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1

Ancient Greece and Rome

The Facts

The Birth of Biology

It is impossible to pinpoint the precise moment when the first notions of our modern understanding of biology emerged. Our interest in the natural world is not a new phenomenon—a preoccupation with reproduction, birth, and the nature of disease, as well as descriptions of animal and plant species, can be traced back to ancient times. With the establishment of settled communities and the changes brought about by the Agricultural Revolution, an early biological understanding of the world began to develop. Plants were increasingly employed to treat disease, and with their greater use, efforts to describe them progressed, first in China and India and later in the Middle East. The earliest explanations of the formation of the world and of living things originated in the ancient region of Sumer in Asia, and these were taken up by neighboring peoples and reinterpreted in various ways. The practice of divination and, to a greater extent, the embalming of corpses in Egypt helped advance people's understanding of human and animal anatomy.

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Overview of Ancient Greek and Roman Biological Sciences

We won't speculate here as to what gave rise to the development of what we call "science" or to attempts to provide rational accounts of natural phenomena in ancient Greece.

In our look at the history of biology in ancient times, the first period, known as the pre-Socratic period, is of little interest to us. Though Pythagoras (580–495 BCE) and Empedocles (490–435 BCE) attempted to provide overarching explanations of the world, their contributions to biology were limited. The influence of outlying Greek colonies that were in contact with Middle Eastern and Indian civilizations was important in these early stages of the development a scientific worldview. In the field of life sciences, two names are worth mentioning: Anaximander (whom we will touch on later) and Alcmaeon of Croton, who, around 500 BCE, carried out dissections and vivisections, described optical nerves and the Eustachian tube, and made the connection between the formation of thoughts and the brain. Conceptual frameworks were developed, which, while not providing a great deal of substance to add to our biological knowledge, would be drawn upon by later authors and shape the way they thought about the world. These included the nature and number of elements and essential qualities, and the notion that souls animated living beings.

Aristotle (384–322 BCE) is without a doubt the father of biology. Indeed, it was not until the second century CE that Galen, a Greek physician working in Rome, would complete and in some cases correct Aristotle's physiological works and the medical works of Hippocrates and his followers, and Aristotle's natural history works would be taken up and distorted by Pliny the Elder in the first century CE. Nonetheless, it is

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thanks to the latter that these works were passed on and have survived to this day.

Atomists developed their ideas in a parallel fashion, beginning with Leucippus and Democritus in the fifth century BCE, followed by Epicurus in the third century BCE. In the first century BCE, Lucretius would outline the principles of atomism in his poem *De rerum natura* (*On the Nature of Things*), which is the only account of atomism from this period that has survived.[1]

Hippocratic Medicine

Hippocrates (460–370 BCE) and his followers borrowed the concept of the four elements—earth, air, fire, and water—and the four qualities, in opposing pairs—wetness and dryness, and hot and cold.[2] He extended these divisions to the humors, and differentiated blood (produced by the liver), phlegm (produced by the lungs), yellow bile (produced by the gallbladder), and black bile (produced by the spleen). The predominance of one or another of these humors would lead to four different temperaments, and an imbalance would lead to disease.

A unique feature of the Hippocratic medical school of Kos is that it considered nature to be self-medicating, and thus capable of correcting imbalances as they arose. A physician's role was therefore to promote this power in the patient.

In the field of biology, it was the Hippocratic model of embryonic development, which would later be labelled as "epigenetic," that would have the most lasting impact. In this model, the sperm and ova play equal roles in reproduction. These two

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1. Lucretius, 1995.
2. Hippocrates, 2012.

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kinds of "semen" are formed in various parts of the parents' bodies, and substances produced from similar parts later recognize each other and combine over the course of the development of the embryo, in a process comparable to fermentation. This model allowed for traits acquired over one's lifetime to be transmitted to the next generation.

Aristotle

In *Timaeus,* Plato (428–348 BCE) added little new to the work of his predecessors, associating life with the presence of multiple souls and framing illness as resulting from imbalances. He considered the entire universe to be a living being.

Aristotle's natural history work has always been considered as secondary and subordinate to his work as a philosopher and physicist.[3] More recently, however, historians have reconsidered this view and some have suggested that Aristotle's natural history and physiological work in fact inspired his work as a physicist and philosopher.[4] Aristotle's work in physics and philosophy can be best illustrated in the living world, and without this context it is often difficult to understand.

