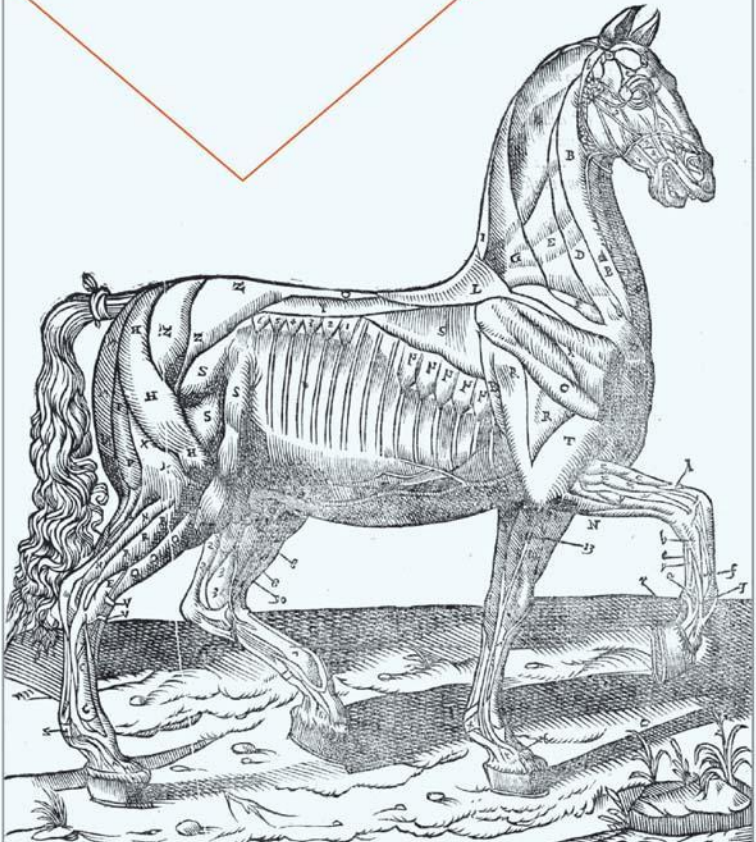
DIVINE MACHINES

Leibniz and the Sciences of Life

JUSTIN E.H. SMITH



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Every realm of nature is marvelous: and as Heraclitus, when the strangers who came to visit him found him warming himself at the furnace in the kitchen and hesitated to go in, is reported to have bidden them not to be afraid to enter, as even in that kitchen divinities were present, so we should venture on the study of every kind of animal without distaste; for each and all will reveal something natural and something beautiful.

—Aristotle, *On the Parts of Animals* I 5, 17–23

Let us free ourselves from the deception of the senses, from becoming, from history, from lies… And above all, away with the body, this wretched *idée fixe* of the senses, disfigured by all the fallacies of logic, refuted, even impossible, although it is impudent enough to behave as if it were real!

—Nietzsche, *Twilight of the Idols*,
"Reason in Philosophy," § 1

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ABBREVIATIONS

Editions of Leibniz are abbreviated as follows:

A	*Gottfried Wilhelm Leibniz: Sämtliche Schriften und Briefe*, ed. Deutsche Akademie der Wissenschaften (Berlin, Darmstadt, and Leipzig: 1923–present).
AG	*G. W. Leibniz: Philosophical Essays*, trans. and ed. Roger Ariew and Daniel Garber (Indianapolis: Hackett, 1989).
Barrande	*Leibniz: Protogaea: De l'aspect primitif de la terre*, ed. Jean-Marie Barrande, trans. Bertrand de Saint Germain (Toulouse: Presses Universitaires du Mirail, 1993).
Bodemann	*Die Leibniz-Handschriften*, ed. E. Bodemann (Hanover and Leipzig, 1895).
Couturat	*Opuscules et fragments inédits de Leibniz*, ed. Louis Couturat (Paris, 1903).
Dutens	*Gothofredi Guilelmi Leibnitii Opera Omnia,* 6 vols. ed. Louis Dutens (Geneva: De Tournes, 1768; repr. Hildesheim: Georg Olms, 1989).
FdC	*Oeuvres de Leibniz*, 7 vols. 2nd ed., ed. A. Foucher de Careil (Paris, 1875).
G	*Die philosophischen Schriften von G. W. Leibniz*, ed. C. I. Gerhardt. 7 vols. (Berlin, 1875–90).
GM	*Die mathematischen Schriften von G. W. Leibniz*, 7 vols. ed. C. I. Gerhardt (Berlin, 1849–63).
Ger'e	*Sbornik" pisem" i memorialov" Leïbnitsa otnosyashchikhsya k Rossii i Petru Velikomu*, ed. V. I. Ger'e (Guerrier) (Saint Petersburg, 1873).
Gerland	*Nachgelassene Schriften physikalischen, mechanischen und technischen Inhalts*, ed. Ernst Gerland (repr. Hildesheim: Olms, 1995).
Grotefend	*Leibniz: Album aus den Handschriften der Königlichen Bibliothek zu Hannover*, ed. C. L. Grotefend (Hanover, 1846).
Grua	*Leibniz: Textes inédits*, ed. Gaston Grua (Paris: 1948).
Guhrauer	*Leibnitz's Deutsche Schriften*, ed. G. E. Guhrauer (Berlin, 1838).
Klopp	*Die Werke von Leibniz. Erste Reihe: Historisch-politische und staatswissenschaftliche Schriften*, 11 vols., ed. Onno Klopp (Hanover, 1864–84).

Kortholt *Epistolae ad diversos, theologici, iuridici, medici, philsophici, mathematici, historici et philologici argumenti*, ed. Christian Kortholt (Leipzig, 1734).

MK Kurt Müller and Gisela Krönert, *Gottfried Wilhelm Leibniz: Leben und Werk. Eine Chronik* (Frankfurt am Main: Klostermann, 1969).

NO *Georgii Ernesti Stahlii Negotium otiosum: Seu Σκιαμαχια adversus positiones aliquas fundamentales* Theoriae verae medicae (Halle, 1720).

OH *Otium hanoveranum, sive Miscellanea ex ore & schedis illustris Viri, piae memoriae Godofr. Guilielm. Leibnitii*, ed. Joachim Friedrich Feller (Leipzig: Johann Christian Martin, 1718).

Pertz *Leibnizens gesammelte Werke*, ed. Georg Heinrich Pertz. 4 vols. (Hanover, 1843–47).

Ravier *Bibliographie des oeuvres de Leibniz*, ed. E. Ravier (Paris, 1937; repr. Hildesheim, 1966).

RC *Discourse on the Natural Theology of the Chinese*, trans. and ed. Henry Rosemount Jr. and Daniel J. Cook (Honolulu: University of Hawai'i Press, 1977).

WBG *Gottfried Wilhelm Leibniz: Philosophische Schriften*, ed. and trans. Hans Heinz Holz, 5 vols. (Darmstadt: Wissenschaftliche Buchgesselschaft, 1985).

Other philosophers:

AA Immanuel Kant, *Gesammelte Schriften*, ed. Deutsche Akademie der Wissenschaften zu Berlin, Königlich Preussische Akademie der Wissenschaften (Berlin, 1902).

AT René Descartes, *Oeuvres de Descartes*, ed. Charles Adam and Paul Tannery (Paris: J. Vrin, 1970).

OCM Nicolas Malebranche, *Oeuvres complètes de Malebranche* (Paris: J. Vrin, 1958–84).

PREFACE

In the very near future, research in the humanities will be greatly transformed. It will be inherently collaborative, geographically diffused, and electronic. If this prediction is correct, then the present book will surely soon appear as a sort of transitional fossil between the two ages, for it could never have been written without the support of a vast network of fellow researchers, many of whom have had only, or primarily, virtual contact with its author. Nor could it have been written without access to the sort of electronic resources that simply did not exist even a decade ago, the most important example of which are the scans of Leibniz's LH III manuscripts graciously, and forward-thinkingly, made available online by the Berlin-Brandenburgische Akademie der Wissenschaften.

Fortunately, behind the nodes in our new, virtual Republic of Letters, there are also human beings, and I have learned from face-to-face encounters with many of them. Dan Garber, François Duchesneau, Christia Mercer, Alan Gabbey, Catherine Wilson, and Roger Ariew are my intellectual models of long standing, and their support for this project has been an absolute sine qua non of its coming-into-being. As a graduate student at the Leibniz-Forschungsstelle in Münster, my early encounters with Martin Schneider, Thomas Leinkauf, Hans Poser, Herbert Breger, and most of all Heinrich Schepers, were also crucial for my eventual formation as a Leibnizian. Along the way I have benefited greatly from interaction with Vlad Alexandrescu, Raphaële Andrault, Peter Anstey, Ric Arthur, Dennis Des Chene, Stefano di Bella, Michel Fichant, Stephen Gaukroger, Ursula Goldenbaum, Tahar ben Guiza, Glenn Hartz, Hartmut Hecht, Mark Kulstad, Mogens Lærke, Christian Leduc, Martin Lenz, Gideon Manning, Yitzhak Melamed, Steve Nadler, Antonio Nunziante, Enrico Pasini, Arnaud Pelletier, Anne-Lise Rey, Markku Roinila, Paolo Rubini, Eric Schliesser, Sebastian Stork, Evelyn Vargas, and Charles T. Wolfe. Andreas Blank and Brandon Look both deserve particular thanks for the extensive comments they offered on early drafts of the manuscript. I have learned much about the history of science, and about why philosophers should take it seriously, from James Delbourgo, Nicholas Dew, Moti Feingold, Vera Keller, Bill Newman, and Emma Spary, among others. Special thanks are also due to Andrea Falcon, Carlos Fraenkel, Alison Laywine, Sara Magrin, Stephen Menn, and Dario Perinetti, among others, for making Montreal such a stimulating place to work on the history of philosophy. My graduate research assistant, the up-and-coming HPS

scholar Cameron Brown, deserves special thanks for his vital role in this project's late-stage completion. Dawn Hall also merits particular thanks for her very careful copyediting of the manuscript.

Significant parts of some of this book's chapters appeared in earlier versions as journal articles. Parts of chapter 3 appeared as "'A Mere Organical Body Like a Clock?' Organic Body and the Problem of Idealism in the Late Leibniz" (*Eighteenth-Century Thought* 4 [2009]); and as "Leibniz and the Cambridge Platonists and the Debate over Plastic Natures," in *Leibniz and the English-Speaking World*, ed. Pauline Phemister and Stuart Brown (Dordrecht: Springer, [2007], 95–110) (co-written with Pauline Phemister). Parts of chapter 4 appeared as "Leibnizian Organisms, Nested Individuals, and Units of Selection" (*Theory in Biosciences* 12, no. 2 [2002]: 205–30) (co-written with Ohad Nachtomy and Ayelet Shavit). Parts of chapter 5 appeared as "Leibniz on Spermatozoa and Immortality" (*Archiv für Geschichte der Philosophie* 89, no. 3 [2007]: 264–82). I am particularly indebted to Ohad Nachtomy and Pauline Phemister for their permission to appropriate ideas here that were initially developed in collaboration with them.

Research for this book was conducted with funding from the Social Sciences and Humanities Research Council of Canada, from the Fonds québécois de recherche sur la société et la culture, and, finally, from the Alexander-von-Humboldt Stiftung. The year I spent on a fellowship from the last of these, in 2007–08 at the Humboldt-Universität zu Berlin, on the kind invitation of Dominik Perler, was for me truly an *annus mirabilis* in which leaps and bounds were made in the research for this book. It was also a period of epiphany in which my first truly intense *Auseinandersetzung* with Leibniz's manic, almost Wölflian pencraft led me to believe, for the first time, that I knew, as they say, where he was coming from.

This book is dedicated to my wife and constant collaborator, Adina Ruiu, who to my great fortune and in more ways than one has obliged me to take leave of my village.

—Bârlad, Romania, June 2010

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.

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PART ONE

First Things

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Chapter One

"QUE LES PHILOSOPHES MEDICINASSENT"

Leibniz's Encounter with Medicine and Its Experimental Context

Introduction

We do not tend to think today of medicine as a foundational science, let alone as an important component of philosophy.[1] For many philosophers in the seventeenth century, however, the picture of medicine was very different. As Descartes writes in the *Discours de la méthode*:

> The mind depends so much on the temperament and the disposition of the organs of the body that, if it is possible to find some way of making men more knowledgeable and able than they have been up until now, I believe that it is in medicine that they should be looking for it.[2]

Leibniz in turn would criticize Descartes for not having practiced what he preached. "It is true that Monsieur Descartes applied himself to medicine from time to time, but one would have wished that he had applied himself more, and with more attachment to observations than to hypotheses." Leibniz maintains that Descartes "believed himself to be skilled in medicine," and that it is as a result of this false estimation of his own knowledge that he ended up dying prematurely.[3] The main problem, in Leibniz's view, was that Descartes' corpuscular theory of nature, however useful in other domains, could simply not be extended to the medical treatment of living bodies: "It must be admitted that the consideration of atoms and of the smaller parts are of little use in practice."[4]

While scholars have complained that Descartes never gave any clear account of what he took medicine to be,[5] the same complaint can certainly not be made about Leibniz. In the *De scribendis novis Medicinae elementis* of 1682–83 (see Appendix 4), to be treated in detail in the following chapter, he provides a supremely clear definition:

> It is clear that the human body is a machine determined to certain functions by its author or inventor. Thus to write medicine is nothing other than to prescribe a method to a given mechanic who is able to conserve the machine that has been entrusted to him, so that it will always operate correctly.[6]

It will take us the extent of this and the following chapter to work out the full implications of this striking definition. What gradually becomes clear through all of Leibniz's scattered, often seemingly trivial comments on medicine and health, along with a handful of straightforward treatises on these subjects, is that Leibniz is not simply interested in medical topics to the extent that he is interested in *everything*. Rather, medical questions are for him not just related to, but directly (though of course not exclusively) constitutive of, his metaphysical inquiry into the nature of substance and of the individual; his natural-philosophical inquiry into the nature of organized matter and the causes of motion; and even of his ethical concern with the good and pious life. As Leibniz writes to Bouvet in 1697:

> Medicine is the most necessary of the natural sciences. For just as theology is the summit of the knowledge of things pertaining to spirit, and just as it contains both good morals and good politics, one can say that medicine as well is the summit and as it were the principal fruit of our knowledge of bodies, to the extent that they are related to our own. But all of physical science and medicine itself have as their final goal the glory of God and the supreme happiness of men, for in conserving them, medicine gives them the means to work for the glory of God.[7]

Leibniz's eventual conception of the harmony between body and soul is ultimately rooted in precisely this perceived parallelism between medicine and theology. By his own account, Leibniz's single greatest innovation is the doctrine of preestablished harmony, according to which bodies and souls (as well as all the infinitely many monads) unfold according to their own laws, while still noncausally coexisting with one another in a perfectly rational order. Correlatively, while each science has its own subject matter, medicine and theology (or the subdivision of theology that Leibniz sometimes calls "pneumatics,"[8] that is, the study of immaterial beings) both seek to offer accounts of one and the same order under different descriptions, pneumatics focusing upon the unfolding of the states of souls according to their laws, and medicine, in the very broadest sense, focusing upon the unfolding of the states of bodies according to theirs. Of course, for us medicine is something rather narrower than the study of living bodies, let alone of bodies in general. But it is important to bear in mind, first of all, that for Leibniz the homologies between animal and human bodies make the study of the former just as central to medicine as the study of the latter; and, second of all, that for him, in the end, every body may be understood on the model of animal bodies. Understood in this light, medicine is very fundamental indeed.

Medicine is also crucial because it alone provides the hope for keeping the bodies of philosophers alive longer, and it is only, Leibniz often emphasizes, within a living body that a philosopher's mind is of any use. Consequently, "after virtue, health is most important of all."[9] Indeed, Leibniz often appears to maintain that the preservation of bodily health is itself a part of the virtuous life. He also believes, however, that in his day this part of the virtuous life is only just beginning to be properly cultivated, and much of his work throughout his life is dedicated to envisioning reforms of medical institutions, and of the state, that would improve public health and in turn the lives of thinking men, and thus that would improve philosophy itself.

We are beginning our study of Leibniz's engagement with vital phenomena by a consideration of his interest in medicine and its various subdomains, for this honors both the chronological and the conceptual priority of the various domains of inquiry of interest to Leibniz in which vital phenomena played a role. Indeed, one might plausibly propose that medicine could serve as an appropriate beginning to *any* study of Leibniz's philosophy: in 1672, early in Leibniz's four-year stay in Paris, Leibniz writes in one of a series of notes on physics the Hippocratic slogan, *sympnoia panta* (all things conspire).[10] He believes that in some fashion or other this slogan should be extended to apply not just to the human body but also to the cosmos as a whole. This belief will, decades later, continue to serve as a succinct expression of his mature doctrine of preestablished harmony. Thus a principle originally articulated for the description of the human body, and as a motto of the preservation of its health, comes to underlie Leibniz's vision of the cosmos, and, even more deeply, his conception of the mutual expression of the infinitely many monads in the order of coexistence.

As early as 1671 Leibniz is seriously thinking about the reform of public health, and in the proposals he makes in this connection, particularly those concerning the state administration of the medical profession, we see a significant early anticipation of his later interest in the establishment of scientific societies. Both the academies Leibniz would later help to establish in Berlin and St. Petersburg, as well as the medical institutions he would propose throughout his life, are in important ways inspired by the organization of religious orders. In a remarkable text titled "Bedenken von Aufrichtung einer Akademie oder Societät [Thoughts on the Establishment of an Academy or a Society]," dated to 1671 in view of its great lexical overlap with the *Directiones ad rem medicam pertinentes* of the same year, Leibniz reveals both the fundamentally political, and national, character of his interest in medicine, as well as the very broad scope of what he takes medicine to be:

> In medicine itself it must be admitted that, as the marvellous discoveries of Asellius,[11] Acquapendente, Pecquet, Bartholin, Rudbeck,[12] Harvey, Lower,

> Dionysius[13] and others reveal, nowhere is practical medicine flourishing more so than in Germany, as all of those well know who come into contact with foreign doctors, pharmacists, and surgeons.

Leibniz provides this long list of well-known non-German physicians, all of whom have in writing praised the accomplishments of Germans, evidently in order to rouse the self-estimation of German physicians to the same degree to which they are esteemed abroad. He continues:

> The best medicines, compositions, and prescriptions used by all of Europe, come from German doctors, chemists, and pharmacists. Already in the old days it was Germany that provided the other countries with alchemists and with laboratory workers [*Laboranten*]. To this day as well the experimenters prefer Germans no less as their laboratory workers. The German and especially the Swiss herbalists, as both of the famous Bauhins,[14] have informed the entire world with respect to botanical matters. However much people may fight over the transfusion of the blood, it was a German, namely Libavius, who first saw it, regardless of whether he valued it or not. And we Germans have grown so oblivious of our glory that it is left to an Italian to come and to give us the praise we deserve.[15]

Leibniz is not a doctor, and so tends in all stages of his career to think about medicine more with respect to its institutional aspects than with respect to the content of its claims, which he leaves to others to determine. Already in the "Bedenken," though, one thing that is particularly striking is Leibniz's inclusion of a broad variety of practices under the disciplinary banner of medicine, which we today might sooner put under various headings, such as "pharmacy," "botany," or "physiology." All of these are relevant to, indeed included in, medicine, Leibniz thinks, insofar as all of them can help to contribute to the improvement and maintenance of bodily life. In this broad sense, all of Leibniz's philosophy of biology is at the same time a philosophy of medicine.

Soon we will proceed to a close examination of Leibniz's principal texts on medicine and related domains. Let us, however, move first to a consideration of Leibniz's interest in chemistry, or what is for him fundamentally the study of the various "mixtures" that make up the fluid parts of the human body, and also the study of the uses of chemical elements and compounds in medical treatment. For Leibniz, as we will see, chemistry is first and foremost iatrochemistry, or the study of chemistry insofar as it relates to medicine.

Chemistry and Iatrochemistry

It is well known that early in his career Leibniz was associated with a secret alchemical society. What is less often noted is that throughout his career Leibniz published a number of works on chemical topics. As early as August 1677, he would publish in the *Journal des Sçavans* a short account of "Le phosphore de M. Krafft ou Liqueur de terre seiche de sa composition qui jette continuellement de grands éclats de lumière [The Phosphorus of Mr. Krafft, or the Liquor of Dry Earth, of Its Composition, Which Continuously Gives Off Great Beams of Light]."[16] Leibniz had traveled to Hamburg earlier that year to see a demonstration by the alchemist Johann Daniel Krafft (also known as Crafft or Kraft) of the properties of the newly discovered, mysteriously luminescent element phosphorus. During that visit, he learned that Hennig Brand (also known as Heinrich or Henning) was also in possession of the element, and that this Hamburg alchemist had obtained it as a distillation of urine. A few years later, in 1682, Leibniz and Brand together composed the report on phosphorus that was sent to Ehrenfried Walther von Tschirnhaus and read by him at the Academy of Sciences in Paris, and also published in the *Mémoires de l'Histoire Royale des Sciences de Paris*.[17]

On February 17, 1681, an excerpt of a letter "touchant une expérience considérable d'une eau fumante [concerning a noteworthy experiment on a smoking water]" is published in the *Journal des Sçavans*. Here Leibniz relates:

> We have seen a remarkable experiment involving a smoking water. It produces smoke when it is cold, and does not cease to do so until it is entirely exhausted. However, one can keep it for as long as one wishes in a well-sealed bottle. When it is poured onto something, it releases from it a smoke so thick that one would judge in seeing it from afar that something was burning in that place."[18]

This may seem a distant concern from his engagement with medicine and the life sciences, but as we will see in the following chapter, here Leibniz is treating a problem that is at the heart of the study of animals, namely, whether there could be a "burning" (a notion broad enough to include the production of heat in the animal body) that endures without taking in new fuel, which would amount to nothing other than a machine of perpetual motion. Leibniz, will deny that animals can sustain themselves for long, and for this reason he will ultimately judge them to be only machines of *quasi*-perpetual motion. In the 1681 article Leibniz seems interested in the possibility that in chemistry there may be perpetual processes that do not require renewal from outside, and that do not give off waste products that would need to be discarded outside of the system itself. If such a process were to exist, it would amount to a sort of "chemical perpetual motion machine."[19] Yet at least in this text Leibniz's language remains merely descriptive rather than involving any commitment to an explanation of how the sustained burning works.

The following year Leibniz publishes in the *Acta Eruditorum* a short "Meditatio de Separatione Salis et aquae dulcis, novoque Separationum Chymicarum genere [Meditation on the Separation of Salt and Fresh Water, and on the Genus of Chemical Separations]."[20] Considering this treatise's appearance shortly after the work on phosphorus and the one on the *spiritus ardens*, and considering that these appear at a time when we know Leibniz was working on the animal-economical texts that will be studied in the following chapter, we may say that the early 1680s mark a high point in both Leibniz's chemical and physiological interests. We may also conjecture that he saw the two domains of inquiry as deeply interwoven, even inseparable: there is, Leibniz believed, an application for chemistry in the study of animal bodies. Animal economy considers these bodies qua structures; chemistry studies them as masses. The fact that the raw material for some of the most important chemical experiments of Leibniz's day came directly from the animal or human body—for example, the use of urine for the production of phosphorus—further shows how difficult it would have been for Leibniz and his contemporaries to make a firm distinction between chemistry as the study of all sorts of mixtures, on the one hand, and on the other what we call "biology."[21]

It is by now certain that Leibniz was employed as a secretary for an alchemical society in Nuremberg as early as 1666, and it may be presumed that this society's central interests were, like those of other such groups, centered on *chrysopoiesis*, or the manufacture of gold from baser metals. We also know with certainty that early on Leibniz was not just secretary to, but also intellectually associated with, members of the Nuremberg society. "In my youth," he later writes, "I often visited Daniel Wülfer," the president of the Nuremberg alchemical society, "and I enjoyed intimate contact with other learned Nurembergers."[22] Such close association with active alchemists would not last long. Later Leibniz would bemoan the consequences of excessive enthusiasm for alchemy, yet he would also acknowledge that a sane and healthy mind might benefit from a cautious interest in it:

> It was first of all into chemical studies that I was introduced in Nuremberg, and I do not regret having learned things in youth that in adulthood would make me suspicious. For later I would often be pressed into studies of this sort, less from my own incentive than from the rulers for whom I worked. Nor did I want for curiosity, even if I kept it within bounds by means of the necessary criticism.

Leibniz concludes by noting somewhat wistfully that "people very well known to me were shipwrecked, when they believed themselves to be sailing with the auspicious wind of their alchemical dreams."[23] Nonetheless, he would maintain his cautious interest long after his association with the Nuremberg society was over. We now know, in large part as a result of convincing evidence adduced by George MacDonald Ross, that Leibniz continues to be interested in the possibility of transmutation as late as the 1690s and perhaps even as late as 1716, even if he also exercises his usual caution in this matter.[24] For example, around 1710 he writes to Nicolaas Hartsoeker: "I do not have the slightest hope of arriving at the transmutation of metals, and I know of no experiment that confirms it. But in order to say absolutely that it is impossible, one would need proof of this."[25] In an undated note, Leibniz cleverly describes alchemy as "a rabbit that no one is able to catch."[26] He appears consistently unwilling to exclude the possibility of the transmutation of metals, but also appears consistently concerned to separate the scientific wheat from the obscurantist chaff. Thus in January 1688, Leibniz happily meets in Sulzbach with the Kabbalist and alchemist Christian Knorr von Rosenroth, with whom he has "lively discussions about chemical processes" as well as about natural-philosophical questions and Knorr's own mystical writings.[27] The subject of minerals comes up, and Leibniz is in turn prompted to pay a visit also to the mineral collector Elias Wolfgang Talientschger de Glänegg, as well as to visit a lead mine.[28] Conversation with a character such as Knorr von Rosenroth complements, rather than obstructs, Leibniz's natural-scientific pursuits. In sum, when Leibniz refers early on to the "fabulosum Philosophorum lapidem [the fabulous philosophers' stone]"[29] as a general denunciation of the chrysopoietic quest and other of the more mystical practices of the alchemists, we should not take this as a denunciation of the chemical tradition *tout court*, since this tradition was about many other things besides, including many experimentally predictive, theoretically sophisticated accounts of the nature of mixtures.

Leibniz's prudence notwithstanding, since MacDonald Ross wrote his important studies of Leibniz's alchemical connections, it has become increasingly clear that the question of a role for alchemy/chemistry in the development of Leibniz's thought is much broader than could possibly be determined simply by a consideration of his connections to would-be gold-makers and his opinion of their particular endeavor. We know today, in large part thanks to the work of Lawrence Principe and William R. Newman, that there is no clear boundary between the practice of alchemy and that of chemistry in the early modern period.[30] It has also become clear that many of the most important chemists, such as Daniel Sennert, Franciscus Sylvius, and Robert Boyle—all of whose work is, in varying degrees, both rooted in the alchemical quest *and* recognized as significant for the emergence of modern chemistry—were crucial in the development of Leibniz's mature philosophy.[31] As Richard Arthur and Andreas Blank have separately shown in recent detailed studies, Leibniz's particular variety of atomism—which we have yet to look at in detail—is best understood as coming at the end of a long tradition of chemical atomism, in which it was perfectly coherent to speak of atoms as having internal complexity, even if they are not further divisible by experimental means without losing their basic properties. As Arthur writes, in chemical atomism, in contrast with ancient atomism, "many authors proposed atoms that were regarded not only as divisible but also as possessing a variety of qualities, powers, and inner complexity."[32] Arthur and Blank both identify two basic features of Leibniz's atomism that are shared with that of Daniel Sennert, and in virtue of which both thinkers may be said to defend a variety of chemical atomism. First, both Leibniz and Sennert, who appears to adopt the view from Scaliger, believe that atoms can be made to "fuse," and that this fusion is part of what explains the cohesion of bodies.[33] Second, both thinkers hold to a variety of atomism that permits to these basic entities their own substantial forms.

As Newman has shown, there was a long medieval tradition of distinguishing between mixtures, in which initial ingredients come to form a perfectly homogeneous mass; and compositions, which were considered as something intermediate between the purely homogeneous and the mere juxtaposition. According to Newman, the medieval alchemists who argued for such an intermediary, sometimes called a *fortissima compositio*, were intuiting something like a molecular bond in today's sense: something that would permit all the properties of an ingredient added to the composition to disappear, while still permitting this ingredient, with its initial properties, to be reestablished through the alchemical method. The medieval alchemists who argued along these lines, Newman maintains, set themselves up starkly against the Scholastics who argued, in contrast, that any given body can have only one substantial form. In this way they significantly anticipated the early modern rejection of the doctrine of substantial forms in favor of a view of the qualitative diversity of bodies as arising from variations in the arrangements of corpuscles. For at least some early modern corpuscularians influenced by the chemical tradition, these corpuscles were not conceived along the lines of Democritean atoms, as indivisible pellets of matter differentiated from one another only by shape, but were conceived as having sundry, irreducibly qualitative properties, including, as for Sennert, an essential animation or quickness. Blank refers to this view as "Latin pluralism," according to which, as he puts it, "there is a plurality of forms in a living being, in such a way that the subordinate forms are dominated by the substantial form of the living being."[34] This plurality of forms is, in turn, very much what Leibniz has in mind in elaborating his model of the infinite nestedness of individual substances in the organic body of a corporeal substance, which is to say that one of Leibniz's central doctrines has a distinctly chemical pedigree. This central fact is not at all affected by whatever we might know, or discover, about Leibniz's rocky relationship with his alchemist contemporaries.

We will return to the role of chemistry in various parts of Leibniz's philosophy—for example, his animal economy, his "organics," and such—in later chapters. Here it is enough to note that quite apart from Leibniz's cautious skepticism about chrysopoiesis, the influence of chemistry in a broader sense on his philosophy is beyond question. As regards medicine, it is difficult to imagine how an author interested in medicine in the mid- to late seventeenth century, particularly a known eclectic such as Leibniz, could have avoided taking some interest in the study of chemistry and in the chemical tradition.

The *Directiones ad rem medicam pertinentes* (1671)[35]

The influence of chemistry is certainly evident in Leibniz's first major treatise on medicine, the *Directiones ad rem medicam pertinentes* (Directions Pertaining to the Institution of Medicine) of 1671. This early German-language text (or, perhaps better, Germano-Latin)—written, at the age of twenty-four, only a few years after Leibniz's first known philosophical sketches—consists principally in a set of propositions for the establishment of a public health system, but in passing tells us many things as well about the young Leibniz's developing views on the nature of animal and human bodies. The *Directiones* are of particular interest because they show, or at least strongly suggest, that even before Leibniz took an interest in the study of animal economy as a problem of natural philosophy, his interest in physiological and anatomical research was initially born of a concern for the advancement of medicine as a social institution.

As Vera Keller has remarked,[36] this early text has all the markings of a typical "wish list," a genre of early modern writing of which Leibniz was something of a master, in which the desiderata in any given domain of research are specified. It is typical of such wish lists that they present their various points in seemingly disjointed or arbitrary fashion. These are not essays, or argumentative treatises, but quite literally lists, with no more perceived need for a connection between neighboring points than the need for a connection between milk and potatoes on a grocery list. But the disjointed character of this work should not occlude from our view the careful and deep thought that went into its composition.

Leibniz shows in this text a particular interest in discovering new methods of probing into the inner workings of living bodies. "We need to find ways to penetrate ever further into the innermost part of a living being."[37] One way of doing this, he proposes, is by developing the science of anesthesia: "We must find a way to put a person into a deep sleep, in order not to harm him, to the extent that he would feel nothing, and could be easily awakened from this state."[38] Should this not be possible, fortunately there are also animals on which experiments can be made without concern for their pain. "We must conduct innumerable anatomical studies on animals, living as well as dead," Leibniz writes, complaining also that veterinary science has been principally based on equine diseases, since the cure of these is of immediate economic relevance. We can learn not just about anatomy from animals but also about pathology and the stages of development of diseases, since, as he writes, "we can cut them open and examine them when and how we please."[39] Autopsy on human beings is also useful for penetrating into the body, even if we do not have the convenience of being permitted to cut them open while still alive, and Leibniz recommends that as many people as possible be subjected to autopsy after death.[40] Leibniz hopes that soon a flesh-eating liquid might be discovered that will leave the veins and arteries intact, the better to study.[41] What is wanted is greater knowledge of the living human being, but the only two paths toward it are the living animal or the dead human, and the hope is that these two together might enable us to converge upon an adequately clear picture of the true subject of interest.

All opportunities should be taken to study bodily excrescences such as sweat, blood, urine, saliva, and even breath, which might, Leibniz thinks, be best investigated when reduced to a solid state.[42] One would not expect to learn much about a philosopher's broader concerns from his preoccupation with vomit, yet here, as elsewhere, Leibniz surprises us. Indeed, emetics are a long-standing interest for him, from the *Directiones* of the early 1670s to the 1696 publication of his 1695 treatise on ipecacuanha, which we know better today as "syrup of ipecac." We will consider his treatise on this root shortly. Leibniz is interested not just in the pathology of vomiting, but also in inducing vomiting experimentally in order to see what the food is doing in the stomach. As we shall see in the following chapter, Leibniz shares in the commonplace view that digestion, the transformation of food into flesh, is, as Walter Charleton would put it, "nothing else but Generation continued,"[43] to the extent that many of the same physical processes must take place in the one case as in the other, and to the extent that at a metaphysical level both involve the transformation of aggregate matter into corporeal-substance matter. In this respect, Leibniz's call for the experimental use of emetics may be seen in the same general light as William Harvey's observation of successive stages of fetal development in deer by cutting open the uteruses of several does in various stages of pregnancy: if pursued it would be a new means of penetrating into a process—generation in the latter case, and nutrition or "continued generation" in the former—that nature ordinarily keeps hidden. Leibniz speaks in the *Directiones* of the opening up of the human body for examination over the course of the preceding century as a "discovery" akin to that of a new continent, or even as akin to the transformation of the model of the cosmos by the work of Copernicus and Kepler.

