Introduction

The Place of "Biology" in Early Modern Natural Philosophy

"Biology," though it did not yet exist in name, or even as a discrete domain of scientific inquiry, was at the very heart of many of the most important debates in seventeenth-century philosophy. Yet while in recent decades much important scholarly work has emerged on the early modern life sciences, the perception persists in the broader scholarly community that the seventeenth century was principally a period in which physics was of central importance, while chemistry only came to center stage with Antoine-Laurent Lavoisier's revolution in the eighteenth century, and biology with Charles Darwin's revolution in the mid-nineteenth. The term "biology" itself makes its first appearance in the title of a Latin work by the Gdansk-based natural scientist, Michał Krzysztof Hanov (Michael Christopher Hanovius) in 1766.[1] Thus there is a perceived chronological priority of physics over chemistry, and of chemistry over biology (we shall allow the scare quotes to drop out, for now), that corresponds directly to the perception of the hierarchy of the "foundationalness" of these three areas of natural science, with physics at the very base, then chemistry, then biology, each in turn building on and incorporating the principles of the more fundamental sciences. Toward the end of this introduction, in a concluding section on terminology, I will explain in what sense I intend to attribute to Leibniz a philosophy of biology. For now, I would like simply to take "early modern biology" as referring to that loose cluster of reflections upon the phenomena of life, generation, animal growth and motion, and so on, in which so many seventeenth-century natural philosophers were deeply engaged, whether they had a unifying name for this endeavor or not.

Steven Shapin maintains that because of "the grip of mechanical conceptions on medical and physiological thought during the seventeenth century," historians "have not in the main found reasons to celebrate a body of notable, still-recognized achievements" in the domain of what we would call "biology."[2] This is true enough, but what it fails to capture is that the asking of life-scientific questions, and the exploration of the boundary between the life-scientific and the "merely" physical, played a central role in that domain of science in which all historians acknowledge the great achievements of the seventeenth century, namely, physics. Although mechanical physics was certainly of central importance in the seventeenth century, one of the central problems on which this science focused was precisely that of determining which natural entities and phenomena were amenable to explanations in terms of the motions of minute particles alone, and, by contrast, which required something more. Moreover, many scientific experiments that appear to us to be of primarily physical interest simultaneously revealed important features of the living world. Thus, for example, an experiment involving a sparrow in an air pump reveals truths not just about the properties of air but also about those of the avian respiratory system, and if we read the work of the experimenters attentively, we will see that they themselves were interested in both of these. The sparrow was not just a bit of equipment in a physical experiment, but was in its own right the focus of another, overlapping experiment.

Generally, the boundary early modern thinkers were seeking to trace out mapped roughly onto the one we today would place between the organic and the inorganic, with inorganic entities (to use today's terminology) taking pride of place among the things to be explained in terms of mechanical physics, and organic entities standing out as something in need of further explanation. This means, in effect, that insofar as early modern natural philosophers sought to mark out the boundaries of mechanical physics, willy-nilly they came right up to its boundary with biology. More often than not these philosophers felt compelled to cross the boundary and to dwell at length among the plants and animals, in the aim, variously, of explaining why the entities found on the other side in fact could be explained in the same terms as the particles and billiard balls that appeared so easily tractable in terms of the new physics; or in order to make a case for the boundary's absolute fixity; or, in some peculiar cases, such as the one we will be considering in this book, to explain why the particles and the billiard balls themselves have something of the animal in them, and thus must be explained in biological terms.

Although seventeenth-century natural philosophers themselves engaged physical and biological questions as of a pair, it has often been presumed that physics is defined by features inherently of more interest to historians of philosophy than those that characterize other sciences. As Pierre Duhem understood this prioritization, physics is a "mature theory" to the extent that it interprets causal relations within an abstract symbolic system, while an endeavor such as physiology is only a "causal theory" that seeks to explain bare facts in terms of everyday causal reasoning.[3] But if, with Lorraine Daston and Peter Galison,[4] we see the emergence of new epistemological categories and problems out of some prior "knowledge practices" (for example, collecting, vivisection, measurement, induction), then the full account of the emergence of some new science, whether "mature" or not, will lead us back to the sort of human endeavor that is perhaps more "primitive" than, but also historically and conceptually prior to, the sort of abstractions that are supposed to be of primary interest to philosophers.

This is one reason for historians of philosophy to turn their attention to the sundry knowledge practices, such as animal experimentation, microscopy, autopsy, and such, that feed into what we today call "biology": in the early modern period, these practices serve to shape the still malleable concepts of, for example, life, organism, individual, environment, order, that would eventually lay down the theoretical bedrock of the modern life sciences. But there is another reason, and one already intimated above, why the *science manquante* of biology needs particular attention from historians of early modern philosophy: it presented the single largest obstacle to a comprehensive account of nature within the terms of the new, mechanical science. That obstacle was, namely, life. Of course, long before there was biology there was "psychology," in the sense of the study of the soul, which was in turn understood as the principle of life. One crucial element in the eventual rise of biology was the elimination in the early seventeenth century of psychology from the study of the natural world, and the consequent need to replace the soul that used to animate nature with something else. This replacement took the form of the concept of "life," but the challenge for many seventeenth-century thinkers was to find a way to study life, or to "do biology," without allowing this to be simply a continuation of psychology under a new name.

