse motivations for this plurality of pluralist views, several of which transcend the particular issues to which pluralism is a response. For philosophers, pluralistic views often mark a departure from traditionally dominant views within the philosophy of science. These include the view of science typically attributed to the logical positivists, according to which the sciences are unified by the hierarchical relationship that holds between them, with the world that the sciences describe featuring entities that stand in a parallel hierarchy, from the very small to medium-sized dry goods to the truly large. And they include a tradition originating in the seventeenth-century mechanical philosophy, what we might call the Cartesian-Newtonian view of the universe as a gigantic machine. On both views, the unity of science is derived from the ways in which small things fit together to form larger things.

Such views are seen, I think rightly, as imposing a sort of straightjacket on the biological sciences, forcing their conformity with the physical sciences taken as a paradigm within the philosophy of science until the last thirty years. In introducing a recent collection of his essays in the philosophy of biology in which pluralism is a recurring theme, Philip Kitcher characterizes the early 1970s as a time when "philosophy of science clearly meant philosophy of physical science," a characterization that echoes that of other leading philosophers of biology, such as David Hull and Elliott Sober. Pluralistic views of explanation, as well as theories, taxonomies, and methodology in science have appealed to those reflecting on the nature of biology in part because they make this a time of the past, allowing the biological sciences to be assessed on their own terms, rather than in the image of physics.[8]

So one motivation for pluralism within the philosophy of biology might be characterized, in the most literal sense, as reactionary in rebelling against dominant traditions within the philosophy of science. But pluralism carries with it a more positive view of the nature of biological reality, of the biological world as more complicated, various, and messy than even our sophisticated views of theories, explanations, and kinds have allowed. Pluralism aims to more adequately capture this complexity and

the corresponding diversity within explanatory practice in the biological sciences. Writing on pluralism about species, John Dupré says that "the more we have learned about the complexity of biological diversity, the clearer it has become that any one theoretically motivated criterion for taxonomic distinctness will lead to taxonomic decisions very far removed from the desiderata for a general reference scheme." Likewise, Kitcher's pluralism about the concept of function in biology aims to do justice to how that concept is used in a broader range of biological sciences than just evolutionary biology.[9]

Both Dupré and Kitcher see their pluralistic views as not only doing more justice to the diversity and complexity of the biological world, but also as providing some recognition of the *social* dimension to scientific practice and theory. It is not simply that the sciences have a social history that influences the conceptual tools that they employ. The practice of science is also subject both to the social division of labor and to regulation by particular social values. Pluralistic views are seen as the natural result of a philosophy of science sensitive not only to what has been called the postpositivist naturalistic turn but also to the interdisciplinary trading zone between the philosophy, history, and social studies of science. Thus, both Dupré and Kitcher have devoted much of their research effort to ways in which the biological sciences are intertwined with social issues and agendas: Dupré to the political pitfalls of reductionism and evolutionary psychology, and Kitcher to the Human Genome Project and eugenics.[10]

Scientists fight different battles. One of the appeals of pluralism for biologists themselves has been that it provides a diagnosis for resolving or perhaps altogether avoiding a debate at an apparent impasse. Consider one of these, the debate over the levels at which natural selection acts. In advocating a form of pluralism about the levels of selection, the entomologists Andrew Bourke and Nigel Franks say that "colony-level, group, individual, and kin selection are all aspects of gene selection. This means that the practice of attributing traits to, say, either colony-level selection or kin selection is illogical." Here there is the feeling that participants in such debates are talking past each other, or that their disagreements are merely semantic. In this context, the adoption of pluralism is a way to represent not so much diversity but underlying, core agreement within the biological sciences. It constitutes the diagnosis of a hidden consensus on which the science can build, bypassing what might otherwise be taken to be irresolvable disagreement limiting scientific progress.[11]