Aristotle's body of work on natural history is quite substantial. Not only did he put forward one of the first classifications of animals that divided them into species and genera, but his descriptions were also generally very accurate. This precision was drawn from his own observations and experience, but also from conversations with fishers and travelers. This doesn't prevent us from pointing out the more questionable ideas that can be found in his work. He took a particular interest in the behavior of ani-

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3. Aristotle, 1955, 1982, 1991.

4. Lennox, 2001.

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mals and their lifestyles, and comparisons between human behavior and animal behavior are a recurring theme in Aristotle's writing, in which humans don't always come out on top! However, we generally find support for the notion of a hierarchy of beings in his work, with humans at the top.

Aristotle did write a work on plants, although it has not survived. However, his successor at the head of the school, Theophrastus (371–287 BCE), would do for plants what his predecessor had done for animals. This work was the product of four years' study (between 347 and 343 BCE) undertaken jointly by Aristotle and Theophrastus, which would result in 200 works written by Theophrastus, of which only 2 have survived: *Enquiry into Plants* and *On the Causes of Plants*.[5] Theophrastus separated trees, shrubs, and herbs, and paid a great deal of attention to the environmental conditions that were favorable to plants, which is why he is sometimes considered the father of ecology. However, his descriptions of plants are written very much in relation to human needs. He would, for example, describe the conditions that foster the growth of trees to produce wood that is easy to work. A large part of these works is devoted to medicinal plants and their uses, and points out that it is often through similarities in shape or color that plants reveal their therapeutic uses to us.

In the first century CE, Pedanius Dioscorides (40–90) would complete Theophrastus's work in *De materia medica* (On medical material) by describing more than 600 substances with therapeutic properties obtained from plants.[6] The great renown of this work stems in large part from the fact that it was accessible both in the West and in the Arab-Muslim world.

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[5] Theophrastus, 1976–1990, 2014.

[6] Riddle, 2013.

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Aristotle was not particularly innovative in his thinking on the nature of the elements or essential qualities. However, the distinction he made between matter and form was quite an important one in biology. Examples borrowed from biology and medicine will allow us to better illustrate the significance of these ideas and, as we have seen, it was in thinking about living things that these distinctions became apparent. In his view, disease (and death) are rooted in matter, while essence (or what something must be) stems from form. An animal or a plant belongs to a species, and this association is due to its form and not what it is made of, which does not differ from other animals or plants. Similarly, reproduction is seen as a coming together of matter from the female seed and form from the male seed. This union was used to explain how embryonic development was initiated.

The same applies to the distinctions established by Aristotle among four causes—material cause, efficient cause, formal cause, and final cause. The main examples used by Aristotle and his successors to illustrate the different roles of these four causes are borrowed from human activity. In the creation of a statue, the stone or wood represents the material cause, the chisel manipulated by the sculptor is the efficient cause, the formal cause is that which the sculptor wishes to represent (the person), and the final cause is the project of the statue. Similarly, when a physician cures a sick patient by administering plant extracts, the material cause is the extract, the efficient cause is the active ingredient found in the plant, the formal cause is the existence of a state of good health, and the final cause is the physician's desire to cure the sick person.

The notion of the final cause would be vindicated when it was applied to the development of the embryo, while at the same time stirring up more debate. If the formal cause explains

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why the result of embryonic development will be a cat or a dog, it is the final cause that accounts for the process of embryonic development toward its intended goal—the formation of an adult organism.

These distinctions among the four causes may seem rather counterintuitive to modern readers. Only the efficient cause is still considered a cause. The material cause is no longer a cause, but rather that which causality acts upon. The formal cause is of no particular use and the final cause is incompatible with our nonfinalistic view of the world and particularly the living world, whereby natural processes are not thought to be driven toward some ultimate goal.

Moreover, Aristotle distinguished between three types of soul in living beings—the vegetative soul, which is common to all; the sensitive soul, which is found only in animals; and the rational soul, which is specific to human beings. However, in contrast to Plato, Aristotle believed that souls, and specifically the rational soul, could not be separated from the body.

Unlike his anatomic work, Aristotle's physiology was dependent upon or even "imprisoned" by his philosophical worldview. Thus, due to the prominence he gave to the quality of heat, he believed that the heart, which heated the whole organism, was home to the soul and, for this reason, was the first organ to be formed. For Aristotle, the heat coming from the heart was the work of the soul, and the role of the lungs and the brain was nothing more than cooling.

Aristotle also observed the development of eggs, and, like Hippocrates before him, considered certain steps in this development to be fermentation processes. The quality of his embryologic observations did not preclude him from believing in the spontaneous generation of complex organisms, including certain types of fish.