We have already noted that biology did not exist as an independent science, and that there was no term to denote it and no discrete domain of inquiry that could be said to have been lacking only a name. But if biology was nowhere, in an important respect this is because it was everywhere. That is, if we do not see thinkers engaged in a distinct research program that overlaps substantially with what would in the nineteenth century be christened "biology," this is because their questions about vital phenomena were from their point of view basic problems of natural philosophy, and were not seen as addressing a different sector of the natural world than physics: if one is a mechanist, one sees biological phenomena as explicable in the same terms as other mechanical phenomena, to wit, in terms of the mass, figure, and motion of particles; if one is an antimechanist, or what would later come to be called a "vitalist," then for the most part this vitalism extends not just to the life of animals and plants, but to all of the natural world. Vitalism was by and large *pan*vitalism. Leibniz, Henry More, Francis Glisson, and numerous others saw everything in nature as biological; René Descartes and his followers, conversely, saw all biological phenomena as explicable in the ordinary terms of mechanical physics. In both cases, though, it is a pressing task for early modern natural philosophers to provide an account, in one way or another, of what we would call "biological" phenomena.

Much of Gottfried Wilhelm Leibniz's natural philosophy may rightly be seen as a deep and extended exploration of the nature of the division between what we would call the "biological" and the "physical." If his achievements would end up being recognized more in physics than in the life sciences, this should not obscure to us his concern to show how explanations drawn from the living world are relevant to our understanding of what happens throughout the physical world, to show, in particular, how the active motion of an animal might serve as a model for understanding natural motion and change in general.

By the end of his philosophical career, Leibniz would come to the view that everything is biological, save for perception, which for its part underlies the biological without itself admitting of biological explanation. This view is remarkable not just for what it says about perception, but also for what it says about everything else. Could Leibniz really wish to say that everything in the natural world is to be understood on the model of living beings? In an earlier era of Leibniz's storied reception history, to describe him as a thinker of the phenomena of life would have been wholly uncontroversial. This is how many of Leibniz's earliest successors saw him, particularly in the French-speaking world. Yet since then, it has often been supposed that this early chapter of Leibniz's reception was an unfortunate consequence of the dearth of published writings of his throughout most of the eighteenth century, of the misunderstanding of his philosophy that was exacerbated by the distortions of Leibniz's popularizers, and of a general lack of scholarly rigor in the high Enlightenment.

As for the dearth of published texts, what was known was, for example, the *Monadology* of 1714, a work Leibniz intended as a summary of his basic philosophical principles for a wide audience. It is in this text that we find the well-known and evocative image of the world as a "fish pond":

> Each portion of matter may be conceived as like a garden full of plants and like a pond full of fishes. But each branch of every plant, each member of every animal, each drop of its liquids is also some such garden or pond. … Thus there is nothing fallow, nothing sterile, nothing dead in the universe.[5]

According to the canonical view of Leibniz as a rigorous metaphysical idealist, eighteenth-century Leibnizians are supposed to have simply skipped over the "like" that introduces the fish-pond image, whereas once we take care to read it back in, the claim amounts to a mere simile. And in any case, the canonical view would have it, even if the world were "like" a fish pond, it would be so only phenomenally, and however it may be at a deeper level, it is certainly not at all like *that*, or indeed like anything with which we are familiar from the physical world. The *Monadology*, indeed, is taken by many scholars to be the expression par excellence of

Leibniz's mature monadological immaterialism, that is, of his reductive ontology of simple perceiving substances. It will be a central argument of this book that, notwithstanding the "like" in this passage, Leibniz's frequent claims to the effect that all of nature is to be conceived after the model of animals are not intended as loose or poetic comparisons. Leibniz means what he says.

Leibniz's fundamental ontology, it will be argued, did in fact consist exclusively in living creatures; his fundamental physics was a physics of organic bodies endowed with living force; his deep theological convictions about the immortality of substances were corroborated and in part shaped by the empirical life sciences of his day. For Leibniz, every body is an organic body, no substance is without its own organic body, and no organically embodied substance is ever generated entirely de novo. In other words, the world consists in infinitely many eternally existing biological entities. There is, one might say, nothing else.

But *what* exactly is organically embodied? The answer is that there are infinitely many immaterial monads, all of which are constantly accompanied by some organic body or other. Yet insofar as the bodies *result* from the monads themselves, as Leibniz often asserts, the philosopher would appear to believe that it is only the immaterial substances, and not their bodies, that belong to the fundamental ontology of the world. "There is nothing in the world but simple substances," he writes to Burchard De Volder in June, 1704, "and in them perception and appetite."[6] What room, then, is there in such a world for biological entities?

The Corporeal Substance Problem: Compatibilism, Incompatibilism, and Beyond

The interpretive problem just sketched out—the existence of two sets of texts, and sometimes two sets of passages within the same text, that seem to commit one and the same author to two different and conflicting fundamental ontologies—is known as the "corporeal substance problem," and has produced by now a great deal of secondary and even some tertiary literature.

Ever since the publication in 1985 of Dan Garber's influential article, "Leibniz and the Foundations of Physics: The Middle Years,"[7] there has been growing interest among English-language scholars in "the other Leibniz," the Leibniz whose basic ontology is not exhausted by simple substances imbued with perception and appetite, but instead takes seriously the existence of fully real composite or corporeal substances. As Garber insightfully put it in his article, for the Leibniz of the "middle period" (roughly speaking, 1676–90), biology constitutes the true foundational science, and physics is only fully comprehensible in terms of biology, rather than the other way round, as is generally held today. In the French-language literature, this other Leibniz was also discovered—if not for the first time since Leibniz's death in 1716—and exhaustively analyzed by André Robinet in his massive *Architectonique disjonctive* of 1986.[8] The "realist" Leibniz has subsequently been defended and brought into vivid focus by a number of very skilled commentators, upon whose work the present study relies heavily.