Leibniz also believes that the condition of the hair, presumably its texture and color, can tell us a good deal about a person's constitution and health. Traditional forms of reading from external signs, such as the shape of the nose, are of course rejected, as it is only what truly emerges from within, what is pushed out from the invisible part of the body and becomes visible, that is diagnostically useful. Physiognomy in contrast, as traditionally practiced, lacks any sufficient reason: "From the figure of the hair of a man all sorts of useful conclusions may be drawn with certainty. Of the nose and other [parts] I do not wish to say."[44] The young Leibniz recognizes that the great challenge to the medicine of his era is not to boldly attempt to do without physiognomy and soothsaying practices such as chiromancy, but rather to attempt to limn the boundary between this sort of illegitimate prognostication on the one hand and on the other the inevitable reliance of medicine upon the reading of bodily symptoms. Nor, interestingly, does Leibniz reject the possibility of astrological influence upon long-term bodily health.[45] This suggests that for a self-identified mechanical philosopher such as Leibniz, the important task of mechanical natural philosophy was not so much to simply purge sympathetic effects in favor of mechanical links between bodies, but rather to determine precisely which effects from among those previously described in terms of sympathies could potentially be redescribed within the framework of the new, pared-down ontology.[46]

Excrescences such as sweat offer a sort of report on the recent state of the body's interior, while the enduring and stable shape of the cranium or the nose cannot tell much about a person's current state and likely future prospects, since these offer no new or recent information about changes within the body. Throughout the treatise, Leibniz's persistent aim is to know the inner through the outer: "We must namely find, by the use of reason, the communications of the external members with the internal viscera, so that it will be possible to do a great deal already through external treatments."[47] Secretions are helpful in this task, as are both opportune and forced drawings-out of what is ordinarily hidden inside, and, finally, as are autopsies. Such an interest in the communication between the external members and the internal parts was at the heart of many questions in seventeenth-century medicine, physiology, and embryology: Descartes, for example, believed that it is two entirely different mechanical-causal procedures that give rise to the integument and the external organs of sense on the one hand and on the other to the internal organs.[48]

The *Directiones* are filled with interrogations as to the possible influence of the soul upon the state of the body. Thus Leibniz writes that "we must set up tests [to determine] what the forces of imagination and the beliefs of the patient" bring about in that patient's health.[49] Indeed, for the young Leibniz, it is not such a large step from a concern with the inner causes of outer features and symptoms, to a concern with the similarities—and not just analogies—between medicine as treatment of the body and religion as treatment of the soul. For Leibniz in the *Directiones* these two projects seem to be two sides of the same coin. He thus proposes a number of measures for the organization of the medical profession, and repeatedly draws a parallel between the way the clergy is organized and the way doctors should, ideally, be organized. Doctors must be brought together in orders, he argues, "for those who are ordained are disinterested."[50] He argues that just as priests are to be found on the main streets of populous cities, so, too, there should be doctors who are easy to find in the same place.[51] "The institution of medicine must be ordained after the example of the clergy [Man muß rem medicam ad exemplum Ecclesiasticae ordenen],"[52] he says unequivocally. And just as priests do not only assign penance for sins committed but also counsel so as to conduct one's life better in the future, doctors should not only cure illnesses but also help patients to lead a healthy life: "For the rules or exigencies of medical father confessors as well should consist not so much in prescriptions as in regulation of the diet, just as the rules and exigencies of the spiritual father confessor should consist more in certain prescribed useful acts, than in the praying of a certain number of Hail Marys or Our Fathers."[53]

The *Directiones* are written by a very youthful hand on a very concrete matter, yet we see in them already some of the features of Leibniz's more mature work on medicine and animal economy. First of all, we see the conviction already in place that for the advancement of medicine the study of animal economy, which conceives the animal body as a sort of machine, is essential. This means, in particular, the study of animals in vivisection (see the section on animal experimentation below), as well as of humans post mortem. With respect to the bodily machine, there is no significant difference between humans and animals. Animal economy ideally studies the internal parts of living bodies, since this discipline is concerned not just with organs but with organs insofar as they are executing their functions, and with animal bodies insofar as they are organized collections of numerous function-executing organs. In his later discussions of the institution of medicine, Leibniz would abandon the explicit parallels between medicine and the institution of the clergy, and in the 1671 text Leibniz's mature theory of the mind-body relation is clearly not yet in place. Yet in the very suggestion that medicine as care of the body and religion as care of the soul are but two sides of the same coin, we may perhaps discern an early expression of the conviction that, while body and soul are causally independent of each other, still the body is at the deepest level of analysis a sort of unfolding or "explication" of the soul. It is entirely distinct, but entirely grounded in the successive states of the soul, just as medicine is entirely distinct from religion, while nonetheless ideally organized and administered according to exactly the same principles.

The Paris Notes

Leibniz would produce a number of texts and letters dealing with medical topics during the 1670s and 1680s. These show a steady engagement with medical issues throughout his career, an approach that remains very consistent with that sketched out as early as the *Directiones* of 1671 and that is repeated as late as the polemic against G. E. Stahl of 1709–10. One of Leibniz's oft-repeated principles in all of these periods is that medicine should not be primarily about administering drugs to those who are already ill, but rather should seek to understand the mechanisms of illnesses so that they may be prevented entirely. In general, he believes, medicines should be administered only very conservatively, particularly those that work in the body less like food than like poison. As he writes in the *De scribendis novis medicinae elementis* of the early 1680s: "All medicines operate either after the manner of aliments or of poisons. The former by degrees and insensibly, the latter by a great and sudden force. Thus these are not to be tried unless we require immediate aid."[54]

Leibniz seems very skeptical of many remedies but also seems to believe that they should be investigated and their proper application determined through experimentation, even if they are recognized frequently to be more damaging than beneficial. He even willingly subjects himself to a sort of auto-experimentation simply, as he puts it, out of curiosity: "I believe that bloodletting is good, but it may be that it is much more often bad and damaging. I only had my own blood let one time, and this just out of curiosity when I was in very good health."[55]

Of particular interest for our picture of Leibniz's views on diagnosis and treatment of illnesses is the collection of very rough notes to himself on medical topics during his stay in Paris, from 1672 to 1676. While he was there principally to advance his knowledge of mathematics under the tutelage of Christiaan Huygens, his medical notes show that he was, as usual, pursuing multiple interests at once during this period. Among other things, on February 24, 1676, Leibniz was invited by Descartes' literary executor, Claude Clerselier, to read and to transcribe a number of Descartes' unpublished writings. From among these, he was interested enough to copy out an *Excerptum ex autographo Cartesii* (Excerpt from Descartes' Writings) on the "Remedia et vires medicamentorum [Remedies and the Powers of Medicines]," which is now the only remaining copy of this important work of Descartes.[56] In addition, there are transcriptions of sundry recipes and pharmaceutical mixtures (a surprising number of which involve chocolate, illustrating the significance for seventeenth-century medicine of new discoveries in, and importations from, America).

While, again, Leibniz's medical notes from this period are far too numerous to even begin to provide a comprehensive study of them here, it will be useful to briefly consider one very representative piece. In a note on gout and "the vapors" of January 25, 1676, Leibniz reveals a sophisticated knowledge of recent anatomical and iatrochemical literature, particularly Thomas Bartholin's *Anatomia reformata*, and the *Praxeos medicae idea nova* (New Idea of Practical Medicine) of 1671 of Franciscus Sylvius (also known as Franz de la Boë), the teacher of, among others, Jan Swammerdam, Regnier De Graaf, and Burchard De Volder, all of whom would later have an important impact on Leibniz's thought. Here Leibniz displays his usual mixture of curiosity and skepticism. At issue in much of the note is whether the diagnostic term "vapors" corresponds to anything real. Leibniz reports:

> There is a sort of sickness in Paris of which the women habitually complain, and which they call "vapors." These are a sort of vertigo, or surprises and sudden weaknesses that seize them and that disappear at once and come back intermittently. And as these blind them as if some thick cloud came and darkened their vision and their spirit, they call them "vapors."[57]

He insists, however, that the origin of the diagnosis is but a weak metaphor drawn from chemical experimentation, and that it does not properly account for what goes on in the body. "It is very clear that these could not be vapors," he writes, since "the comparison of the head to an alembic[58] is very groundless; there are no passages for distillation and for there to be a vapor in the head itself there would have to be empty spaces where the vapor could accumulate."[59] Leibniz's skepticism borders on social constructionism: he clearly believes that the vapors are not just a medical condition but are also a complex of behaviors associated with a certain group of people, to wit, Parisian women.

Leibniz expresses in this case a view that he repeats in many others, that the poor diagnosis of the illness leads to misguided treatment. In this case the diagnosis of vapors, which arises from a misguided comparison to the alembic, leads to the dangerously misguided effort to "condense" the vapors by means of acids: "Now since the physicians base their diagnosis, ridiculously, on the name of 'vapors,' it is necessary, they say, to condense them, so they prescribe lemonades and other acids, which prolong the affliction, since they serve to increase the coagulation that is in the blood."[60] Leibniz's confidence in his own medical expertise is striking here, and indeed is much greater than it would be in his post-Paris period.

In broad outline, though, it contains many of the convictions that would guide his views in medicine, and, what's more, in the metaphysical modeling of the body, throughout the remainder of his career. For him, the body is a sort of machine, but one must nevertheless not exaggerate the similarity of this machine to some artificial device or process that a human being is capable of creating and controlling. For the proper understanding and treatment of the body-machine, all paths are potentially useful but likely also quite damaging. The best way to proceed is by experiment, coupled with a proper philosophical model of what sort of entity the living body subjected to experiment is. Also important is Leibniz's burgeoning awareness, perhaps initially triggered by his association with the alchemical society in Nuremberg but made more sophisticated and precise by his reading of Sylvius, that the body has, as he will later put it, a "chemistry specific to it," and that it can be treated by remedies first developed in the context of research into "inorganic" nature, even if, again, the body-machine has its own particular properties not shared by the compounds, mixtures, and solutions of primary interest to the chemists.

Leibniz produced a number of other texts of medical interest throughout the late 1670s and early 1680s after his return to Germany from Paris in 1676. Since these texts will be the focus of the following chapter, on animal economy, let us move now to a brief summary of his contributions to medicine in the 1690s.

The 1690s: Griping Pains and "Fables to the Deaf"

In the 1690s, Leibniz's interest in medicine seems to rotate around three broad sorts of endeavor: the standardization of record keeping, the promotion of autopsy and other means of making the interior of the human body visible, and the promotion of pharmaceutical study. His most significant contribution to the last of these was without doubt his *Relatio ad inclytam Societatem Leopoldinam Naturae curiosorum de novo antidysenterico americano magnis succsessibus comprobato* (Relation to the Illustrious Leopoldine Society of Naturalists concerning the New American Anti-Dysentery Drug, Attested with Great Successes) of 1695–96, written after reading extensively about, and evidently after conducting his own experiments with, the ipecacuanha root from Brazil.[61] The root had been brought back to Europe by the Dutch physician Wilhelm Piso in 1641 and had been written about extensively in his *Historia naturalis et medica Brasiliae* (The Medical and Natural History of Brazil), co-written with Georg Markgraf in 1648. The root was introduced in Paris in 1672 and was made famous when the physician Helvétius used it successfully to treat Louis XIV's dysentery.[62] It is clear from Leibniz's study that he has a detailed knowledge of Piso and Markgraf's work.

How did Leibniz come to have this particular interest? Unfortunately, the whole story cannot be reconstructed. We do know that on April 19, 1695, Leibniz reports having experienced earlier that day "a small griping pain [*ein Kleines Grimmen*], as if I had taken a purgative."[63] Two weeks later, Leibniz asks the Duchess Maria Aurora von Königsmarck to arrange for the distribution of the ipecacuanha root in Saxony.[64] Within a year he will have composed his extensive treatise on this root's purgative power. This treatise will also be the most comprehensive and influential of Leibniz's contributions to the history of medicine and pharmacy.

By the time Leibniz writes about it for the Leopoldine Society and brings it to the attention of the German public, the root has been well known for some years in France already, and it is likely that Leibniz himself had already learned of its use while in Paris a quarter of a century earlier. He is aware of its widespread use among the Brazilian natives and of its more recent successes in France, but he is nonetheless the first to give an exhaustive account of its many uses, not only against dysentery, but also as an emetic, a diaphoretic (causing one to perspire), and an expectorant (causing one to salivate). In these last three applications, it works very much as a "poison," and thus is a medicine of the sort that Leibniz had insisted in the *De scribendis novis* must be used only cautiously. It is also the very potion for which Leibniz had expressed a desire as early as the *Directiones* of 1671: one that through its ingestion can immediately make the internal external, thereby giving an instant report of the state of the body from where it cannot be directly perceived.

One long-standing concern Leibniz has, as we already began to see in the *Directiones*, and one that he thinks can be better dealt with by experimental methods, is the project of discerning the fine line between medical practice and fraudulent natural-magical healing. He writes in the *De novo antidysenterico* that "medicine is an uncertain art, which sustains the credulity of men, like the great dream of the philosophers' stone."[65] Leibniz's attitude toward chrysopoiesis, seen above, is echoed in the cautious skepticism he expresses about a number of common diagnostic methods, such as astrology and chiromancy.[66] He recognizes medicine's inherent tendency toward fraudulence and its inherently uncertain character—uncertain because so reliant upon empirical methods and so lacking in first principles—while at the same time recognizing that, like cosmology before it, medicine may finally be on the verge of gaining secure foundations. In the aim of bringing this about, choosing among the forces that tradition had invoked to explain observable effects was by no means a self-evident matter. Like the funding of research into alternative medicine provided by the National Institutes of Health in the United States,[67] Leibniz recognizes that in medicine fraudulence must be courted in order, with time, to gain the richest knowledge of real effects flowing from real causes.

One important theme of the *De novo antidysenterico* is the newness of medicine as a properly scientific discipline. Leibniz writes:

> We have lost the majority of ancient remedies; sometimes their salutary character resides in their names alone. It was barely two centuries ago that medicine was reborn; it has been no more than one century since anatomy has flourished. Indeed it is less than half a century since the interior constitution of the human body was revealed through the discovery of the circulation of the blood. And thus it is surprising that there are so many … efficacious remedies, given so great an ignorance of causes.[68]

This is a point that will be repeated again in the controversy with G. E. Stahl of 1709–10. Leibniz believes that the modern period has witnessed revolutionary progress in medicine, and this for reasons having to do not just with the emergence of exact anatomical study in the Paduan school in the sixteenth century, but also, perhaps most significantly, with innovations in the methods of obtaining and compiling medical data.

In the *De novo antidysenterico* Leibniz continues to offer familiar prescriptions not just for pharmacy but also for the social institution of medicine. A new idea, one that seems to have been inspired by his encounter in Italy with the physician to the Duke of Modena, Bernardino Ramazzini, concerns the improvement of medical record keeping: "I think that above all historical medical annals must be founded, … and that those who wield influence in public affairs should apportion funds from the public treasury more liberally for [medicine] than for any other art."[69] Leibniz is making these grand proposals in the course of introducing a rather concrete examination of the medicinal effects of a certain plant, and we may assume, in view of this incongruity, that he is using the pretext of his report on the root for the scientific society as an occasion for promoting some of his enduring ideas about the proper organization and practice of medicine.

For Leibniz, the advancement of any science or discipline is directly connected not just with discovery and theory but also with the creation of a proper institutional structure for the facilitation of discovery and the production of theories. In a letter "on the method of perfecting medicine" of 1694, Leibniz shows the remarkable manner in which modern record keeping and statistics have, as their closest historical antecedent, the divinatory practices of the authors of almanacs and medical calendars. He writes:

> I do not know whether in Paris they still keep the estates or anniversary lists of Baptisms and of Funerals in this large city, which they composed during

> the time I was there. This project seemed very useful, as much so as the *Bills of mortality*[70] of London, from which able men have drawn conclusions of consequence. However one could go further, in having an annual medical history written up of Paris and the Ile de France.[71]

Here, as in a letter to Hertel of 1691, Leibniz mentions a book by Ramazzini, which he cites as *Vom Zustande voriges Jahres, die Menschliche Gesundheit betreffend, gerichtet auf die Lombardey* (On the State of the Previous Year, as Concerns Human Health, Directed toward Lombardy). He writes that Ramazzini "would like to make a sort of *Medical Calendar*, but not, as the astrologers do, before the year has started, but rather when it is over."[72] Of course, this seems like an obvious point: retrodiction is more accurate than prediction. But Leibniz seems to be on the verge of an important discovery, one stimulated no doubt by Ramazzini,[73] that the compilation of health data for entire populations would not be a mere cataloguing of what has already happened; it would also help to predict what is likely to happen in the future in individual cases.

Although it seems to reach its peak in the 1690s,[74] Leibniz has a longstanding interest in compiling health statistics. Thus there is a report of an early conversation taking place with Duke Johann Friedrich on the subject of calculating mortality rates on December 31, 1675.[75] This interest is only increased by his exposure to the work of Ramazzini. Many years later, in 1701, Leibniz composes two German works on this same subject, the "Summarische Punctuation die medicinalische Observationes betr. so durchgehends anzustellen und beständigt fortzusetzen seyn möchten [Summary statement concerning medical observations that may be constantly implemented and perpetually advanced],"[76] and the "Verordnung betr. regelmäßige Beobachtungen zur Förderung des Sanitätswesens [Prescription concerning regular observations for the promotion of the health system]."[77] This interest arguably has a family resemblance with the wide variety of other public projects that occupy Leibniz's imagination: city water works, lighting the streets of Vienna, the improvement of public transportation, to name only a few. But public health is of particular importance for Leibniz since, again, the health of the individual is, as he puts it, second only to morality.

Leibniz had another griping pain in the period of the *De novo antidysenterico*, arising from what he perceived as the persistent refusal of his contemporaries to take his recommendations for the reform of medicine seriously. Evidently, one of the most important figures influencing Leibniz's interest in medicine in the period in question was Johann Bernoulli, a well-trained physician who wrote a number of influential treatises on organic chemistry and its importance for medicine, including the *Dissertatio chymico-physica de effervescentia et fermentatione* (Chemico-Physical Dissertation on Effervescence and Fermentation) of 1690, and the *Dissertatio inauguralis physico-anatomica de motu musculorum* (Inaugural Physico-Anatomical Dissertation on the Motion of the Muscles) of 1694.[78] The Swiss doctor was mentioned in a letter from Leibniz to Bernoulli's brother Jacob, in which Leibniz promotes Johann as the sort of "philosopher physician" who may be able to bring about the needed reform of medicine:

> And if only those to whom it is possible were to undertake to think about instituting medicine more attentively, I indeed do not doubt that even now many things could be furnished to us, if we were to understand, that is, if we were to wish to think about, those things that are most in our interest. And thus in fact I have encouraged your most illustrious brother repeatedly to change his mind on this matter; I should not so much want him to be some sort of attending physician, such as those of his greatness are in the habit of being only reluctantly, but I should rather hope that at this age, and with this talent, something great should be able to proceed from this man who is no stranger to medical matters.[79]

Leibniz had written to Huygens in much the same vein a few months earlier:

> May it please God that our studies should serve to advance medicine significantly. But until now this science remains almost entirely empirical. It is true that sometimes empiricism itself may be of great use, if one is committed to observing well, and even to employing well all the observations already made, but as medicine has become a profession, those who make a career out of it only do so in the way they were taught, and as much as possible in order to save the appearances, well concealing the fact that few people are capable of making judgments about what they do. I would like for some order, such as that of the Capucins, for example, to be associated with medicine by a principle of charity. Such an order, well governed, could carry it very far.[80]

By 1696, Leibniz seems frustrated that no one has heeded his call for the reform of medicine, either by making it more philosophical or by organizing it after the model of religious orders. He writes to Guillaume François de l'Hospital in May 1696, repeating the invocation of God's pleasure he had earlier used in writing to Huygens: "May it please God that it should come about that doctors philosophize, and philosophers occupy themselves with medicine [*que les philosophes medicinassent*]. I believe that one could go much further, but I have often futilely preached a 'fable to the deaf' on this subject."[81]

In addition to Leibniz's interest in emetics, and in the reform of the public health system, throughout the 1690s he remains intensely focused on the study of iatrochemistry[82]—perhaps in part as a result of continued reading on this subject, including the work of Bernoulli—as well as in the study of anatomy and physiology as these relate to the advancement of medical practice. One of the more interesting expressions of this interest from the years around the time of the composition of the *De novo anti-dysenterico* is found in his correspondence with Jacques Bouquet, though regrettably only the latter's letters have survived. Bouquet had gone to witness autopsies in the great Theatrum anatomicum of Padua, and fastidiously reported back to Leibniz on what he observed. He writes to Leibniz in March 1695:

> Among the number of cadavers that we opened up in the anatomical theater we found one that had half of its spleen in the chest and the other half in the abdomen; another [cadaver] had two separate livers, one of the normal size in the normal place, and the other between the tunics of the diaphragm and of the size of two fists, and weighing about two to three pounds.[83]

Although Leibniz's letters to Bouquet have been lost, we may assume that he had requested a complete report on any abnormalities his correspondent was lucky to observe in the anatomical theater. Bouquet concludes his report: "This [is] what I saw and what I can affirm, I myself having assisted the anatomist in the dissection of these two bodies."[84] Bouquet provides further details a few months later on the condition of a man with a divided spleen: "This man was a legless cripple [*cul de Jate*, that is, literally, the butt of a vase] who had never walked. For a long time he had had illnesses that had left him with obstructions in the lower abdomen and that had hardened all of the parts contained there." Bouquet goes on to relate a speculative physiological account of how a part of the spleen could have migrated so far, but then, remarkably, concludes that this entire story, like that of the unusual liver, amounts to a mere curiosity of little scientific interest:

> This concludes, sir, what I am able to relate. I do not believe that this observation helps much to understand the functioning [usage] of the spleen; as to the first of these [the double liver] I consider it to be a game of nature (to speak with certain authors), as with those whom she causes to be born with six fingers on their hand, without this being capable of changing their health, nor bringing about any unusual symptoms.[85]

We may at least speculate that if Leibniz's replies to Bouquet were available, we would find him rejecting the account of developmental abnormality Bouquet provides. As we will see in the section of chapter 6 on fossils and geomorphology, Leibniz will strongly deny that nature plays games, either in the development of human bodies or of rock formations, and this view will come to play a central role in his theory of the origins of organic forms as well as in his theory of preestablished harmony. As we will see, further, in chapters 7 and 8, Leibniz will also hold that malformations, or animal bodies that are derailed from their normal course of development, far from being mere curiosities may serve as guides to what takes place in ordinary cases. This increasing tendency in early modern natural philosophy to learn about the regular through the irregular, and correlatively to abandon the view of the irregular as mere "games of nature," is a process that has been vividly described by Lorraine Daston and Katharine Park with respect to the history of the perception of monsters.[86] Leibniz deserves a prominent position as one of the representatives of the new teratology, which strongly rejects games of nature. In Leibniz's case, as we will see in chapter 6, this rejection also involves a rejection of spontaneity in nature in general.

The *De causis febrium* (1704–05)

Leibniz continues writing on medical topics into the eighteenth century. One of his more significant, and evidently original, works from this period concerns the nature, origins, and treatment of fevers. The explanation of fever had been of central importance to seventeenth-century medicine.[87] Classical Galenic theory had treated fever as a disease in its own right, while it was only toward the end of the seventeenth century, principally through the work of Hermann Boerhaave, that it came to be seen instead as a symptom or epiphenomenon of other illnesses.[88] Leibniz remains for the most part devoted to the traditional model of fever, which, as Thomas Willis defines it, "is only a fermentation, or an excessive effervescence of the blood, induced by the humors [sit tantum fermentatio, seu effervescentia immodica sanguini, & humoribus inducta]."[89] To the extent that a theory can be discerned from Leibniz's rather skeletal text, he appears to agree with Willis that fever is a disease unto itself, and that it occurs when spirits, originally excocted from the blood and ultimately from aliment, become excessively rarefied and penetrate across the boundaries of the vessels that ordinarily contain them:

> Nerves, membranes, tendons, and fibres form a sort of continuum that may be penetrated, even if insensibly, by which sense and motion are propagated to the whole body. In this consists the proximate cause of many illnesses, but most of all of fevers.[90]

Beyond this text Leibniz speaks frequently of fever, of both his own bouts of it as well as of its causes in general, and it is generally very difficult to determine the precise nature of the illness to which he is referring. As Ekkehard Görlich has noted, Leibniz generally speaks of his own bouts of fever as though they were themselves the illness from which he was suffering, rather than symptoms of another illness.[91] If we accept that there were two dominant theories of fever inherited from antiquity—the first a Hippocratic theory of fever as a sort of cooking that defeats dangerous, invasive elements; the second a Galenic explanation according to which the fever results from a humoral imbalance—then Leibniz may be placed more certainly in the second camp. However much Leibniz tends toward iatrochemical explanations, at least in his account of illnesses that strike close to home, he is not at all uncomfortable with traditional humor-pathological explanations. Yet perhaps this shows only the dangers of extrapolating too much from Leibniz's self-observation. Leibniz writes to Schelhammer, for example, with a very different account of the origins of fever:

> Nor is the suspicion absurd that the immediate cause of fevers is more in [the nerves and membranes] than in the humors. From which it arises that, immediately after some fright, or some other sudden and great change in the mind, fevers are indeed brought on by the imagination.[92]

Here Leibniz seems unworried about the implications for his mature system of preestablished harmony of psychosomatic explanations for the origins of medical conditions such as fevers (it would seem, after all, that if body and soul are not causally coordinated, then it is at least problematic to suppose that a state of the soul could be the cause of an illness). This lack of concern might appear to speak to the relative independence of Leibniz's medical interests from his philosophical ones. Yet on other occasions, as we will see, Leibniz goes to some length to argue that the explanation of somatic states in terms of psychic origins is in the end just a manner of speaking, an "as if" that can ultimately be cashed out in terms of the perceptions of immaterial monads.

The Polemic against G. E. Stahl in Relation to Leibniz's Earlier Works on Medicine

Leibniz's so-called *Animadversiones in G. E. Stahlii* Theoriam medicam veram were composed in 1709–10 and were first published at the behest of the vitalist physician from Halle, Georg Ernst Stahl, in 1720, under the provocative title *Negotium otiosum: Seu Σκιαμαχια adversus positiones aliquas fundamentales* Theoriae verae medicae *a viro celeberrimo* (Idle Annoyance, or, Shadow Boxing from a Celebrated Man against Certain Fundamental Positions of the *True Medical Theory*).[93] This edition, as the title suggests, is clearly biased in favor of Stahl's position: prima facie, it is striking that Stahl would accuse Leibniz of shadow boxing against an unresponsive enemy, when it is Leibniz who has been dead for four years already at the time of publication, and who is in no position at all to respond to this harsh framing of his objections to Stahl's vitalism. Yet, curiously, it was on the basis of this edition that Louis Dutens produced his edition of the work in his collection of Leibniz's *Opera omnia* of 1768.[94]

The *Animadversiones*, unlike many of the preceding texts, have been relatively well studied in the secondary literature, and in many respects they constitute the most mature, and important, expression of Leibniz's medical and physiological thought. What the earlier literature has generally failed to notice, however, is that they also show a remarkable continuity with the earlier texts on the same subject. Indeed, we find many of the same points about, for example, the function of the heart, being made, in exactly the same language, in this text of 1712 as we have already seen in the 1670s. In our treatment of the text, we shall be careful to bring out its continuities with Leibniz's earlier physiological thought, while also emphasizing what is truly new in it.

We will treat Leibniz's polemic against G. E. Stahl, written in 1709–10 in response to the Halle doctor's *Theoria medica vera*, at great length in the following chapter. Here it will be useful just to briefly consider the relevance of this text for our understanding of Leibniz's views on medicine. In the polemic, Leibniz shows himself to be no less interested in the advancement of medicine than he had been in the *Directiones* of 1671. One important theme here, again, is the infancy of medicine and the idea that the discipline could not truly develop as long as its practitioners remain reliant on ancient authority. Leibniz sees this discipline as a distinctly modern one in which the great thinkers have only been around "for the past 200 years." As in the *De novo antidysenterico*, written some fourteen years prior, Leibniz presents a picture of the medieval decline, and recent rebirth, of medicine. Most of the experiments of the Greeks and Latins have disappeared, Leibniz argues, "and the reflections that remain from these are very diminished. During the Dark Ages, the Arabs and the Latins were able to add some elements to pathology and to pharmaceutics, but without much value." Often, however, Leibniz believes that the Arabs not only did not advance beyond but even "neglected and corrupted" the ancient texts.[95]

Also as in the *Directiones*, here again anatomy and medicine are intimately connected to the extent that greater anatomical knowledge will lead to improved diagnosis and treatment of illnesses. But the enhancement of anatomical knowledge must also be accompanied by improved botany, chemistry, and such, in order for medicine to advance at a desirable rate. As in the *Directiones*, written more than forty years prior, Leibniz is intent to make a special case for the study of anatomy and animal economy, and for the promotion of anatomical study by the state, particularly where official assistance is needed for finding, developing, and implementing new methods for probing into the inner workings of living and dead bodies. At the same time, Leibniz recognizes his own limitations as a contributor to this field of knowledge and is no doubt reckoning with the fact that at his mature age he will probably never get around to doing the serious empirical work in animal physiology and medicine to which he may once have hoped to contribute. Thus, for example, though he is convinced of the importance of volatile salts for understanding animal chemistry, he acknowledges that he cannot judge their utility in certain, specific treatments and writes in response to a question from Stahl concerning their use: "Whether the use of the volatile salts of urine is unhelpful is a question of fact, for which I refer the author of the *Responsio* to other physicians."[96] Leibniz's status as a nonphysician engaging with physicians is something that had preoccupied him already for some time. In the *De novo antidysenterico* of 1695–96 he explains that "nothing is more precious to men than health," and adds: "This may be said all the more fervently by me, who is not a doctor, since I will be less suspect of seeking to advance my own usefulness."[97]

In the polemic against Stahl, we see that by the near-end of his career, Leibniz has never come to have much of a stake in the great medical debates of his day. He never takes sides, for example, with the iatrochemists or any other particular school of thought. As Görlich rightly notes, Leibniz tends to agree with the iatrochemists "when he is considering the human body as a mechanism that is to be studied by natural-scientific methods," while, in contrast, when reflecting on the nature of his own illnesses the traditional humor-pathological explanation of the body comes to the forefront.[98] His primary stake remains at the level of the organization of medicine. Yet he engages enough to be able to say with confidence what tendencies in medicine contain within them philosophical ideas amenable to, or incompatible with, his own.

Before moving on to Leibniz's contribution to animal economy, in which he may perhaps be said to have more of a stake, to the extent that his models of the animal body will contribute directly to his metaphysical model of corporeal substance, let us stay a bit longer in the experimental context of Leibniz's interest in medicine in the broad sense. This context included experimentation on animals as a key element, and the perception of the relevance of this sort of experiment to the advancement of medicine—a relevance we have already seen Leibniz ardently defending—involves a number of implicit presuppositions about what an animal is and what can be learned from intervening in its normal functioning. Let us now turn briefly to this sort of intervention.

Leibniz and Animal Experimentation: The Passage from Vivisection to Microscopy

It might be surprising to learn that Leibniz was, early on, a vociferous advocate of vivisection. As early as Kant's *Lectures on Ethics*, the legend has circulated that Leibniz was far too gentle to condone such a thing. As we learn from the lecture notes taken by Collins: "Leibniz used a tiny worm for purposes of observation, and then carefully replaced it with its leaf on the tree, so that it should not come to harm through any act of his." Kant goes on to say that Leibniz "would have been sorry—a natural feeling for a humane man—to destroy such a creature for no reason."[99] For Kant, famously, animals are only a means to an end. Nonetheless he finds Leibniz's gesture worthy of praise since, Kant thinks, we do have moral duties regarding what is beautiful and purposive in nature, even if in the end these are not duties toward morally relevant subjects.

Kant's gentle Leibniz comes across rather differently from the one we now know, and Kant certainly could not have known, from the 1671 *Directiones*. There, Leibniz beseeches his contemporaries: "We must conduct innumerable anatomical studies on animals, living as well as dead." The advantage of working with animals, he notes, in contrast with humans, is, as we already saw above, that "we can cut them open and examine them when and how we please."[100] But are these really two different images of the same man? After all, Kant notes that Leibniz replaces the caterpillar because there is no reason to destroy it. In Leibniz's view in the *Directiones*, however, there is a very good reason to perform vivisections: the advancement of medical knowledge. Where this can be advanced by other means, Leibniz seems to prefer these.

The perception of the relevance of animal experimentation changed immensely over the course of the seventeenth century, both for Leibniz and in general. As Anita Guerrini notes, in the early seventeenth century many criticized William Harvey's experiments on animals on the grounds that they "could tell us nothing about humans because humans were unique." But by the latter half of the seventeenth century almost all researchers began their research with two fundamental assumptions: "that organisms and machines are analogous, and that all vital functions involve only the substances and processes of inanimate nature."[101] These two assumptions, it is worth adding, are connected: it was in large part the mechanization of physiology and embryology that made it possible to conceive humans and animals as variations upon one basic form and that also called into question the long-standing belief in rigid and impassable boundaries between species. After all, if it can be shown how a particular kind of animal can arise through a series of "minor causes" (Descartes' phrase), then speciation itself will be revealed to be only the result of varying arrangements of parts rather than the inherence of irreducibly unique essences. Leibniz, as we will learn in detail in the following chapters, is a mechanist about animal *bodies*, but decidedly not a mechanist about animals themselves. There is for him more to an animal than its body, in contrast with the well-known Cartesian view, but as far as the body is concerned humans and animals are for Leibniz fundamentally the same sort of thing.

In the mid-seventeenth century, the experiments on animals from which many hoped to gain new insights into the workings of the human body, in view of a presumed analogy between animals and humans, involved most often the study of the circulation of the blood and of respiration. The animals placed in Robert Boyle's "evacuated chamber" served not only as a sort of gauge of the atmospheric conditions into which they had been placed; these animals also provided information about the nature of living bodies themselves and about the nature of their dependence on their ambient environment for their survival. These animals were simultaneously instruments in physics experiments and the subjects of what we would think of as biology experiments. To the extent that these two sciences had not yet been separated, it is not surprising to see experimenters making observations about the one and the other in the course of the very same experiment.

Some of Leibniz's earliest theoretical views on animals appear indirectly through his observations of animal experimentation and his recommendations as to their usefulness. In order, again, to believe that animal experimentation is of use to medicine, one must believe that humans and animals are sufficiently similar that the results of what is done to the latter may be presumed to be an accurate predictor of what would happen in the case of the former. The experiments that likely inspired the interest Leibniz expresses in the *Directiones* in vivisection and transfusion, namely, those conducted by the Royal Society throughout the 1660s,[102] were not only based on a presumed analogy between human and animal; often, it was hoped that the very nature of species difference could be unraveled through the study of interspecies transfusion.

In the *Directiones*, Leibniz speaks enthusiastically of transfusion experiments: "One should test all sorts of liquors injected into the blood. One should not cease to make tests involving the transfusion of the blood, at least in animals, as in England a weak horse was made strong again by the use of fresh sheep's blood."[103] In chapter 7 we will discuss the theoretical problems Leibniz faced in seeking to understand the nature of biological species and the boundaries between them. For now, it will suffice to note that early on Leibniz is as enthusiastic as many of his contemporaries for experimentation involving interspecies transfusion and is likely as intrigued as those who were performing the experiments by the philosophical implications of their results for the understanding of species membership, individuality, and animal souls.

In a 1669 work titled *Tractatus de corde* (Treatise on the Heart), which, in the *Directiones*, Leibniz mentions having read, the Cornish physician Richard Lower denounces the view that the possibility of blood transfusion is nothing more than "an old fable of Pythagoras, and like another ridiculous metempsychosis."[104] The reason why one might have thought that to believe in the possibility of transfusion is tantamount to belief in the transmigration of souls, seems to have to do with the intense and widespread association of the blood with the animal soul, either through the animal spirits that are seen as the most rarefied product of the blood, or as in the case of William Harvey, who maintained that the blood itself just *is* the soul. Transfusion, on such a view, much like cloning today, was an intervention in nature that seemed to make a hash of many of our most basic metaphysical distinctions. But it was in part precisely these distinctions, and the need to either corroborate them or reject them, that drove such experiments. Some of these experiments involved human subjects; Lower, for example, describes an experiment performed "on a certain A[rthur] C[oga], who had a harmless sort of madness, and into whose arm, in the presence of the Royal Society, we injected at various times a few ounces of sheep's blood, without causing him any harm. . . . But he eluded our aims, preferring his own inclination to debauchery to the pursuit of healing."[105]

The idea that sheep's blood could make a sick horse healthy, or an insane man sane, is evidently premised on the supposed moral character of the sheep, which in turn is rooted in a long history of religious iconography and allegory. Lower believes that "just as the illustrious Harvey was the first to teach that the blood that circulates outside of its own vessels conserved the life of the body," so in turn has he, Lower, been the first to discover that blood transferred out of an animal can rehabilitate the health of another body.[106] These experiments could easily lead one to think of life and health not as properties of individuals but as diffuse quantities that might be shared or exchanged. One can imagine that for the young Leibniz, reading the *Tractatus de corde*, the significance of these discoveries easily trumped any ethical concern about the well-being of the test subjects and perhaps even indicated that such concern is misplaced, to the extent that the experiments suggested that individuality is something of an illusion.