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Aristotle's finalistic views did not, however, go so far as to exclude mechanisms altogether, when, for example, he described the role of tendons in the movement of limbs.[7]

Galen's Physiology

Galen (129–201 CE) was born in Pergamon in modern-day Turkey, where he practiced as physician to the gladiators, and later settled in Rome, where his reputation earned him the title of personal physician to Emperor Marcus Aurelius. Galen's work is characterized by the prominent role he gave to experiments and his strong, sometimes "absolute," finalistic views, whereby natural processes are directed toward some goal.

For Galen, reason and experiments were the two pillars of a physician's work. Galen liked to distinguish his approach from that of more "dogmatic" physicians who denied the importance of experimentation. His role models were Alexandrian physicians from the third century BCE (which we will touch on again later). He practiced animal dissection and, with some restrictions, vivisection. However, in contrast to the Alexandrian physicians and owing to widespread condemnation of the practice, he did not carry out dissections of human cadavers, which would lead to some errors in his anatomic descriptions of the human body. Nonetheless, he made significant contributions to anatomy and physiology, particularly in nerve anatomy and physiology. He demonstrated that the brain was the seat of thought and sight, and situated the soul in the third ventricle (under the cerebellum). He distinguished sensory nerves from motor nerves, and made the connection between spinal cord problems and the sensory and motor deficiencies that result from them.

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7. Aristotle, 1991.

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The views Galen held on reproduction were a middle ground between those held by Hippocrates and Aristotle on the respective roles played by the man and the woman. Moreover, he was the first to suggest that male and female sexual organs shared a common embryologic origin.

Galen believed that each organ had a specific function and was designed in the best possible way to accomplish it. In his view, organs carried out their functions thanks to the abilities with which they were endowed, to which Galen added many more. As with Aristotle, this finalism did not exclude a more mechanistic approach, and the focus on abilities was sometimes replaced by precise descriptions of the mechanisms involved. Galen fiercely opposed the atomists (more on this later), who believed that organs were not created to perform a function, but rather that it was the nature of the organ that led to its function.

Galen's finalistic worldview, which was linked to his firmly held Stoic beliefs in the existence of a benevolent deity, would allow his work to gain a foothold in a newly Christianized world. Though he liked to think of himself as restoring Hippocrates's work to its rightful place, Galen's work would dominate Western medicine to a greater extent than Hippocrates's until the middle of the nineteenth century.

Pliny the Elder's Natural History

Pliny the Elder (23–79) is known for his tragic death in 79 CE during the eruption of Vesuvius.[8] Wishing to save those in danger but also to learn more about what was happening, he landed with his galley south of Naples and was no doubt asphyxiated by the toxic gases emitted during the eruption.

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[8] Schmitt, 2013.

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Pliny is also famous for having written the 37-volume *Natural History*. His political writings, which were the result of his close relationship with Emperor Vespasian, are much less known, but just as prolific: *Bella Germaniae* (The wars of Germany), which he took part in, and *History of His Times*.

Natural History was the product of knowledge he acquired through book learning and a compilation of prior descriptions, and did not come from study in the field as had been the case with Aristotle. What interested Pliny was not nature itself, but nature that was accessible to and used by humans, and more specifically Roman citizens. When referring to "exotic" animals, he thought it important to mention when the first specimen had been seen by Romans as well as to detail its characteristics. In describing vines, he also detailed methods for preparing wine and their flavor profiles. In keeping with the authors he borrowed from, Pliny endowed animals with human emotions and behaviors: an elephant kneels and prays and studies his lessons, like humans.

Pliny's work is puzzling and can seem to have regressed when compared to Aristotle's, from which he drew much of his inspiration. However, his work had a considerable influence during the Middle Ages and even into the modern era.

The Atomists

The debate around atomism was sparked not by the hypothesis that matter was made up of atoms (indivisible, as the name implies) that were infinite in number but finite in type, as much as the atomists' search for a totally natural explanation of the world, based on chance encounters between atoms. Epicurus (341–270 BCE) built on the ideas developed by Democritus (460–370 BCE) and Leucippus (460–370 BCE), and introduced the notion of *clinamen*—a slight swerve from a straight

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line in the movement of atoms, which allowed them to preserve their free will. A text by Lucretius (98–55 BCE) is the only work by atomists that has survived.[9] Its poetic form allowed it to endure through the Christianization of society.