Most of the commentators who have sought to introduce us to this other Leibniz, and to revise—and complicate—our understanding of the idealist philosopher we had drilled into us as undergraduates, have portrayed Leibniz as possessed of something of a split personality, the idealist Dr. Jekyll giving way in his less guarded moments to Mr. Hyde's monstrous organic body. Thus Catherine Wilson maintains that Leibniz's interest in the empirical study of nature "was perhaps . . . one reason why Leibniz would not embrace a pure phenomenalism in which it would have made no literal sense to speak of a natural world within which a subject was situated."[9] Even Glenn Hartz, perhaps the strongest defender in recent years of the realist view of Leibniz, believes that the metaphysics of simple monads and that of animals were two systems that Leibniz kept going simultaneously for different purposes, but which were nonetheless incompatible.[10] Michel Fichant believes that the corporeal-substance metaphysics of the late period remains fundamentally at odds with the alternative idealistic metaphysics that Leibniz sought to develop simultaneously.[11] If I have understood her account correctly, it is only in Pauline Phemister's recent *Leibniz and the Natural World*[12] that we find a thoroughgoing and compelling case for the compatibility of the monadological and corporeal-substance metaphysics, showing how these are both descriptions of one and the same world, without attempting to explain away the latter or to make it somehow less committal than it really was.

Our purpose in this study is not simply to add to the now rather enormous list of literature on this ultimately quite hermetic and recondite debate, even if it is ultimately with the compatibilist and realist interpretation offered by Phemister—that is, the view that there *are* bodies, and that their existence does not present any real problems, but only apparent ones, for Leibniz's claim that the world consists in simple substances—that the deepest sympathies of this study lie. Rather, what this study aims to do is to help change the terms of the debate, and thereby to gain a clearer picture of the actual range of Leibniz's own theoretical concerns, by taking seriously his own repeated claims that the phenomena of life are of tremendous interest for his philosophical project, and indeed that the world is to be understood in what we today would describe as fundamentally biological terms. On the account offered here, what happens as Leibniz moves into his final, "mature" period is not a shift in ontological commitments from realism to idealism, but rather a shift in the conception of the nature of body, from being decomposable more or less along earlier iatromechanical lines into homogeneous parts, to being constituted out of infinitely many corporeal substances, each of which is in turn so constituted, and each of which is activated by an entelechy or dominant monad. On this new conception it is true that body comes to need to be underlain by true unities in order to attain to the status of reality or substantiality, and that these unities are in the end to be understood as immaterial nodes of perception. But the invocation of these basic entities underlying body is not intended by Leibniz as a means of *explaining away* body. Instead they offer a means of *accounting for* body.

On such an account, the incompatibilist perspective on Leibniz's realist texts loses much of its force. Much like Aristotle before him, Leibniz now appears not so much to be looking to accommodate living creatures within a world that is ultimately to be explained in terms of some more fundamental entities operating according to more fundamental principles. Rather, he is hoping to explain the world in terms of the fundamental principles he takes to hold paradigmatically of living creatures. In this respect Leibniz's natural philosophy is much more akin to that of Aristotle than of his immediate predecessor, Descartes. Leibniz looks to the living world for answers to deep metaphysical problems, and he explains the entire world in terms that we today think of as holding only for that subdomain of the world populated by biological entities. As had been the case with Aristotle before him, it is not that Leibniz was principally a metaphysician who then developed a side interest in living phenomena, as a string theorist today might take up butterfly collecting as a hobby to help her get her mind off of work for a spell.

On the account offered here, organic bodies are entirely explicable in terms of the perceptions of simple substances, true, but this does not require us to conclude that Leibniz wishes to explain organic bodies away. After all, water is entirely explicable in terms of hydrogen and oxygen, and this fact alone does not entitle us to strike it from the list of existents. In fact, when we take the passages on organic body seriously, and consider Leibniz's arguments for the constant organic embodiment of monads, what is most at risk of being explained away in terms of what is no longer so clear. The reduction of the simple to the composite seems just as real a possibility as the reduction in the other direction.

In the chapters to follow we will see that the tendency to explain away bodies in terms of the immaterial nodes of perception underlying them, rather than to explain monads in terms of the organic embodiment that is a basic condition of the existence of created substances, flows largely from an assumption, in which Leibniz did not share, that philosophy and natural science, and "biology" most importantly among the natural sciences, are two different domains of inquiry to which different principles apply. There is certainly textual evidence that Leibniz wanted to account for the biological world in terms of immaterial "metaphysical atoms," but there is also, and frequently in the same texts, evidence that Leibniz conceived these metaphysical atoms as living, in the sense that they are units of internally driven activity as well as in the sense that they cannot exist without a concomitant organic body. In sum, Leibniz saw the problems of biology not so much as relevant to his philosophical projects, but indeed as central to and constitutive of these projects.

Leibniz's Towering Predecessors: Aristotle, Descartes, and Hobbes

In all periods of his long career Leibniz would remain devoted to the mechanist project of explaining natural phenomena without recourse, or at least without premature recourse, to immaterial or vital principles in nature. Leibniz would insist throughout his career that he "fully [agrees] that all particular phenomena of nature can be explained mechanically if we explore them enough, and that we cannot understand the causes of material things on any other basis."[13] At the same time, however, other elements of Leibniz's model of living bodies involve a return to the Aristotelian tradition, while others still are entirely original. Although Leibniz's model of the animal may be seen, in important respects, as a synthesis of the Aristotelian and mechanical models, his understanding of the theoretical importance of the animal in relation to his philosophy as a whole is not at all a synthesis of these predecessors but rather a clear echo of the views of his ancient predecessor. Overall, the place occupied by biology in Leibniz's philosophy is closer to the one it enjoys in Aristotle than in Descartes: it is a field of application par excellence of general philosophical principles rather than an obstacle to the viability of these principles.[14] Let us focus briefly on the role of the phenomena of life in the systems of each of these important figures in the background of Leibniz's philosophy.