For both philosophers and scientists, pluralism has been defended together with at least a tempered form of realism about science. Realists

hold, roughly, that the sciences not only aim at, but at least sometimes achieve, accuracy in how they depict the world. This is so whether we consider "observational" aspects of science, such as whether an organism has blue, brown, or white eyes or the particular temperature that a liquid has at a given time, or its "theoretical" claims that transcend what can be observed. When Mendel posited particulate "factors" inside his pea plants that were causally responsible for the patterns of character traits that they produced, he was making a theoretical claim in this sense, one that realists view as capturing part of an unobserved structure to reality, that part which we now refer to with the concept "gene" and associated concepts. As such, realism contrasts both with empiricism, which ascribes more significance to variations of the divide between the observational and the theoretical, and social constructivism, which emphasizes historical and social aspects of science over its putative search for Truth.

While pluralism takes some steps from traditional realism toward social constructivism, its proponents are clear to distinguish their view from more radical, relativistic forms of constructivism. Like other middle-ground positions, pluralistic realism faces pressures from views on either side of it: from traditional realism (against its pluralism) and from constructivism (against its realism). This issue will loom large as we turn to particular pluralistic views: about organisms and species (Part Two), genes and developmental resources (Part Three), and the levels of selection (Part Four).

6. Within the Evolutionary Hierarchy: Genes, Organisms, Groups

The "Modern Synthesis" refers to the amalgamation of distinct biological disciplines that emerged during the 1930s and 1940s. At the heart of the Synthesis was the putative integration of two traditions within biology – evolutionary theory, stemming from Charles Darwin, and genetics, originating with Gregor Mendel. One of the architects of the Synthesis, the geneticist Theodosius Dobzhansky, has said that nothing in biology makes sense except in the light of evolution. While this no doubt exaggerates the significance of the fact of evolution and the place of evolutionary theory within the practice of the biological sciences, it serves as a reminder of the centrality of evolution and evolutionary theory to a full understanding of the biological world, something fundamental to the Synthesis. Our paradigmatic biological agents, organisms, form lineages, bear adaptations, and are differentially selected accordingly to their level

of fitness. These are all features of organisms that make sense in the light of evolution. Organisms are evolutionary agents, and this fact about them underlies many explanations of the facts that we can observe about them.[12]

But as the genealogical hierarchy in Table 1.1 makes clear, organisms are not the only evolutionary agents. This raises the question of the place of organisms in the hierarchy of evolutionary agents. This question is typically addressed as a central part of the issue of the level or levels at which natural selection operates. A brief discussion of it here will illustrate that how one conceives of biological agents, and the role that one ascribes to those individuals, structures and constrains theory and practice within the biological sciences.

In the traditional Darwinian theory of natural selection, the individual organism plays the central role as the agent on which natural selection operates. Organisms are the individuals that bear phenotypic traits, that vary in their fitness within a population, and that, as a result, are selected for over evolutionary time. Organisms are the bearers of adaptations, such as thick coats in cold climates, or porous leaves in humid climates. They are the units of selection, the level at which selection operates. On Darwin's own view, units larger than the individual, such as the group, were for the most part unnecessary, and units smaller than the individual, such as the gene, unknown.

By contrast, in the postsynthetic view of evolution by natural selection often glossed in terms of the concept of the selfish gene, individual organisms play a very different role. On this view, genes rather than organisms are the agents of selection. They come to play many of the roles, and have many of the features, ascribed to organisms on the traditional Darwinian view. On this view, organisms are not much more than ways in which genes get to propagate themselves. In terms that Richard Dawkins uses, they are the *vehicles* in which the real agents of selection, genes, the *replicators* in the story of life, are lodged. As Dawkins says in *The Selfish Gene*, "A monkey is a machine that preserves genes up trees, a fish is a machine that preserves genes in the water." Genes are the ultimate bearers of adaptations, coding for the phenotypes that are expressed in the organisms they build. Variations in fitness between genes provide the basis for the process of natural selection. Furthermore, not only is the individual organism no longer the agent of selection, but as Dawkins has also argued, it is only an arbitrary boundary for phenotypes. Phenotypes are extended, reaching into the world beyond the organism, rather than being organism bound.[13]