Lucretius believed that the primitive Earth was capable of producing all living creatures, including human beings, but also other organisms that have disappeared because they were poorly formed. To survive, specific qualities were needed—speed or visual acuity. When it came to heredity, Lucretius adopted a model that was close to that proposed by Hippocrates—the difference being that he could designate as atoms that which Hippocrates had difficulty naming.

Historical Overview

The Role of Experimentation in Greek Science and Particularly in Life Sciences

You may be asking yourself why we are revisiting this topic. I have already touched on Galen's vivisection experiments, which allowed him to describe different types of nerves and advance our knowledge of the nervous system. The Alexandrian scholars I mentioned before included Erasistratus (310–250 BCE) and Herophilos (310?–250? BCE), who carried out the first quantitative experiments on living things. They weighed them (to estimate the invisible weight lost owing to exhalation), and measured their pulses and how these varied with relation to disease and age. They also conducted dissections of human cadavers, and, according to their rivals, carried out vivisection experiments on human beings.

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[9] Lucretius, 1995.

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However, we must also contrast these achievements with the obstacles that prevented a more systematic implementation of the experimental method—namely, the weight of theoretical reasoning and the priority given to experiments conducted "by analogy." The first of these impediments was felt particularly strongly in medicine, which would very quickly be perceived as a settled discipline, whose principles had been well established since the time of the School of Kos. Even for a thinker such as Aristotle, who was fond of direct observation, it was reason and solely reason from which fundamental principles were derived, which experiments confirmed or occasionally clarified. This preference for reason can be clearly seen in his physiological work: it was not experiments that demonstrated the heart's central role in the organism, but rather reason that allowed us to deduce it thanks to the qualities that this organ possessed.

Experiments also appeared to go against nature. They were a distortion of it, and therefore could not reveal anything about it. It was not only scholars and thinkers in antiquity who held this prejudice—the same criticisms can be leveled against seventeenth-century experimenters. A mistrust of experiments and the hope that reason on its own would suffice to arrive at the correct explanation has probably not been completely eliminated even from the thoughts of modern-day biologists.

The second hurdle was the value accorded to experiments by analogy (or similarity). To illustrate this type of experiment (and explanation), which is particularly common in the Hippocratic corpus, let's look at an example. Why does the female body seem to be more susceptible to water retention, as can be observed in certain diseases? For Hippocratic authors, the answer was simple: because it was less firm. The proof was derived from the following experiment: take raw wool and a sheet of woven wool and place both in the same humid conditions—the

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raw wool will absorb much more water than the sheet. The result is so obvious that conducting the experiment is often seen as pointless; the experiment itself is a thought experiment.

In *Le chaudron de Médée* (Medea's cauldron), historian Mirko Grmek tried to understand why scientific experiments had not played a major role in Greek science, and particularly in the area of life sciences.[10] Others had advanced the hypothesis that experimentation was curbed by the low status given to technical work (technical trades being reserved for slaves). Grmek came to a different conclusion; namely, that the establishment of an experimental approach is a complex process, which involves several stages to get beyond a groping empiricism. Greek scholars had made it through some of these stages, but not all. There were some attempts at quantification, but it was not widely practiced. What they probably needed most is what Pasteur called an "experimental reflex,"[11] or the widespread recourse to experiments.

Mirko Grmek was right in reminding us that modern-day science and its way of functioning are the result of a long process that was built over several centuries. Greek science was only a chapter in the history of its development.

Anaximander and the Atomists: The Futile Search for Pioneers

Despite repeated warnings from science historians, the hunt for pioneers—the first people to have conducted an experiment or put forward a hypothesis—remains as strong as ever.[12] But this search is of little interest to science historians trying to piece

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[10] Grmek, 1997.

[11] Quoted in Grmek (1997, p. 20).

[12] Barthélémy-Madaule, 1979.

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together the genesis of an area of scientific knowledge. This is due to the fact that, in most cases, such forerunners were ignored by their contemporaries and successors and thus played no role in the development of the idea. However, more importantly, the notion of a pioneer is a false one, in that it is a retrospective and distorted view that provides the illusion of discerning the beginnings of later ideas in older writings. It is often difficult to disprove the validity of a so-called pioneer. However, the result is always gratifying as it precisely reveals the ways in which our modern-day understanding differs from that of the past.