Montgomery Furth has written of the usefulness of studying Aristotle's biology: "Perhaps by tracing his ideas as to the manner in which the complex biological objects are constructed and what they are like, we may not only lay a firm grasp on the strands that form some of the snares of ontology, but even see to some of their unraveling."[15] One is justified in adopting a similar approach to Leibniz. As with Aristotle, an account of Leibniz's view of how complex biological objects are constructed and what they are like is a crucial part of any complete account of his mature ontology.

With Aristotle we witness perhaps the first biological revolution in the history of Western thought. Some commentators have seen this as a revolution with respect to method as much as to content. Jim Lennox argues that what is truly new with Aristotle is that he is the first Greek thinker to taxonomize intellectual pursuits.[16] In *On the Parts of Animals*, for example, Aristotle dedicates the first book to articulating "standards by reference to which one will judge the manner of the demonstrations [of natural inquiry]" (639a 12–14), while in the second through the fourth books he sets about attempting to provide causal explanations for facts concerning the parts of animals. Lennox thus writes that *On the Parts of Animals* consists in a philosophy of biology followed by straightforward biology. While Aristotle himself does not make this distinction explicitly, there is certainly nothing anachronistic about our perception in Aristotle of a working distinction between two levels of inquiry, one we now call "philosophical" and one we call "scientific." As with the parts of animals, so too with their generation Aristotle invites us to distinguish between the particular questions involved in his period's generation research on the one hand and on the other the fundamental, natural-philosophical problem of becoming or *genesis* that motivated them.

Aristotle usually does not seek to mark off the study of animals as distinct, referring instead to the study of *nature*, a study that includes animals. In the *Meteorology* (I 338a 20–339a 9; IV 12 390b 20–22) he discusses the construction of uniform parts in organisms as a way of illuminating points he is making about similar parts in inorganic nature. Meteorology is for him, in the end, the study of mixed bodies, and Aristotle takes everything from comets to animals as instances of these (though animals are, in addition to being mixed bodies, also organized bodies). In *On the Parts of Animals*, Aristotle is focused principally upon animals, but only, on his own account, in order to establish the principles of natural inquiry (639a 12–16). Discussing these very examples, Lennox explains that "Aristotle, unlike us, would see the study of animals and plants as most fundamental, precisely because the formal and final cause operate there, and in such a way as to direct the material and efficient causes toward goals. Thus, while when we think of identifying a particular science with natural science, it is physics, when Aristotle does so, he thinks of the study of animals and plants."[17] In sum, the study of living beings is an important part of the study of nature because these beings embody so many of the principles that one observes more generally throughout nature. This does not mean that zoology *is* philosophy for Aristotle, but at least it means that the study of animals is one of the most promising pathways to the drawing of conclusions of general natural-philosophical interest.

What now about Descartes? Where does the theory of living beings stand with respect to his broader philosophical project?

It is clear that most of Leibniz's philosophical engagement with the problems of biology may be characterized as a radical rejection of the central tenets of Descartes' doctrine of the body-machine. Commenting on Descartes' account of human embryogenesis, for example, Leibniz derides "Monsieur des Cartes with his man, the generation of whom costs so little, but who so little resembles a true man."[18] Yet at the same time Leibniz never denies the enormous debt of his own philosophy to Cartesian mechanism.

In his revolutionary and minimalist natural philosophy, Descartes had hoped to deprive animals of souls, and even of soul-like immaterial principles. For him, such principles could properly belong only to human beings, and it is in virtue of the inherence of souls in human bodies that human beings may be said to participate or share partially in the divine. Whether this means that Descartes is a sort of hylomorphist with respect to humans, and a mechanist with respect to everything else, is a controversial issue. For our purposes it is sufficient and hardly controversial to attribute to Descartes the view that whereas nonhuman animals can be exhaustively understood in terms of their bodily conformation, "human being" for Descartes is a notion that requires appeal to the inherence of a mind. This is a rational mind, as it happens, but the ontological rift between humans and animals would have been just as great, or nearly so, if Descartes had seen human beings as capable merely of imagination or sensory awareness.

Descartes believed that on the traditional Aristotelian picture, natural beings, in view of their capacity to strive toward their appropriate ends, partake too much of the divine, and thus that Aristotelian natural philosophy in the end amounts to a sort of animism that is at clear odds with Christian theology. The proper model of animals, along with all other natural beings, was for Descartes the mechanical one: they are machines fundamentally no different from the machines that human beings are capable of building. This is the central principle of Descartes' natural philosophy, in virtue of which he may be called a mechanist par excellence: the collapse of the ontological distinction between the natural and the artificial.[19]

Early on, Leibniz would agree with Descartes that animals are in fact machines, but he would come to believe that there are certain respects in which they are fundamentally different from the ordinary machines made by human beings. Later, he would come to believe that only animal *bodies* are machines, while the animal itself is a corporeal *substance*, over and above its organic body, the latter being distinguished from the ordinary mechanical body in that it consists, as Leibniz often puts it, in machines within machines ad infinitum. These are crucial distinctions that will occupy us for much of the book (particularly chapter 3). Earlier as later, a large part of Leibniz's account of the important respects in which animals, or animal bodies, differ from ordinary machines would involve the reintroduction of Aristotelian elements into his model of animals. For Leibniz, as for Descartes, animals are machines, but they are also, as for Aristotle, machines that are in their own way divine or akin, if only distantly, to the most perfect being.[20]