In the *Directiones*, Leibniz makes clear that his interest in experiments of this sort has not just to do with practical or economic benefits that could arise from an improved understanding of animal bodies. Thus he bemoans the excessive attention of his contemporaries to equine anatomy,[107] not, evidently, because he believes that horses are irrelevant to our understanding of human medicine, but only because it is, he thinks, a shame to limit our detailed knowledge to one kind of animal when there are so many out there that may yield different insights about the working of bodies in general. Leibniz's complaint positions him in a long-standing debate as to the justification of the study of animals: in spite of the common injunction among sixteenth-century Italian anatomists to return to the study of animals as wonderful in their own right, there was a consistent tendency to demand justification for the study of animals by asking of what relevance this study might be to human existence. The most obvious relevance would be an economic one: healthier horses invariably mean better work and better profits. But the sort of relevance Leibniz would like to see is more basic: one that teaches us about human beings in virtue of what human and animal bodies have in common.

Throughout the remainder of his career, Leibniz never again expresses such enthusiasm as in the 1671 *Directiones* for vivisection and other forms of animal experimentation. We do find in his notes on Henry More's *The Immortality of the Soul* of 1677 or 1678 a reference—to our knowledge the only reference in Leibniz's writings—to a vivisection at which Leibniz himself was present. Here Leibniz is responding affirmatively to More's observation that the heart cannot be the seat of the soul, since, as More notes, and Leibniz paraphrases, "it has been remarked that the crocodile will fight and defend itself for quite a long time after its heart has been removed, and Calcidius reports the same thing of the sea tortoise and the wild goat." Leibniz goes on to mention Galen's observation of beasts that had been sacrificed by having their hearts ripped out, but that went on suffering for some time after that: "after their heart was removed," Leibniz recounts, "and laid on the altar, they were seen at the same time not only breathing and roaring loudly, but also rushing and running quite far away, until the loss of their blood made them fall." At this point, Leibniz recalls his own observation of the removal of a frog's heart by an unfortunately unnamed colleague. "This appears to me all the more credible," Leibniz writes,

> since I have seen with my own eyes a frog completely disembowelled, its heart, stomach and guts taken out of its body by a very skillful anatomist friend of mine, and after all that it continued for quite a long time to see, to avoid objects in its path, and to jump with as much agility as before, whereas a small wound to the head deprives these animals of life and motion in an instant.[108]

Around the same time, according to the Academy's dating, Leibniz writes: "That other men think is no more certain to me than that beasts have feelings."[109] These passages taken together show that a theoretical anti-Cartesianism with respect to the animal's capacities or the inherence of an animal soul has no obvious ethical implications from Leibniz's point of view. To put this slightly differently: it is not the Cartesian model of the *bête-machine* that is responsible for the explosion of interest in animals as objects of research in the early modern period.[110] One could continue to hold a very different model of animals, and still not object to their objectification; for example, one could hold that these objects of scientific study are also subjects. This was precisely the case for Leibniz.

Moving into the 1680s we find Leibniz mentioning experimentation on animals in the *Corpus hominis*, a text that will be a central focus of analysis later in this book, as a confirmation of his account of the production and function of the blood, but he does not give any indication of what experiments he may have in mind. In another text of the mid-1680s, Leibniz focuses not on the animal's capacity to suffer but rather to feel pleasure, seeing this as equally relevant to the case he wishes to make against "the Cartesians":

> If every pleasure consists solely in the knowledge of our strength, not only would beasts not feel pleasure, which Descartes would concede, but neither would we perceive the signs of pleasure in them which we plainly recognize as similar in men. Therefore pleasure should be explained in such a way that its material aspect, as I would call it, can also be observed in beasts, for it is not apparent how those corporeal movements, which are also in beasts, follow from the feeling of our powers.[111]

It is hard to say exactly what Leibniz might mean by the "material aspect" of pleasure. Clearly, he does not really want to agree with the Cartesian view that animal bodies realize in an entirely corporeal way functions that in human beings are also mental, even if Leibniz appears to be saying something just such as this. In another text of the early 1680s, the *De scribendis novis Medicinae elementis*, Leibniz identifies pleasure as "agreeable perception," and perception is something that, by this point, invariably involves the activity of a mindlike substance.[112] The question of animal pleasure—and pain—had become an important issue in early modern philosophy in large part because there was an active scientific research program based on Cartesian metaphysics that took it for granted that apparent expressions of pleasure and pain in animals were *only* apparent. In a 1684 letter to Tschirnhaus, Leibniz indicates explicitly his awareness of the strain of Dutch Cartesianism that would seem to condone—or, perhaps better, deny the impossibility of—cruelty toward animals. Leibniz seems to agree that the "common people" are justified in ridiculing the Cartesian view: "In Holland people are now disputing loudly and passionately about whether beasts are machines, and even the common man amuses himself with it, and ridicules the Cartesians, who imagine that a beaten dog cries in much the same way as an accordion when touched." Leibniz continues with his familiar take on the problem, according to which the pure mechanism of the animal body does nothing to prove the absence of a soul: "Although I grant the Cartesians that all the external operations of beasts can be explained mechanically, I nevertheless believe that beasts have some knowledge, and that there is something in them which is not actually extended, and which can be called a soul, or, if you like, a substantial form."[113]

By the early 1690s, Leibniz begins to show a marked shift in the kind of research on animals he believes will be most beneficial to the advancement of knowledge. In a letter to Huygens of May 1691, Leibniz writes: "I prefer a Leeuwenhoek, who tells me what he sees, to a Cartesian who tells me what he thinks."[114] It is not clear to which Cartesians Leibniz is referring, but in any case this statement is not only remarkable in that it shows a penchant for observation over armchair philosophizing that, as so much else in Leibniz's corpus, problematizes his categorization as a "rationalist" as opposed to an "empiricist." Leibniz is without doubt a rationalist philosopher, to the extent that he is fundamentally committed to a priori knowledge, but evidently this commitment does not carry with it any devaluation or dismissal of knowledge gained by empirical means. This statement is also remarkable in that by 1691 Descartes' followers are well known, perhaps notorious, for their active research program in the study of animal physiology through vivisection and other experiments, and we have already seen Leibniz make explicit reference to this program in his 1684 letter to Huygens. With this in mind, Leibniz's preference for "a Leeuwenhoek" over "a Cartesian" may have not just to do with a preference for observation over abstract contemplation but also with a change of focus on Leibniz's part as to the kind of observation of animals that will yield the most valuable insights. This change of focus parallels the shift we will be charting throughout this book from animal economy to subtle anatomy. If we may draw on a comparison from contemporary science, it is as though Leibniz has progressed from a youthful interest in the behavior of lobotomized monkeys, to an interest in his mature years in genetic drift across generations of *Drosophila* fruit flies. That is, he grows less interested in studying live animals that bear a particularly close analogy to human beings and more interested in learning about the conditions of life *as such*, a level of inquiry at which the organisms studied need not enjoy any *particular* likeness to human beings.

In the *Animadversiones* against G. E. Stahl of 1709–10, Leibniz continues his familiar refrain, that anatomy is essential to medicine, and that no line of inquiry should be rejected that might, if followed, contribute to the advancement of medicine. But there seems to be no lingering belief that experiment on animals might be necessary for the advancement of anatomy. What interests him most are experimental treatments of humans that can reveal new information about the inner workings of the human body without irreversibly damaging the body and certainly without requiring recourse to an *Ersatz* animal body. Thus, for example, Leibniz writes:

> I believe not that I should condemn, but rather that I should praise, the doctors who have done the following experiment: having determined the efficaciousness of the volatile salt of the urine for preventing the coagulation of

> blood that has been drawn, they studied the action of this sort of salt in the blood. Of course, they had to foresee that it was neither necessary nor useful to administer such a [large] dose in the body, since in the interior several auxiliaries compete with one another. However, even in the absence of any success, they would have done well, with justice and reason, if only they had proceeded by degrees in order not to complete the experiment at the cost of the death of the patients, nor to lead to their detriment.[115]

Leibniz cites experiments, explicitly those of Robert Boyle and implicitly also of Marcello Malpighi, that had shown that animals rely not just on alimentation by solid food but also on a constant exchange of material with their environment. These experiments, Leibniz thinks, provide experimental evidence for the view that an animal is, corporeally speaking, as unstable as a river, that its material components have no stability at all, in contrast with the relative stability of inanimate objects such as rocks. He writes:

> Perpetual perspiration, as well as a number of indices, show that animal bodies not only must take in solid nutriments at regular intervals, but also that they are in perpetual flux like a river. *Boyle* has confirmed through a number of observations that there is nothing solid in sensitive bodies that is not agitated by internal movements brought about by the penetration of surrounding elements.[116]

Leibniz cites old experiments such as those of Boyle, but remarkably when it comes to calling for new experiments to advance the state of medicine, about which he insists "the interest of the republic must omit nothing that might contribute to its future progress,"[117] he has nothing to say about experimentation on animals. It is as though he believes that everything that can be learned already has been learned by looking into the bodies of living animals. What remains to be filled out—with respect to medicine—is our knowledge of the effects of various medicines upon the body, which can be pursued for the most part nonintrusively. With respect to natural philosophy, for example, generation theory, and what we will be calling "organics," Leibniz seems to believe that we may learn just as much from the study of "lower" organisms that bear no particular analogy to human beings as from the study of what we today call "mammals": animals that in Galen, and then again in the rebirth of the Aristotelian zoological program in sixteenth-century Padua, appeared for anatomical purposes to serve as suitable *Ersätze* for human beings.

Rightly or wrongly, Leibniz's perception seems to have been that by some time in the 1670s, all had been learned in these areas that could be learned by probing into the bodies of living animals. What remained to be learned, for Leibniz, concerned remedies for particular illnesses rather than the regular functioning of the body's invisible parts. Animal economy, for Leibniz, is subservient to medicine, and there are many aspects of medicine that cannot be advanced by the study of animal economy. Once general animal economy has contributed what it can to medicine, therapeutics still remains a field in which much is to be learned, and here Leibniz seems to perceive animals as entirely irrelevant. Remarkably, though so little was known about the inner workings of animal bodies by the dawn of the eighteenth century, animal experimentation seems in general to have fallen off of Leibniz's long list of interests as a result of the perception that for the most part everything that medicine had to learn from it had been learned. Significantly, again, this shift of interest parallels the shift we will be exploring in chapters 3 and 4, from animal economy to organics, which is to say in large part a shift from the model of animal that takes macroscopic creatures such as dogs and horses to be the best representatives of animals in general, to a view that takes microorganisms, variously described as "insects" or "worms," to be paradigmatic.

For the most part, toward the end of his life the sort of experimentation on animals that is of interest to Leibniz has nothing to do with mammalian physiology. It is now entomology and vermicology that interest him, not for what these show about insects and worms in particular, but about the ubiquity of complicated animal bodies further down than perception can go. Vermicology, of course, encompasses not just worms in our sense, but also the "worms" held to lie at the origin of embryogenesis and eventually to transform into a variety of species, including what we call mammals, and among them humans. To cite one of many allusions to Leibniz's favored experimenters in his mature period, he notes in a letter to Hartsoeker of October 1710:

> Messieurs Swammerdam, Malpighi, and Leeuwenhoek, who are among the greatest observers of our time, have come to my aid and enabled me to admit more easily that the animal and any other organized substance does not have its beginning when we think it does, and that its apparent generation is only a development and a sort of augmentation.[118]

In view of the gradual decline in Leibniz's interest in mammalian vivisection, and of his gradual shift from an interest in mammalian physiology to entomology and vermicology, is there any ground for Kant's apocryphal account of Leibniz's respect for all of living nature? The short answer is no: in spite of his declining interest in vivisection, and in spite of his anti-Cartesian commitment to the view that animals are capable of suffering, Leibniz seems not to have considered the possibility of any general moral obligation to animals. He did not see the metaphysical commitment to the reality—and indeed immortality—of animal souls as translating into moral obligation. Leibniz's contemporary, the English naturalist John Ray—with whom, it will be argued in chapter 6, Leibniz shared a great deal with respect to the theoretical understanding of biological kinds—boldly declared against the Cartesians: "If it is argued that this is mere prejudice unworthy of a philosopher, then I shall stand by that prejudice: put it down to my stupidity or the weakness of [the Cartesians'] arguments as you like: the torture of animals is no part of philosophy."[119] But Leibniz said nothing similar. His anti-Cartesianism does not seem to have stimulated so much as an interest in the *question* of our moral commitments to animals. A few contextualizing points, anyway, need be made here. First of all, it is not clear that for Leibniz, or for most of his contemporaries, the reality and immortality of *human* souls could be translated directly into a list of such and such moral obligations toward them. Leibniz does believe in moral obligations toward human beings, but these flow in the first place from theological considerations and not from any sort of utilitarian calculus of pleasure and pain, or any other consideration of humans as bearers of what we now call "moral status." It is worth noting in this connection that the same year Leibniz wrote the *Directiones*, he also wrote a plan for the ethnic cleansing of an island off of Africa, and the importation there of barbarian warrior slaves.[120] Leibniz would grow more gentle as he aged, both as regards human and animals, but this does not seem to have involved any corresponding changes in his theoretical grasp of human and animal nature and of the difference between these. Second, it is arguably the immortality of souls that makes the question of moral obligations toward them in this world a question of secondary importance: what counts is their salvation. But Leibniz believes that animal souls are also immortal: any soul, being immaterial and simple, is by definition indestructible. While they are not eligible for salvation (their exact fate after what appears to be death will be considered in later chapters), the simple fact that they are incapable of dying might have served for Leibniz to diminish the perception of anything morally problematic in experimenting on their living—"living" in our vulgar, everyday sense—bodies.

One important lesson here, again, is that it is not necessarily just the *bête-machine* model that in the context of early modern science can be seen as licensing any arbitrary objectification or abuse of animals. The belief that animals have souls, and, indeed, souls that cannot be destroyed or even truly damaged by abuse, could serve just as well as a metaphysical model of the animal underlying a program of scientific research that expresses no concern for the animal's well-being qua living, corporeal creature. That said, Leibniz seems to move over the course of his life away from the rather callous talk of the status of animals we see in the *Directiones* toward a view closer to what Kant imagines of his predecessor.

But enough about ethics. Let us turn now, for the remainder of the book, to Leibniz's theoretical interest in animal bodies—their structure, motion, generation, and kind-membership—beginning, in the following chapter, with an investigation into Leibniz's understanding of the science of animal economy, and moving on in chapters 3 and 4 to his theory of the infinitely nested organic structure of animal bodies, which we will be calling "organics." As we will see over the course of the following three chapters, Leibniz's gradual shift away from an interest in the vivisection of macroscopic animal bodies toward an interest in the microscopic study of the smaller parts of these bodies as well as of microorganisms, parallels a shift in Leibniz's long history of attempts at modeling the animal body, from "the hydraulico-pneumatico-pyrotechnical machine" of the animal economy of the 1670s and early 1680s, to the "machines within machines to infinity" of the organics of the 1690s and later.

Chapter Two

THE "HYDRAULICO-PNEUMATICO-PYROTECHNICAL MACHINE OF QUASI-PERPETUAL MOTION"

Leibniz on Animal Economy

In the previous chapter, we saw one of Leibniz's early "wish lists," detailing a motley grouping of desiderata for the improvement of the institution of medicine. There is another such list from a few years later, in 1675, to which Leibniz gave the title, *Une drôle de pensée* (A Funny Thought). He had just been to a spectacle in Paris in which an automaton in the form of a man was made to run across the surface of the Seine. The experience filled him with excitement and with ideas of his own. He rushed away to jot them down, and the resulting sketch tells of "a new sort of representations," which would involve "magic lanterns, kites, artificial meteors, all manner of optical marvels; a representation of the sky and the stars." There would be "fireworks, jets of water, vessels of strange forms; mandragores and other rare plants, … [r]are and extraordinary animals," as well as a "machine for races with artificial horses," not to mention "speaking trumpets." He imagines that "the representation could be combined with some sort of story or comedy," and that this story might include "extraordinary tightrope dancers. Perilous jumps." The public could see "a child who raises a great weight with a thread,"[1] and there would be an "anatomical theatre," as well as a "garden of medicinal plants." There would be "little number machines and other [things]. … Instruments that play themselves." Leibniz imagines that "all honest men would want to have seen these curiosities, so that they would be able to talk about them" afterward. "Even women of quality," he adds, would wish to be taken there. At this wonderland of "new representations," "one would always be encouraged to push things further," though it would also be necessary that in this charmed place "no one ever swears, nor blasphemes God."[2]

Leibniz is wishing for many disparate things here, and in this list we see the kernels of interests that would in time develop into his great contributions to the study of subjects as various as mechanics, computing, chemistry, and anatomy. The one preoccupation that seems to pervade the list, however, beyond his lifelong interest in cultivating an institutional context for the promotion of natural philosophy and the mechanical arts, is the investigation of the boundary between the natural and the artificial. This is a preoccupation that within a few more years of composing the *Drôle de pensée* would yield Leibniz's first contributions to the science of animal economy. It is already clear from this early text that Leibniz is interested in investigating the boundary between the natural and the artificial not simply so as to bring the latter to bear metaphorically on our understanding of the former, as had been the case with Descartes, but rather in order to work out a comprehensive account of nature as a whole, one that would account for fountains and animals in a single, comprehensive model. In this connection, as Jon Elster has sharply noted: "For Descartes the fountains offer only an analogy of a certain metaphysics, whose genesis certainly owes them nothing; Leibniz in contrast is intensely and concretely interested in the fountains as such."[3] Leibniz is not looking for points of analogy between hydraulics and other areas of mechanical physics on the one hand and a given model of corporeal substances on the other. Rather, he intends to show, as we will see in this chapter, that these apparently different domains of the natural world require substantively the same sort of explanation. Leibniz's "physiology" is a physiology of the entire world, including animate and inanimate beings as well as artifacts.

Unlike medicine, which is interested in the human body and its preservation—and only instrumentally in such things as animals, plants, and chemical compounds—anatomy, physiology, and related disciplines are concerned with human and animal bodies in the aim of determining the manner in which their interrelated parts together execute the functions proper to an animal life. These disciplines remain, however, subordinate to medicine. They also remain at a level of analysis of the animal body that does not take into account its "organic" structure, that is to say, in Leibniz's technical sense of the term, its composition out of machines within machines to infinity. It is in terms of this infinite composition that Leibniz will ultimately dare to propose that he can account for the self-motion of animal bodies by appeal to their "vegetative structure" alone (as he puts it in the controversy with G. E. Stahl), which is to say to the "material plastic nature" of organic bodies (as he puts it to Ralph Cudworth). This will be what enables Leibniz to remain, by his own lights, a mechanist, and to reject vitalist theories of animal growth, development, and motion such as those of Cudworth and Stahl, while at the same time radically modifying earlier notions of what could qualify as "mechanism." But first things first. In this chapter let us remain focused on Leibniz's contribution to "animal economy," an area of inquiry that is both temporally prior to, and more grounded in empirical investigation than, Leibniz's theory of organic body, which will in turn be the focus of the following chapter.

The Idea of Animal Economy

In the introduction, we considered not just the scientific treatment of some of the phenomena of life by Leibniz's predecessors, but also their understanding of the place of this sort of study within their respective philosophies. It was maintained that while for Aristotle the living world had been a domain of application par excellence of his most general philosophical principles, for Descartes the living world was perhaps equally important, but for an opposite reason: it was a domain to be explained away, rather than to be held up as paradigmatic of nature in general.

The question of the place of this domain in Leibniz's philosophy as a whole is one that it will take us the rest of the book to flesh out. We will be considering Leibniz's metaphysical analysis of the animal—which takes into consideration the union of, or harmony between, the animal soul and its corresponding organic body—in later chapters. In this chapter, we will consider Leibniz's earliest efforts to model the animal body prior to the development of his theory of natural machines, as well as the continuing importance of these early efforts for Leibniz's mature account of animals. The theory of natural machines or organic bodies that would emerge over the course of Leibniz's middle-period philosophy would lead him to a natural philosophy akin to Aristotle's in the sense that he would come to believe that the structure and motion of nature as a whole should be understood on the model of animal structure and motion. In his early animal-economical texts, in contrast, Leibniz would continue to seek, like Descartes, to understand the structure and motion of animals as just one, not atypical, case of the study of "merely" mechanical nature.

For Leibniz as for his contemporaries the study of any element or system of the natural world—including everything from forestry to hydrology to painting—is ultimately a part of "physics." That particular subdomain of physics that deals with animal bodies and their motions, in turn, is animal economy. Leibniz may have adopted this term from Benjamin van Broekhuizen's *Oeconomia corporis animalis sive cogitationes succinctae, de mente, corpore, et utriusque conjunctione* (The Economy of the Animal Body, or, Succinct Thoughts on the Mind, the Body and the Conjunction of Both) of 1672.[4] Another important antecedent is Walter Charleton, who published his *Oeconomia animalis novis in medicina hypothesibus superstructa et mechanice explicata* (A New Animal Economy, Built upon Hypotheses in Medicine and Explained Mechanically) in 1659.[5] There are other, still earlier occurrences of this term or some close cognate, such as Cornelis van Hogelande's *Cogitationes sive de Dei existentia item animae spiritualitas et possibilis cum corpore unio demonstrantur; nec non, brevis historia oeconomiae corporis animalis proponitur, atque mechanice explicatur* (Thoughts, or, On the Existence of God, also Demonstrating the Spirituality of the Soul and Its Possible Union with the Body, Wherein Otherwise a Brief History of the Economy of the Animal Body Is Proposed, and Explained Mechanically).[6] Usage of the term explodes in frequency in the second half of the seventeenth century, and Leibniz's use of it seems to be but one instance of this explosion. It goes without saying that in the seventeenth century the social science of economics as we understand it did not exist, and so "animal economy" should not be understood as making reference to systems of exchange, markets, and such, nor as anticipating some future theory of "biopolitics." That said, it is interesting nonetheless to reflect on the notion of animal economy in relation to the later science of economics. We might say that animal economy is a sort of limit case of microeconomics, looking into the internal economy of what in today's economic science would be taken as the basic unit of analysis: the individual active body.

For Leibniz, "animal economy" denotes the study of the relation between organs and functions; thus it comprises anatomy and physiology, but particularly with an eye to the way the elements of these disciplines are coordinated in a living system. It is anatomy, physiology, and ethology at once. What it decidedly is *not* is "pneumatics,"[7] as Leibniz strictly eschews any appeal to the inherence of a soul in the animal body within the context of animal-economical explanation. It is not that the animal does not have a soul (as will become clear in chapter 3, the animal body itself results from infinitely many souls or soul-like substances), but only that there is in his view a rigorous and autonomous scientific discipline that gains nothing from its mention. Of all his contributions to animal economy over a forty-year period, it is only in the polemic against Stahl, the final text we will be considering in this chapter, that Leibniz seeks to make explicit the boundary between animal economy and pneumatics, in the course of his argument against Stahl that the soul can play no theoretical role in the former discipline. In this chapter, we will be speaking of two distinct periods of Leibniz's direct, active contribution to animal economy: first, the period extending from 1677 to roughly 1683,[8] in which he wrote a series of very detailed studies of the nature of animal motion and "vegetation"; and the second, from 1709 to 1710, when he engages in debate with Stahl, returning to many of the ideas developed in the first period, while superimposing upon these the sophisticated metaphysics and the organic model of body that had been developed in the intervening years. In between these two periods, Leibniz develops his theory of organics, focusing upon the microstructure and infinitely complex organization of living bodies, with little evident interest in the core problems of animal economy as we have defined it above. To the best of our knowledge, between 1683 and 1709, Leibniz does not use the term "animal economy."

To the extent that Leibniz is engaged in the study of animal economy, the animal is for him no less a machine than it had been for Descartes, but there are a number of differences between the two philosophers' respective analyses of this machine. For one thing, Leibniz is willing to speak of animal machines in terms of their functional, as opposed to merely dispositional, unity. Machines of nature, for Leibniz, like the machines that we construct for our own reasons, have ends, and these ends may be understood in entirely mechanical terms, as rooted in the structure and motion of the mechanical body. Another difference lies in Leibniz's ascription of species membership to animal machines, whereas, as we saw in the introduction, Descartes remains fairly silent as to how it is that a particular animal machine comes to be the kind of machine that it is. Yet another difference is the motivation each thinker has for studying animal economy: for Descartes, again, a complete account of the animal in mechanical terms was a necessary, if otiose, step in the comprehensive case he spent his life seeking to make for a mechanized natural philosophy. For Leibniz the initial interest in animal economy grows out of a prior interest not in mechanical natural philosophy but in the advancement of the institution of medicine. Finally, whereas for Descartes the analysis of the animal qua machine constitutes an exhaustive analysis of the animal, for Leibniz it is just the beginning. In the study of animal economy, Leibniz's model of the animal is fairly independent of the one familiar to most students of Leibniz from his broader metaphysical concern with organic bodies and corporeal substances. As we will see in the following chapters, moreover, once Leibniz moves beyond animal economy and into metaphysics, the animal is a good deal more than a machine.

Leibniz offers his most comprehensive account of what is involved in animal economy in the *De scribendis novis Medicinae elementis* of 1682–83:

> Analysis is the Method for as long as we are investigating the media or organs of any given function and the mode of their operating; and therefore we come to acquaintance with the body through its parts, by which when completed we will come to the Synthesis, and we will describe all of them coordinated into one, and the first Motor of motion and the liquid and solid instruments, and their connection, and altogether the entire economy of the animal, especially when by this very analysis we should discern by inquiring into the organs of a given function, that often the very same organ is devoted to several functions, just as in Machines the wisdom of their maker shines through especially, when many effects are brought about by few things.[9]

Animal economy, then, is ultimately a synthetic discipline, dedicated to apprehending the coordination of the organs of an animal body with one another. This coordination is, to speak anachronistically, literally "economical" in the sense that the designer of natural machines (which is to say, in the end, the chooser of this world of maximal variety and compossibility) may be seen to have brought about the maximum of effects with the minimum of organs, and with individual organs fulfilling multiple functions.

Medicine, as a practical endeavor, and indeed as a social institution in need of regulation and state support, is never far from Leibniz's mind when writing on animal economy. As we saw in the previous chapter, Leibniz defines "medicine" as the prescription of a method to a mechanic, so that he will "be able to conserve the machine that has been entrusted to him, so that it will always operate correctly." This definition clearly shows the intimate link between the disciplines of animal economy and medicine: because the human body is a machine consisting in organs with functions, study of the functioning of this sort of machine will yield tools for the diagnosis and treatment of malfunctioning machines by medical practitioners. Ultimately, for Leibniz, the study of animal economy is to be justified in terms of its usefulness to the practice of medicine. On his vision, animal economy, alongside chemistry, botany, and a handful of other fields, should contribute in its own way to the improvement of the diagnosis and treatment of illnesses.

In the study of animal economy, as we have seen, Leibniz believes no less strongly than Descartes that the animal is a machine. But what kind of machine is it? It is, to put it succinctly, a *hydraulico-pneumatico-pyrotechnical machine of quasi-perpetual motion with a trademark activity specific to it*. The principle aim of the present chapter is to make sense of this all-too-cryptic answer by providing a developmental summary of the early animal-economical texts, and also to consider in the light of these Leibniz's late-period controversy with G. E. Stahl, in which the term "animal economy" makes one final appearance. This controversy will be of particular interest to us insofar as it constitutes Leibniz's only comprehensive attempt to demarcate the study of animal economy from the study of the animal qua living thing, which is to say—as we will see by the end of this chapter, a perceiving and acting thing—and in so doing to mark out the boundary between animal economy as a domain of empirical science and the metaphysical reflection on animals that lies beyond its scope.

In saying that the animal body is both hydraulico-pneumatic as well as pyrotechnical, Leibniz is positioning himself in both the iatromechanical and the iatrochemical traditions. That is, he believes in a modified mechanical account of animal growth and motion, on which certain elements of these natural processes cannot be accounted for in terms of the motion of minute particles, but instead must be clarified by appeal to irreducibly qualitative, chemical processes.[10] Recent scholars have argued that the line between iatromechanism and iatrochemistry is not nearly so clear as it was previously thought to be: virtually no one, in fact, defended an account of biological processes that did not grant a special explanatory role to chemistry.[11] Leibniz's hyphenated definition of the animal body, then, needs to be understood as a product of the widespread, and growing, perception in the late seventeenth century of the inadequacy of strict mechanism for explaining biological phenomena, as well as of the desire among many, including Leibniz, to retain the model of the machine in conceptualizing the animal.

Introducing the Animal-Economical Manuscripts

In Leibniz's view, Descartes had been correct to hold that the animal may be studied qua machine, but eventually the German philosopher would come to believe that this is not all an animal is, and in order to get the full account of it one must return to the Aristotelian view of the animal as a sensing and acting being. Leibniz's contributions to the study of animals that are collected in the LH III manuscripts, currently being edited by the Berlin-Brandenburg Academy of Sciences for Publication in Series VIII of the Academy Edition of Leibniz's writings, help us to gain a fairly clear picture of Leibniz's development through these stages. It is first in the *Machina animalis* of 1677 that we see the doctrine of the animal machine defended as a distinctly natural-philosophical thesis, and over the course of the 1680s Leibniz continues to develop this doctrine by incorporating arguments not principally from Descartes and the Cartesians, defenders of the doctrine par excellence, but from Thomas Bartholin, Franciscus Sylvius, Thomas Willis, and other sources. Over the course of the late 1680s and into the 1690s, Leibniz grows increasingly dissatisfied with the "merely" mechanical model of the animal and struggles to develop a new model of it that can surpass the central ideas of the science of animal economy without, for that, rejecting them as simply false and lapsing into an untenable vitalism, according to which the soul is directly responsible for the motion of the body. The culmination of Leibniz's long developing interest in animals *both* as machines *and* as something "more exquisite" or "more divine" than an artificial machine with respect to its structure, *and*, finally, as substances capable of perception and action, is undoubtedly to be found in the polemic against G. E. Stahl of 1709–10.

Let us turn now to a detailed analysis of the major treatises among the LH III manuscripts focusing on animal economy.

The Machina animalis *(1677)*[12]

In this text of his early post-Paris period we find Leibniz's first explicit reference to animal economy and also his first effort to contribute to this discipline as a domain of natural philosophy of *intrinsic* interest, even if ultimately subordinate in importance to medicine. In this short and, in parts, highly illegible manuscript, Leibniz seeks to explain how motion first arises in the animal body. As in the passage from the *De scribendis novis Medicinae elementis* cited above, here as well Leibniz describes the study of animal economy as ultimately a synthetic activity in which the interconnection of all the parts of the living system is considered, rather than the isolated functioning of any particular organ. Leibniz illustrates the synthetic character of this discipline by analogy to the proper understanding of a mill:

> And this indeed in sum is seen to be the machine of the body, which sustains motion; other things should not be mixed into this description, as the description of motion in a mill-house is one thing, while another is the description of [its] various applications to squeezing out oil, to crushing grain, to splitting timber, which may be brought about by the work of this mill.[13]

Just as one would fail to grasp the principles of milling if she were to focus exclusively on any one subprocess involved in this industry, so too with the animal body. Leibniz continues:

> [The] first motion is able to bring about the propulsion of the chyle from the stomach into the lacteous and subclavial veins, as well as the peristaltic motion of the intestines, and as well as the secretion of excrements by various ducts. All of which are to be separately explained by the intellectual reason of the *first motion*, or, which is the same, by that of *Life*. Whence it may be understood, to the extent that the Anatomists should retreat from the true method of describing a given machine, there is no more reason than that [they] are ignorant of the true economy of animal motion.[14]

It interesting to note in this connection that Leibniz will also draw on the example of a mill in one of his more famous arguments against a materialist theory of mind. Decades later, in the *Monadology*, he writes:

> In imagining that there is a machine whose construction would enable it to think, to sense, and to have perception, one could conceive it enlarged while retaining the same proportions, so that one could enter into it, just like into a windmill. Supposing this, one should, when visiting within it, find only parts pushing one another, and never anything by which to explain perception.[15]

In both the *Machina animalis* and the *Monadology*, the body is no less mechanical than a windmill. Implicitly in the earlier text, and explicitly in the later, Leibniz believes that the capacity for perception can be understood neither by looking at some part of the mill nor at the totality of its structure. By the time of the *Monadology*, however, indeed by the time of the polemic against Stahl five years prior to it, Leibniz would come to see life as fundamentally wrapped up with perception, and thus as something alien to the study of animal economy. The details of the account Leibniz offers in the *Machina animalis* would change dramatically by the time of his most mature engagement with the problems of animal economy. In the 1677 text, Leibniz maintains that life itself may be understood as this first motion arising from the coction of nourishment. Later, in contrast, he will insist instead that there is a fundamental difference between force and the motion that arises from it; that the motion of animal bodies may be described by animal economy entirely without any consideration of the force that underlies it; that this force is ultimately to be accounted for in terms of the perceptions and appetites of immaterial subjects; and that life itself just is this perception and appetite. Here, in 1677, Leibniz is still a good distance away from such an understanding of animals and their place in his philosophy.

In the above passage from the *Machina animalis* we saw Leibniz expressing the common view to which he would remain committed throughout his work on animal economy, that the very first stage in the production of vital phenomena is the transformation of nutriment into chyle. His account of the early stages of this process is quite clear, from the intake of nutrition, which starts the process of vital motion, up through the circulation of the blood. We may divide this process into seven principal stages as follows:

1. Nutriment enters the stomach.
2. Chyle is excocted from the nutriment.
3. Chyle passes to the right ventricle of the heart through the "lacteous veins."[16]
4. Fermentation results from the mixture of chyle and blood in the heart.
5. Newly effervescing blood moves from the right ventricle through the arterial veins to the lungs.
6. Diastole begins, in which blood moves from there back through the venous artery to the left ventricle of the heart, which thereby becomes dilated. This is diastole.
7. Systole occurs, in which the blood is expelled with great force to all parts of the body.

As Enrico Pasini has noted, Descartes also begins *L'homme* with the transformation of aliment into chyle, the process of the production of blood, the movement of the heart, and the circulation of the blood. According to Pasini,

> Leibniz, in his own version, departs in this connection from Descartes, preferring instead the formulation of Sylvius, whose description of the production of blood in the *Praxeos medicae idea nova* Leibniz follows in its essential points. Leibniz insists still more clearly on the rejection of final

> principles in the description of the animal machine, setting out from the conviction that it is one thing to describe the functioning of a machine in terms of the motion of its parts, while the ensemble of ends to which the machine can be determined is something else.[17]

Beyond the seventh stage in the outline above, it is not clear how Leibniz conceives the transition from circulation *within* the animal to locomotion *by* the animal. It is one thing to account for the inner motions of an animal body in entirely thermomechanical terms, quite another to explain how these motions might be translated into the goal-directed self-motion of the animal in its environment. This, however, as we will see, is a problem to which he would devote a great deal of thought within the next few years, particularly in the *Corpus hominis* of the early 1680s.