Ancient Greece still provides fertile ground in the search for these forerunners. The small number of texts (which is why people try to extrapolate things from them) and difficulties translating and interpreting them make it even more so. Let's look at some examples to illustrate the recurring myth of pioneers. Conflicting theories of embryonic development in the seventeenth and eighteenth centuries placed scholars in two camps. Those in the preformation camp believed that organisms were already formed in the egg (or the spermatozoon) and simply grew over the course of embryonic development. Those in the epigenesis camp believed that the organism was formed over the course of its development and did not exist prior to this. Some have claimed that these two models can be traced back to pre-Socratic notions of the universe. For Parmenides (sixth–fifth century BCE) nature was one, and from the beginning contained everything that would later appear. Heraclitus (544?–480 BCE) and others believed that the diversity observed was the result of transformations and that it did not preexist in that which gave rise to it.

One can draw an analogy here, but we have learned to be wary of analogies. The conflict that divided embryologists in

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the seventeenth and eighteenth centuries was not a revival of an earlier debate, but rather resulted from new observations, particularly in microscopy. While it cannot be denied that this debate can be framed within these older schools of thought, it did not originate from them nor was it shaped by them.

It is with respect to evolution that the search for pioneers has been most actively pursued. When Anaximander (610–546 BCE), in Ionia, described the appearance of life and the formation of the first human beings as fish, did he anticipate our modern-day view of the evolution of the living world?[13] Clearly not, as there are large discrepancies between the scenario he was describing and the account that is widely accepted today. The first discrepancy is the amount of time needed for these processes to run their course. The second and no doubt more important difference is that the transformations described by Anaximander are commonplace in Greek mythology, as indeed they are in the mythologies of various peoples. Developing ideas on the evolution of living forms first required renouncing these fanciful notions. And evolutionary changes would make sense only in the context of our understanding of the stability of living species.

To take the argument further, it is not only the idea of evolution that ancient authors would have had to anticipate, but rather the Darwinian mechanism of evolution. Lucretius described the random recombination of the atoms that generate living beings, leading to misshapen individuals and to others with qualities that allowed them to survive. Lucretius's text does seem modern (or, more precisely, consistent with modern science) in its desire to find a natural explanation for biological phenomena. However, is it truly Darwinian evolution? It seems

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[13] Kocandrle and Kleisner, 2013.

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to me that there are two fundamental differences between Lucretius's view and modern-day thinking. The first is that Lucretius's misshapen individuals disappear—that is to say that natural selection eliminates only individuals that are not viable. This is not in keeping with modern-day thinking on the role of natural selection, even if many have interpreted Darwin's writings in this way, as we will see. The second is that, for Lucretius, individuals that survive do so only because of their particular traits. There is no reference to the central tenet in Darwin's theory that selection acts on relative differences between individuals and not on particular traits. This is a good example of how historical comparisons allow one to refine modern-day thinking.

Other examples of these so-called pioneers must be mentioned briefly, as they have recently found some resonance. The "living universe" described by Plato in *Timaeus* is reminiscent of the living Earth in the Gaia hypothesis that James Lovelock proposed in the 1970s. This is analogous to what we have seen with theories of embryonic development. These are, of course, analogies, and we will see that this idea of a living Earth was a view also held by alchemists. However, to consider the Gaia hypothesis to be simply the revival of an ancient idea does not recognize everything that this hypothesis owes to scientific knowledge accumulated up until 1970.

Similarly, to call Aristotle one of the pioneers of molecular biology by likening the genetic program to the final cause, as proposed by Max Delbrück, one of the fathers of molecular biology, makes little sense. Such a suggestion would not only neglect the novelty of genetic information as an idea, but also be erroneous because for modern-day biologists the genetic program does not represent a final cause but an efficient cause.

Finally, to claim that Theophrastus (or even Empedocles) is the father of ecology is to look at the field in a very simplistic

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way. As the first farmers no doubt quickly learned, there is much more to ecology than the rather obvious fact that plants don't grow in the same way in different soils, when it is hot or cold, when it is raining or when it is dry.

Could the accomplishments of these alleged pioneers be removed from the scientific record without negatively impacting our comprehension of its history? The answer is less obvious than the preceding remarks may lead one to believe. At least in some cases, these forerunners were able to put together a thought framework within which the models and theories they are credited with having originated could later be understood. I am thinking specifically of the ancient atomists here. Though it would be a stretch to raise their concepts to the status of scientific theory or to claim that the ideas of modern atomists were a continuation of their work, they nonetheless set the stage for new ideas.

Contemporary Relevance

Mechanistic and Molecular Explanations

Models and ways of thinking from antiquity can seem so strange to our modern sensibilities that our first instinct is to dismiss them as irrelevant. However, is this reaction justified? Two types of explanations that still hold sway in biology have their roots in this period: mechanistic explanations and explanations involving the action of ferments.