All of the observable phenomena of animal physiology, Descartes believes, can be explained without appeal to the activity of a mind, and so there is no reason to hold that animals have minds. But this is not to deny that animals are alive, so long as we understand life, as Descartes did, to be a certain kind of mechanical phenomenon, namely, a thermal one: "I do not deny life to animals, since I regard it as consisting simply in the heat of the heart; and I do not even deny sensation, insofar as it depends on a bodily organ."[21] One of Descartes' greatest challenges was to account for the growth, development, and organization he observed in the biological world without recourse to any account of what these are for. As Dennis Des Chene has shown, Descartes is constrained in his discussion of animal bodies to radically reinvent the seemingly harmless language of functions. For on a strict mechanist understanding, bodies can have no functional unity, but only physical and dispositional unity.[22] Thus Descartes writes, for example, of the way the nerves "serve to move the exterior members," and of how the passions "serve to dispose the heart and liver,"[23] always avoiding any suggestion that these may exist for something or other. As Des Chene writes, "The unswerving aim of [Descartes'] physiology is to show how the body is made—the structure and the processes—without ever mentioning what it is for. Even the weakest hypothesis about mechanical causes is preferable to the ascription of ends."[24]

One might think of Descartes' effort to purify animal physiology of any talk of ends as anticipating the demand made by adaptationists that in the end talk of any adaptation as being for something or other must be a metaphor, cashable in strictly selectionist terms along the following lines: this trait exists because it happens not to have been selected out, but it does not exist for the sake of doing what we observe it to do. As contemporary philosophers of biology have often noted, cashing out this metaphor is no easy task. In effect, Descartes' challenge was to account for the formation of the animal from the purely ateleological mixing of the two parents' materials and the purely mechanical process this mixing sets in motion. While one might plausibly explain how blood congeals into tissue and organs in this way, it seems a much more difficult task to explain how this tissue and these organs eventually come to be the tissue and organs of a particular kind of entity, for example, of a human being rather than a pig.[25] The account Descartes attempts to give is at once both tentative and very matter of fact. His primary concern is to show how conception, and subsequently fetal development, can occur without recourse to any ends or immaterial principles of development governing the process of embryogenesis. Thus, for example, at the very beginning of the process Descartes explains that the semen is retained in the uterus simply because the female genitalia happen to be so formed as to facilitate retention. In the *Description du corps humain*, written in 1647, Descartes explains that the drops of seed in the uterus following coition begin to separate and differentiate, because "the heat is excited there, and acts there in the same way as it does in new wines as they boil." Some of these de-homogenized particles then move toward one edge of the uterus, and, becoming dilated there, "they press on the other particles surrounding them, which is what begins to form the heart."[26]

Life only begins when the heart has fully formed and begins to distribute the blood and spirits throughout the body. Blood and spirits mix in the heart, Descartes writes, "and begin there this continuous battle, in which the life of the animal consists, no differently than the life of fire consisting in lantern oil." The "spirits" are conceived by Descartes as a subtle, vaporous body that pervades the blood; while the subtlest ingredient in an animal body, it is nonetheless still an entirely corporeal entity, no more a part of the domain of *res cogitans* than are the bones or muscles. Descartes explains in the *Primae cogitationes circa generationem animalium*, published posthumously in 1701, that once the pure spirits are "scattered by the aorta throughout the whole body … the animal begins to be, since the fire of life has been kindled in its heart."[27]

Descartes' account of fetal development, were it successful, would be the crowning achievement of his natural philosophy: to account for the emergence of the most complex entities in nature without needing recourse to the intelligent principles thought throughout all of premodern science to have guided or helped these entities along. Fetal development would be a natural process like any other, capable of being explained in terms of the laws that bind all of mechanical nature. Indeed, Descartes believes that such an account would offer the most fitting means of vindicating God from responsibility for abnormal births as well as of properly exalting God by attributing to him the wisdom to make all phenomena flow from just a few eternal laws of nature. Thus he summarizes his approach to embryology in the *Primae cogitationes* as follows:

> I expect some will say disdainfully that it is ridiculous to attribute such an important phenomenon as human procreation to such minor causes. But what greater causes could be required than the eternal laws of nature? Do

> we need the direct intervention of a mind? What mind? God himself? Why then are monsters born?[28]

Yet accounting for human reproduction through minor causes remains more a challenge to Descartes' basic theoretical commitments than an opportunity for him to showcase them. Unlike Aristotle, for whom the theory of living beings constituted a fruitful field of application of general natural-philosophical principles, and may even have served as the source of principles applicable far beyond the ontological domain of living beings, for Descartes, in sharp contrast, living beings presented a stark challenge to the universal applicability of the natural-philosophical principles to which he was committed on a priori grounds.

It is also worth briefly mentioning the role of Hobbes in Leibniz's background, for there is much textual evidence to suggest that the German philosopher's conception of what mechanist philosophy ought to be owes more to his English predecessor than it does to Descartes. In particular, Leibniz agreed with Hobbes that Descartes' conception of the physical world as consisting on the one hand in bodies defined as *res extensa*, and on the other hand in a fixed quantity of motion, certainly would not be adequate for explaining the complex activities of certain kinds of body, particularly animate ones. In this connection the young Leibniz is very happy to draw on Hobbes's notion of *conatus*, which the latter defines in his *De corpore* of 1654 as "a motion through a space and time which is less than is given, i.e. is determined, whether by being displayed, or by being assigned a number; in other words, it is a motion through a point."[29] Thus, for Hobbes, the conatus is the instantaneous propensity for motion even though, since it occurs in an instant, it cannot itself be said to be a motion. Leibniz would draw heavily on Hobbes's notion in his youthful—and somewhat sycophantic—letter to Hobbes of 1670, as well as in his *Theoria motus abstracti* of 1671. In these texts, conatus will be understood as a sort of infinitesimal motion, or that in the body which brings it, from one instant to a next, into its successive states. Without such an added element in body, Leibniz thought, along with Hobbes, there could be no accounting for motion. In Descartes, by contrast, motion was a mere posit and could in no way be deduced from the concept of body itself.