The Corpus hominis *(1680–86)*

This text, which might also be given the longer title *The Body of a Man, As of Any Animal, Is a Sort of Machine*,[18] reveals the great extent to which Leibniz sought to comprehend the problem of the body-machine in terms of sophisticated physiological science, independently of the metaphysical principles of perception and appetite that he would ultimately hold to be necessary in the most exhaustive account of the nature of animals. It also appears to be Leibniz's first attempt to engage philosophically with the nature and ontology of biological species and with the very difficult problem of the transmission of kind-membership through sexual reproduction. We will investigate these aspects of the text at length in chapter 7.

Leibniz's account in this text of the nature of the animal machine is remarkably similar to a passage in a work by Robert Boyle published only in 1686, thus most likely after the *Corpus hominis*. Boyle writes in the *Free Inquiry into the Received Notion of Nature*:

> I look not on a human body, as on a watch or a hand-mill, i.e., as a machine made up only of solid, or at least consistent parts; but as an hydraulical, or rather hydraulico-pneumatical engine, that consists not only of solid and stable parts, but of fluids, and those in organical motion: and not only so, but I consider that these fluids, the liquors and spirits, are in a living man so constituted, that in certain circumstances the liquors are disposed to be put into a fermentation or commotion.[19]

Both Boyle and Leibniz want to say that fermentation or explosiveness needs to be added to fluidity, and that both of these need to be added to mechanicity in order to get at the true nature of the animal machine.[20] Both Boyle and Leibniz are adding a further hyphenation to the already cumbersome "hydraulico-pneumatic machine" described in detail in Kaspar Schott's *Mechanica hydraulico-pneumatica* of 1657. In this fascinating work, the German Jesuit scientist describes at length many of the same sort of machines that would so excite Leibniz's imagination in the 1675 text with which we began this chapter. Schott explains that the term "hydraulico-pneumatic," or the equivalent "aquatico-spiritual," means simply "that which is driven by water and air," and that by means of these two basic natural elements one can construct statues that are "hurled into the air by the violent force of the compressed air trapped inside, letting pipes and tubes swell up, imitating the motion and song of birds and other animals, and producing other such wonderful and exotic effects, that one can hardly understand how this could be done by the human spirit of invention."[21]

Schott is a "mechanist" only to the extent that he is an enthusiast for machines, but is certainly no "mechanical natural philosopher" in the sense in which we understand this term, that is, someone committed to the view that all natural change can be explained in terms of the mass, figure, and motion of basic particles. Schott does not believe that exploration of the purported boundary between the natural and the mechanical must carry with it any presumption that the natural world consists only in such particles. In fact, for Schott mechanics is one of several branches of what he calls "magic," alongside many others, including "magnetic, gnomonic, static, optic, dioptric, catoptric, hydraulic, pneumatic, pyrobolic, harmonic, phonocamptic, anacaptic, anaclastic, physiognomic … sympathetic, steganological, cryptographic, divinatory, kabbalistic, hieroglyphic," and, finally "holy" magic.[22] For the Jesuit author, the most basic kind of machine is the "tractoric" machine described in antiquity by Archimedes, Vitruvius, and others, which operates by means of gears and wheels. Schott's own work takes its direct inspiration from Hero of Alexandria, the author of the first-century treatise *Pneumatica* and supposedly the inventor of the first steam engine.[23]

The Jesuit scientist's work provides an example of early modern thinking about machines that goes well beyond the gear- and pulley-driven contraptions sometimes cited as a sort of caricature of the analogical imagination of seventeenth-century mechanist thinking and that also involves no presupposition of the absence of functional unity or teleology in machines. Although by the time Leibniz wrote the *Corpus hominis* in the 1680s he had considerably distanced himself from the somewhat backward and hermetic thinking with which Schott was surely associated (Schott's greatest inspiration was the fellow Jesuit, Athanasius Kircher, who would in turn greatly influence the young Leibniz, and embarrass the somewhat older Leibniz), it is nonetheless clear that Leibniz's conception of machines owes at least as much to the work of Schott, and perhaps others writing in a similar vein, as, for example, to the well-known animal-machine doctrine of Descartes. When Leibniz or Schott says that an animal body is a machine, this is not necessarily in order, as it were, to take the magic out of it. Leibniz is more cautious than Schott, and his vocabulary more in line with that of the *novatores*, but the lineage remains clear.

The *Corpus hominis*, along with the *De scribendis novis Medicinae elementis* of the same period (or perhaps somewhat earlier), is probably Leibniz's most significant attempt at offering a systematic account of the hydraulico-pneumatico-pyrotechnical machine. He begins with the bold assertion that the human body, like the body of any animal, is a sort of machine, and that this machine is best understood in terms of its final causes. Unlike an earlier mechanist such as Descartes, however, who was only prepared to speak of the animal body in terms of its dispositional, rather than its functional, unity,[24] Leibniz is fully ready to say that the body-machine is best understood in terms of its ends. "Any machine," he writes,

> is best defined in terms of its final cause, so that in the description of the parts it is therefore apparent in what way each of them is coordinated with the others for the intended use. Thus one who is to describe a given clock will say that it is a Machine made to display equal divisions of time, and therefore the function of a clock-hand lies in its uniform motion for some period of time.[25]

But if a clock is a time-telling machine, what sort of machine is an animal? It is, in the first place and most generally, a sort of perpetual-motion machine, superior to the artificial approximations of such machines in that it (i) is able to move itself so as to find and consume new fuel; and (ii) before it, as an individual machine, ceases to function, it can transmit its likeness to another, similar, machine through sexual reproduction. The animal is not only a perpetual-motion machine (of sorts) capable of nourishing and reproducing itself, it is also, depending on its kind membership, a machine that carries out an activity or cluster of activities peculiar to that kind. Leibniz makes both the general and the particular point in the *Corpus hominis* as follows:

> The Bodies of Animals are Machines of perpetual motion, or, to put it more clearly, they are machines comparable to a certain fixed and singular species of perpetual organic motion that is always maintained in the world. Thus for as long as there are spiders there will be weaving machines, for as long as there are bees there will be honey-producing machines, and for as long as there are squirrels there will be dancing machines.[26]

In our treatment of the problem of species in chapter 7, we will return to some of the problems in this fascinating passage relating to the particular ends of particular kinds in greater detail. For now, it will be sufficient to briefly elaborate upon the two forms of perpetuity just noted. The first, again, is that of continuing to exist, either through the "refueling" that is nutrition or, since an individual animal machine cannot be sustained in this way forever, through transmission of the animal's likeness, with the same functional ends, to other animal machines through sexual reproduction. Is this enough, though, to count as a perpetual-motion machine? It certainly would not have been for most of Leibniz's predecessors who had dreamed of such things. Leibniz frequently criticizes his contemporaries for claiming to have designed perpetual-motion machines that nonetheless require an external energy source such as water.[27] When Leibniz begins in the late 1670s to plan to develop wind-based energy sources for everything from the winding of clocks to the ventilation of mines, he nonetheless insists that "this invention will have the effect and the advantage of perpetual motion, even though there is none: for this perpetual motion, in the form in which it is sought, is impossible."[28]

The idea of perpetual-motion machines and the history of the search for them in the seventeenth century is a very complicated one, as there were many different possible understandings of what might constitute such a machine. Many believed that if such a thing *could* be invented, it would function, like the perpetual motion of the tides, through the influence of a hidden *spiritus mundi* by which celestial motion is transmitted to an earthly contraption that bears some microcosmic affinity to the celestial bodies. Some, such as Cornelis Drebbel, claimed to have produced such contraptions. Leibniz, who mentions Drebbel on a number of occasions, and who may have had the Dutch alchemist in mind in rejecting the possibility of "pure" perpetual motion in the *Corpus hominis*, obviously must reject such a picture of perpetual motion for a number of reasons. For one, he firmly rejects any account of earthly motion as a consequence of a microcosm-macrocosm relationship between terrestrial beings and the planets. For him, a basic feature of mechanism, which he takes up from Descartes and Hobbes, is that motion everywhere obeys the same laws, and that what happens here on earth is in no way a "trickle-down" effect of some sort of more perfect motion elsewhere. When Leibniz clarifies in the *Corpus hominis* that animals are in fact machines of "quasi-perpetual motion," then, he is using this term in a very attenuated sense, and also very consciously in a way that goes against accepted meanings.[29] First, it seems odd to speak of a machine that has as its end simply being perpetual; there ought to be in addition some particular activity that it does perpetually. Second, some critics might argue, a perpetual-motion machine that needs perpetual refueling is not really perpetual at all. The dream of a perpetual-motion machine had always been that of a perpetual *closed* system.[30]

So an animal is a quasi-perpetual-motion machine with a species. It differs from the ideal perpetual-motion machine in that it requires constant refueling in order to exist. It differs from ordinary machines, or "organica artificialia," in that it is both self-sustaining and self-reproducing.[31] Leibniz berates other mechanists who dream in vain of a perpetual-motion machine in the stricter sense of a machine that requires no fuel at all:

> In order that men should obtain this durability of action in their machines, they now add to them a quasi-perpetual machine that is made by nature, which is of course man himself, the pilot, who repairs what is weakened or broken down in time, who applies an external force, bringing agents together with patients … or in some other way conserves the power of the Machine.

In other words, artificial machines are only able to continue running because a certain kind of natural machine—a human being—tends to them by bringing them new fuel. But natural machines themselves require no such attendance: "Nature … brings it about that her Machine is able to do this very thing on its own, that is, that it be able now to be nourished, whereby worn-down parts and forces are renewed."[32]

And even if the individual animal will eventually cease functioning, in death, it is still capable of a sort of perpetuity to the extent that it is capable of reproduction: "Machines of this sort are able to produce others similar to themselves [Machinae huiusmodi alias sibi similes producere possent]." Animals are perpetual-motion machines not just to the extent that they are self-nourishing machines but also, and more fully, to the extent that they are reproductive machines. Again, Leibniz believes that this is as close as nature ever comes to a perpetual-motion machine, and mechanists are deluding themselves if they hope for something both self-contained and perpetual. Eventually, the individual machine breaks down, but if all goes well it will not break down before transmitting its likeness to another machine; and even before it breaks down it requires constant sustenance from the outside. But it still qualifies as "a sort of" perpetual-motion machine to the extent that it moves itself so as to obtain its own sustenance and see to its own reproduction.

Self-nutrition requires self-motion, and as we saw in the *Machina animalis*, one of the great difficulties of the mechanical account of animal motion is the tremendous leap one has to make from the description of the internal motions of an animal body to the account of how these motions give rise to motion of the animal body as a whole. In the *Corpus hominis*, Leibniz attempts to explain this process as resulting from the swelling of bodily vessels:

> As therefore the entire Machine must be moved with respect to place, it is necessary that the liquid be contained within the firm part or the vessel, and from there it is necessary that the liquor be able to move the vessel itself in which it is contained … The machines are able moreover to obtain something from the swelling; thus with one part inactive and restrained, another part will be moved forward, whence if done by alternations a progression arises … as comes to pass in leaping, swimming, and flying.[33]

This account is not much of an improvement over the *Machina animalis*, but at least Leibniz gives us some idea of how we might get locomotion out of internal thermomechanical processes. The basic insight is that a body is a vessel in which parts may differentially swell at different times, and that in swelling a part can bring about a resistance against the air, water, or earth supporting it. Through the alternating swelling of parts—limbs, fins, or wings, to be precise—an animal can move itself and thereby seek out its own fuel. Locomotion is thus conceived as nothing more than a facilitator of nutrition.

Nutrition is for Leibniz the process that underlies the machine's pyrotechnical functioning, to the extent that the animal body is maintained by the conversion of fuel (that is, food), into a vital heat analogous to fire.[34] Leibniz asserts in Section IV of the *Corpus hominis* that "the first mover in this machine is something analogous to a flame or to the Sun or a fixed star, from which there arises an ebullition which feeds itself."[35] The clearest antecedent for this view is Jean Fernel, who in his *Physiologia* of 1567 had argued that "all living things live by means of the heat enclosed within them," and further that "if any basis is needed for advocating this, let it be the excellence of the Sun alone that is scrutinized: it acts as leader and ruler and regulator of the world, sheds its light over all living things, warms them equally by the temperament of its heat."[36]

Leibniz, like Descartes before him, would hope to transpose Fernel's theory into a distinctly mechanistic framework, arguing not that the animal body derives its vitality from a celestial source, but that it is literally a machine that harnesses the very same powers that make the celestial bodies hot and bright. For Leibniz, something similar to celestial burning happens when the excocted chyle mixes with the blood and produces fermentation:

> Many think that it is the hot in the body that is fed by the humid; some appeal to the little flame in the heart, others to the fire without light,[37] a certain I-know-not-what[38] analogous to the elements of the stars … ; some say it is a certain fermentation, some that it is innumerable little explosions comparable to gunpowder: we think that in all of these a moderate and enduring boiling obtains, which is fed by a circulating matter that grows more

> and more rarefied and is also restored little by little. … We will thus rightly assert that an animal is not only a Hydraulico-Pneumatic machine, but also in a certain respect a Pyrotechnical one.[39]

In order to more adequately understand Leibniz's account of the animal as a pyrotechnical machine that "burns" its food and gives off a waste analogous to smoke it will be useful to briefly summarize the scientific and natural-philosophical discussion of nutrition in Leibniz's era, and to show also how exactly Leibniz positions himself within this discussion.

NUTRITION

It might seem odd to think of nutrition as a metaphysical problem, yet within the framework of a corporeal-substance metaphysics, one cannot avoid the question as to precisely how what was previously external to and nonidentical with the corporeal substance becomes incorporated into it, and is thereby literally substantially transformed. Nutrition had been one of the basic processes of interest to the chemical tradition. For Paracelsus, digestion is an alchemical process par excellence, and the stomach is nature's supreme alchemist to the extent that it skillfully separates the good from the bad (for Paracelsus alchemy is the "art of separation") and incorporates the food into the body. It is the "archaeus" of the body for Paracelsus that is in charge of digestion and so of the preservation of life. According to one scholar, Paracelsus's idea of archaeus (which, as we will see in the following chapter, is again picked up by Leibniz's contemporary Henry More, and which serves as a fertile point of departure for Leibniz's alternative theory of "material plastic natures") is a later descendant of the "*archonten*" or "daimon of digestion" introduced by Proclus and Iamblichus.[40] We do not have space to pursue this ancient pedigree here, but bring it up only to show how importantly linked, traditionally, were the problems of nutrition on the one hand and that of life on the other. For many premodern thinkers, to live is just to eat, or to endure in existence by substantially transforming the world into oneself. Indeed, as late as the polemic with Stahl of 1709–10, Leibniz has occasion to argue against the Helmontian theory of the "gastrianax," according to which the stomach is ruled by a subordinate soul—ridiculed by Leibniz as a "little kinglet"[41]—that serves to carry out the process of nutrition and digestion. The various theories of immaterial principles in nature that would emerge in the late seventeenth century, such as Jean-Baptiste van Helmont's gastrianax, More's archaeus, Cudworth's plastic natures, or Stahl's body-preserving soul, emerge directly out of this long tradition of explaining the process of nutrition within the context of a corporeal-substance metaphysics.

In Leibnizian terms, an aggregate has whatever low degree of reality it has in virtue of the relative stability of the cohesion of its parts. A corporeal substance, in contrast, has no such cohesion; there is constant flux between it and its environment, and yet it is this capacity to endure throughout the flux that wins for it the status of true substance as opposed to mere aggregate. The corporeal substance is what is in constant communication with its environment, what has its being only through its environment, to the extent that it takes in material from its environment and transforms that material into itself. The soul or dominant monad has appetite, to be sure, but this is an appetite for ever more perceptions, not for food. Leibniz and many of his contemporaries are thus sharply opposed to many of the late Aristotelians, such as Agostino Nifo, for whom nutrition could not be reduced to the coction of chyle and its fermentation when mixed with blood, since on this account there is no fundamental change of the quality of the nutriment whereby it would become substantially part of the corporeal substance that has ingested it.[42]

In the debate with Stahl, as we shall shortly see, Leibniz repeatedly accounts for the cohesion of the organic body, and its simultaneous dependence on constant influx of material from the environment surrounding it, by comparison to the flame's constant consumption of fuel. The image of a flame burning wood or oil is a common theme in early modern accounts of nutrition. For example, Pierre Gassendi believes that sensation arises when the soul is "kindled" in the body as fire is kindled in a log. "Food such as bread or herbs," he writes,

> is no more distant from living and sensing flesh than a log is form a light-giving and burning flame. … Just as … particles can be disentangled from a log, which particles will have a new power of lighting and heating once they move and arrange and dispose themselves in a new way, so spirituous particles can be obtained from dissociated food, which particles will possess an *energeia* of sensing once they are divided in a certain manner and disposed in a new way.[43]

Although Leibniz repeatedly denounces the "Epicureans" in his physiological writings, there is nonetheless considerable overlap in the problematics, and even in the terminology, of his work in the area of animal economy on the one hand and on the other that of Gassendi as well as his English disciple Walter Charleton.[44] As already mentioned, Leibniz may, whether by a direct or indirect route, have appropriated the idea of a special science of "animal economy" from Charleton, who writes of the "Oeconomy of Nature in the body of Man; a System of innumerable smaller Machines or Engines, by infinite Wisdom fram'd and compacted into one most beautiful, greater Automaton: all whose parts are among themselves different in their sensible elements."[45] In the following chapter we will be discussing Leibniz's belief, which he shares with Charleton, that the body-machine consists in "innumerable smaller machines"; here we are intent on understanding only the Leibnizian conception of animal economy, which does not include the machines-within-machines conception of the animal body that would emerge in Leibniz's organic model some years later.

For Leibniz as for Charleton, animal economy is fundamentally rooted in the process of nutrition. Charleton sees the question of nutrition as the natural starting point of the science of animal economy,

> not only because the Stomach, Gutts and other parts principally inservient thereto, being, by reason of impurities contain'd in them, more prone to putrefaction, ought therefore first to be taken out of the cavity of the Abdomen, to prevent noisomness; but because Nutrition seems to be, if not one and the same thing with, yet at least equal or contemporary to Generation it self.

He goes on to explicitly identify nutrition and generation as two aspects of one and the same process: "To nourish, what is it but to substitute such, and so much of matter, as is, by reason of exhaustion, wanting to the solid parts of the body, namely flesh, nerves, veins, arteries, &c.? … Nutrition is nothing else but Generation continued."[46] Both of these aspects are governed by what Charleton calls a "Plastic Spirit," which works

> within us through the whole course of our life, from our very first formation to our death; doth in the same manner perpetually regenerate us, out of a liquor analogous to the white of an Egg, by transmuting the same into the substance of the solid parts of our body. For, as I said before, Nutrition is necessary to all Animals, not only in respect of the Augmentation of their parts, while they are little Embryons; but also in respect of their Conservation after during life: because their bodies being in a natural consumption or exhaustion, would inevitably be soon resolv'd into their first elements, unless the providence of Nature had ordain'd a continual renovation or reparation of the parts, by substitution and assimilation of fresh matter, in the room of those particles dispers'd and consum'd. … The Depraedator … or Efficient cause of the perpetual consumtion of our bodies, seems to be, what all Philosophers unanimously hold it to be, the Vital Heat of the bloud, therein first kindled by the Plastic Spirit, continually renew'd by the Vital Spirit, and by the arteries diffus'd to all parts of the body, that they may thereby be warm'd, cherish'd, and enliven'd.

Thus, for Charleton as for Leibniz, what sets the animal body off from an aggregate such as a rock is precisely the lack of stability of its corporeal parts: it is constantly burning from within, and needs the burned or exhausted matter to be perpetually replaced. The fact that it is able to replace its "depredated" parts, and that fresh matter is able to come in and take on the form of the matter that has been burned up, already shows that the animal body is something of quite a different nature than an aggregate, and also shows that there can be no clear distinction between the initial generation of an animal and its subsequent manner of existence: for an animal to continue to live is for it to be continually regenerated.

Charleton suggests that "the Human Embryo perhaps is nourish't before the Empsychosis."[47] Descartes, too, it is worth noting in passing, had seen the initial formation of the fetus as explicable in terms of nutrition. Stephen Gaukroger calls this account of fetal development "about as mechanist a route as is possible,"[48] but whether this is what it is, or not, depends however on the metaphysics of nutrition of the author in question. For Agostino Nifo or, as we will see, for Stahl, nutrition is by no means a merely mechanical process: the preservation of the unitary body throughout the perpetual flow of the new material that it takes in is in fact the work of the soul, indeed it is the soul's principal function. Charleton and Leibniz both align themselves with Descartes, as it happens: the fact that nutrition occurs before empsychosis means for them that nutrition cannot itself be a soul-driven process. As Leibniz repeatedly emphasizes, nutrition is a more basic process in the study of animal economy than is sense or voluntary motion, since sense requires the prior possession of organs of sense, which were in turn initially formed through nutrition. But for a Stahl or a Nifo there is nothing at all "mechanical" about the grounding of physiological processes, even fetal development, in nutrition.

Certainly the most common view of nutrition in the decades preceding Leibniz and Charleton's interventions was that it involves the substantial transformation of food. To cite one useful reference work, Goclenius's *Lexicon Philosophicum* of 1613 defines "nutrimentum" or "alimentum" in both the proper and metaphorical senses. The metaphorical sense includes odors and other signs of possible nutrition that do not themselves nutrify. In the proper, literal sense, nutrition may be either potential or actual, potential when the aliment is brought to the mouth and delected, and actual "when this aliment has been decocted and is incorporated into the substance of the living thing [ut in rei viventis substantiam concedat]." Goclenius cites Thomas Aquinas, for whom "to be nourished means, properly speaking, that in oneself something is received toward ones own bodily conservation."[49] Here the substantiality of the body is not explicitly mentioned, but in the context of Thomist metaphysics there is no reason why it should have to be.

Leibniz, as mentioned, agrees with Charleton that nutrition precedes—if not temporally in the development of the fetus, then at least in the order of explanation—the capacities for voluntary motion and sense. Indeed, as just mentioned, the study of nutrition is the foundation of the science of animal economy, as nutrition gives rise to those organs that are required for sensation. As Leibniz explains in the *De scribendis*:

> In truth our medicine is better informed concerning nutrition than voluntary motion, and more concerning this Motion than the functions of sense, and it may be supposed that the machine is capable of nutrition, and sense free from animal motion; it is easier moreover to explain in what way we are nourished than in what way we perceive and act; indeed from aliments those parts are also generated which we require for the functions of the sensitive soul. It will be preferable to inquire into those parts first which are seen by a certain reason to be held in common with plants, than those that are characteristic of animals [alone].[50]

We have seen that for Leibniz, as for many of his contemporaries, nutrition is of fundamental importance in explaining the nature and motion of animal bodies, yet we have yet to determine what the precise mechanism of nutrition is. By what means is food transformed into bodily matter? We have also seen that Leibniz agrees with most other moderns in holding that nutrition is not a variety of corruption, and in holding that whatever it is, it must be entirely mechanical. In his view, nutrition is an instance of fermentation.

FERMENTATION

Ferments play a central explanatory role in the chemical tradition and are closely linked semantically to a number of notions, such as archaeus and seed, that would supposedly be anathema to the mechanical tradition. Yet fermentation is also, significantly, by far the most important process in early mechanist physiology.[51] By appeal to fermentation, for example, Descartes believes himself able to account not just for the heat of the heart but also digestion and a number of other bodily processes. This is the same basic process, Descartes believes, that we witness in many seemingly distinct natural phenomena, including the production of heat in moist hay and the making of beer and wine. In all of its manifestations, fermentation may be defined as calorification from corruption, and Descartes holds it responsible for digestion, respiration, conception, and certain components of fetal development, among other phenomena.

Fermentation had been a central concept of chemical medicine since Paracelsus, and more noticeably with the transportation of Paracelsianism into the Anglo-Dutch sphere by Jean-Baptiste van Helmont and Franciscus Sylvius in the early seventeenth century.[52] For these iatrochemical thinkers, fermentation occupies a central place in natural philosophy, as it makes possible an account of the origination of forms from—as in the case of van Helmont—the universal empty matter of water. As Betty Jo

Dobbs explains, "the ferment originates [for van Helmont] in a divine idea and, as it operates upon the 'empty' matter, the ferment itself is internalized and becomes the archeus, the internal governing principle of the created being that insures the working out of God's plan for its existence."[53]

In Dobbs's view, Descartes' incorporation of the concept of fermentation into his physiology amounts to a prime example of the habit of early mechanists to restate common cultural assumptions "in terms of corpuscularian mechanisms that disguised but by no means eliminated their vitalistic components."[54] Yet this criticism may not be entirely fair. While there is no doubt some truth in the general point that the mechanists gain nothing in explanatory force by substituting "microstructure" for "form" or "virtue," it is clear that Descartes conceives fermentation as a straightforwardly microstructural process, and that he conceives the changes it brings about not in terms of the emergence of new forms but in terms of the quantitative alteration of preexisting corpuscles. If he could not account for the details of these changes at the microlevel, this does not mean that in granting to fermentation a central place in physiological phenomena he does not have reason to hope that someday it might be explained in entirely mechanical terms. The same certainly holds true for Leibniz.

Another important figure in the background of Leibniz's contribution to animal economy—including his eventual adherence to the view that the animal is a fermenting or pyrotechnical machine—is Thomas Willis, a physician and founding member of the Royal Society who published the treatise *De anima brutorum* in 1672. In many respects this treatise poses an important contrast to Charleton's Gassendian physiology. Willis believes that fermentation is an inorganic process, defining it as the "inorganic motion of natural bodies."[55] He also believes that it can happen, however, in any number of kinds of body, including animate ones: "Bodies that are susceptible to fermenting are of diverse consistencies and conditions, as fine or course, liquid or solid, animate or inanimate, natural or artificial."[56] While he conceives fermentation as a strictly physical process, Willis nonetheless thinks that it can serve to propel a living body along the course of development proper to it: "Fermentation is the motion of internal particles, or of the principles of any given body, as the tendency towards perfection of the same body, and even by means of its transformation into another."[57] Willis sees fermentation spreading across the different natural kingdoms or "families," and thus as a basic explanatory principle of geology, botany, and animal physiology.[58] He believes that in the end fermentation is always the same across kingdoms: it is the motion of internal particles. But depending upon the sort of body in which it happens, it will contribute to transformation in a different way.

For Leibniz as well, fermentation is a strictly chemical process, but each kingdom of nature has a chemistry specific to it:

> There is so to speak a chemistry proper to animals, and the transformations that occur in the animal humors arise from chemistry no less than do vegetable liquors. Consequently, all bodies arise from chemistry, when we consider them not as structures but as masses, and when we apply to them physical operations consisting in an insensible process.[59]

This last point is key to understanding the role of fermentation in Leibniz's conception of animal economy. For him, fermentation is a fundamental principle governing a number of processes in animal bodies, as it is also in plants and in minerals. However, it operates in the animal body not as an integrated structure of interconnected organs, but rather as a mass of fluids. Fermentation is at the root of the process that yields organs with functions out of a mass, and it is in this respect that for the study of animal economy fermentation is more basic or primitive than the study of voluntary motion or sense. It is also in this sense that an animal can be the object of study for chemistry and biology at once.

For Willis as for Descartes, fermentation is fundamentally a thermal process, responsible for the production of heat in the body. Thus Willis maintains that the souls of animals are at once "corporeal" and "igneous [*igneam*]":

> And even Brutes make use of a material and divisible soul inferior to that of man, [which is] coextensive with the whole body, as it is seen to be constituted from several [parts], … seeing therefore that between the soul and the body there is no intermediate, but rather the members and parts of the body are organs of the soul.[60]

While Willis presents much of his work in opposition to Charleton, this is not because he objects to the revival of Epicurean philosophy with which Charleton was associated, but because he believes that he is the superior interpreter of it. He calls upon Epicurus as an ancient authority for the view of the soul-body relationship he defends:

> With this agrees the teaching of Epicurus passed on from antiquity, and revived again in our century, which introduces the clearly corporeal Soul, [and] which consists in the texture of subtle atoms, and asserts, … that from the mind of Gassendi there resounds this same, that the animal is a sort of loom, in which the body is the warp, while the soul is the woof.[61]

Leibniz takes up the view that with respect to animal economy the principle of life is "igneous," but he denies strongly that this igneous principle is a soul. Instead, it is the body-machine *itself* that is igneous, and the full account of this igneous body-machine, at least from the *Corpus hominis* on, requires no mention of the soul. One may doubt that there is much difference between saying that there is an igneous and corporeal soul, on the one hand (Willis's view), and on the other that the body is moved by a vital, igneous principle while the soul is something to be invoked only quite apart from any corporeal function (Leibniz's view). But Leibniz's insistence that the body-machine itself, and *not* the soul, is the igneous principle behind vital phenomena shows the extent to which he remains in his theory of animal economy true to the Cartesian view of the animal-machine, and to the Cartesian view—to which Willis assents, while nonetheless adopting the very un-Cartesian idea of a corporeal soul in animals—that there can be no subtle or rarefied substance that serves to mediate between the soul and the body.

The *De scribendis novis Medicinae elementis* (1682–83)[62]

This text overlaps significantly with the *Corpus hominis* of the same period, and even in its title reminds us of the great extent to which Leibniz conceives the study of animal economy as valuable principally in the service of the advancement of medicine.[63] In this text, Leibniz calls the animal body a "Hydraulico-Pneumatico-Pyrobolic Machine."[64] More so than in the *Corpus hominis*, here Leibniz emphasizes the role of "spirit" in the body, which he conceives along with Descartes not as an intermediate principle between body and soul, but as the most rarefied part of the blood, separated out through excoction. This spirit, as already mentioned, has "the likeness of solar rays or of a flame or indeed of gunpowder … which we note in fermentations and reactions."[65] Leibniz calls this spirit the insensible "motor" in the body. Because he goes to such lengths to account for the production of this spirit directly through a mechanical process from the blood, Leibniz's identification of it as the "motor" of bodily activity is a clear rejection of the alternative identification of the soul as the first mover in the body: "The motor in our body is insensible. Indeed, this is a certain continuous fluid diffused throughout the whole body, from which it can be understood that all things that are in contact with any given part of our body are easily sensed by us."[66]

Ultimately, Leibniz traces the activity of spirit back to the process of nutrition, and he tellingly compares this relation to that between a flame and its oil. He asserts that "food is useful to spirit as oil is to the flame." By the time of the polemic against Stahl, this comparison will come to play an argumentative role much more important than that of a mere analogy. Eventually, for Leibniz, the fact that vital motion in an animal may be traced back to aliment in the same way that the burning of a flame may be traced back to oil shows just what a superfluous measure it is to take recourse to the soul in accounting for vital phenomena: if you are going to insist that an animal moves only because it has a soul, then you may as well insist that candles are ensouled too. Leibniz will of course mean this point as a *reductio ad absurdum*, not as a defense of psychopyrism.[67]

In the *De scribendis*, as in the *Machina animalis*, Leibniz is interested in accounting for "life" (that is, perception and motion) in terms of the "economy" of the animal body. Later, in the polemic against Stahl, Leibniz decouples the faculty of perception—in view of which a substance may be said to be living—from the body and roots it in the simple immaterial substance. In the later writings, life is just perception, and perception is a nonbodily, spiritual faculty. What is most intriguing about the *De scribendis* is that it suggests that Leibniz's mature metaphysical elaboration of just how perception, and the complementary notion of appetite, work in the nonbodily monad seems to have first been worked out in the course of explaining the perception and appetite of animal bodies in straightforwardly animal-economical terms. As Pasini notes, in this text the principal function of the human being is perception:

> The individual substance, as we have seen, has an essentially perceptual nature, and accordingly is a machine oriented first of all towards perception. … There is a perfect correspondence, even if it is not made explicit, with Leibniz's idea of appetition as the tendency of the substance towards perfection, manifested in the passage towards more distinct perceptions.[68]

Paragraphs 4–7 of the text (see Appendix 4) constitute its philosophical core. Here Leibniz says that perception is the primary function of the human body, and the procuring (*procuratio*) of perception is the secondary function. Here, in sharp contrast with the later writings, perception is dependent on the organs of sense; and the ordering of perceptions is dependent on the motion of the body. The greater facilitation of perceptions is the greatest end for an animal or human and is itself experienced as an agreeable perception. In this connection, the organs of generation are included among the organs of motion, as generation is the procurement of "a most agreeable perception through motion."

The organs of nutrition, which humans and animals have in common with plants, must already be functioning in order for motion, and then sense, to arise. While Leibniz distinguishes these from the organs of motion, he also describes both the organs of motion and of nutrition as facilitating conditions for the procuring of perceptions (and thus as requisites for the achievement of the greatest human end), describing nutrition as the greatest facilitator of perceptions insofar as the particles of the body are continually in flux. Without nutrition neither the organs of motion nor of sense could continue to cohere for very long.

In this text, Leibniz continues to uphold the possibility of "perceiving machines," and asserts that perception is a faculty of the organs of sense, which rely on the organs of motion for the procuring of more perceptions, which in turn rely on the organs of nutrition for their initial formation and for their enduring existence. In Leibniz's most mature work on physiology, in contrast, as one would expect from the contemporaneous philosophical texts of the same period, the perception that is identified with life is no longer seen as a bodily process; and the body's motion is something Leibniz now hopes to derive, as he writes to Stahl in 1709–10, from the body's "vegetative structure alone." Vegetation or nutrition, in turn, neither give rise to motion and perception, nor are they any longer something that need be explained in terms of the inherence of a soul-like substance, which is to say in terms of perception.

One of the great innovations to take shape by the time of the controversy with Stahl, an innovation that enables the mature theory of monads to take shape, is the separation of perception from the organs of sense, and the separation of appetite or *procuratio* from the organs of motion. The mature analysis of these faculties, though, seems unmistakably to be rooted in Leibniz's early physiological interests, and only subsequently transferred out of the domain of physiology, all the while retaining its original structure. It could thus be argued that this is a case in which Leibniz works out a general account of what's going on fairly early, but then eventually changes his idea as to what sort of entity this is to be an account *of*. Before looking at this important later development in detail, let us briefly consider some other developments in Leibniz's animal-economical thought that occur between the period of the *De scribendis novis* and that of the encounter with Stahl.

Nerve Fibers and Muscular Contraction: The Influence of Bernoulli, Baglivi, and Hoffmann

In the previous chapter we saw Leibniz praising Johann Bernoulli as the ideal philosopher-physician in a letter to Bernoulli's brother Jacques. Leibniz was evidently very impressed with Bernoulli's two treatises from the 1690s, the one on effervescence and fermentation, the other on the motion of the muscles. What were the most important features of Bernoulli's physiology for Leibniz? In the two treatises, the Swiss physician had sought to explain the contraction of muscle tissue (*crispatio*) in terms of a strictly mechanical effervescence. In his view, active tetrahedric corpuscles become lodged in the angles of star-shaped corpuscles, causing them to explode and setting free the bubbles of elastic air that they had contained, which in turn creates an effervescence visible to the observer.[69]

As Raphaële Andrault has argued,[70] Leibniz's earliest writings on medicine, including the project of animal economy that accompanies it, were marked first and foremost by the influence of Lorenzo Bellini and Nicolas Steno. At this early stage, as we have already seen, Leibniz is enthusiastic about the possibility of "mathematizing medicine"; as he writes in the *Directiones* studied in the previous chapter: "Bellini, if I am not mistaken, has begun to mathematize in medicine, and also Steno, as nearly everyone does." By the dawn of the eighteenth century, Leibniz is much more skeptical about the possibility of such a mathematization, particularly in his encounter with the work of Johann Bernoulli.[71] What seems to have changed, principally, is Leibniz's understanding of the complexity of the animal body, and in particular of the infinite subdivisions in the body that bring it about that we cannot exhaustively know the ultimate processes of nature, even if we remain committed to the view, in principle, that what we can observe in the body needs to be tethered to mathematical concepts. As Leibniz writes to Michelotti in a letter on animal secretion of 1715: "There may be many mechanical causes that explain secretion. I suspect however that one should sooner explain the thing in terms of physical causes. Even if in the final analysis all physical causes lead back to mechanical causes, nonetheless I am in the habit of calling "physical" those causes of which the mechanism is hidden."[72] Here, then, "physical" contrasts with "mechanical" to the extent that the latter lends itself to immediate mathematization, given the state of our knowledge and our capacity for observation, whereas physical explanation remains avowedly hypothetical.