A mechanistic explanation is an explanation by analogy. That is, the biological phenomenon taking place in the organism is compared to a machine and the explanation hinges on there being mechanisms analogous to those present in machines within the organism. In explanations relating to the action of

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ferments, it is proposed that phenomena take place that are analogous to those used by humans to transform foods: making bread, alcoholic beverages (wine, beer), cheese, and so on. In a process that is poorly defined, fermentation brings together heat, changes in form and appearance, and small amounts of matter to produce some effect—features that are useful when trying to explain incomprehensible phenomena.

Mechanistic explanations can be found in the writings of Aristotle and Galen. For these authors, such explanations do not account for all physiological phenomena, but they played a role in movement for Aristotle and digestion in the case of Galen, for example. Explanations involving action by ferments come into play in descriptions of embryonic development, but also in explaining the functioning of certain organs, such as the liver or the heart. Both of these types of explanations would have a bright future. Mechanistic explanations would feature prominently in the seventeenth century, without forgetting the action of ferments. The action of enzymes, the successors to ferments, would play a central role in explaining biochemical processes in the first half of the twentieth century. Explanations based around the action of ferments would progressively shift toward molecular ones. Macromolecular mechanisms are now ubiquitous in our explanations of biological processes. The phenomenon of self-organization shares certain characteristics with the action of ferments, including its nearly limitless ability to explain things.

The Role of Analogy

Given the persistent nature of these two types of explanations, we should ask ourselves about the role that analogy plays in the modern-day models we use to explain the natural world. Were

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we right to scoff at Hippocrates's thought experiments? Analogy is an indispensable tool in science, in particular for the development of models, but it must not, as was the case with Hippocrates, replace experimental facts. It is particularly prevalent in biology, perhaps because it makes use of everyday language. Can we distinguish a good analogy from a bad one? It appears not, as we can know only in hindsight whether the analogy will have advanced our understanding of the phenomena in question.

The disciplines from which analogies are drawn depend on the culture that prevails during the period—i.e., its "episteme," or system of thought and knowledge. This explains why analogies from the past sometimes seem absurd to modern readers. Perhaps in a few centuries some modern-day analogies will appear as ridiculous as those of Hippocrates.

The Beginnings of the Chain of Being

Aristotle was the first to develop the idea of a *scala naturae*, or chain of being, in a scientific way—i.e., that organisms could be more or less positioned along a "ladder" with human beings at the top. This idea would later take root among the naturalists who would follow Aristotle, as well as among embryologists such as Baer, who would characterize embryonic development as a progression from general to specific or from simple to complex.

The concept would not disappear with the rise of Darwin's theory of evolution. The first evolutionary trees naturally positioned human beings at the end of the highest branch. One could argue that it remains influential today, given the position that human beings occupy in many representations of evolutionary trees, or indirectly and in a reactionary way through the

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often clumsy and unsuitable attempts by those who would like to counter this ancient view and thus make the human line a nearly invisible branch of the evolutionary tree. Their arguments, such as referring to the "small genetic distance" between humans and their closest cousins (chimpanzees), unfortunately often don't make sense from a biological point of view. The chain of being still poisons biological thought.

Pliny's Legacy

In Pliny's writings, it is not uncommon to find distortions of fact or human behavior projected onto animals that he is describing. His works would be nonetheless praised by many naturalists, including Buffon. Do we not have some modern-day Plinys—authors who have poor scientific credibility and who use second-hand information, but who nonetheless receive wide coverage in the media because they know how to frame their ideas for the public to attract attention much better than do scientists, at the risk of sometimes going beyond or even sidestepping scientific knowledge? Regardless of their perceived value, the ideas in Pliny's scientific writing certainly have proved nothing if not remarkably persistent.

Ever-Present Finalism

We should not be too quick to poke fun at Galen's finalism either, which led to justifying the small size of human ears by our need to wear hats! Do we not also indulge in the same finalist thinking when we describe the functions of certain organs? Interpretations of brain imaging are almost as naïve as those put forward by Galen, when they attribute certain cognitive abilities to certain parts of the brain. The same thing occurs when "func-

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tions" are attributed to genes and their products. What usually happens is that after a phase of optimistic simplification, genes are found to have multiple functions, which are much more complex than the first observations had led us to believe.

However, finalism had and still has some utility. What Galen proposed was a sort of plan of action—to uncover the functions of different organs—which has proven itself useful in enabling discoveries over the centuries. However, we must nonetheless accept its limitations as demonstrated by experiments.

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