Hobbes distinguishes, further, between vital and animal motions, circulation and respiration being examples of the former, and running and swimming of the latter. In both cases, conatus or something analogous—namely, volition—plays a role. Volition is conceived as an infinitesimal beginning of a bodily motion. As Hobbes writes in *Leviathan* VI, 1: "These small beginnings of Motion, within the body of Man, before they appear in walking, speaking, striking, and other visible actions, are commonly called endeavour."[30] In line with Hobbes's strict materialism, this volition, happening in the body of a man or of an animal, is entirely the result of prior external causes and does not need to be explicated in terms of the animating power of a soul. This notion of volition, as the animal body's variety of conatus, would also play an important role in Leibniz's understanding of the beginnings of animal motion, as we will see in chapter 3.

Yet another very important predecessor for Leibniz is the second-century Greek physician Galen. Leibniz speaks very favorably of Galen's anatomical work, and even says that he would like to see written a work with the title *The Hymn of Galen*, which would be an exhaustive account of the structure and function of the parts of the animal body, an account that Galen began in his own work, *On the Usefulness of the Parts*, but that Leibniz believed could be completed only through the collective scientific effort he believed was taking shape in his own era.[31] While Leibniz has nothing but praise for Galen, he does not appear to engage very deeply at any point in his career with Galen's theoretical views; rather, Leibniz admires his ancient predecessor principally as an excellent observer, which is to say as an "experimentalist" in the broad sense. Excelling in this way, as we will see, is quite enough to win Leibniz's highest praise, and indeed Leibniz's praise for Galen, and his desire to see a "hymn" written to him, vividly illustrate Leibniz's abiding commitment to empirical inquiry.

Leibniz's Synthesis

Leibniz would borrow elements from each of the two principal legacies we have considered—the Aristotelian and the mechanical—and he would shape them into something entirely novel. For him, as for Aristotle, animals are end-driven natural beings, but they are also, as for Descartes, at least with respect to their bodies, a variety of machine. Leibniz does not entirely accept Descartes' collapse of the Aristotelian ontological divide between the natural and the artificial insofar as he believes that the animal body is a *natural* machine or, which is the same, a divine machine whose infinite complexity and consequent indestructibility are enough to place it in a different ontological category from the ordinary products of human artifice. Ultimately, as we will see, it is from this infinitely complex structure that Leibniz believes its vegetation and motion can be derived: it is this structure that constitutes the organic body's "material plastic nature," which Leibniz proposes as an alternative to the vitalist account of motion in the body as arising from an immaterial principle quite distinct from the body. This material plastic nature is ultimately nothing other than the derivative force of the organic body, which for its part results from the infinite aggregation of immaterial monads, all of which themselves come equipped with primitive active and passive force. Thus, for Leibniz, the body is not ultimately something ontologically apart from the world of immaterial perceivers; it does not need to be activated by a source of motion that belongs to an ontological domain distinct from it.

Although Leibniz agrees with Aristotle that animals are end-governed, he does not believe that their organs are in any sense congealed functions, or that the active, soul-like principles that are in some way most fundamental in nature in any way make or bring about the structure of their own bodies. Instead, for him organs are designed by an omniscient creator for the execution of functions that are all brought into existence together at the creation and that unfold in time from their latent state within organically preformed beings. God makes bodies as the constant companions of souls, and souls have no responsibility for the formation or for the maintenance of the bodies with which, along Cartesian lines, Leibniz believes them to have nothing in common. In contrast with Descartes, however, Leibniz is perfectly comfortable speaking of what the body does, created independently of the soul and causally closed off from it, in explicitly functional terms.

These, in barest outline, are the main points on which Leibniz distinguishes his theory from those of his predecessors in the history of philosophical reflection on the nature, structure, and generation of living entities. It will take us the rest of this book to see how Leibniz came to his very original, yet also very deeply rooted, account. We will do this through a developmental study, by looking at the way in which Leibniz first came to be interested in concrete problems related to the understanding of living bodies. To the extent possible, we will be careful to pay attention to the chronological development of his ideas, for it is in this way, rather than by treating Leibniz as the representative of some fixed and singular system, that we will best be able to distinguish the true character of his philosophical engagement with the living world. On such an approach, we will see that Leibniz's earliest engagement with the life sciences would not at first involve an interest in the problems of generation or the sources of animal motion. Rather, early on he begins with an interest—one that seems to emerge from his training in law—in the reform of medicine as a social institution. He moves from medicine through a number of treatises in the 1670s and early 1680s on general physiology, or what he calls "animal economy," only arriving at his views on the organic structure of the world little by little over the course of the 1680s and 1690s.