Earlier, it had been the work of Steno that served as a model for the possible mathematization of medicine and related fields of investigation. Steno had argued, most importantly in his *Elementorum myologiae specimen seu Musculi descriptio geometrica* (Specimen of the Elements of Myology, or a Geometrical Description of the Muscle) of 1667, that the nerves and muscles alike contract and expand without the influx or efflux of any new material: for the Danish physician, this argument was of particular importance for the broader argument against the animal spirits playing a role in animal motion. Steno is effectively attempting to demonstrate the mechanism of contraction *more geometrico*, namely, by showing how the shortening of the fibers that constitute the muscles is alone sufficient to account for muscular contraction.

Bernoulli's invocation of effervescence was intended as in part a way of accounting for the swelling of the muscles through the "boiling of nerve juice with blood," and thus through the motion of liquids, without for that having to reintroduce an account of muscular motion in terms of animal spirits.[73] Leibniz expresses his full agreement with Bernoulli in this regard, as against Steno: "I shall easily concede to Steno that the nerves act by a certain shriveling [per crispationem], but this shriveling cannot be explained but by the influx of a fluid. Thus water makes cords contract, and so does heat in the case of the hair."[74]

Ultimately, Leibniz believes that the sort of mechanical explanation that should be hypothesized in accounting for the motion of the muscles will be one that attributes an important role to elasticity, rather than to the action of fluids such as animal spirits. The elasticity of the inner parts is conceived as a sort of force (*vis elastica*) that keeps the body in motion through countless imperceptible vibrations in a manner analogous to the "vibrations" of perceptions that endure in the soul as memories. As Leibniz writes in a letter to Bernoulli of May 6, 1712:

> In organic beings many things seem to consist in perpetual, imperceptible vibrations, which, when we perceive them to be at rest, are in fact being held back by contrary vibrations. Thus in truth we are led back to an elastic force. I suspect that memory itself consists in the endurance of vibrations. Thus there does not appear to be any use for a fluid that goes by the name of animal spirits, unless it is traced back to the reason itself of the elastic force.[75]

This strategy of explaining the dilation and contraction of the parts of the body in terms of an effervescence that brings about a sort of vibration far antedates Leibniz's correspondence with Bernoulli and seems to be traceable most directly to the influence of Boyle's *New Experiments Physico-Mechanicall, Touching the Spring of the Air, and its Effects* of 1660.[76] Leibniz writes as early as the *Corpus hominis* of the mid-1680s:

> While it is granted that the seat of effervescence is in the heart, it nonetheless is easily communicated to the whole body by the blood vessels, just as [when] we attempt to heat an enormous cask of wine with a small fire, if the fire be applied through a small copper utensil, connected with the vessel through a tube. Seeing moreover that in any ebullition there is an excessive dilatation, the vapor is nevertheless not expelled, but rather it is necessary that it in turn be pushed along, whence arises respiration, indeed in all exceedingly great efficient [causes] there is a certain reciprocation of restitutions such as we note in oscillating pendula, or in vibrating chords.[77]

What will be new by the time of the 1712 letter to Bernoulli is Leibniz's interest in describing a mental process such as memory as parallel to the bodily vibration that is brought about by the elastic force and that keeps the body in perpetual motion. Bernoulli would hold that "in the whole machine of the human body, every smallest particle involved in a movement is moved either directly by an order of the soul or by muscles. All these muscles follow strictly and steadily the laws of mechanics."[78] We have already seen that Leibniz was very impressed with Bernoulli's work, yet there is no way, given Leibniz's conception of body and soul as parallel automata, that he could have agreed with his physician friend as to the dual sources of motion in the body. Leibniz would certainly agree that the muscles follow the laws of mechanics, and that the origin of motion in the muscles is a mechanically explicable pyrotechnical event, yet for him no "order of the soul" could make a difference in the succession of a corporeal substance's states. The reason for this is spelled out at length in Leibniz's arguments against Stahl's account of how the soul moves the body.

As François Duchesneau has compellingly shown, around the same time as Bernoulli was accounting for the source of muscular motion in mechanical effervescence, Friedrich Hoffmann, Stahl's mechanist colleague in Halle, was also introducing physiological agents of impetus in living bodies in order to account for vital phenomena.[79] Hoffmann construed these agents as innate organic forces (*vires insitae*) that nonetheless could be accounted for in avowedly mechanical terms. Another important figure in the background to Leibniz's own views is the Italian physician Giorgio Baglivi,[80] who discerned irreducibly vital properties in nerve fibers.[81] In the case of Hoffmann and Baglivi, what unites Leibniz with them is not support of or opposition to a vitalist account of animal motion: in the end, this is an anachronistic notion that could have meant nothing for Leibniz and his contemporaries. Rather, Leibniz, Hoffmann, and Baglivi are unified, against Stahl, in the view that the motion of an animal arises in the final analysis from a principle inherent in the nerves or muscles of the animal body rather than from the soul. Leibniz agrees that the body contains the principles of its own motion, and this will be the major point of contention around which his debate with Stahl circles. The debate, at least as both of its participants understood it, was not about vitalism, a notion that would not even come to be meaningful until well after the deaths of both Leibniz and his opponent. Yet if we must categorize Leibniz anachronistically in terms of this doctrine, we may say with firm conviction that he is an antivitalist: for him, the growth, motion, and preservation of a living body can be exhaustively accounted for without appeal to the soul. The soul is not responsible for life.

The Animadversiones in G. E. Stahlii *Theoriam medicam veram (1709–10)*

We have already seen that although chemistry and biology are distinct for Leibniz, he nonetheless recognizes that there is, as he repeats in the *Animadversiones*, a "chemistry specific to animals."[82] A clear example of this is his belief that volatile salts play a more important role in animal chemistry than in vegetable. Another example is the view that the specific trait of "animal glutinosity" lies in the fact that bodily fluids can harden when heated without diminishing in humidity, as he believes he has observed to happen in egg whites.[83] Leibniz may not be able to contribute to medical research, but he can at least observe eggs frying and draw conclusions from what he sees. In the polemic with Stahl, Leibniz has developed a clear means of distinguishing the study of animal chemistry from that of animal economy. While it is true, he explains, that any given animal body arises from chemical processes, the chemical study of the animal body is the one that takes it as a mass, while the science of animal economy is interested in animal bodies not as masses but as *structures*. The fact that an animal is a structure rather than a mass may be discerned from its functioning as a whole, and this is precisely, as in the *Corpus hominis* of the early 1680s, its end-directedness, its only apparently oxymoronic "mechanical teleology."

As in earlier texts, in his polemic against Stahl Leibniz explicitly distinguishes the natural machine from the "hydraulico-pneumatic machine" in that it is also a "pyriac [*pyria*]" machine. [84] Leibniz writes that "there are in animals eruptions and explosions similar to those of a cannon,"[85] and again that "the animal body is a hydraulico-pneumatico-igneous machine; the force of impulsion [in animals] is born from explosions that arise in it like cannons."[86] Also as in the *Corpus hominis*, Leibniz compares the animal moved by the beating of the heart, or first motor, to the alchemical furnace whose heat is modulated by bellows and other implements: "We can easily conceive that the motive principle can augment or alter the energy in the body of an animal, in the same way that registers, bellows, or combustibles intensify or diminish the force of a stove."[87]

As in the *Corpus hominis*, in the polemic against Stahl Leibniz discusses the status of species and their dependence upon sexual reproduction. In the later text, Leibniz understands the descent of animals through sexual reproduction to be a central part of this wisely chosen world, and just as the successive states of substances are always already contained in the present, preestablished harmony also brings it about that succeeding generations of a species are literally bound up with the prior generations, like so many links in a chain: "God created everything in his very great wisdom so that beings are born the one from the other like the links in a great golden chain."[88] As is the case with nutrition, mating and reproduction prove the divine coordination of things, in that an individual substance requires something outside itself, provided by divine wisdom, in order to fulfill its ends. For Leibniz, the natural machine differs from the aggregate precisely to the extent that the machine has its ends ordained by its structure, whereas if there are any ends to be had in aggregates, these will be ends that arise from the coming together of sundry machines.

> We have recognized a great difference between machines and aggregates—or masses—, insofar as machines have their effects and their ends by virtue of their own structure, while the ends and the effects of aggregates are born of a series of struggles, thus of the meeting of diverse machines.

All the same, natural machines, too, have to "meet" other natural machines for the accomplishment of their ends:

> The worm labors on its own in the sole aim of producing silk; however, in order for another silkworm to be born, there must also be the union of the male and the female, and thus the combination of a single animal with a foreign element; for this combination shows more clearly its coordination with divine wisdom.[89]

Ultimately, the end of every natural machine is reproduction, but there must also be a subordinate end in order for there to be a clear fact of the matter as to what is being reproduced. Thus silkworms give rise to silk-producing offspring, and, as Leibniz puts it in the *Corpus hominis*, "as long as there are squirrels there will be dancing machines."

SOUL AS PERCEIVER VERSUS SOUL AS BODY PRESERVER

The point of contention around which the entire debate between Stahl and Leibniz rotates is the question whether or not the soul need be invoked in order to account for the structural unity of the animal body. Unlike in earlier texts, notably the *Machina animalis*, in which Leibniz maintains that the study of animal economy ultimately serves to unravel the nature of *life*, here Leibniz seeks to radically separate animal economy from inquiry into the nature of life, which he now sees as synonymous with perception. An animal is alive, but none of the phenomena treated by animal economy can reveal this. An animal is alive in virtue of its capacity to perceive, which is a soul-based and not a machine-based activity. The polemic against Stahl, then, is Leibniz's first and only attempt to treat the subject of animal economy and at the same time to clearly demarcate it from the study of the soul, with which, he believes, Stahl himself has conflated it.

For the mature Leibniz, every living thing is ensouled, but it is not the soul's function to hold the body together, as it is for Stahl. In Leibniz's view, this function can be taken care of by the "vegetative force"[90] alone. Leibniz mocks Stahl's view of the soul as having a body-preserving function, borrowing a mocking comparison, originally made by the third-century Stoic philosopher Chrysippus,[91] of the soul's role in the body to that of salt in cured ham: "The very celebrated author identifies [the role of the soul] with the power of preserving the body from its own tending towards death, since otherwise the bodies of living things would decompose, so that future life would have the value of salt, as was said in jest of the soul of a pig."[92] In other words, if the body-preserving account of soul were correct, salt could just as easily be brought in to take over the porcine soul's role once the pig has been slaughtered, since it would keep the flesh from rotting.

Leibniz is optimistic about the possibility of deducing the vegetative force, which preserves the body, "from the structure of the machine itself."[93] For him, life could not possibly consist in the preservation of the body, since the nutrition, metabolism, and excretion of wastes through which this preservation is effected is fundamentally little different from the manner in which a flame avoids extinction by burning up surrounding matter. And a flame, Leibniz insists, is patently not a living thing. In Leibniz's view, again, this comparison shows that there is no sound reason for cordoning living beings off from mechanistic explanation on the grounds that their capacity for self-preservation cannot, as Stahl would have it, be explained without appeal to the inherence of a soul: "That life preserves itself in casting off alien substances and in conserving the substances that it appropriates to itself does not rule out mechanism any more than the fact that the flame attracts air and sends off smoke."[94] Leibniz cites experiments by Boyle to corroborate his view that an animal, like a flame, is in perpetual flux, and is nothing in itself without the constant appropriation of materials from the surrounding environment. The animal, in contrast with the flame, is constituted from fundamentally liquid parts, whose solidity arises only from the "cohesion that is produced by the conspiring movements of the fluid bodies."[95]

ANIMAL ECONOMY, PREESTABLISHED HARMONY, AND THE BEST OF ALL POSSIBLE WORLDS

In the end, Leibniz's argument against the soul as body-preserver rests on the doctrine of preestablished harmony. For him, as we will discuss in detail in the following chapter, there can be no fundamental metaphysical distinction between what happens organically and what happens mechanically; the organic just is a "more exquisite [*exquisitior*]" and "more divine [*divinior*]" form of the mechanical. Indeed, such a distinction as Stahl would hope to make, in which organic phenomena happen through the action of the soul upon the body, would amount to a "violation of the mechanical laws of the body."[96] As Duchesneau explains, in the polemic against Stahl, "the concept of organism serves to establish the respective jurisdictions of the respective authorities of the corporeal and the psychic."[97] Leibniz denounces the soul-body relation imagined by Stahl as one of obedience through violence, whereas Leibniz envisions an "obedience through accord."[98] The soul cannot impose anything upon the bodily machine that the machine is not capable of producing spontaneously. The body is thus an automaton, as is the soul (by analogy to the body), in that both move from one state to the following state entirely in accordance with their own laws. The soul need not constantly "worry about the body"[99] in order for the body to do what it has been made to do.

We see in this text Leibniz's only comprehensive effort to explain the relation of animal economy to the study of the soul, or, to put this in a different way, the study of animal machines to the study of animal life. We see, for example, Leibniz's mature expression of his view of the limitations of mechanistic explanation, that is, explanation in terms of sequences of proximate, efficient causes. The ultimate explanation lies in the metaphysics of divine creation, in God's choice of the best of all possible worlds:

> The full reason of things cannot be found in particular causes, but must be sought after in a general cause, from which immediately emanate the present state as well as the prior one. This general cause is the intelligent Author of the Universe, who chose this series among an infinity of others of which matter was capable.[100]

Although every body is ensouled for Leibniz, the soul nonetheless has no bodily function. The soul perceives, and this is a supercorporeal function. Any function of the soul within the body would be a violation of the doctrine of preestablished harmony, which by the time of this polemic has come to occupy a central—likely *the* central—explanatory position in Leibniz's philosophy. In later chapters we will have occasion to discuss the full philosophical significance of the doctrine of preestablished harmony for Leibniz's theory of the organic structure of bodies. Here, however, we will do well to succinctly lay out its uses in the polemic against Stahl.

In the polemic's most thorough discussion of the doctrine of preestablished harmony, the twenty-first reply to Stahl's "Observationes," Leibniz makes oblique reference to his earlier publications on this revolutionary new doctrine and complains that the doctor from Halle has evidently not read these. Leibniz claims that the doctrine of preestablished harmony is justified by the fact that a soul is an unextended substance,[101] insusceptible to natural creation or destruction. Since there is no "proportion [*proportio*]"[102] between the monad and the bodily machine, Leibniz claims, there can therefore be no connection between the appetitions of the soul and the motion of matter. Thus, Leibniz thinks, one of the following two hypotheses must be true. Either, as the "Cartesians" hold—which is to say Malebranche and other occasionalists—God implicates himself in the affairs of the world in order to directly bring about the states of the body that are required by the appetites of the soul; or these two agree with one another by a preestablished harmony.

To hold that there can be some sort of proportion between soul and body, and thus causal influence from the one to the other, as does Stahl's account of animal economy, is, Leibniz thinks, to do nothing more than to "substitute the soul for the animal spirits by a change of name," a move Leibniz derides as "resting on I-don't-know-what incoherent principles lacking in any value."[103] This is particularly interesting when we recall from the introduction Descartes' vehement denunciation of the view that animal spirits are endowed with truly spiritual or soul-like properties. For both Descartes and Leibniz, a crucial component of the true mechanistic theory of bodies, including ensouled bodies, is that there can be no intermediate principle between the soul and the body that facilitates their cooperation. Leibniz believes that Stahl has unwittingly turned the soul *itself* into that intermediate principle between soul and body.

An important argument to which Leibniz returns frequently in this polemic is that if the soul could act upon the body, there would be no limit to its power, and thus no limit to what the body could do under its influence (*potentia animae nullis limitibus coerceretur*).[104] Causes would have exceedingly great effects, whereas in fact Stahl, in Leibniz's view, attributes *too much* cause to minimal effects. Leibniz notes in this connection that "inert" bodies also have impetus, which is in fact all that is required to explain motion in animals. Indeed, if one thinks something more is required, then one would be hard pressed to explain why, for example, an animal's heart often continues beating long after it has been removed from the animal's chest.

One theme of the late metaphysics of body, generally underemphasized in the secondary literature and very prominent in the polemic against Stahl, is the conceptual, if not actual, separability of the soul and the body. Thus Leibniz writes that "the soul, considered in itself, tends through final causes towards the goal that the corporeal machine, considered in itself, attains through efficient causes."[105] Leibniz believes that as with everything else in nature the states of a living body result directly from "internal movements and from the structure of the machine," but that "since the internal parts are unknown to us, it may be easier to understand [the effects] from the final causes than from the efficient ones."[106] Everything in nature is governed by both final and efficient causes. For the science of animal economy, explanation in terms of efficient causes is more appropriate, yet because this science is at present underdeveloped, Leibniz thinks, physiologists must sometimes rest content with final causes. This view appears to contrast with Leibniz's opening claim in the *Corpus hominis* that machines are always best understood through their final causes, though it is likely that the contrast is only apparent: throughout his physiological thought, Leibniz believes that both sorts of cause are of equal interest. Depending on the problem at hand, one may be of more interest than another. Where the most general description of an animal as a whole is what is at issue, final causes will tend to be of more interest; where the diagnosis of a particular, local illness is what is sought, correspondingly local, efficient causes will be more relevant.

In the encounter with Stahl, we see for the first time Leibniz's explicit effort to distinguish between the animal-economical study of the body-machine on the one hand and the study of the *organic body* on the other. Yet we have not considered, except in passing, Leibniz's theoretical understanding of the nature and structure of organic body. This will be the subject of the following chapter.

Conclusion

Let us first, however, seek to summarize the main points of both the method and content of Leibnizian animal economy. This discipline is, for Leibniz, the study of the animal qua machine. The animal is, in particular, a hydraulico-pneumatic machine, as earlier mechanists had recognized, as well as being a pyrotechnical machine, to the extent that its first motion is generated out of the production of heat in the excoction of chyle from the aliment it takes in. Because it is able to take in its own aliment, rather than being fueled by an external agent, it is also a sort of perpetual-motion machine. The fact that it can eventually pass on its likeness to another machine before ceasing to exist contributes to this perpetuity, even if Leibniz acknowledges that other theorists had understood the notion of perpetual-motion machine in a rather more narrow sense. Animal economy incorporates findings from a domain-specific science of animal chemistry—such as those concerning the excoction of chyle, or the fermentation that gives rise to vital heat—but it is distinct from chemistry to the extent that this discipline takes the animal as a mass, while animal economy is intent to understand it as a structure. Animal economy is, so to speak, doubly economical, both in that the designer of natural machines brings about the maximum of effects with the minimum of organs, and with individual organs fulfilling multiple functions, and in the sense that it eschews in principle any appeal to the inherence of a soul in the animal for the explanation of vital phenomena. The Leibnizian animal is, unlike that of Descartes, an ensouled entity, but the soul is responsible only for perception and appetition, functions that are beyond the scope of the study of animal economy.

We have begun to see why the artificial horses, speaking trumpets, and instruments that play themselves so fascinated Leibniz in the 1675 text with which we began this chapter. In blending the categories of the natural and the artificial, these creations would push the limits of our hard and fast distinction between these basic ontological categories. In important respects, Leibniz believed throughout his life that many elements of the traditional ontological distinction between these categories would need to be discarded: his animal economy, after all, amounts to a lifelong project of showing that the animal body is a special kind of machine. While we have traced Leibniz's animal economy back to the 1670s, it is not until somewhat later that one of the most important special features of the machine of the animal body would take shape in Leibniz's mature philosophy, namely, his notion of the *organism* of the body. This is a crucial theoretical development of Leibniz's later philosophy, one that would only begin to be developed in the 1690s and that would only be explicitly described and given a name in the first decade of the eighteenth century. It is also a concept whose emergence in Leibniz's thought marks the most significant moment in the general transition over the course of several decades, beginning already in the 1670s, from animal economy to subtle anatomy, or, to put it differently, from the macrostructure and overall functioning of hydraulico-pneumatico-pyrotechnical machines to the microstructure and organization of divine machines. It is to the notion of organism, and the related notion of organic body, that we will turn in the following two chapters.

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PART TWO

From Animal Economy to Subtle Anatomy

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Chapter Three

ORGANIC BODIES, PART I

Nature and Structure

All organism is in truth mechanism,
but more exquisite.[1]

In the introduction we saw some of the respects in which the place of the life sciences in Leibniz's philosophy is similar to the one it occupied in Aristotle, yet there is one enormous difference, arising from the different states of empirical knowledge in the different philosophers' eras. Montgomery Furth describes the Stagirite's project as one of "endeavoring to understand the fundamental character of the natural world at a time when its *micro structure* was quite unknown."[2] By the seventeenth century the microstructure of biological entities was not quite fully known, nonetheless, as a result of the recent invention of the microscope the study of organic microstructure had become a central component of much investigation into, and reflection on, the living world.[3] If Aristotle's was a biological metaphysics, Leibniz's was thoroughly *micro*biological. While for Aristotle horses and humans had served as paradigmatic substances, discoveries in the seventeenth century made it more plausible, as we will see in this and the following chapter, to think of "worms" as the paradigm, and of cephalopods and other bulky creatures as literally made up out of these more basic creatures. The Aristotelian conception of substantiality as consisting fundamentally in unity and activity persisted, but a new account was needed of the composition of organic substances, one that did more justice to the microscopic discoveries of the seventeenth century than, for example, Aristotle's theory of the four elements possibly could.

Aristotle had been committed to a view of nature on which it "flies from the infinite, for the infinite is unending or imperfect, and Nature ever seeks amend."[4] For him, a living body does not have to be divided up very far in order to reach homogeneous parts, that is to say, among other things, parts of the living body that are not themselves living bodies. It is exactly this decomposability into homogeneous parts that for Aristotle qualifies living bodies as natural. For Leibniz, in sharp contrast, not only does nature not flee from the infinite, but it is also the involvement of the infinite in the composition of a body that makes it a machine of nature, which is to say, that makes it "organic" in Leibniz's very narrow, technical sense. This account of things would emerge gradually over the course of

Leibniz's career, and would only receive its mature expression in the mid-1690s. This view is what I have already identified as Leibniz's "organics," which, after medicine and animal economy, marks the third stage in the development of Leibniz's engagement with the life sciences. The first begins in 1671, with the *Directiones ad rem medicam pertinentes*, and lasts throughout the rest of Leibniz's life. The second begins in 1677, with the *Machina animalis*, and receives its final treatment in the polemic with Stahl of 1709–10. The final stage begins to take shape as early as the 1670s, while only coming to maturity in the 1690s, and will remain a central component of the philosophical system to which Leibniz would remain committed until his death.

Leibniz's organics is perhaps one of the most distinctive and original features of his mature philosophy. Yet it too does not lack direct predecessors in early modern science, particularly in the tradition of what is commonly called "subtle anatomy." François Duchesneau identifies Marcello Malpighi in particular as the "most brilliant of the microstructuralists,"[5] whose greatness consisted largely in the fact that his method, unlike Descartes' reliance on analogical models intended to account for global functions, gives pride of place to analysis, and is limited to observable entities and processes.[6] Malpighi's preferred instrument of research is the microscope, and by its use he is able to discover the capillaries, among other subtle structures. Malpighi's contribution to *anatomia subtilis* is vitally important for Leibniz's mature conception of the animal body, to the extent that his Italian predecessor conceives of it not so much as a global, composite machine, but rather as a collection of *little machines*. As Malpighi vividly describes his approach to the study of the body:

> The machines of our body … form the basis of medicine: for these are composed of threads, of filaments, of joists, of levers, of webs, of stagnant fluids, of tanks, of canals, of filters, of sieves, and other like machines. In examining these parts with the help of anatomy, philosophy, and mechanics, man is made the possessor of their structure and their function.[7]

Yet however much the microstructural strain of iatromechanism provides a starting point for Leibniz's mature conception of organic body, the German philosopher's conception nonetheless amounts to a radical departure from the earlier subtle-anatomical conception of bodies as consisting in numerous little machines. The crucial difference lies in Leibniz's introduction of *infinity* into his account of the assemblage of machines that make up the body: for him, an organic body is contrasted with a mere machine to the extent that there is literally no lower limit to its mechanical composition. Leibniz's theory of organic body develops out of the *anatomia subtilis* of his predecessors, yet Leibniz takes his predecessors' work and renders it, so to speak, distinctly Leibnizian by means of the introduction of infinity as a way of accounting for what he takes to be not just a difference of degree of complexity between natural and artificial machines but a fundamental difference in kind.

There is another important difference between Leibniz and his microstructuralist predecessors; evidently for him the infinite little machines that constitute the body of the animal are not simply levers, sieves, tanks, and so on, even if, as we saw in the previous chapter, there is important overlap between the mechanical and chemical processes that occur in the body and those that can be produced under experimental conditions in a laboratory. For Leibniz it is crucial that the constitutive machines not be conceived along the lines of artificial machines; instead, they are themselves, in turn, animals. As Catherine Wilson sharply notes, early iatromechanism, describing the animal body as a system of filters, valves, and pumps, is often not so much a serious endeavor to explain anatomy, as it is a reflection of the analogical imagination of the period.[8] Leibniz, however, rejects this analogy in his organics, and instead takes his model for the composition and structure of animal bodies not from clocks or water pumps, but from more basic animal bodies.

Another important difference has to do with the extension of the model of nature originally developed for the explanation of animal bodies. For Leibniz, as for the earlier iatromechanists, animal bodies are machines; but in opposition to a predecessor such as Descartes, for whom the mechanical character of animal bodies justifies a reduction of what we would think of today as biology to what we would call "physics," Leibniz comes to envision instead what might be seen as a reduction of physics (again, in our sense) to biology (in our sense). The more basic animal (or animal-like) bodies that are invoked to explain the macroscopic bodies of the animals are also invoked to explain the composition, as well as the activity, of everything in the natural world. This is an aspect of Leibniz's thought that has been widely noted in recent English-language scholarship on Leibniz's natural philosophy. Dan Garber, for example, has described "biology" as in some sense the foundation of Leibniz's physics. On his account, at least in the middle period Leibniz conceives of entities such as blocks of marble as aggregates of infinitely many corporeal substances. "One is tempted to suppose," Garber wrote in 1985,

> that the physics of such phenomenal bodies must be something altogether different from the quasi-physics that governs genuine corporeal substances. But this turns out not to be the case. From Leibniz's point of view, the physics of the two domains, corporeal substances and their aggregates, the non-organic bodies of everyday experience, is *exactly the same*.[9]

While Leibniz strives to naturalize biological entities by arguing that they can be described in the same terms as can anything else in nature, his method for doing this is in some sense exactly opposite to the effort of his mechanist contemporaries to do the same. Earlier mechanists, on the one hand, would seek to demystify the category of living beings by explaining them as mere machines, fundamentally no different from man-made contraptions. Leibniz, on the other hand, seeks to assimilate biological entities to the rest of nature by describing all of nature as infinitely complex, as consisting in machines in its least parts, or, in other words, as being organic. It is also in terms of this organic structure that Leibniz will account for the dynamical properties of bodies.

We have already seen that in the early engagement with animal economy, Leibniz is no less a mechanist than Descartes. He does have an original view of the animal machine, as a hydraulico-pneumatico-pyrotechnical machine of quasi-perpetual motion, but he agrees nonetheless with Descartes that for the purposes of the science of animal economy the living being may be studied exhaustively as a "mere" machine. Organics, in contrast, engages the animal at a deeper level, at which the animal body is not a "mere" machine but a special kind of machine, a "more exquisite" or "more divine" machine, as Leibniz puts it. This is the machine of nature, or the organic body, whose exquisiteness resides in the fact that it remains a machine in its least parts, which is to say that there is no stage in its decomposition at which one arrives at nonmachinic components.

This more exquisite mechanism may be seen as an intermediary step between the mere machine studied by animal economy on the one hand and on the other the corporeal substance of interest to Leibniz the metaphysician. If in its broad outlines the machine of Leibniz's animal economy comes from the Cartesian tradition, while the corporeal substance of his metaphysics is fundamentally Aristotelian, the organic body we are about to consider is Leibniz's own invention (with inspiration from Malpighi and other subtle anatomists). It appears, first and foremost, to be an attempt to provide an adequate theoretical model of the living world, as the empirical science of Leibniz's day was revealing it to be. It also serves, as we will see, as a sort of intermediary through which simple monads come to represent the order of coexistence within themselves.

The distinctions we have made so far may be represented graphically as follows:

Domain of inquiry:	*The living being is treated as:*	*It is distinguished from a "mere" machine in that it:*	*This distinction is:*
Animal economy	A hydraulico-pneumatico-pyrotechnical machine	Is a machine of quasi-perpetual motion with a species-specific activity.	Functional
Organics	An organic body or natural machine	Remains a machine in its least parts	Microstructural

Again, at neither of these levels does the soul need to be invoked in order to understand the living entity under investigation. At the level of the organic body, however, Leibniz has left behind the traditional mechanists who view the living entity as a mere machine and replaced this model with a machine that remains a machine in its least parts. A good deal hangs, philosophically, on understanding this new sort of machine, since Leibniz hopes, at a certain level of description, to be able to derive the vital activity of living beings from this structure alone. Leibniz's full account of how this happens emerges in large part, as we will see in the second part of this chapter, out of his debate with the Cambridge Platonists over their invocation of immaterial plastic natures for the explanation of growth, development, and motion in living nature. And it draws on the deepest principles of both his metaphysics, in particular the doctrine of preestablished harmony, and of his dynamics, in particular the concept of derivative force.[10]

Toward the end of the *Corpus hominis*, treated at length in the previous chapter, Leibniz gives a hint as to the boundaries of animal economy: "Force is one thing," he writes,

> motion quite another, and motion indeed inheres in an extended mass, while motive force inheres in a certain other subject, which is called in common bodies the substantial form, in living bodies the Soul, in Man the Mind. Whence in animals the origin of sense as well as appetite, and the union of the soul and the body.[11]

In his early animal-economical texts, for the most part Leibniz is interested in the motion of animal bodies but not the force that underlies it. From the early 1680s on, Leibniz will grow increasingly concerned to distinguish between the two, arguing that the movement can be explained without appeal to the "more real" force underlying it. He continues to insist that there must be an autonomous and self-sufficient domain for the study of bodies. He repeats frequently his view that every particular thing in the world of bodies may be explained in mechanical terms, even if the *general* principles of bodies are derived from higher—which is to say metaphysical—principles.[12] At the same time, Leibniz believes that he can give an exhaustive account of the phenomena of living bodies without taking recourse to higher principles. To offer such an account is the highest goal of his study of organics.

Organic Body and the Question of Leibniz's Idealism[13]

Although there has been considerable debate in the recent secondary literature as to whether Leibniz may properly be considered an "idealist," a "realist," or some combination of both, and also as to whether his place on the continuum between these positions changed over the course of his career,[14] not as much effort has been made to come clear as to what sort of entities Leibniz might have been a realist about.[15] It has for the most part been taken for granted that "realism" is a transparent notion that remains fixed in its sense across the centuries, and consequently the common approach has been to hold that if he was a realist he was so concerning whatever entities are not minds or mindlike. But there is a long list of candidates for this role, including organic body, corporeal substance, mass, secondary matter, derivative force, organism, and animals. We must be careful not to understand all of these as interchangeable, nor to assume that a realist-sounding invocation of one of them speaks for a realist interpretation of any or all of the others. Correlatively, we must not take an idealist-sounding treatment of any one of these as grounds for an idealist interpretation of the others.

But this tendency is exactly what we see in much Leibniz scholarship. Marie-Noëlle Dumas, for example, tells us that the term "organism" first appears in 1676 in Leibniz, but gives us no references for occurrences of the term.[16] If she did not have specific occurrences in mind, perhaps she felt her claim was justified by a presumed synonymy with some other concept, even if we cannot determine which one. Such presumption of synonymy, particularly between the related but by no means synonymous notions of *organism* and *corporeal substance*, is just what we see in a great deal of Anglophone scholarship as well. Thus, for example, in Loemker's index to his influential English translation of Leibniz's philosophical writings, "organism" leads us back to the correspondence with Antoine Arnauld of the mid-1680s, where we find no reference to organism, but only to "corporeal substances, of all of which one can say in general that they are living."[17] Donald Rutherford (in the course of a very compelling account of Leibniz's theory of corporeal substance) appears also to take "organism" as a synonym of "corporeal substance," writing that by the time of the *Système nouveau* of 1695, Leibniz "is clear that at a fundamental level we are to conceive of such organisms as mere results."[18] But the term "organism" does not even make its first appearance in Leibniz until 1704,[19] and when it does finally appear it does not mean for Leibniz what it means for us: a single, particular, flesh-and-blood, biological entity. "Organism" is a term complementary to "mechanism," and both of these complementary terms end in an abstract suffix that, like "Leninisms" or "Judaisms," can only be rendered with difficulty in the plural.

Let us consider also the pair "corporeal substance" and "body" or "organic body." Robert Adams, pushing for an idealist interpretation of Leibniz's deepest ontological commitments, writes that "the concept of corporeal or composite substance, while by no means absent from Leibniz's later writings outside of the Des Bosses correspondence, is noticeably less prominent there than in his writings of the 1680s and 1690s about the philosophy of body."[20] What this observation fails to capture is that there is a crucial distinction between corporeal substance and body. Glenn Hartz, pushing for the opposite, "realist" interpretation, similarly writes, "at the very least, detractors of corporeal substance need to explain why Leibniz would include in *so many* essays and letters explicit references to organic bodies, animals, and corporeal substance—if all these are ontically negligible at the end of the day."[21] But again Leibniz could very well have gone on talking about body, and certainly organic body, even if corporeal substance had dropped out of his ontology. Organic bodies and corporeal substances are not the same thing. "An organism," in turn, at least with that indefinite article in front of it, is nothing at all in Leibniz's ontology, whether early, middle, or late.

The distinctions we are making here are of more than just terminological significance. Indeed, it may be that it is only by coming to understand Leibniz's model of organic body, and its explanatory role within his broader metaphysical project, that we may make progress in resolving the long-standing question of Leibniz's most basic ontological commitments.[22] For it is *body*, as opposed to either matter or monad (the usual representatives of the doctrines of realism and idealism, respectively), that provides the key to determining what these commitments are, while it is matter and monad that have received the most attention in recent English-language scholarship. In one recent article, for example, Rutherford makes a crucial distinction between "substance idealism" on the one hand, according to which "the only things that meet the conditions on being a substance are unextended, mind-like entities,"[23] and on the other hand "matter idealism," according to which "material things exist only as appearances, ideas, or the contents of mental representations."[24] On Rutherford's view, the mature Leibniz must be seen as a substance idealist who defends "an unusual form of matter realism" to the extent that "he holds that the constitutive stuff of bodies—matter—consists of monads."[25] This account appears to contrast with that of Michel Fichant, for whom the extent to which monads make matter real is precisely the extent to which they make the bodies of corporeal substances real. On Fichant's interpretation, organic embodiment is a condition of the existence of monads as well as of matter, and thus there is no sense in talking about matter that is not implicated in some organic body or other, and there is also no sense in talking about a monad that is not involved in the constitution of an organic body. As Anne-Lise Rey similarly argues, it is in virtue of the organic body or machine of nature that any monad can be said to have *situs*, or situation; and it is only as a consequence of this that the monad is able to do what Leibniz consistently maintains it is made to do: to express the order of coexistence of monads from a particular point of view.[26] Thus Leibniz writes in a letter to De Volder of June 20, 1703: "Even if the monads are not extended things, they nonetheless have a certain sort of situation [*situs*] in extension, that is to say that they have a certain ordered relation of coexistence with other things, through the intermediary of the machine that they govern."[27] Monads are situated precisely to the extent that they are implicated in the organic body or natural machine, and it is through this situatedness that they may be said not just to exist but to coexist.

Even if in this study we are committed to the view that Leibniz never wavers from his interest in accounting for the embodiment of substances, the interpretation offered here is highly compatibilist with respect to other, apparently conflicting views in the recent secondary literature. That is, there is not necessarily any conflict between the view that Leibniz remains committed throughout his middle and late periods to the organic structure of bodies, on the one hand, and on the other hand the view, recently defended with great force by Dan Garber,[28] that Leibniz moves from a corporeal-substance metaphysics in the middle period to a strict monadological immaterialism in the late. The reason why there is not necessarily a conflict is because, in the end, whether Leibniz thinks bodies are "really" there, or whether he thinks that bodies result from the perceptions of immaterial monads, either way he believes that bodies are "things" (understood broadly) with a certain structure that is eminently worth analyzing. Garber's recent analysis, according to which the introduction of monads really does separate the late metaphysics from the middle-period metaphysics, may very well be the correct one. This does not change the fact, however, that Leibniz continues talking about organic bodies until the very end, as ample textual evidence, some of which we have already seen in previous chapters, shows. The only thing that changes, at most, is the ultimate ground of these bodies. Indeed, a central argument of Garber's own book is that when monads are finally introduced, they do not replace bodies so much as complement them. In this respect, the analysis offered here is very much in line with Garber's.

But while Garber emphasizes the fact that up until the very end Leibniz never was able to work out a satisfying account of the nature of this complementary relation between bodies and monads, what I wish to emphasize is that the absence of a fully satisfactory metaphysical account of the relationship between monads and bodies certainly did not prevent Leibniz from talking about bodies and from maintaining his avid interest in the structure and organization of bodies right up to the very end, particularly of bodies qua bodies of living beings. When we focus on Leibniz's abiding interest in bodies and their structure, what is striking in his philosophical development from the middle to the late period is not so much a shift in the account of the ultimate metaphysical ground of bodies as rather a change in the account of the structure of bodies, from finite structures decomposable into homogeneous masses, to infinitely structured machines, or bodies endowed with organism. Significantly, this very shift is one that occurs during the crucial period of the fitful development of the late-Leibnizian theory of monads so carefully analyzed by Garber. In other words, organic body and monad emerge together, rather than the one succeeding or replacing the other. This is a fact about Leibniz's theory of organic body that can only become clear, moreover, by rigorously distinguishing it from its semantic neighbors, such as "corporeal substance" or "animal."

The account offered here of the shift from standard-model hydraulico-pneumatico-pyrotechnical machines to machines of nature or organic bodies is ultimately compatible with the view of Leibniz's development that holds that he shifts from taking corporeal substances as the basic ingredients of the world to taking monads as the basic ingredients. The only view with which the account here is not compatible is the one that simply says that in the late period (or, a fortiori, in the late and middle periods), Leibniz is not interested in bodies, and that takes this supposed lack of interest to be due to Leibniz's "idealism." This, it will be argued, is an anachronistic projection back onto Leibniz of concerns he gives scant evidence of having had.

Let us turn now to a detailed analysis of Leibniz's conception of organism and of organic body, beginning with an effort to distinguish these conceptions from other, related ones in Leibniz's philosophy.

Organism

We have already noted that for Leibniz there is no such thing as "an organism," but this is not to say that there is no such thing as "organism." Other than one singular occurrence of the term as a count noun, "organism" is an abstract term, very close in meaning to "organization" or, less ambiguously, "organizedness."[29] Thus, in a letter to Masham of May 1704, Leibniz offers the closest thing to a definition of the term that we may find in any of his writings: "Organism, that is to say order and artifice, is something essential to matter produced and arranged by the sovereign wisdom."[30] Order and artifice are essential features of matter produced according to God's wisdom. It is the imposition of these features on matter that makes it into body. In another letter, implausibly dated by the Academy editors to around 1686, Leibniz uses the term "organism" in a similar, abstract way: "The general and exact relation of all things among themselves proves that every part of matter is full of organism [*pleine d'organisme*]. Since every part of matter must express the others, and among the others there are many organic things, it is obvious that there must be something organic in that which represents the organic."[31] Leibniz says here that matter is "full of organism," not "full of *organisms*," and this is in line with his usual understanding of the term: by it he does not have in mind a synonym of corporeal substance, but rather, again, something closer to a synonym of "organization." It is an abstract noun, complementary to "mechanism," for describing the general condition or structure of nature as a whole, and for this reason it generally occurs in the singular and not the plural. This same sense of "organism" is expressed, evidently independently, by Nehemiah Grew in his *Cosmologia Sacra* of 1701 when he writes: "How admirable ... is the natural structure or Organism of Bodies."[32] When Leibniz wishes explicitly to employ a count noun, he generally prefers "corpus organicum" or "corps organique," or sometimes simply "corps." Nonetheless, English-language commentators have consistently read Leibniz's "organism" as "organisms." Thus Roger Ariew and Garber translate Leibniz's claim in the *Antibarbarus physicus*, written between 1710 and 1716, "Ita adesse ubique organismum," as "And so I have shown that organisms are everywhere."[33] But again Leibniz makes no mention of "organisms" here. He only mentions "organism," and this is a term that is semantically parallel to "mechanism," not as in a machine or contraption, but as in a principle of the organization of bodily things.

For Leibniz, to say that "organism" is parallel or complementary to "mechanism" is to say also that it is not opposed to "mechanism," but is rather a variety of it, as we already saw in the epigraph at the beginning of this chapter. As Leibniz writes to Samuel Clarke, similarly: "The organism of animals is a mechanism that presupposes divine preformation: what results is something purely natural, and completely mechanical. Everything that happens in the human body, and in the body of any animal, is just as mechanical as what happens in a watch."[34]

Of the handful of occurrences of "organism" in Leibniz's corpus, this one perhaps best captures what Leibniz intends by it: organism is to natural machines what mechanism is to artificial machines, and this organism is not contrasted with mechanism, but rather is conceived as a variety of it (why Leibniz believes that this variety of mechanism must be divinely preformed is a question to which we will return in chapter 5). It is the general condition of organic bodies.

Organic Body/Machine of Nature

"Organic," as an adjective, in the seventeenth century had no particular biological connotation (and of course "biological" had no connotation whatsoever). Rather, it was first and foremost a description of anything that has interrelated, working parts, whether physical or conceptual; anything, that is, that the Greeks would have recognized as an *organon*, a term any serviceable Greek-English lexicon would translate as "instrument" or "tool." Working with this minimal definition, we arrive already at the surprising conclusion that if we wish to avoid anachronism we must stop reading early modern occurrences of the term "organic" as antonyms of "mechanical," and instead interpret them as *synonyms*.

Anne Conway illustrates this original synonymy of "organic" and "mechanical" very clearly in her *Principles of the Most Ancient and Modern Philosophy*, published posthumously in 1690, when she writes that an animal is *not* "a mere Organical body like a Clock, wherein there is not a vital Principle of Motion."[35] Similarly, in his *Lexicon Philosophicum* of 1662, Johannes Micraelius defines "organic parts" as "composite heterogeneous parts, … [T]hey are members of the body, which nature exploits for uses that are necessary for life." The "inorganic" in turn is the "intellect, for it does not have its own organ of the body of which it makes use."[36] The organic is whatever has working parts—machines and animals alike—and the inorganic is that which lacks parts, which is to say, that which is mental or intellectual. But Micraelius gives no possibility for distinguishing among different kinds of organicity, just as some efforts to describe animals as simple machines offered no criteria for distinguishing among different varieties of mechanicity. This is what Leibniz would provide: for him, organicity is a special variety of mechanicity; for Leibniz, in contrast with Conway, the horse's body *is* "organical." A body is organic, Leibniz explains, "when it forms a kind of automaton or natural machine."[37] For Leibniz, unlike Conway, the horse's body, even though it is organic, is not simply like a watch, since to be an organic body is not to be a "mere" organic body. Leibniz defends the organicity of the horse by denying it to the watch. This distinction might seem obvious today, but until Leibniz made it, it went against the very meanings of the words involved.

For Aristotle, natural beings had been distinguished from "things which are not constituted naturally," such as "a bed or a cloak," in that the latter lack an internal principle of activity other than the principles of activity of the primary elements composing them.[38] As one commentator explains, an *organon* or organ is for Aristotle "an entity whose essential nature is to be telic, an entity whose being is to be for the sake of that activity of which it is the organ."[39] The whole animal, what we today would call an "organism," can be seen as the "global organ," as distinct from the "local organs" that contribute to the telos of the global organ. In animals, the telos of the global organ is living, and this telos includes the lesser telos of, for example, the eye, which is seeing.[40] For Aristotle, it had been the function as opposed to the organ that is ontologically basic, while the material organ itself is a sort of conformation of matter to the deeper ontological requirement that this or that function be executed. What an animal is at the deepest level is a bundle of functions, and its organs are merely the material vehicles through which these functions are executed. It is in view of this ontological order that Aristotle is able to claim in the *De Anima* that a blind eye is an eye "in name only."[41]

Leibniz would agree with this general line of reasoning. For him it is impious to argue that eyes see simply because they are so structured as to be able to see, rather than that they were structured *in order to* see. As will be discussed in detail in chapter 7, Leibniz will favor the function of the organ by tracing its existence to a divine creator and to its, so to speak, "intelligent design." Such a consideration certainly could not have interested Aristotle, yet in his as in Leibniz's case the organ exists for the execution of a function, rather than it being the case that it happens to fulfill that function simply because it exists. Leibniz would certainly also agree with Aristotle that just as a blind eye is an eye in name only, so, too, a cadaver is a man only by convention. What makes the blind eye merely a nonfunctioning organ, rather than a dead animal, is that the seeing eye that it once was, was what it was only insofar as it contributed to the telos of the creature as a whole.

While Leibniz's understanding of "organic" does mark a new turn in the history of the concept, it is still not the antonym of "mechanical" that many commentators have taken it to be. In Leibniz's view, an organic body is distinct from a clock with respect to the complexity of its constitution, but Leibniz continues to agree with Conway that an organic body, considered in itself, lacks a single, dominant, vital principle. For Leibniz, an organic body is distinct from a mere mechanical body in that it is infinitely complex, but this does not mean that the organic body per se is something the explanation of which requires the introduction of an immaterial vital principle. It is true that metaphysically speaking an organic body is always dominated by the soul or form of the animal or corporeal substance to which it belongs, but physically speaking, the difference between an organic body and an inorganic body is found in the complexity of the organic body: it and all of its parts and the parts of the parts, ad infinitum, are machines of nature.

The organic body of the fish, then, insofar as it is the body *of* the fish, will in fact never be without a dominant monad or unifying entelechy.[42] Yet the block of marble, at least as a whole, is always without one, even though every part of the organic matter making up the block of marble is part of some corporeal substance. An organic body can at most be conceptually distinct from a corporeal substance, while in fact there is never an organic body that is not the organic body of a corporeal substance.

Any arbitrarily chosen parcel of matter is extremely unlikely to constitute in itself one organic body, even if there is no part of it that is not so constituted. As Leibniz writes in 1702, the organic body, taken separately, is just a special kind of aggregate, while the union of this organic body with an entelechy

> is one *per se*, and not a mere aggregate of many substances, for there is a great difference between an animal, for example, and a flock. And further, this entelechy is either a soul or something analogous to a soul, and always naturally activates some organic body. Which, taken separately, indeed, set apart or removed from soul, is not one substance but an aggregate of many, in a word, a machine of nature.[43]

The organic body, then, is a machine of nature, even if, taken together with the soul rather than separately, the whole thing is not a machine at all, but a corporeal substance. We will return to this important notion shortly.

Insofar as we are considering the organic body of the fish, as distinct from its soul, we are considering something on an ontological par with a pile of sawdust, even though the fish itself, which consists in this organic body and an ichthyoid soul, is of an ontologically higher rank than the pile. The block of marble is made up entirely of organic matter, but is only an aggregate, insofar as it is not, as a whole, unified by a dominant monad or entelechy. The fish's body is also made up entirely of organic matter, but the fish itself is a corporeal substance and not an aggregate, insofar as there is a dominant monad, the fish's soul, uniting the organic body. Leibniz frequently makes the point that while it is true that souls and bodies are not *really* separable, their conceptual separation is of central importance. For example, he writes in the polemic with Stahl of 1709–10: "And if—*which is impossible*—we could remove the soul from the body without modifying it, the same effects would come about in the body from the same impressions, although there would not be substance inside that would be conscious of them."[44]

We find the same point also in the *Nouveaux essais*. Animated bodies, Leibniz says there, can be picked out by their interior structures. Body and soul can each be taken separately, and each suffices for the determination of the identity of the thing in question. Neither influences the other, but each expresses the other perfectly, the one being the concentration in a unity of what the other disperses throughout a multitude.[45] Leibniz emphasizes that the organic body may be taken separately (*pris à part*), which is to say that organic bodies just are the machines of nature, or that which remains mechanical in its least parts, and which does not require the introduction of the capacity for perception that would be required in the exhaustive account of a corporeal substance.

Leibniz's full account of what a corporeal substance is involves both the organic body and the unifying immaterial component. The concept of organic body, in sum, is best understood as one introduced to explain the microstructure of the bodies of corporeal substances, not to explain what a corporeal substance is. By distinguishing between the corporeal substance and its organic body, the latter of which can be wholly understood by an investigation of its microstructure, Leibniz helps to open up the possibility of studying biological entities biologically, that is, independently of soul-based features such as unity and activity. This new possibility would ultimately help to stimulate a naturalistic conception of biological entities, which, in turn, would come to underlie the newly independent science of biology: the study of vital phenomena without appeal to immaterial vital forces. In the following chapter, we will consider this aspect of Leibniz's legacy, particularly in the eighteenth century.

Corporeal Substance

For Leibniz, a corporeal substance is a unified entity, the body of which is subdivided into infinitely many organic parts, each in turn a corporeal substance with a similar structure. In this sense, the corporeal substance is a compound of the two elements of Leibniz's most "fundamental meditations": unity and infinity. As Leibniz writes to Sophie Charlotte in 1696: "My fundamental meditations revolve around two things, to know unity and to know infinity. Souls are unities and bodies are multitudes."[46] The body of a corporeal substance is composed of infinitely many other corporeal substances; it is "an aggregate or composite out of many corporeal substances, as a flock is composed of many animals. . . . Substance has its mass or its secondary matter, which is itself an aggregate of other, smaller corporeal substances, and this continues *ad infinitum*."[47]

The other half of Leibniz's conception of composite substance, in turn, concerns—depending on the period in which he is writing—the soul, dominant monad, entelechy, or substantial form: "Each animal and each plant as well is a corporeal substance, having its principle of unity in itself, which makes it truly a substance and not an aggregate. And this principle of unity is what we call Soul, or something that is analogous to the soul."[48] Leibniz says here not that the soul is a unity and the body a multiplicity, but rather that the soul is the principle of unity *of* the body. Often, he appears to hold that only that which lacks parts and is immaterial and indestructible can count as a unity. This conception of unity plays an important role throughout Leibniz's thought, and in his mature period becomes attached to the notion of monad: "*Monas* is a Greek word which means Unity, or that which is one. Composites are Multitudes; and simple substances, Lives, Souls, and Spirits, are Unities."[49] Indeed, it is among Leibniz's most fundamental—and enduring—convictions that only what is endowed with unity is to be considered real or substantial. He gives eloquent voice to this conviction in a letter to Bartholomew Des Bosses of March 17, 1706: "Being and one are interconvertible [*ens et unum convertuntur*]."[50]

Because of Leibniz's insistence that real entities must have unity, and because of his frequent account of unity as absolute simplicity and partlessness, many commentators have argued that Leibniz could never have been committed to the full reality or substantiality of composite entities. If whatever is composite is *per definitionem* divisible, these commentators reason, and if divisibility is inconsistent with unity, then whatever is divisible lacks unity and so also reality. As Donald Baxter explains the position of this interpretive camp: being divisible entails having parts, but having parts entails not being a perfect unity, and not being a perfect unity entails not being real. Baxter maintains that "perfect unity" is to be understood as interchangeable for Leibniz with "true unity," and insists that "what is *not* a true unity is not really a unity at *all.*"[51]

Leibniz believes that true unities function as the principle of unity of composite substances, which, in the absence of this principle, would be mere aggregates. The inherence of this principle in a body separates that body ontologically from aggregates. An aggregate, for Leibniz, is whatever consists in parts that may in the future come apart from one another, bringing it about that the thing they had previously constituted no longer exists. Leibniz explains to Des Bosses in August 1715, that aggregates, such as armies or piles of stones, are "semi-substances," elsewhere in the same correspondence mentioning choirs of angels, herds of animals (but not animals themselves), fish ponds (but not fish themselves), houses, rocks, and cadavers as examples of entities by aggregation. Much earlier, in the correspondence with Arnauld of the mid-1680s, Leibniz had described an aggregate as something the essence of which is constituted exclusively by the entities from which it is composed. "For example," he writes, "what constitutes the essence of an army is only a state of being of the men who compose it."[52] An organic body or machine of nature, however, cannot be decomposed or, for that matter, brought into being through composition. An infinitely complex machine is of such a nature that it can never be taken out of existence through disassembly; only God's miraculous creation or destruction is powerful enough to do this (this aspect will be treated in detail in chapter 5, on preformation). A machine of nature is thus a special variety of aggregate: it is an aggregate to the extent that it can be exhaustively understood without appeal to the inherence of an immaterial principle of unity, yet unlike a flock or an army or a pile of sawdust it cannot be taken out of existence through decomposition, since it is infinitely complex and there is no lower limit to its organization.

A machine of nature, insofar as it is always the organic body of a corporeal substance, is thus something very different from an army or a flock. An army is an aggregate because it is a state of all of the men who compose it, and thus, as Leibniz explains in the *Notationes generales*, written at some point between 1683 and 1686, an army is not the same thing from one moment to another. The army "has nothing real in itself not resulting from the reality of the parts from which it is aggregated."[53] The particular material constituents of an organic body are no less in flux than those of an aggregate, yet this fluidity does not threaten the very existence of the machine of nature, since this existence is guaranteed by the underlying immaterial principle of unity, and not by the temporary assemblage of some particular components or others.

Biological entities, though not partless, might be said to have unity per se for Leibniz for the following reason: while it is true that whatever is divisible lacks true unity, the composite substance is not divisible, even though its body is infinitely so. The composite substance is, as Robert Sleigh writes, "deconstructible component-wise," with respect to its bodily component (its other component being its soul), but as a whole it is not divisible. As Sleigh explains, an index finger is divisible from a body, and so a body is divisible. Because the corporeal substance as a whole is not divided as a result of this amputation, and because the amputation does not yield two spatially discontiguous instances of the same substance, nor does the rest of the body, minus the finger, cease to be the body of the individual of which it had been the body prior to the amputation, it is therefore incorrect to say that the substance itself has been divided. Even if both halves of a bisected composite substance go on living, the corporeal substance has not been divided. It survives in only one of the halves, while the other half falls under the governance of a new, previously subordinate substantial form, just as in a newly independent territory a once subordinated city rises to the status of national capital. For example, Canada would remain one whole entity even if the province of Quebec were to become sovereign, while Quebec City would be promoted from a mere provincial capital into a national one. In the same way, a corporeal substance, the body of which is divided, would remain one substance, while the bodily parts that are separated off from it would come to be dominated by new, previously subordinate, dominant monads. Thus to Arnauld's question, "what reply can one make about those worms which are cut into two, each part of which moves as before?" Leibniz answers: "At least the soul of the whole animal will remain only in one part."[54]

Following Sleigh, we may say that for Leibniz, with respect to the organic body of the corporeal substance, division *is* possible. However, with respect to the entire corporeal substance, of which the body is a component, only component-wise deconstruction is possible. If, for

Leibniz, some composite entities may qualify as substances, while others remain mere aggregates, this is in virtue of the property of componentwise deconstructibility, as a result of which changes in parts do not affect the identity of the whole. Take away my finger, and I am still me; remove some sheep from a flock, or planks from a ship, and at some point you will be left with a different flock or ship. Sleigh sums up this distinction nicely:

> Divisibility is not really the vital matter here; the vital matter is whether the particular entity in question can remain the same entity over time while undergoing change of components. Leibniz's claim amounts to this: given a substantial form suitably related to various components, we have a composite entity that can pass the test of remaining the same through change of components; absent the form, we do not.[55]

As Glenn Hartz has suggested, in a similar vein, the mistake of interpreting corporeal substances as aggregates, having their existence only by convention, rather than as true substances, comes from the assumption among commentators that "corporeal substance" must be a synonym of "body" ("*corps*"). Thus, for example, Steven Nadler writes that "every body (or corporeal substance) and soul is itself the source of its own sequence of modifications."[56] Hartz recommends rather that when Leibniz claims that "all bodies … are only well-founded phenomena," he has in mind common aggregates, for example, a metal rod or a stone, whereas when Leibniz discusses corporeal substance, he has in mind animals and plants.

Corporeal substances are, then, different things from organic bodies, to the extent that they consist in bodies together with dominant monads or substantial forms. In a letter of 1715 to Nicolas Remond, Leibniz makes the distinction between these two very clear: "Secondary matter (as for example the organic body) is not a substance but … a mass of many substances."[57] This is not to say that there are no corporeal substances (as passages such as this have sometimes been taken to mean), but only that organic bodies are not they: organic bodies are instead the organic bodies *of* corporeal substances. Leibniz continues: "a true substance … is composed of an immaterial soul and an organic body, and it is the composite of these two that is called an *unum per se*."[58] In the *Addition à l'explication du système nouveau touchant l'union de l'âme et du corps* of 1712 Leibniz writes similarly:

> Complete corporeal Substance, truly one, which the Schools call *unum per se* (as opposed to the Being by aggregation) should result from the principle of unity which is active, and from the mass which constitutes the multitude and which would be strictly passive, were it to contain only primary matter.[59]

Leibniz does on occasion write in a way that would seem to disconfirm the terminological distinction we are making between corporeal substances on the one hand and organic bodies or machines of nature on the other. Thus he tells Isaac Jaquelot in March 1703: "I consider as corporeal substances only the machines of nature that have souls or something analogous; otherwise there will be no true unity."[60] But one plausible interpretation is that, even here, Leibniz does not count any machine of nature *itself* as a corporeal substance, but only the machine together with the soul. While initially this seems to signify that it is the unifying function of the soul that designates the corporeal substance, we must nonetheless go further. As Fichant notes of this passage, "in order for there to be a corporeal substance, it is necessary that this unifying function meets, as a condition of its deployment, with a physical ensemble structured as a machine of nature."[61] A machine of nature may be divided, even if it may not be taken out of existence through decomposition. A corporeal substance, in contrast, may not be divided, but only, in Sleigh's terminology, deconstructed component-wise.[62] This is to say that no cut or carefully placed karate chop upon the body of a corporeal substance could bring it about that the corporeal substance itself be divided in two. Rather, the corporeal substance remains one whole no matter the number of pieces into which its body is divided.

On Fichant's account, the concept of "machine of nature" (which is, again, identical to that of "organic body") is first formulated in the *Système nouveau* of 1695, and is, in the first instance, noteworthy for permitting a distinction between natural things and artificial things. Natural things may be distinguished in two ways: the infinity of their composition, and their true unity:

> It must thus be known that the machines of nature have an infinite number of organs, and are so well apportioned and resistant to all accidents that it is impossible to destroy them. A natural machine remains a machine in its least parts, and what is more, it remains that same machine that it always was, being merely transformed by the different folds that it receives, now extended, now contracted, and as concentrated when it is thought to be lost.

So far, what we have is the microphysical, that which is wholly explicable in terms of the infinity of composition. One might object to Fichant at this point that we thus have only infinity of composition, and nothing of unity. But Leibniz continues, with a revealing "de plus":

> Moreover [*De plus*], by means of the soul or form, there is a true unity that corresponds to what we call "moi" in ourselves, which could not occur in machines of art, nor in a simple mass of matter—however organized it may be—, which can only be considered as an army or a flock, or as a pond of fish, or as a watch composed of gears and wheels.[63]

On our interpretation, which in broad outline agrees with Fichant's, it is only in the first paragraph of this passage that Leibniz is talking about the machine of nature or organic body, and thus it is only the infinity of composition, and *not* true unity, that distinguishes the machine of nature from the artificial machine. When Leibniz introduces true unity in the second paragraph, this is by means of the *addition* of the soul or form to the machine of nature described in the first paragraph, and here we see the true significance of the phrase, "de plus." The soul or form is not part of the machine of nature. Put another way, the machine of nature is not the corporeal substance.

"Animal" and the Question of Mid- to Late-Period Continuity

When the mature Leibniz argues that mass-endowed organic bodies are in some way the results of, and thus reducible to, the perceptions and appetites of simple substances, we should not presume that the corporeal substances he once defended are now rejected in favor of these more foundational simple substances. Organic bodies are not corporeal substances; *animals* are, and there is massive textual evidence that these stay real right through 1716 (and, if Leibniz is right, then after 1716 as well!). Once we understand "animal" as a variety or subset of "corporeal substance," we are able to discern a remarkable continuity between Leibniz's middle and late periods.

It is, again, with respect to Leibniz's theory of composite unities in the correspondence with Arnauld, from the mid-1680s, that Sleigh devised the distinction between divisibility and component-wise deconstructibility. Garber, for his part, has discerned the most evidence for what he describes as an Aristotelian (realist) view of composite, biological entities in the period of the correspondence with Arnauld and the *Discourse*. On the currently most-accepted reading of Leibniz's *later* philosophy, the only entities that qualify as having per se unity are absolutely simple, immaterial entities, namely, the monads. On this reading, the implicit distinction of the middle period that Sleigh observes between divisibility and component-wise deconstructibility falls by the wayside, to be replaced by a view according to which true unity requires absolute partlessness, and thus not only indivisibility but nondeconstructibility as well. This shift is sometimes thought to occur somewhere between the 1690s and the very early years of the eighteenth century, as the substantial forms that Leibniz had boldly reintroduced into his philosophy in 1679[64] now give way to an account of the "unity," such as it is, of the corporeal substance in terms of the perceptions of a dominant monad, and mere perception, it may be thought, cannot possibly function as any sort of unifying bodily glue.

There are many passages from Leibniz's later period encouraging such a view. For instance, Leibniz famously writes in a 1704 letter to De Volder that "there is nothing in the world except simple substances, and in them, perception and appetite."[65] One might presume that there is no way to get to the unity of the corporeal substance from this rather austere starting point. Observing this apparent change in Leibniz's thought, Robert Adams writes that "the concept of corporeal or composite substance, while by no means absent from Leibniz's later writings outside of the Des Bosses correspondence, is noticeably less prominent there than in his writings of the 1680s and 1690s about the philosophy of body."[66] Garber, perceiving the same change, characterizes the most mature philosophy, of the period of the *Monadology*, as "a variety of idealism."[67] Nicholas Rescher argues that the numerous allusions to animals in the *Monadology* are to "substances by courtesy only, mere collectives of totally separate units."[68] Indeed, many commentators agree that if we can agree on anything concerning Leibniz's most basic ontological commitments, it is that Leibniz most decisively rejected corporeal substance in the last years of his life, roughly from 1704 to 1716.

Rutherford, too, argues for a shift in basic ontological commitments from the middle to the late periods, maintaining that the new notion of dominant monad, which appears in 1703 in the correspondence with De Volder, does not simply translate the notion of unity-endowing substantial form familiar from the 1680s. He acknowledges that we might be tempted to see the dominant monad as playing the role of a substantial form, which would ensure that the monadic aggregate it dominates must be one real thing. But, he argues, "if Leibniz accepts the theory of monads, he is committed to the rejection of organic creatures as genuine corporeal substances: animated bodies that possess the property of being an *unum per se*."[69] But again Leibniz never claims that organic bodies themselves have unity per se, since he does not believe that these bodies are genuine corporeal substances. This does not, however, mean that he is committed to rejecting organic *creatures* as genuine corporeal substances, if we take the "creature," as does Leibniz, to be something more than just the organic body, namely, this body together with the principle of unity that underlies it, which was brought about at the Creation by the Creator (the semantic link between "creature" and "creation" is more than coincidental here).

Again the standard arguments for a shift in ontological commitments chart Leibniz's trajectory from middle-period talk of substantial forms to his mature notion of dominant monads. Garber, in his influential 1985 article, notes that the philosophy of body of the mid-1680s owes a debt to the Aristotelian tradition. By this, he means not principally to Aristotle, but to Scholastics such as Francisco Suárez and Eustacius. In a passage stating this tradition's view of Aristotle, and illuminating Leibniz's own position within this tradition, the Coimbran commentators offer the following gloss on Aristotle's *Physics*:

> Natural things are not composed of matter alone, since if that were so, human beings, stones, and lions, being made of the same matter, would all have the same essence and definition. Therefore, in addition to matter, they have their own forms which differentiate them from one another.[70]

Garber notes of this passage that just as the substantial form of a corporeal substance is employed in Leibniz in obvious recognition of its origins in Scholasticism, "the body to which that form is united is intended to correspond to the Scholastics' matter."[71] Garber thus suggests that "it is fair to call the metaphysics of the [correspondence with Arnauld] 'Aristotelian' to distinguish it from the later, more (obviously?) idealistic monadology."[72] Garber acknowledges that some texts of the period of "idealistic monadology" do sound reminiscent of the middle period with regard to the unity of composite entities. For instance, in the *Monadology* Leibniz writes: "It is clear … that there is a world of creatures, living beings, animals, entelechies, souls, in the smallest particle of matter."[73] But the difference between Leibniz's *Monadology*-era talk of animals, and his *Discourse*-era talk of corporeal substance, Garber maintains, lies in the very beginning of the work of 1714, where Leibniz contends that "the monad which we are to discuss here is nothing but a simple substance which enters into compounds. Simple, that is to say without parts."[74]

Fichant, too,[75] believes that in his late period Leibniz "only uses 'composés' as a nominalized adjective, while carefully avoiding making an adjective out of it that qualifies substance; in the *Monadology*, there are no substances but simple substances."[76] Yet Leibniz does not at all avoid the substantive use of "animal" (a term that is admittedly, in its origins, an adjective often found modifying *ens*) in his late-period philosophical works. Thus in the *Principles of Nature and Grace*, Leibniz writes of perceiving and sensing beings that such "a living being is called 'animal,' as its monad is called a 'soul.'"[77] And later in the same text: "[The monad] constitutes the center of a composite substance (as, for example, of an animal), and the principle of its unicity."[78] In the *Monadology* he puts it as follows: "The body belonging to a monad (which is the entelechy or soul of that body) together with an entelechy constitutes what may be called a living being, and together with a soul constitutes what may be called an animal."[79] And in a 1698 letter to Johann Bernoulli: "not the flock but the animal, not the fish pond but the fish is one substance."[80] These passages clearly indicate that late-period references to animals, even where corporeal substance is not explicitly invoked, should be taken as references to a variety of corporeal substance.

It is worth noting that both the mid-period and late-period conceptions of body we have identified are present in various strains of the premodern Aristotelian tradition. As Bill Newman has compellingly argued, it was principally the Thomist strain of Aristotelianism that held that any given substance must have one, and only one, substantial form.[81] But there were many opponents of this view, identified by Newman as "pluralists" (in opposition to Thomas's "unitism"), who held that there could be a plurality of substances within matter, and that we must posit such a plurality if we are to account for a vast array of chemical operations. For Thomas, a given body—for example, that of a human—contains the substantial forms of the four elements only potentially: these will come to actuality only after the body dies and the elements separate out from it in the decomposition of the cadaver. For a pluralist such as Paul of Taranto, in contrast, the endurance of the wood after the chopping down and killing of the tree shows that the substantial form of wood was there all along, and, similarly, mercury and sulfur are always there in a certain fashion in any complete metal. Since fused metals can be made to return through laboratory operations, Paul believes, "it is manifest that they were only resolved to certain components of theirs and not to the simple elements or to the prime matter."[82] Newman remarks that this passage is particularly noteworthy for "the way in which it foreshadows Daniel Sennert's much later use of the *reductio in pristinum statum* as a defense of atomism."[83] Given what we now know about the influence of Sennert on Leibniz (discussed briefly in chapter 1), it seems plausible to suggest that the true shift in Leibniz's philosophy is not from Aristotelian hylomorphism to idealism, but rather from a traditional Scholastic Aristotelian account of forms to a more "chemical Aristotelian" account of bodies as consisting essentially in infinite subordinate forms, always already actualized, even if dominated by other hierarchically superior forms. This shift probably did not occur as a result of any new exposure to or engagement with active chemists, but rather as a result of further reflection on empirical results of both "organic" microscopy (in our sense of the term) and of chemical processes with which he was already quite familiar by the 1670s.[84]

It is, in sum, not so much that Leibniz shifts from Aristotelian hylomorphism to idealistic monadology, but rather from a "one body, one form" model to a model according to which bodies are conceived as essentially consisting in infinite subordinate forms. Leibniz pursues this shift not in order to do away with body, but rather in order to account for the way in which the phenomena of bodies, such as growth and motion, can be traced back to their structures alone. The importance of this project for Leibniz's philosophy as a whole was already discussed in some detail in chapter 2, in connection with the polemic against G. E. Stahl, and will also be discussed at length in the second section of the present chapter.

The Machine of Nature in Comparison

To sum up the distinctions made so far in this chapter:

i. There is (other than in one single occurrence) no such thing for Leibniz as *an* organism. "Organism" is a term complementary to "mechanism" in its seventeenth-century usage: it describes a state of bodies in general.
ii. To continue with this comparison, if "organism" is complementary to "mechanism," "organic body" in turn complements "machine." The organic body is a certain kind of machine, namely, a "machine of nature."
iii. An organic body or machine of nature is the body of a corporeal substance. It is not itself a corporeal substance.
iv. An animal is a kind of corporeal substance. Every mention of animals in the later texts should be taken as a mention of corporeal substances.[85]

Schematically, we may present the distinctions we are making as follows:

	Block of marble	*Clock*	*Cadaver*	*Living animal body*	*Animal*
Machine in least parts	Yes	Yes	Yes	Yes	No*
Machine as whole	No	Yes	No	Yes	Yes
Machine of nature	No	No	No**	Yes	No
Divisible	Yes	Yes	Yes	Yes	No
Deconstructible component-wise	No	No	No	No	Yes
Aggregate	Yes	Yes	Yes	Yes	No
Corporeal substance	No	No	No	No	Yes

* One way of putting this surprising point, that an animal is not a machine in its least parts, is that an animal does not, strictly speaking, have parts; it has, as Sleigh has emphasized, "components," two of them, only one of which has parts. It is a corporeal substance, to be sure, but insofar as it is a substance its being does not depend on its composition by parts. It must be attached to some body or other, but not to *this* body with *these* parts.