Looking at his career as a whole, we may say that Leibniz's biological interests lie at the center of at least three core issues in his philosophy:

1. The problem of the structure and motion of the physical world, both of living entities as normally understood as well as of apparently lifeless things. This will be the focus, more or less directly, of the first two parts of the book. Leibniz's theory of organic bodies and of corporeal substances is a unique response to the radical break with the Aristotelian tradition that Descartes brought about. Here Leibniz seeks to give an account, so to speak, of the general and developmental physiology of the whole world. Both of these were profound stumbling blocks for the project of what might be called a universal, as opposed to a domain-specific, mechanism. They are what made some philosophers throw up their hands and concede that the growth and conformation of animal bodies could only be explained by appeal to something supermechanical, such as an *archaeus* or plastic nature. Leibniz's response avoids the pitfalls of both Cartesian mechanism and post-Cartesian vitalism, or the view that animal life, growth, and motion cannot be accounted for in terms of the conformation of the body: rather than saying that the origins and structure of animals can be explained in terms of "mere" mechanism, and rather than saying that animals constitute an exception to the mechanical laws that otherwise govern motion and change in nature, Leibniz held that all motion and change is to be explained in the same way, but that this way is the way of birds and fish, not of projectiles and billiard balls.
2. The problem of coming into being, or generation. This will be the focus of the third part of this book. The problem of generation has been more important in the history of philosophy than scholars have generally noticed. More specifically, it has not been adequately understood that the abstract philosophical problem, of how something can exist at a later point in time that did not exist at an earlier one, is directly connected to very concrete questions concerning the nature of semen, the role of each of the two parents in reproduction, the possibility of spontaneous generation, and so on. Leibniz's own generation theory offers a vivid example of this confluence of the abstract and the concrete.
3. Species. The focus of the fourth and final part of the book, the problem of species in Leibniz's thought has generally been investigated as though it were exclusively a problem of early modern philosophy of language. To be sure, Leibniz's debate with Locke about species and essence does contain rich insights—from both sides of the debate—about how language works and about the nature of meaning. But the most common examples of species that Leibniz and Locke cite are very dependably biological kinds, and the meditation of these philosophers on the possibility of, for example, hybridism and cross-species fertility, clearly evidences an interest in biological questions that do not arise with, for example, the occasional examples they deploy of lead or gold (not to mention geometrical entities or moral concepts).

In examining these issues, all of which have been previously recognized as of interest to understanding Leibniz's philosophy, a cluster of original theses will be defended. One is that in attempting to understand the nature of the changes that take place over the course of Leibniz's philosophy, we may do better to change our focus away from the purported ontological shift from realism to phenomenalism about bodies and instead to focus on changes in Leibniz's account of the *structure* and *organization* of bodies, whatever may be their ultimate ontological status and ground. What we find when we approach Leibnizian bodies in this way is that there occurs over the course of his career a broad shift from what was called *oeconomia animalis* to the study of *anatomia subtilis*. This is to say that while never fully abandoning his interest in the questions of animal economy, understood as the study of the overall end-governed function of macroorganisms, Leibniz gradually comes to be more interested in looking into the subtle, subvisible elements of living bodies and into the way the complex organization of these elements gives rise to visible structures. This is a broad shift that is in turn echoed in areas of Leibniz's thought seemingly quite distant from one another, such as his views on mammalian vivisection (he gradually loses interest in this, coming to favor empirical research on insects and worms over research on dogs and horses) (chapter 1), his very technical account of the organic structure of animal bodies (chapter 3), and his theory of nested individuality (chapter 4).

Another central thesis is that Leibniz is much more an empiricist than he is ordinarily recognized to be, where "empiricism" is understood broadly to mean the view that abstract or theoretical truths can be arrived at from the starting point of experience. Leibniz never feels the need, as Francis Bacon had, to lay his notions by and to concentrate on particulars, but many of his "notions" or philosophical commitments could not have taken precisely the shape they did without the prior consideration of a variety of particular facts. This comes out particularly clearly when we focus on his engagement with exact questions of natural science rather than broad speculative issues in metaphysics. When Leibniz says he prefers "a Leeuwenhoek" who tells you what he sees, over "a Cartesian" who tells you what he thinks, he is saying this not only with respect to some particular question; he is also saying that troubling philosophical questions in general are often such that they can better be resolved by observing the world than by producing a priori theories about it. In some cases, Leibniz's relatively great commitment to empiricism can help to shine new light on questions concerning the origins of some of his views (as in the case of the doctrine of the organic preformation of corporeal substances, treated in chapter 5). But it can also, perhaps more importantly, help us to understand not just the origins but also the content of some of his philosophical positions, and indeed a focus on Leibniz's engagement with exact scientific problems may force us to revise our understanding of what his philosophical views are. For example, as discussed in chapter 7, Leibniz's purported nominalism vanishes when we switch from the study of mathematical entities to the study of, for example, the classification of plants. These latter have been given short shrift in determining what Leibniz's philosophical commitments were. But as we will see they were not unimportant to Leibniz himself.

A third argument of the book, if somewhat less sustained than the others, will be that we can learn much about Leibniz by paying attention to his legacy in eighteenth- and early nineteenth-century natural science and philosophy, particularly, though not exclusively, in France. As we will see, for the first chapter of his long reception history, Leibniz was understood by many naturalists, such as Charles Bonnet and Abraham Trembley, by microbiologists such as C. G. Ehrenberg and Otto Friedrich Müller, by obscure polemicists such as Friedrich Bertram, and, arguably, by major philosophers such as Immanuel Kant and Ludwig Feuerbach, as centrally a philosopher of life, who elaborated a metaphysical system in order to account for the observable phenomena of the living world, including, most importantly, living bodies. This version of Leibniz will not be defended as *the* correct one, in contrast to the much better known logician and metaphysician, for of course it is undeniable that to a great extent Leibniz's German followers, such as Christian Wolff, Alexander Baumgarten, and Johann Brucker, understood Leibniz as principally an abstract theorist of immaterial entities, and they were not delusional. But it will be maintained throughout the book that much can be learned from recovering long-abandoned threads of interpretation. After all, it is Leibniz's work itself, rather than the misunderstandings of his immediate successors who were admittedly working with a very limited portion of the Leibnizian corpus, that first gave rise to these threads.