** The fact that a cadaver is not "organic" for Leibniz shows how far our own concept of "organic" has drifted from his. For us, a dead body is organic in virtue of its composition out of organic compounds. Even a pile of fertilizer, no doubt a paradigmatic case of aggregate in Leibniz's terms, is organic for us.

The ways in which this account differs from the widely accepted one have to do primarily with the distinctions made in the final two columns, between the living animal body and the animal. Of course, wherever you find a living animal body, you will find an animal. But this does not mean there is not a conceptual distinction to be made, and indeed Leibniz makes it repeatedly: the living animal body, *pris à part*, is characterized by infinity of composition, the animal by this together with the unity imposed by the soul. Another important distinction concerns the block of marble: on Leibniz's view, it is machinic in its least parts, yet is not itself a machine of nature. Positively everything in the world is composed of organic entities, even if not every arbitrarily chosen sector of the world itself constitutes *one* organic entity. Leibniz is thus a panorganicist,[86] but this does not commit him to holding that every rock and every block of marble is *itself* a machine of nature. Spinoza, to cite another well-known position of the period for the sake of contrast, believes that relatively spatiotemporally discrete entities such as rocks count as entities just as much as animals do, in virtue of their unique "proportion of motion and rest." For Leibniz, on the contrary, every rock is entirely constituted by machines of nature—which may be individuated without appeal to the inherence of a soul in them, by appeal to their proportion of motion and rest, or their functional unity—while aggregates are just poorly selected collections of natural machines: poorly, that is, if what we are looking for are real things.

With respect to the division of the domains of inquiry appropriate to the various entities we have distinguished, we may now complete the table with which we began this chapter as follows:

Domain of inquiry:	*The living being is treated as:*	*Distinguished from a "mere" machine in that it is a:*	*This distinction is:*
Animal economy	A hydraulico-pneumatico-pyrotechnical machine	Machine of quasi-perpetual motion with a species	Functional
Organics	An organic body or machine of nature	Machine in its least parts	Microstructural
Metaphysics	Corporeal substance or animal	Perceiving and acting subject	Soul- or entelechy-based

It is only at the last of these levels, metaphysics, that the soul need be considered. At the middle level, the living entity is distinguished from the "mere" machine, but only in view of its microstructure, and not in view of its soul-based capacities of perception and appetite.

Organic Body and Aggregate

Leibniz believes that organism is the general condition of body, that is, that body is by definition organized. Organic body is not by definition unified by some immaterial principle, since it is conceptually possible to imagine a machine of nature that is not the body of a corporeal substance, even if there is no such thing. Matter itself is (or would be, if it were ever to occur separately) inorganic body, which is just to say body that is not organized. It is, however, conceptually impossible that there be matter that is not organized, while it is, in turn, conceptually possible but naturally impossible that there be organized body that is not unified by a simple substance into a corporeal substance.

Interestingly, an aggregate can give us some idea of what nonbodily matter would be like, if there were such a thing. To be sure, every bit of a pile of sawdust is entirely constituted by organic entities, but when we pick out the pile we are not picking out *an* entity. The pile qua pile lacks organization, even if there is no part of the pile that is not organized. The aggregate is not “mere matter,” since everything that constitutes it is part of some organic body or other. Just as machines of nature can be characterized by the fact that they are “machines all the way down,” nonbodily matter, were there such a thing, would be characterized by the fact that it consists in “aggregates all the way down.” Every part of it would be akin to a pile of sawdust, just as in the actual world every part of, say, a fish’s body is akin to a fish.

Leibniz could have held that there were physical ensembles structured as machines of nature that did not meet with the unifying function of a soul. If that were the case, there would have been organic bodies without corporeal substances. As it happens, Leibniz believes only that such things can exist conceptually: they can be mentally *pris à part* from the corporeal substance, even if mere machines of this sort can nowhere be found in nature. If he had deemed mere natural machines without an associated corporeal substance possible, and if in turn he had held that machines are never unified substantially, while also holding onto simple substances, then he would have been an antirealist about corporeal substances but a realist about machines of nature. This would have made him a dualist: he would have believed, with Descartes, that *res extensae* can be arranged through the laws of nature (or, in Descartes’ language, through “minor laws”) into self-standing machines, while souls in turn could do nothing but cogitate, without playing the role of activator in some organic body or other. Or he could have held, alternatively, that machines of nature *only* exist insofar as the unifying function of a soul makes them exist. But what he seems to have actually believed, for the most part, is that in order for there to be a corporeal substance it is necessary, as Fichant puts it, "that [the] unifying function meets … with a physical ensemble structured as a machine of nature."[87] Other than conceptually, there are no machines of nature that are not unified in this way by a soul or soul-like monad. There are in turn no corporeal substances except insofar as an organic body is made substantial through a monad's unifying function. Finally, there is no monad that does not function as the unifier and activator of some organic body. Natural machines are matter organized into organic body, and as such are the condition sine qua non of the real existence of body, while body is the corporeal or "external" manifestation of the "unfolding" of simple substances. Organic body can be exhaustively understood without appeal to the activity of simple substances—which is why organic body and corporeal substance are not the same thing—but this is not to say that organic body is something that exists, dualistically and independently, apart from mindlike substances.

But what about Leibniz's famous conviction, very clearly articulated to De Volder, that "there is *nothing* in things but simple substances and in them perception and appetite" (italics added). Surely, a passage such as this shows that bodies must somehow be less real than the perception and appetite constituting the simple substance? Well, let us look at this passage in its context:

> And considering the question carefully, one can even say that there is nothing in things if not simple substances, and in them perception and appetite, but that matter and motion are not so much substances as they are the phenomena of perceivers, whose reality resides in the harmony of the perceivers with themselves (at different times) and with other perceivers.[88]

In response to this passage, Fichant sharply argues that Leibniz is not talking here about bodies, but about *matter*. What Leibniz is intent on denying is not a bodily world, but rather the existence of matter independently of the organic bodies of living beings. To say that matter is not independently existent is not to say that everything that is real is an idea, but rather it is to say that it is a condition of the existence of real things that they be bodily, that is, that they be organized, which is to say organic in the sense elaborated earlier in this chapter. The denial of matter qua matter does not lead Leibniz to idealism, but rather to panorganicism.

Leibniz's denial of matter as an ingredient of nature, and his account of it as one of the principles of things that are in the end soul-like, in no way makes him an idealist in the Berkeleyan or Kantian sense. As Martial Guéroult already noted, Leibniz's account of the corporeal world as flowing from primitive forces only gives us a phenomenalism if we "give to the word 'phenomenon' a sense that is no doubt familiar, but that it did not possess prior to the Kantian philosophy."[89] The reason why Leibniz's rather common view of matter earns him the label "idealist" has a lot to do with the fact that, unlike Aristotle and the Alexandrian Neoplatonist Origen, whom we will discuss in the following section, Leibniz is writing after Descartes introduced his novel and peculiar conception of matter as bare *res extensa*, and with the fact that he is read by those who were educated on a Kantian and/or Berkeleyan notion of idealism.[90] But there is no reason to think that, in the context, Descartes' was the standard view from which Leibniz's view deviates.

If we understand modern biology as the study of the way in which the physical world gives rise to the phenomena of life, then the animal, in turn, is not "biological" for Leibniz, since understanding it requires invoking the principle of unity provided by the soul. Descartes' animals *are* biological, and as we have argued the closest thing to them in Leibniz are not Leibnizian animals but Leibnizian organic bodies. In this respect, Leibniz remains rooted in a thoroughly pre-Cartesian world, and confusion arises when we attempt to classify him in terms of post-Cartesian categories. Fichant contends that it is the Aristotelianism (which Descartes fought so hard to overcome) lingering in Leibniz that preserves his philosophy from collapsing into a sort of Berkeleyanism. We might expand on this point by saying that it is Leibniz's roots in ancient body theory more generally, which takes body as something distinct from matter in that the former is by definition organized, as preserving him altogether from the modern compulsion to take up sides in the debate between realists about the external world (whether of the dualist or materialist variety) on the one hand and idealists on the other.

Platonist Body Theory and the Debate over Plastic Natures

On the account we are offering, what really happens from the middle to the late periods 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—somewhat along the lines proposed by the subtle anatomists but also with clear influence from the "pluralist" Aristotelian tradition—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, but the invocation of unity as underlying body is not intended by Leibniz as a means of explaining away body, but rather of accounting for it.

The perceived shift from realism to idealism parallels chronologically a number of real shifts we have already begun to see: the shift from traditional animal economy to organics, and the shift from interest in the vivisection of large animals to an interest in microscopy and entomology as the domains of research that will be more instructive as to the nature of life. We explored the latter shift, and what precipitated it, briefly in chapter 1. What of the former shift? What brought Leibniz to this very novel view of the structure and nature of animals? In part, as has already been suggested, it was microscopy. But it was also the deep engagement with the broadly Platonist ideas of Leibniz's English contemporaries that began in the 1690s. Let us now turn to this side of the development of Leibniz's mature conception of the structure of corporeal substance.

Origenism and Panorganicism

As we have seen, Leibniz does not simply think of some bodies as ensouled and some souls as embodied. Rather, for him there are no disembodied souls, while the very notion of an unensouled body, or a body without a soul-like principle, is a contradiction in terms. Every part of the world is a compound of soul and organic body. As Leibniz explains in 1705, he believes

> that there is no part of space which is not full, that there is no part of matter which is not actually divided and does not contain organic bodies, that there are also souls everywhere as there are bodies everywhere, … that organic bodies are never without souls, and that souls are never altogether separated from organic bodies.[91]

Every soul is embodied, and every part of the universe is ensouled (or dominated and activated by a soul-like entity). The ensouledness of every part of the universe results, moreover, not from the diffusion of one soul throughout the cosmos, but from the presence of a unique individual soul in every part of the universe. We have been describing this variety of pananimism, following Rutherford, as "panorganicism." This doctrine holds that all truly real entities in the universe represent themselves to themselves as organically embodied. Rutherford understands this doctrine to be compatible with monadological immaterialism,[92] but whether interpreted along immaterialist lines or not, one key feature of Leibniz's pananimism is that there is no part of the physical world to which it does not apply. The concept of organic body is to be understood as providing an account of the microstructure of all matter rather than simply of those entities that common sense would pick out as animal bodies. This does not mean that for Leibniz the concept of organic body is not one that concerns biological entities, but rather that there simply are no nonbiological entities. Every *corps* is the bodily component of some corporeal substance, and all corporeal substances are in the end what we would think of as biological entities: entities to be understood on the model of "worms" rather than atoms.

Yet Leibniz's replacement of atoms with worms does not make him a vitalist. As we have already seen, in the polemic against Stahl Leibniz positions himself squarely against medical vitalism to the extent that he believes that physiological processes can be accounted for without invoking the activity of the soul. In the end, it is misguided to look for some distinction in Leibniz between the vital and the nonvital, or to argue that he believes only in the existence of the former variety. Instead, we should be focusing on the distinction between body and matter. The roots of this distinction run quite deep. As an admirer of the third-century Christian Platonist Origen, Leibniz is aware of the concept of *soma pneumatikon*, or the "spiritual body" of resurrected believers mentioned by Paul at 1 Corinthians 15:44. This concept sets the apostle sharply apart from the authors of the gospels, who emphasized the entirely physical, flesh-and-blood resurrection of Christians. While in earlier, Platonic philosophy Paul's phrase may have sounded like something of an oxymoron, the Platonizing strain of early Christian theology would take its lead from him, incorporating an idea of the pneumatic as that which lies between the noetic and the somatic, that is, of the spiritual as lying between the mental and the corporeal. Origen, for example, holds that all souls began as pure minds, but that as a result of distraction became "cold" and fell away from the divine "warmth."[93] In this way, turning away from God results in embodiment, initially in an ethereal body, and ultimately, as distance from God increases, souls descend "from a fine, ethereal and invisible body to a body of a coarser and more solid state." As Origen explains in *On First Principles*:

> Material substance of this world, possessing a nature admitting of all possible transformations, is, when dragged down to beings of a lower order, moulded into the crasser and more solid condition of a body, so as to distinguish those visible and varying forms of the world; but when it becomes the servant of more perfect and more blessed beings, it shines in the splendour of celestial bodies, and adorns either the angels of God or the sons of the resurrection with the clothing of a spiritual body, out of all which will be filled up the diverse and varying state of the one world.[94]

In his early *Democritus Platonissans*, the Cambridge Platonist, Henry More, similarly writes that matter was initially "*Psyche*; which at first was fine / Pure, thin, and precious till hid powers did pull / Together in severall points and did encline / The nearer parts in one clod to combine."[95] Anne Conway, too, argues in her *Principles of the Most Ancient and Modern Philosophy* that the distinction between body and spirit is only one of mode and not of substance, much like the distinction between ice, liquid water, and water vapor.[96] For her, as for Origen, the condensation of spirit into body is a consequence of a sort of moral failure, described now not as distraction, as in Origen, but rather as "sluggishness." And it is not so far from Conway's metaphysics to Leibniz's conception of the embodiment of monads as a consequence of their confused perception: monads, themselves immaterial, perceive the world and themselves as a combination of corporeal substances, but only because they lack the perspicacity to perceive the immaterial monads directly. If they were not in this dejected state—"confused," for Leibniz; "sluggish" for Conway; "cold," "bored," and "distracted" for Origen; a "clod" for More—they would see right through the phenomenal realm of bodies to the things themselves. But this sort of clear-sightedness is reserved for God alone.

Matter as the principle that both limits and particularizes an otherwise merely homogeneous abstraction is a conception already very familiar in many different schools of ancient thought, and Leibniz is well aware of this heritage. He often mentions the Patristic authors in this connection. For instance, he writes in the short text of 1702, "On What Is Independent of Sense and Matter": "I am inclined to think that all finite immaterial substances (even genii or angels according to the opinion of the old Church Fathers) are joined to organs and accompany matter."[97] And in the *Eclaircissement sur les natures plastiques et les principes de vie et de mouvement* (Explanation concerning Plastic Natures and Principles of Life and of Movement) of 1705, he explains that as a result of the requirement that all souls be embodied, he is "of the opinion, most accepted among the ancient philosophers and the Church Fathers, that Angels, or what the pagans call the good and evil Demons, are animals, and also have animated Bodies, though very different from ours."[98]

Thus for Origen God made corporeal nature in order to facilitate alterations in the qualities of things; it is necessary on such an account for corporeal nature to endure only "as long as souls who need a corporeal garment last."[99] Now, nobody would think to argue that Origen had denied the existence of a "real" bodily world. Instead, readers see his account of body for what it is: an *account* of body. Mutatis mutandis, one might expect that readers of Leibniz would similarly appreciate his account of the bodily world for what it is: a fascinating and complex alternative to physical atomism that takes force as its most basic notion, and seeks, not without difficulty, to harmonize the world of forces, motions, and impacts with the world of perceiving and striving subjects, indeed to show that these are one and the same world.

The Church Father maintains, again, that God made corporeal nature in order to facilitate the permutations of qualities in things, and that it is necessary for corporeal nature to endure as long as souls who need a corporeal garment last. He goes on to assert that "there will always be rational creatures that need a corporeal garment, and so there will always be a corporeal nature, the garments of which rational creatures must use."[100] Every creature *needs* a corporeal garment because insofar as a creature exists at all it must always be a this or a that and not some indeterminate *je ne sais quoi*. Or, to put this differently—since the claim that a created soul needs a corporeal garment involves a distinction of reason between the soul and the garment—[101] every creature must appear in a bodily way. Matter has no real existence independently of its role as the facilitator of having of qualities by created things, and created things have no real existence except insofar as they have the qualities that matter facilitates. Matter "limits" creatures, but all the better for them, since it is only as limited that a creature can exist. There is no brute, underlying matter in nature onto which qualities are (ontologically or temporally) subsequently imposed. Rather, matter is one of the principles of nature, one of the ingredients that must be posited in order to account for the existence of finite, created beings. Is then an ancient philosopher such as Origen an "idealist"? If he is, the term loses most of its meaning, as the only figures to whom this label would fail to pertain in the ancient period are the atomists.[102]

Cudworth on Plastic Natures

One of the most extensive accounts Leibniz gives of the structure of the organic body comes in the course of his rejection of the theory of plastic natures defended by his Cambridge Platonist predecessor, Ralph Cudworth, who, along with a number of his Cambridge contemporaries, is noteworthy for having introduced Alexandrian Neoplatonism such as that of Origen, as distinct from that of Plotinus, into the mix of ancient legacies available for reappropriation for modern ends.

One of the most important philosophical concepts developed in Cudworth's *True Intellectual System of the Universe* is that of "plastic nature." Cudworth appears to understand either of two quite different things by the notion of plastic nature. One is something more or less the same as Henry More's notion of Archaeus,[103] namely, a singular plastic or animating faculty belonging to a world-soul, which, as Leibniz would describe it, "animates … bodies wherever it meets them, just as the wind produces music in organ pipes."[104] In this first sense, for Cudworth the plastic nature of the world is nothing other than an "Inferior and Subordinate Instrument" of God, which "doth Drudgingly Execute that Part of his Providence, which consists in the Regular and Orderly Motion of Matter."[105] This universal plastic nature is what keeps the dead or inorganic world moving in accordance with natural laws. Expressing his commitment to the first of the two sorts of plastic nature, Cudworth, for instance, writes that "there is a *Mixture* of *Life* or *Plastick Nature* together with *Mechanism,* which runs through the whole Corporeal Universe."[106]

The other conception in Cudworth is of particular plastic *natures*, in the plural, each belonging to a particular creature. On this second conception, somewhat more akin to—though by no means the same as—Leibniz's understanding of the entelechy of an animal, particular living beings in nature possess their own plastic natures, which serve as the "Inward Principles" of their growth and motion.[107] Cudworth sees his dual notion of plastic nature as rooted in the Platonic tradition. "The Platonists seem to affirm both these together," he writes, "namely that there is a *Plastick Nature* lodged in all particular Souls of Animals, Brutes, and Men, and also that there is a *Plastick or Spermatick Principle* of the whole *Universe* distinct from the Higher Mundane Soul, though subordinate to it."[108] According to Duchesneau, the individual plastic natures would ultimately win out over the universal plastic nature, as "the followers of More and of Cudworth … passed from the singular of the *plastic nature* to the plural of the *plastic natures*."[109] This latter version of plastic nature, as Duchesneau notes, makes room for a system of nature that focuses on the phenomenal characteristics of living beings. And it is in response to this notion of plastic nature that Leibniz's mature conception of the organic bodies of corporeal substances is developed.

The individual living being has two aspects for Cudworth: the immaterial active force and the body upon which this active force acts and with which it forms a living being. Each plastic nature is an inner force that moves its own particular body. In so doing, there appears to be no further need to resort to God's influence in either moving or changing the direction of a body. Acting as "God's instruments," plastic natures unconsciously bring about changes in extended matter, just as minds or souls do consciously.[110] The unconscious powers within each individual living creature mean that each moves in accordance with God's will without being moved directly by God.[111] Once created, the natural world is capable of forming and moving bodies of its own accord. In moving from a singular conception of plastic nature to the plural of plastic natures, Cudworth is evidently seeking to avoid hylozoism, the variety of atheism he would see as characteristic of a metaphysical system such as Spinoza's, according to which nature as such is ensouled.

Opposed to the view that there could be one singular world soul, Cudworth might be taken as rejecting the Platonic tradition of cosmological thinking, rooted in the *Timaeus*, according to which God is no detached father, but rather an active and immanent craftsman. But in fact, Cudworth sees his account as a return to true ancient wisdom, simultaneously Mosaic and Platonic, which itself was a sort of atomism—and thus a partial anticipation of modern mechanism—but which nonetheless understood that spirit is prior to matter and that without the animating force of spirit in nature, modern mechanism will be unable to account for growth and change. A vivid example from antiquity of this Platonic-Mosaic natural philosophy, according to which matter is inert and inferior but everywhere quickened by spirit, may be found in the first-century Jewish Platonist Philo, a thinker who likely only influenced Cudworth indirectly, but who, like Cudworth, was committed to the common esoteric roots of the Hebrew and Greek traditions. For Philo, as for the Plato of the *Timaeus*, there is an "artificer"; but for the Alexandrian the artificer works through the "all-incising Logos," which "divide[s] the formless and quality-less universal being, and the four elements of the world that had been separated off from it, and the animals and plants constituted from these."[112] The entire universe is "held together" for Philo, that is, kept perpetually both orderly and dynamic, by "invisible powers," yet in agreement with his version of Moses and in opposition to the pagan Platonists, "neither the universe nor its soul is the primal God."[113]

In sum, for Cudworth as for Philo, matter is in itself inert, but everywhere animated, not by one common soul that pervades the universe, let alone directly by God, but rather by individual spirits. The first part of this agreement, concerning the essential inertness of matter, cannot be stressed too much. According to the Platonic tradition that informs both thinkers on this question, matter is not so much an ingredient of the world, let alone the basic ingredient, but rather the very opposite of that which is, namely God. The extent to which something is material is a measure of the extent to which it *is not*. It would make no sense, then, to attribute a capacity for sensation or thought to matter, as Cudworth thinks the hylozoists would like to do. Matter, as the principle of nonbeing, can limit or hinder the mental activity of a spirit mixed up with it, but certainly cannot itself engage in mental activity.

Cudworth—in complete ignorance, naturally, of what would still take decades to emerge as Leibniz's mature metaphysics—describes the view that matter might be endowed with perception in terms remarkably similar to Leibniz's theory of individuals nested one within the other in the composite substance:

> If matter, as such, had life, perception, and understanding belonging to it, then of necessity must every atom, or smallest particle thereof, be a distinct percipient by itself; from whence it would follow that there could not possibly be any such men as now are, compounded out of them, but every man and animal would be a heap of innumerable percipients and have innumerable perceptions and intellections. … And to say that these innumerable particles of matter do all confederate together; that is, to make every man and animal to be a multitude or commonwealth of percipients, and persons,

> as it were, clubbing together, is a thing so absurd and ridiculous, that one would wonder the hylozoists should not rather choose to recant that their fundamental error of the life of matter, than endeavour to seek shelter and sanctuary for the same, under such a pretence.[114]

In other words, in Cudworth's view, Spinozan hylozoism can't but lead to what we will describe in the following chapter as Leibniz's theory of "nested individuality."[115] For Leibniz, in turn, every man is indeed a "heap of innumerable percipients," even if he does not hold this to be the case as a result of the scenario Cudworth imagines, in which life is possessed by "matter as such." Rather, for Leibniz "life" is in the end a nonbodily property; it is the immaterial perceiving monads that have life, not the organic body, and the body is ultimately a consequence or result of the innumerable percipients that serve not as its parts but as its requisites.

Both Leibniz's panorganicism and Cudworth's theory of plastic natures are proffered as accounts of the causal order of nature. Both are put forth, in particular, as alternatives to the occasionalism of thinkers such as Nicolas Malebranche, according to which God single-handedly causes each change that occurs; and as alternatives to the interpretation of all of nature as governed by blind chance. Cudworth explains that if plastic natures are denied,

> it seems that one or other of these two things must be concluded: that either in the efformation and organization of the bodies of Animals, as well as the other phenomena, everything comes to pass fortuitously and happens to be as it is, without the guidance and direction of any mind or understanding; or else, that God himself doth all immediately, and. as it were with his own hands, form the body of every Gnat and Fly, Insect and Mite, as of other animals.[116]

The Cambridge Platonist understands occasionalism, the theory according to which "every thing in Nature should be done immediately by God itself," to be no less atheistic than the other alternative, that of chance, insofar as "it would render Divine Providence Operose, Sollicitous and Distractious, and thereby make the belief of it to be entertained with greater difficulty."[117]

Leibniz's distinct alternative to Cudworthian vitalism as well as to Cartesian mechanism would involve an attempt to show how divine providence might be preserved, even as immaterial principles of growth and development in nature are denied. Leibniz's constant refrain in response to any suggestion of the need for plastic natures is that organism, together with divine preformation (the subject of chapter 5), gives him everything he needs. That is, the infinite nesting of immortal, organically embodied corporeal substances one within the other is enough to account for all natural change. It is this line of argument that Leibniz would develop in a fascinating if short-lived correspondence, in 1704–05, with Cudworth's daughter Damaris Masham.

Leibniz, Masham, and the Theory of "Material Plastic Natures"

Early in his correspondence with Masham, Leibniz audaciously declares to her that he does not need the immaterial principles of her father, since he has what he calls his own "material plastic natures," and these will do just fine. Here Leibniz is announcing his commitment to a paradoxical thing, for the very reason the concept of plastic nature had been adopted by late seventeenth-century thinkers such as Cudworth in the first place was to shore up the perceived explanatory failure of attempts to account for natural change in terms of the motion of matter alone. Leibniz's particular response to the Cambridge Platonists' conception of plastic natures is rooted in his conception of organic body and in his notion of derivative force. For Leibniz, the "material plastic nature" just is the derivative force that flows from the perceptions of the immaterial substances from which the body results and manifests itself corporeally as impetus. As Leibniz clearly explains in his polemic with Stahl a few years later, "impetus or the derivative forces are modifications of an active thing, namely the entelechy or the primitive active power. Indeed, all modifications, to the extent that they are accidental and liable to change, are certain limitations of the substantial and persisting thing, and add nothing new that is positive to the substance, but rather only limits or negations."[118] Cudworth's position, in turn, may be seen as an attempt to creatively synthesize a version of atomism with his Platonic conviction that the workings of nature must be guided by some spirit or active principle superadded to its material parts. Both Leibniz's position and that of the Cambridge thinkers represent varying degrees of deviation from the austerity in the explanation of natural phenomena called for by Descartes some decades earlier.

Leibniz sees a mechanist such as Descartes, who believes that "no other principles are necessary for the explanation of natural phenomena than those taken from abstract mathematics, or from the doctrine of size, figure, and motion," as mistaken, insofar as this sort of mechanism fails to consider how it is that mechanical principles and general laws of nature arise from higher laws. At the same time, Leibniz thinks vitalists such as Cudworth, who believe that an incorporeal principle is needed to describe the "immediate and particular causes of natural things,"[119] abandon mechanism too readily. Like the Scholastics, Cudworth errs not in holding to immaterial forms, but "in applying them where [he] ought rather to have sought the modifications and instrumentalities of substance … that is, mechanism."[120] As Leibniz similarly has his own Théophile say to Locke's Philalèthe in the *Nouveaux essais*: "The movement of the plant, which we call sensitive, arises from mechanism, and I do not at all approve of taking recourse to the soul when it is a matter of explaining the details of the phenomena of plants and animals."[121]

As already mentioned, it is in correspondence with Damaris Masham that Leibniz first introduces the term "organism"—as distinct from "organic body"—in May 1704. Here Leibniz insists to Masham that there is nothing over and above the mechanism of the corporeal substance's body—which is to say the corporeal substance's organic body—required in the course of such explanation, and that the possibility of mechanistic explanation requires that there be infinitely many particular embodied animated beings, occupying each part of the universe. He explains:

> As far as plastic nature is concerned, I admit it in general, and I believe, along with Mr. Cudworth, that animals are by no means formed mechanically by something that is not organic, as Democritus and M. Descartes believed. … Matter is plastic or organic throughout, even in those portions that are as small as can be conceived.[122]

"Plastic" and "organic" are treated here as synonyms. From its earlier meaning in Micraelius and Conway as simply "that which has functioning parts," "organic" now comes to mean, roughly, that which is independently capable of growth, motion, and all of the activities ordinarily associated with life, such as digestion, calorifaction, and so on. These capacities, Leibniz believes, moreover, can be deduced from the infinitely complex structure of the organic body alone. But how? When Leibniz writes in 1705 that he has "no need to resort, as does Cudworth, to certain immaterial plastic natures," insofar as "this infinitely complex organism provide[s] me with material plastic natures that meet the need,"[123] what is it exactly about the complexity of the organism that he believes is able to do the work Cudworth attributes to the immaterial plastic nature?

For Leibniz, the fact that higher, soul-based principles need play no active role in any account of immediate efficient causes in the material world, rather than positioning the soul in a powerless role, subordinate to matter, is simply a consequence of the distinction between the two different kingdoms constituting all of reality. In the kingdom of nature, the order of efficient causes unfolds with no influence from the souls in the kingdom of grace. While the phenomena in the kingdom of nature can be explained by appeal to efficient causes alone, by nothing other than geometric and quantitative principles, in order to explain the reason for these principles, higher principles, from outside of the order of efficient causes of natural phenomena, must be brought into consideration.

In a letter written to Damaris Masham in mid-1705, Leibniz has occasion to bemoan his own recent loss of his close friend and confidante, Sophie Charlotte of Prussia, as well as to offer condolences to Masham in view of the recent death of John Locke, who had lived in Masham's home for a number of years. In fact, it is only after his lengthy account of his own loss and grief that Leibniz offers his condolences for Masham's loss of Locke. Grieving out of the way, he quickly goes on to comment that the French translation of Locke's *The Reasonableness of Christianity*, which she sent him with her last letter, has been sent along to the editors of the Leipzig *Acta eruditorum*, as he had already read it some time before. He adds that he is "very disappointed" that Locke has "taken with him" the notion that he had considered so different from his own, which made him believe that the creation of an immaterial substance is less conceivable than the creation of a material one. For Leibniz, it is exactly the opposite: since bodies are not, properly speaking, substances, but only assemblages or results of substances, they presuppose the existence of immaterial substances. Material substances cannot be created, then, because they are not really substances at all.

Leibniz next goes on to list all the points at which his views agree with the intellectual system of the late Mr. Cudworth. The only point at which he disagrees is on the subject of plastic natures. In her next letter, Masham makes a final, comprehensive case in defense of the theory. Her father had not, she writes, maintained that "creatures [possess] a facultie of produceing excellent works … separate from all knowledge," but only one "of executeing instrumentaly [God's] ideas or designs," so that there is an "inseparable union betwixt the power of produceing excellent works, and the idea of theire essence and manner of produceing them." Masham believes that there is no threat of atheism here, since it is not asserted "that God had been able to give to creatures a facultie of producing excellent works, the ideas whereof never were in any understanding."[124] Her father's view does not help the atheists' cause, since "the pow'r giv'n to plastick natures" is "only a pow'r to execute the ideas of a perfect mind." Without God's mind, "this pow'r in the matter must lye for ever dormant and unproductive."[125] God has the idea, and the plastic power in nature is just the power to execute that idea.

The only other option, Masham seems to think, just as her father had before her, is "perpetual direction," which is to say occasionalism. In his follow-up letter, undated, Leibniz repeats to Masham his well-known concern that in the end occasionalism would reduce to a sort of recourse to perpetual miracle, but that plastic natures are not the only alternative.

> In natural things, I would not wish to employ that particular direction of God that can only be miraculous, nor to take recourse to incorporeal plastic natures that will have no advantage over the machine. I will thus say that bodies have plastic natures in them, but that these natures are nothing other than their machine itself, which produces excellent works without having knowledge of what it does, because these machines were invented by a master still more excellent.[126]

Leibniz hopes to confound Masham's received understanding of her father's theory in order to show her that it can be rejected without any loss in ability to explain the phenomena of nature for which Cudworth had invoked it. He draws on the example of workers, "whose talents are so limited [dont les talens sont si bornés]," but who are nonetheless capable of providing a semblance of reason by using a calculating engine built by someone with greater talents. This in effect shows that the machine is channeling reason, while still operating according to entirely mechanical laws. Of course, from the animal-economical texts of the 1670s and early 1680s, we know that one crucial difference between a machine such as the calculating engine on the one hand and an animal body on the other is that the former has its principle of motion and activity outside of it; it is activated by an external agent. With this one crucial difference in mind, in the comparison that Leibniz makes to Masham of the natural and artificial machine, we may say that the natural machine for Leibniz is the machine that in its motion and activity channels reason, but without requiring an external activating principle. Its "plasticity," which is to say its capacity for growth and change, is entirely mechanical.

Leibniz, like Masham, would not approve of either occasionalism or chance, and thus would hold that Cudworth must be mistaken in his claim that these are the only alternatives to the theory of plastic natures. Leibniz sees the appeal to particular immaterial principles in the explanation of natural phenomena as no more satisfying than the occasionalist theory or the doctrine of a world soul. As he explains in his *Animadversiones* against Descartes of 1692:

> It is as vain [in the explanation of natural phenomena] to introduce the perceptions and appetites of an archeus, operative ideas, substantial forms, and even minds, as it is to call upon a universal cause of all things, a *Deus ex machina,* to move individual natural things by his simple will.[127]

Recall, now, Cudworth's account above of the dangers of accepting the doctrine of "hylozoism," an element of which is his fear that one would have to accept "innumerable percipients with innumerable perceptions and intellections." Leibniz does accept just this, yet not as a result of any commitment to the belief that, as Cudworth puts it, matter *as such* has perception attached to it. In order to understand Leibniz's embrace of these two doctrines, and his simultaneous rejection of the positions that More and Cudworth see as giving rise to them, we must remember that according to Leibniz's concept of organic body, everything that happens in nature can be explained without introducing immaterial principles of activity. Cudworth's doctrine of plastic natures had been invoked to explain the formation of plants and animals from unintelligent matter. As we have seen, however, they do not fulfill this purpose since they fail to provide an adequate explanation of the immaterial action on the material. Leibniz does not need them because he is not concerned to explain any interaction of the material and the immaterial. In view of his doctrine of preestablished harmony, Leibniz is able to claim that there simply is none.

Conclusion

In the account of Leibniz as a monadological immaterialist, matter is phenomenal because substances are simple and immaterial, and whatever arises from the immaterial can at most appear to be material. Organic bodies are not incompatible with the simple substances at the heart of this immaterialism; indeed, they flow directly, as modifications, from the primitive active and passive forces of these simple substances. We are thus entitled, without entering into conflict with the immaterialist interpretation of Leibniz's deepest metaphysical convictions, to attribute to Leibniz the view that substances involve real, physical bodies, which are themselves composed out of other substances with real, physical bodies, and so on to infinity. These bodies are organic, which is to say, among other things, that they are not naturally generable or corruptible; insofar as they are infinitely complex, there is no process of rearranging preexisting matter so as to bring them into existence, and no process of decomposition that would take them out of existence. This is why Leibniz insists, repeatedly, that organism together with divine preformation gives him everything he needs to explain the origins, structure, and motion of organic bodies. As he writes to Clarke: "The organism of animals is a mechanism that presupposes divine preformation: what results is something purely natural, and completely mechanical."[129] This is, in a word, Leibniz's theory of divine machines: divine, because initially generable only by God directly; machines, to the extent that one need take no recourse to God's constant concourse, nor to some subordinate God-like principle within the machine, in order to obtain an adequate understanding of it.

We will be turning to a comprehensive treatment of Leibniz's theory of divine preformation in chapter 5. In the following chapter, we will turn to a deeper consideration of the scientific context in which Leibniz's unique theory of organic bodies took shape.

Chapter Four

ORGANIC BODIES, PART II: CONTEXT AND LEGACY

Organic bodies, as we have already begun to see, are, taken separately, never individuals, since they are always mutually interdependent with countless other organic bodies, just like the termite and the protozoa in its stomach that enable it to digest wood, or the rhinoceros and the bird on its back. The real individuals are the simple substances, and their individuality consists precisely in their status as worlds apart, or as causally self-sufficient automata. Organic bodies, while not individuals in any rigorous sense, may be picked out as this or that organic body in view of their functional unity and activity, but to be an individual in any robust metaphysical sense necessarily involves a unifying soul or soul-like principle, insofar as the matter of the organic body is constantly in flux.