A Note on Terminology

Despite the hesitant deployment of the term "biology" in this introduction, in the chapters that follow a concerted effort is made to respect actors' categories and so to label the areas of natural-philosophical investigation of interest to seventeenth-century thinkers in the way they themselves labeled them. (To this end, I have also tended to prefer "natural philosophy" and its variants over "science" and its.)

Leibniz's "biology" encompassed what we today would describe as medicine, anatomy, physiology, microscopy, entomology, ethology, embryology, reproduction science, organic chemistry, and botanical and zoological taxonomy. Each one of these subdomains of life science will receive explicit attention in this book, either as the subject of a chapter, or of a section of a chapter, but seldom under the names I have just listed.

While the body of knowledge we call "medicine" has expanded tremendously since the seventeenth century, this term continues to describe more or less the same thing it did in Leibniz's lifetime: that mixture of theory and practice that has as its goal the maintenance of health and the curing or alleviation of illness. With this one exception, however, the terms we use today to describe the subdomains of biology either were not available for Leibniz or had different connotations, and usually also denotations, than they have today.

Leibniz's central "biological" concern from at least as early as 1677 until at least 1710 was with an area of study he called "animal economy," which was for him the study of the animal body as a particular kind of machine, with an eye to the way in which the organs of the animal machine are coordinated with one another for the execution of that machine's intrinsic ends. Clearly, Leibniz's animal economy is very different from Cartesian physiology, for which animals, precisely insofar as they are mere machines, cannot properly be said to have ends. Animal economy for Leibniz encompasses certain aspects of anatomy, physiology, and what in the twentieth century would come to be called "ethology," or the study of the characteristic behavior of a given kind of creature.

I have coined the term "organics" to describe Leibniz's effort to elaborate a model of the animal body—in scattered comments beginning as early as the 1670s, but as an explicit focus beginning sometime in the mid-1690s—according to which what distinguishes it from an artificial machine has to do principally with its infinite structure, with the fact that, as he puts it, it is a machine that remains a machine "in its least parts." This distinction will be the central concern of chapters 3 and 4. One of Leibniz's preferred synonyms for the infinitely structured natural machine is "organic body," and his term for the variety of mechanism that such a body instantiates is "organism." I have remained faithful to these usages (thus, I have steadfastly avoided speaking of "an organism" or "organisms," as if this were a count noun for Leibniz). Since organism is a variety of mechanism, it seems reasonable that there should be a name for the study of organism analogous to the common name for the study of mechanism, to wit, "mechanics." Thus I have tended to use "organics" as the name for Leibniz's study of the animal body as a certain kind of infinitely complex structure (from which, as we will see, certain forces, complementary to those of mechanical physics, are derived), while reserving "animal economy" as the name for the study of animals, along more traditional lines, as self-moving, self-nourishing, and self-reproducing machines.

When focusing on this last capacity of the animal—its unique ability to generate copies of itself—I have preferred the term "generation theory" as this was understood in the seventeenth century. This area of study encompassed what we would call embryology and reproduction science, this latter being understood as the study of the mechanics of conception. But it also involved a great deal of philosophical questioning about the nature, and indeed the very possibility, of coming into being.

Generation theory was closely related to what we would call "taxonomy," since one of the central theses on which classificatory projects were based was the view that "like begets like" (though this view, taken as a universal claim, certainly had its opponents). Leibniz was working before the great Linnaean revolution, of course, though important contributions to taxonomy were already being done, and paving the way for Carolus Linnaeus, by figures such as John Ray, whom Leibniz greatly admired, as well as Joachim Jungius and others. No single name existed for this endeavor, so I have defaulted on the label "taxonomy," though I have also often described it simply, as Leibniz does, as zoological or botanical "method."

Finally, some readers may by now be asking: so much for the list of ingredients of Leibniz's "biology," what now of his *philosophy* of biology? Where will this be treated? The simple answer is: everywhere and nowhere. Unlike Aristotle, for whom some authors have discerned a clear distinction between the philosopher's scientific interest in seeing how, for example, sponges reproduce on the one hand and on the other his philosophical concern to establish epistemological and methodological foundations for the investigation of things such as sponges,[32] I have found no good reason to distinguish between Leibniz's study of, for example, anatomy and embryology on the one hand, and on the other his deeper philosophical interests in the metaphysics of corporeal substance, the ontology of species, and such. For Leibniz, any effort to separate the "biology" from the philosophy thereof would be untrue to the spirit and aims of what he took himself to be doing. If all we mean by "philosophy of science" is "method of science," then Leibniz, like Aristotle, certainly had that. But since Leibniz has no conception of science as an enterprise distinct from philosophy, to speak of his philosophy of science cannot help us to make any sense of his understanding of the disciplinary division of labor.

What Leibniz was doing was natural philosophy: he was reflecting on and making hypotheses about the nature and causes of the basic entities of the world, and in the course of these reflections and hypotheses he was actually talking about the ingredients of the world such as actual flesh-and-blood animals familiar to those people we today call "scientists." If Leibniz felt constrained by any disciplinary boundaries, these were not the ones subsequently erected by academic philosophers. Blood, organs, food, spermatozoa: these, too, were of interest to Leibniz qua philosopher, and they were directly implicated, as I will show, in what today we take to be his deepest philosophical concerns. Leibniz has a "philosophy of biology," I mean to say, in the same sense in which Molière wrote "comedies of manners": in both cases we are dealing with a genitive of description. Leibniz has a philosophy that, by and large, is "of biology," focused upon biological phenomena and concerned to demonstrate their relevance to our understanding of nature as a whole, and even of the divine wisdom that underlies nature.