Living, perceiving, corporeal substances consist in part in organic bodies, and so do all of the infinitely many substances implicated in these bodies. In seeking to determine what considerations led Leibniz to propose such a picture of substance, some of the first and most visible road signs appear to point in the direction of the empirical life sciences. In this chapter, we will first be focusing on the biographical and historical context of Leibniz's model of organic bodies. In particular, we will look at the relation of Leibniz's model of organic body to the empirical life sciences of his era, especially to the seventeenth century's discovery of the ubiquity of subvisible living creatures as well as its growing awareness of the deep interdependence of all living entities. We will conclude with a consideration of the legacy of the model of individuality developed by Leibniz in today's philosophy of biology.

Leibniz's Model of Nested Individuality

As we have seen, for Leibniz every corporeal individual has parts, at least in its bodily component, and whatever consists in parts is divisible. The divisibility of an individual suggests, if only for purely etymological reasons, that the "individual" in question is not really one at all. Since whatever is divisible is a physically cohesive bit of matter, and, vice versa, since any cohesive bit of matter is at least in principle divisible, philosophers throughout history have argued that inanimate portions of matter most definitely cannot be considered true individuals. There is an inherent vagueness to the identity of any entity that is thrown together from sundry parts: rocks and tables, no less than heaps and balding heads, fall victim to *sorites* paradoxes, as there is no crucial piece of them such that after its removal they cease to be the thing they previously were. But if physical cohesion is the only criterion of individuation we can find for each of the two halves of a split chunk of organic body, should we then conclude that such a body is on a par with rocks and tables, and that each of the two halves are not really individuals at all?

For Leibniz, again, a corporeal substance consists in the union of a soul or entelechy and an organic body. Insofar as a finger is divisible from the organic body, the bodily component of a corporeal substance is divisible. But because the corporeal substance as a whole is not divided as a result of this amputation, because the amputation does not yield two physically separate instances of the same substance, and because the rest of the body, without the finger, does not cease to be the body of the individual of which it had been the body prior to the amputation, it would be incorrect in Leibniz's view to claim that the substance itself has been divided. Analysis of organic bodies will yield neither homoeomeries nor atoms, but only more, smaller entities of the same kind as the initial object of analysis. Analysis of the organic body of a corporeal substance will yield only more corporeal substances. These, being corporeal substances just like the corporeal substance whose body they compose, will in turn also yield only more corporeal substances upon further analysis.

Why does Leibniz insist, contrary to Aristotle and to the atomists alike, on the impossibility of analysis of organic bodies into ultimate constituents? Part of the answer is deeply theoretical and a priori: for Leibniz, the world consists exhaustively in individuals. All that there are in the world are individual substances and their properties. Such individuals must be unique and have unity and identity over time. But individuals also contain other individuals (as the bodies of animals include worms or germs). Not only that, an individual corporeal substance (or, as Leibniz puts it in his most mature period, an individual "animal") may properly be seen as being the substance it is in virtue of the fact that it involves these other individuals, organized in a hierarchical structure, nested one within another. This structure of nested individuals,[1] however, must have substantial unity, that is, it must be united as one substance. As Leibniz writes to Burchard De Volder in 1703:

> Although I said that a substance, even though corporeal, contains an infinity of machines, at the same time, I think that we must add that a substance constitutes one machine composed of them, and furthermore, that it is activated by one entelechy, without which there would be no principle of true unity in it.[2]

As opposed to artificial machines, as we saw in the previous chapter, a machine of nature for Leibniz entails an infinity of machines that form a single unit. This very distinction seems to indicate that there is an intrinsic connection between Leibniz's notion of organic unity and this unity's nested structure. As we have seen, the unity of a composite substance derives from the entelechy or dominant monad, which is at once its singular source of activity as well as its source of unity.

On Leibniz's model of nested individuality, an individual substance is a union of an active entelechy or substantial form animating and organizing its organic body.[3] In order to qualify as an individual substance, an entity requires true unity, and it is the organic, living unities, such as animals and plants, that constitute the paradigmatic examples of such substantial unities, in contrast with aggregates, such as rocks, lakes, flocks, and armies. Nonetheless, there is no part of an aggregate that is not entirely composed of entities conceived on the model of plants and animals. Animals and plants are individual substances that are composed of other such animals and plants, or similar organic unities, nested in them, and the animals entailed in an individual substance are complete individual substances that have a similar structure. They are not mere "parts of the substance but are immediately required for it."[4] The structure of nested individual substances, finally, involves a hierarchy of dominating and dominated substances, which is constitutive of the nature of living individuality.

To the extent that, for Leibniz, a corporeal substance is a stratified structure of infinitely many substances, his model suggests a radical break from the implicit formula of at least the unitist strain of the Aristotelian metaphysical tradition: "one body, one substance." Such a break comes at a price, however. Leibniz's model is in tension with some deeply rooted intuitions about individuality that are still alive today. In addition to the counterintuitive claim that many substances may be implicated in one greater or more encompassing substance, the notion of nested individuality seems to conflict with the traditional logical and grammatical characterization of an individual substance as that which is "neither said of a subject nor in a subject."[5] Aristotle's formulation of what is essential to individuals would remain extremely influential, as it provides not merely an articulation of our common intuitions about individuality but also underlies some of our scientific notions concerning biological individuality.

In our current notion of biological individuality, biological individuals are identified with multicellular organisms—organisms in our sense, that is, not "organism" in Leibniz's sense—and for this reason groups or parts of organisms are excluded from the ranks of the complete individuals.[6] Both of the extreme cases, of genes and groups—which have been proposed not only as biological individuals but also, within the context of evolutionary biology, as units of selection—illustrate our intuitive response. It is hard to accept a group, say, a beehive, as a single individual, because it already consists in multiple organisms, to wit, bees, notwithstanding the fact that they can only multiply as a group, and notwithstanding the fact that there is a cohesion to the beehive as a whole that seems to justify calling it at least as much a unity as, say, the body of a large mammal (which, of course, requires the cooperation of a number of internal, microscopic symbionts in order to survive). Ludwig Feuerbach, interestingly, understood Leibniz's theory of nested individuality on the model of the beehive. He writes in an 1837 study of Leibniz's philosophy:

> The body, which the monads bring together and hold together, is the beehive. The dominant monad is the queen or mother bee. The bees do not live in such a loose connection as the beasts of a herd; they constitute *one* whole; every individual bee is to be seen as just one member of this organism, having only a partial life [*Theilleben*], a particular function, like an organ in my body. At the same time, though, every bee is an individual in itself, a particular being that stands on its own legs. Just as the self-standing bees constitute one organism, in the same way we must also understand the monads, as they together constitute a body.[7]

Feuerbach's comparison is suggestive, but strictly speaking it does not get things quite right. In Leibniz's model, the mammal's body, considered apart from the soul that unifies it into one corporeal substance, truly is like the beehive in that it is constituted out of subordinate individuals and in that it has, on its own, at least a sort of mechanical, functional unity. Individuals function as constituents of other individuals. According to Leibniz's model, a given component of my body may be considered simultaneously as a complete individual *and* as a constituent or requisite of me.

Leibniz thus significantly alters the unitist model of the structure of the bodily component of a form-body compound. For him, as for Aristotle, existing individuals are characterized by their inherent entelechy or inherent principle of activity, which also gives them their unity and identity over time. Leibniz holds that each component of an individual substance has its own entelechy while being included in a body and subordinated to the entelechy of the whole corporeal substance. In contrast with prevailing ideas about bodily parasites in the ancient world, which took them as by definition abnormal, for Leibniz nestedness, or the presence of other individual corporeal substances in the constitution of corporeal substances, is precisely constitutive of individuality. What it is to be such and such individual corporeal substance is a question that is inseparable from that corporeal substance's constitution out of other corporeal substances.

It is worth noting that the notion of nestedness described here is not foreign to current biology, even if commonsense ideas about biological individuals remain out of step with biological reality. Thus David Hull writes that "the first thing a biologist does in arguing that an entity can or cannot function as a unit of selection is to argue that it is or is not an individual."[8] "One body, one substance (or individual)" remains, nonetheless, a formula that has proven difficult to abandon in the philosophy of biology, perhaps because it is ultimately a formula that is very much in keeping with common sense, whereas empirical data about the structure of the living world, ever since the development of microscopy in the seventeenth century, have consistently demanded that we reject our commonsense understanding of that world. To cite one example of the endurance of the ancient formula, in metaphysics if not in biology, Peter van Inwagen writes:

> It cannot be that the activities of the *x*s [i.e., the proper parts of a living being] constitute at one and the same time two lives. Lives are, in fact, [such that] only in certain special cases can two lives overlap: Only in certain special cases can there be *x*s and *y*s such that the activity of the *x*s constitutes a life and the activity of the *y*s constitutes a life and the *x*s are not identical with the *y*s and, for some *z*s, the *z*s are among both the *x*s and the *y*s.[9]

According to Leibniz, in contrast, as, mutatis mutandis, for the Latin pluralists before him, full individuals may at the same time function as subordinate constituents of greater individuals. There is for him no difficulty in conceding levels of individuality. For much of history the true individual was thought to be simply the "organism" (again, in a non-Leibnizian sense), and still today many who are involved in the debate concerning the true unit of selection in evolution continue to search for *the* unique level—whether the gene, the organism, the group, or the ecosystem—at which the true individual may be said to reside. As Hull also notes there is a close relation between the question of what may count as units of selection in evolutionary theory and what may count as a biological individual.[10] He defines a biological "individual" as "an entity which is systematically the target of selection,"[11] while a "unit of selection" is in turn generally defined by three criteria: phenotypic variance, fitness variance, and heritability of characters relating to fitness.[12]

To sum up, one important consequence of Leibniz's understanding of a living being is that it implies a plural notion of individuality, which recognizes infinitely many levels of it within any corporeal substance. Another consequence is that in this model, individuality and unity are defined through activity, not primarily through spatiotemporal cohesiveness. There must always be some spatiotemporally cohesive, organic body parts or other, but what makes these parts the parts of this or that organic body is by no means this cohesion, since, after all, the cohesion never lasts very long, and in the end an organic body has no more of it than, as Leibniz enjoys telling us, does a fountain or river. Thus what enables us to talk about an individual organic body is its functional unity and activity, which in the end may be traced back to the inherence of a soul, but which may also be discerned, as Leibniz shows in, for example, the *Corpus hominis*, looking at the body only qua machine.

Nested Individuality and Microscopy

Leibniz's attempt to do justice to the new empirical life sciences in his metaphysics of corporeal substance has been noted by many scholars, but often this is in the course of denying the importance of corporeal substance to Leibniz's central philosophical concerns. Corporeal substance is treated as a "concession" to the empirical, which itself is beneath the usual high standard of Leibniz's rationalist philosophy. Robert Adams, who maintains that Leibniz never took seriously the ultimate reality of corporeal substances, no more in his middle period than in his later period, asserts that Leibniz's "talk of 'corporeal substance' was usually rooted in an interest in accommodating within his system at least verbally, and if possible more than verbally, a common sense or traditional realism about bodies."[14] Catherine Wilson writes similarly, though with different basic commitments guiding her claim: "That the animalcula were so obviously and interestingly 'there' 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."[15] Wilson asserts that Leibniz could easily have bought consistency for his metaphysics by giving up his insistence that a soul cannot exist independently of a body, and suggests that while for Descartes the most important activity of a soul is abstract thought, for Aristotle and for Leibniz it is perception and motive power. The split in Leibniz's thought between phenomenalism and realism comes, as Jacques Roger similarly explains, from Leibniz's desire to "rendre compte du réel," to avoid excessive detachment from the subject matter of natural science:

> In [biology, Leibniz] remained above all an attentive spectator, a philosopher striving to ground the close relations between his thought and the most re-

> cent discoveries of contemporary thinkers. The study of these relations is not less useful, for it allows us to see that Leibniz's thought does not intend to remain in the abstractions of ontology or pure logic, but rather seeks to take the real into account, including that reality represented by the living being, which is so resistant to abstract generalization.[16]

Perhaps a more interesting question, one that Adams, Wilson, and Roger do not ask here, is not so much why Leibniz would be willing to compromise his most pristine and abstract philosophy of simple substances, but rather why, in his effort to "take account of the real," Leibniz does it precisely *in this way*. His philosophy of body cannot *simply* be a regression or concession to traditional realism, for there is nothing at all traditional about the account of bodies that Leibniz gives. The theory of nested individuality outlined in the previous sction is in many respects a radically new account,[17] and Leibniz surely would not have gone to the trouble of developing it if organic bodies were not something he took seriously. He would have settled with an available model rather than elaborating a revolutionary one. Even if in the end the body is just part of the "story of science," why does Leibniz give the particular account of it he does, as *organic* body? We have already argued that this has something to do with empirical science and also with Leibniz's philosophical project of accounting for "material plasticity" or capacity for growth and motion in terms of the vegetative structure alone of the body. Let us turn now to some of the historical factors, particularly those stemming from empirical science, involved in Leibniz's model of organic body.

Before the development of microscopy in the seventeenth century, parasitism was the variety of symbiosis, understood broadly as mutual occupation of the same body, which garnered the most attention from philosophers and physicians alike. On Aristotle's view, for example, the presence of a worm in another animal body never bodes well. In the *Historia animalium* he mentions dogs driven by the insatiable hunger intestinal parasites cause to eat the standing corn,[18] thereby inconveniencing the humans who would have eaten it, and fish in which "an intestinal worm, which develops in them at the time of the dog-star, makes them surface and weakens them: and having come to the surface they are destroyed by the heat."[19] He also describes the misfortunes of worm-ridden sponges.[20] In the *De generatione animalium*, Aristotle mentions on at least three occasions the problem of parasitism in various animals (sponges, fish, dogs). Nowhere does he mention any sort of nonharmful mutualism or symbiosis between individual organisms.

In addition to Aristotle, many authors of ancient medical texts devote a great deal of attention to the causes and treatment of sickness due to intestinal and other parasites. Alexander of Tralles, for instance, a sixth-century Byzantine physician, writes that "the wide worms ultimately reach such a size that they extend throughout the entire intestine. . . . They grow when food enters and the undigested juices turn into rottenness." Alexander recommends taking attar of roses in order to kill the worms and "purge them through the stool, reawakening the lost and weakened appetite." He warns against trying to starve the parasites to death, since often, out of a shortage of food, "the worms eat right through the entrails, so that they can be seen to come through the skin."[21] Two creatures sharing the same body was considered abnormal and pathological, and, correlatively, the paradigmatic animals were the more or less discrete and autonomous ones, the ones that any nonexpert could enumerate without worrying about overlap. Cases of overlap in the same body or the same spatiotemporally cohesive organic assemblage were consequently taken as exceptions to the norm and certainly as more characteristic of odd or exotic species than of horses, men, and other such paradigmatic instances of substance.

Jack Wilson has argued that throughout the history of philosophy and science, metazoan animals such as horses and men, and easily individuated plants such as oak trees, have served as the paradigm cases of biological individual.[22] This is in large part true, but in glossing over a very long history Wilson misses the sharp shift that takes place in the seventeenth century in scientific thinking about the paradigmatic or most basic corporeal substances in nature: from the horses and men of Aristotle's *Categories*, science shifted its attention to "worms," just as the broader scientific and popular culture of the era became fascinated with the plurality of worlds both too large and too small to be detected through unaided perception. In the seventeenth century, for the first time, the idea began to circulate that smaller organic bodies in the body of a larger one are not just inhabitants but indeed *constituents* of the body in which they were found. This shift of focus from macro- to microorganisms compelled researchers to search for microscopic "worms"—a term that in its early modern usage, again, referred to all small, creeping or slithering creatures, and sometimes even insects—at the source of a wide variety of biological phenomena, the investigation of which the ancients could only carry as far as their natural faculty of vision would allow. These phenomena included the explanation of epidemics, which in the seventeenth century came to be understood as the result of the presence of microscopic contagion in the environment rather than in terms of the Hippocratic miasma theory. As we will discuss in the following chapter, they also included the phenomena of generation.

How does Leibniz's own work reflect these broad changes? According to what has been called Leibniz's "worlds-within-worlds" doctrine, as stated in the notes he took on a letter of Michelangelo Fardella dating from 1690,

> there are substances everywhere in matter, just as points are everywhere in a line. … [J]ust as there is no portion of a line in which there is not an infinite number of points, there is no portion of matter which does not contain an infinite number of substances.[23]

This thesis, as Leibniz explains in his *Primae veritates* of 1689, is tantamount to the claim that "there are no atoms," and thus that "there is no body so small that it is not actually subdivided."[24] Matter has no ultimate, indivisible parts any more than does a line.[25] The earliest description of this position in explicit terms of "worlds" is found in the 1671 text titled *On Primary Matter*: "Matter is actually divided into an infinity of parts. There is in any body whatever an infinity of creatures."[26] For the moment, the precise nature of these "creatures" remains unspecified, but this will change in later elaborations of the same doctrine. Leibniz writes to Antoine Arnauld some years later that

> the human is a being endowed with a true unity given him by his soul, in spite of the fact that the mass of his body is divided into organs, ducts, humors, and spirits and that these parts are undoubtedly filled with an infinity of other corporeal substances endowed with their own Entelechies.[27]

In the same correspondence, Leibniz cautiously suggests that what he has in mind when speaking of "worlds" are in fact living beings:

> And since matter is infinitely divisible, no portion can be designated so small that it does not contain animated bodies, or at least bodies endowed with a primitive Entelechy or (if you permit me to use the concept of life so generally), with a vital principle; in short, corporeal substances, of all of which one can say in general that they are living.[28]

In 1699, Leibniz writes to De Volder similarly: "You ask further if an animate body has its own entelechies distinct from the soul. I reply that it has innumerable such entelechies, since it consists in turn of parts each of which is animated."[29] And in a striking passage in a letter to Bernoulli of the same year: "I confess that there are parts in cheese in which there appear to be no worms. But what prevents there from being other smaller worms or plants in those parts in turn, or other organic things that are *sui generis*, and so *in infinitum*, so that there would be nothing in the cheese free from such things?"[30] In correspondence with Des Bosses, Leibniz quite often makes explicit the nature of the substances making up the organic bodies of larger substances: "you [Des Bosses], ask (for example) whether the soul of a worm existing in the body of a human is a substantial part of the human body, or whether it is rather a bare requisite, and that not by metaphysical necessity but only because it is required in the course of nature."[31]

There is perhaps a difficult interpretative question that must be asked in looking at passages such as these. Sometimes, philosophers choose their examples because they are interested in just that kind of thing that is serving as the exemplar. But sometimes philosophers choose their examples because they require a neutral object that will help them to make a point that could be made about many different sorts of object: thus in the classroom philosophers regularly talk about chalk, not because they are interested in chalk, but because they need a simple (and, ideally, uninteresting and therefore nondistracting) example of a physical object. Similarly, when Leibniz mentions armies as an example of aggregates, he has no intention of contributing to military science; he is doing metaphysics, and armies happen to provide a useful illustration that could have been made just as well by reference to something else. The usual approach to Leibniz's mention of worms in passages such as those we've just looked at has been to take them as neutral examples of a much broader interest, a model of the structure of corporeal individuals that could be instantiated by any number of kinds of being. But there is good reason to think that these statements about worms are more narrowly vermicological than Leibniz's statements about armies are military-scientific. To the extent that the category of "worm" is understood by Leibniz to include any small corporeal being, and given that the model of nested individuality, or the doctrine of worlds-within-worlds, is explicitly intended to account for the structure of organic bodies (which may in the end be traceable back to the perceptions of simple substances but is not for that reason deprived of its intrinsic interest, for Leibniz), it follows that Leibniz's worms are not intersubstitutable with other, equally useful examples. Worms really are the elements of bodies.

Leibniz's response to the question he has attributed to Des Bosses in the last passage cited above is that the worm is indeed a substantial part of the human body, and, moreover, at the same time it is itself a substance, that is, a dominant monad with an organic body: "Some worm can be a part of my body and be subject to my dominant monad, and the same worm can have other animalcules in its body subject to its dominant monad."[32] Again, while Jack Wilson is in general correct in holding that the commonsense view of biological individuation has remained the same from Aristotle to the present day, Leibniz's own work is indicative of a noteworthy shift in the latter half of the seventeenth century, if not in common sense, then at least in natural science and philosophy, toward widespread acknowledgment of the cohabitation of multiple individuals in larger organic bodies. This shift is also evidenced by the publication of treatises such as Nicolas Andry's *De la génération des vers dans le* *corps de l'homme* (On the Generation of Worms in the Human Body) of 1700 (two years after Leibniz first identifies the corporeal substances in his body as "worms" in a letter to Bernoulli[33]). Andry does not, as had Alexander in his treatise on worms, offer advice on how to purge the worms, thereby returning to one's normal state, but instead describes with amazement and pleasure the utter normalcy of their presence there. Catherine Wilson has described Andry's work as primarily concerned with the misfortunes wrought by worms. Indeed, Andry does blame them for "vomiting, pain, bloating, sweating, convulsions, stagger, and muteness."[34] The overall aim of Andry's book, however, is not to indict worms as villains, but rather to give an account of their important role in the composition, and in all of the processes, including but not limited to the painful and unfortunate ones, of the human body.

Similarly, the microscopist Nicolaas Hartsoeker, in a 1699 letter to Andry (from the same period as Hartsoeker's correspondence with Leibniz), describes the normalcy of worms in the human body without mentioning their role in disease: "[Worms] have been found in all the parts of the human body." Curiously, he reports that they have "even [been found] in the pineal gland, if what I have been assured of is true."[35] The intention is evidently to challenge traditional ideas about what constitutes the individual human being, going so far as to allow "worms" into that very organ that for Descartes had stood out as the great hope for fixing the individual human's soul-based identity to a particular body part. If the pineal gland, like the rest of the body, turns out to be inhabited by creatures nonidentical with the self, indeed not even human, then its candidacy for the role of "seat of the soul" must clearly be called into question. With Andry, Hartsoeker, and Leibniz, the pineal gland is now the seat of many souls.

This process of normalization of symbiosis that is evident in Hartsoeker, Andry, and Leibniz at the end of the seventeenth century would continue into the eighteenth century. In Friedrich Lesser's 1738 treatise *Insectotheologia*, a work that could fairly be said to belong to the genre of theodicy, the particular aim being to demonstrate that the apparent nastiness of mosquitoes and worms is not evidence against the perfection of God, the author notes with joy that it is further evidence of "the wisdom and power of God" that "man, the most noble of animals, is a world in which a multitude of insects live. … Our intestines are not more free of them than those of other animals. … Our whole body is nothing more, so to speak, than a butcher-shop, providing meat to an infinity of insects."[36] While Lesser concedes that this newly discovered role of the human body may under some circumstances be painful and unhealthy, ultimately he sees it as yet more evidence of God's goodness, power, and wisdom. He continues:

> How admirable is the providence of God! It has seen not only to the housing of man; but with an infinite wisdom it has also seen to that of all the other species of animals that there are on earth. They are all destitute of reason; nonetheless there is not one of them that is not endowed with a natural instinct, which brings it to inhabit the environment proper to it, and where it will find the nourishment that best suits it.[37]

Charles Bonnet, similarly, in his *Considérations sur les corps organisés* of 1762, will offer this vivid description: "The mite, like the elephant, the louse, like the ostrich, the vinegar eel, like the whale, are nothing but composites of animals; all of their liquors bring them forth: all of their vessels are seeded by them."[38]

These accounts seem not to bemoan, but only to acknowledge and sometimes to celebrate the ubiquity of microorganisms and their presence in the bodies of macroorganisms. Leibniz's account to Des Bosses of the presence of worms in his body is a very good example of this celebration. Another is Balthasar de Monconys's remarkably prescient claim in 1647 that "nature has provided all animals and plants with an infinity of minute invisible insects, which are for the purpose of sucking and drawing out the corruption and impurities of living things."[39]

Leibniz, in sum, fits very well in this tradition of theodicy-style reasoning that extends from Monconys to Bonnet about the ultimate goodness and normalcy of symbiosis. In a striking passage from the *Entretien de Philarète et d'Ariste* of around 1713, he explicitly claims a bodily dependence on "worms" gnawing at him: "What does it matter if the worm that gnaws at me is within me or outside of me? Am I any less dependent upon it? Only incorporeal substances are created independent of every other created substance."[40] Leibniz's purpose is apparently to distinguish between the independence of monads considered apart from the corporeal world that results from their perceptions, on the one hand, and on the other the essential dependence of bodies upon other bodies for their continued existence. Considered as an immaterial monad or soul, Leibniz is indeed independent; everything would remain the same if it were only God and he existing in the universe. But considered as a corporeal substance—that is, as the immaterial monad that is Leibniz's soul together with an organic body—Leibniz's identity is essentially dependent upon the coexistence and mutual representation of infinitely many monads, all with their own organic bodies and all implicated in the functional unity of Leibniz's body-machine. The body is the body it is in consequence of this infinite aggregation of mutually gnawing worms. If this sounds macabre, let us recall that a similar point was made—albeit without worms—in the *Corpus hominis* of the early 1680s, in which Leibniz identified the animal as a quasi-perpetual-motion machine that perpetually requires something external to it—namely, food—for its continued existence. It is of the nature of a living body to be in constant interchange with what lies beyond it. It is in this sense that the body has no more diachronic fixity than a fountain, and it is also in this sense that Leibniz can understand the body mechanically without having to resort to the power of the soul to hold it together. Properly speaking, the body is *not* held together at all; it "gnaws" constantly at the outside world and is gnawed at in turn, and the only thing that gives it identity over time is the perpetual incorporation of newly gnawed bodily matter into the same functional unity in which recently cast-off bodily matter had previously been implicated.

The body's constant interchange with the world *outside* of it seems to have come into Leibniz's philosophy via the chemical and iatrochemical conception of nutrition as a sort of fermentation. From where, though, did the idea come of worms gnawing from *within*? Again, some of the first signs seem to point to the developing empirical research program of microscopy. The neologism "microscope" was invented by Johan Faber in 1625, but Galileo had been looking through his "fly-glass" since at least 1610. Catherine Wilson reports that the Jesuit priest Athanasius Kircher, who exercised tremendous influence on the young Leibniz, had microscopes in his possession by 1634.[41] Kircher had devoted an entire chapter to the study of nature by means of the microscope in his 1646 work *Ars magna lucis et umbrae*. In his *Scrutinium physico-medicum* of 1658, the Jesuit scientist presents a theory of putrefaction that is based, as he claims, on decades of microscopic research.

Kircher is known to have been among the figures who influenced Leibniz during the latter's most formative years.[42] In the *Dissertatio de arte combinatoria* of 1666—a work, incidentally, in which the young Leibniz espouses the earliest version of his worlds-within-worlds doctrine—Leibniz describes Kircher as "immortal" and anticipates that in his forthcoming book, the *Ars magna sciendi,* the Jesuit will "penetrate into the heart of things."[43] Leibniz's familiarity with Kircher's work in general during this period makes likely a familiarity with Kircher's microscopic interests in particular. In a 1669 letter to Thomasius, in turn, Leibniz, drawing on his knowledge of Robert Hooke's microscopic study of rusted iron, seeks to corroborate the theory of putrefaction espoused by Kircher in his 1658 work. Hooke had published his landmark *Micrographia; or, Some Physiological Descriptions of Minute Bodies Made by Magnifying Glasses* in 1665. In this work, he attributes to the microscope a significant role in opening up the secrets of nature as it really is:

> [We can add] artificial Organs to the natural, which has been of late years accomplisht with prodigious benefit to all sons of useful knowledge, by invention of Optical Glasses. By means of Telescopes there is nothing so far distant but may be represented to our view: and by the help of microscopes, there is nothing so small, as to escape our inquiry; hence there is a new visible world discovered to our understanding. … By this Earth it self, which lyes so neer us, under our feet, shews quite a new thing to us, and in every little particle of matter, we now behold almost as great a variety of creatures, as we were able to reckon up in the whole Universe it self.[44]

Enthusiasm for the microworld was shared by many of Hooke's contemporaries; his book was received very positively and was much sought after and difficult to acquire. Leibniz himself, as Catherine Wilson notes, tried persistently for years to obtain a copy, receiving one finally only in 1678.[45] Leibniz does, however, indicate in the 1669 letter to Thomasius, just cited, that he is familiar with some of its contents. "Putrefaction consists in little worms invisible to the naked eye," he writes to his former teacher, adding that "any putrid infection is an alteration of man, a generation of worm. Hooke shows similarly in his *Micrographia* that iron rust is a minute forest which has sprung up; to rust is therefore an alteration of iron but a generation of little bushes."[46]

At times, Leibniz seeks to diminish the importance of the microscope as a factor in the development of his ideas concerning the subvisible structure of physical reality, including his worlds-within-worlds doctrine. For instance, he claims at one point that the microscope did not discover for us anything we had not already known:

> Although the conservation of the animal is favored by the microscopes, nonetheless we were aware of small bodies before their discovery, and thus we were already very well able to foresee the small animals, as Democritus foresaw the imperceptible stars in the Milky Way before the discovery of the telescope.[47]

In Leibniz's animal-economical texts as well, treated in chapter 2, we do not find microscopy wielding any significant influence. In his work on medicine and animal economy, Leibniz seldom invokes the findings of microscopists such as Leeuwenhoek, Swammerdam, and others, with the same enthusiasm we see in his writings on what we have been calling "organics." Why would Leibniz consider the apparent composition of animal bodies out of smaller organic bodies relevant to the broader philosophical questions treated in these texts, but not to medicine and animal economy? It appears that the model of the animal as nested is one that Leibniz perceived as being of little use to the practice of medicine, to which his interest in animal economy always remained subservient. With respect to animal economy, the microscope was just one of many tools that might assist in coming to know the workings of the body better, alongside purgatives, scalpels, and flesh-eating acid.

Leibniz mentions the usefulness of convex lenses in the *De causis febrium* of 1704–05, which in spite of its late date is remarkably consistent with and similar to the animal-economical texts of twenty years prior. Here Leibniz recommends inspecting a fluid "either with the naked eye or by means of a convex lens."[48] Microscopes are useful, but if the naked eye will work just as well, then it should be preferred. In spite of this preference in animal economy for unaided observation, the majority of texts in which Leibniz mentions the device suggest a belief on his part that it is an important tool in the search for knowledge of the natural world. He often notes that the microscope is useful for getting at the reality behind the appearances of colors: "We do not discern the blue and the yellow that enter into the representation … in the composition of green, though the microscope makes us see that that which appears green is composed of yellow and blue parts."[49] And he writes in the *Discours touchant la méthode de la certitude et l'art d'inventer* (Discourse concerning the Method of Certainty and the Art of Invention), written between 1688 and 1690, that "microscopes make us see, in the least atom, a new world of innumerable creatures, which help us to come to know the structure of bodies."[50] It is only a few years later that Leibniz will announce, in a letter to Huygens, that he is much more impressed with "a Leeuwenhoek" than "a Descartes,"[51] that is, with someone who makes claims about how the world is after looking into its fine-grained structure rather than pronouncing that the world must be so and so on the basis of first principles.

Leibniz first looks through the lens of a microscope in 1676, thus some time after many of his core metaphysical principles have taken form. It has accordingly been assumed that, at most, microscopic discoveries might have served as empirical corroboration of doctrines such as that of nested individuality, at which Leibniz arrived, it is supposed, by means of strictly nonempirical reasoning. Prior to his visit to Leeuwenhoek in Holland in 1676, and before his acquisition of Hooke's work in 1678, Leibniz's acquaintance with microscopy was casual and secondhand. However, against Catherine Wilson's claim that Leibniz only acquired knowledge of Hooke's work in acquiring a copy of it in 1678, we have seen that Leibniz had already absorbed some of the content of the book by 1669 and, more importantly, that already in the late 1660s, as his metaphysical principles were still taking shape, Leibniz considered the evidence of microscopy—as presented, for instance, by the avid microscopist Kircher—to be useful and informative in philosophy. Looking at

(1) the citation from Hooke above, in which the microscopist describes the object of his study as "worlds within worlds," six years before Leibniz's first description of his antiatomist doctrine in these terms, and (2) at Leibniz's 1669 letter to Thomasius, in which the student indicates to his former master familiarity with the microscopic research of both Hooke and Kircher, and (3) at the transformation in Leibniz's later thought of the worlds-within-worlds doctrine into an explicitly microbiological thesis concerning the composition of macroorganisms out of worms or microorganisms, it seems plausible to suppose that the worlds-within-worlds doctrine, or the model of nested individuality, was inspired by microscopy from the very beginning.

Some authors have rejected as implausible the view that microscopy may have been part of the initial inspiration for Leibniz's model of organic bodies for the simple reason that Leibniz, as a philosopher, had to have been drawing his inspiration from, as Leibniz himself puts it, "higher principles." This conviction can at its worst lead commentators to muddle the historical facts about Leibniz's philosophical development and his knowledge of empirical science. Hans Poser, for example, correctly discerns evidence of the doctrine of worlds within worlds as early as the *De conditionibus* of 1665, and, more clearly, in the *De arte combinatoria* of 1666, "thus long before the discovery of microorganisms by Leeuwenhoek in 1672."[52] From this, Poser concludes that when Leibniz finally looked through a microscope in 1676, "it was for him a matter of empirical corroboration of a principle which for him had to be true on primarily metaphysical grounds."[53] But Poser is simply mistaken in his claim that microorganisms were unknown in 1665; it was only a particular *kind* of microorganism, the spermatozoon, that was discovered in 1672, seven years after Leibniz first considered some version of the worlds-within-worlds doctrine. As Hooke's *Micrographia* clearly reveals, the microworld was already at the center of scientific attention by the time of Leibniz's first formulation of the doctrine in 1665. Indeed, as we have already seen, Monconys reports of the presence of "an infinity of minute invisible insects" in the human body as early as 1647.[54] One of the people known to have influenced Leibniz very early on, Kircher, had already conducted decades of microscopic research and developed a theory of putrefaction involving invisible insects by 1658. In 1669, Leibniz expresses agreement with this theory, as well as indicating familiarity with Hooke's work. To suggest that Leibniz could have had no idea of the existence of microorganisms earlier than 1672 is simply wrong.

We have the positive conclusion that Leibniz's mature period is characterized by the appearance of explicitly biological terminology to describe the worlds-within-worlds doctrine as well as some evidence that Leibniz was interested in microscopy during his early, formative period. The explicit biological character of Leibniz's later thought, the emergence of this later thought directly out of the earlier thought, and the evidence of interest in biological nestedness and in microscopic creatures in the young Leibniz's writings together suffice as grounds to take seriously the hypothesis that microscopic discovery played an important role in the development of Leibniz's metaphysics of corporeal substance. Naturally, there were numerous factors influencing Leibniz's model of organic bodies, many of which had nothing to do with any of the empirical sciences. But there is evidence that microscopy was among these factors.

This evidence grows, moreover, as our knowledge of Leibniz's medical and natural-scientific manuscripts of the Paris period and earlier grows. One such manuscript, likely from the end of Leibniz's stay in Paris, gives a vivid account of his awareness of the nestedness of invisible creatures within visible ones:

> Tschirnhaus believed himself to be able to show that no animals are not from animals that do not arise from other animals. Fleas and lice of various sorts are produced in various animals; various animals are able to produce themselves, where no animals were before. Redi performed experiments, [and] if he had followed them through, he would have arrived at this. There are at length certain black spots in men's nostrils, and if they are pressed a sort of worm can be squeezed out of them, a larva, and this is confirmed by the example of pediculosis,[55] but these perhaps demonstrate as much. Visible animals often arise from invisible ones that make the air full, from undetectable spiders [come] these webs that fly through the air, which are called vulgarly *Mariengarn* ["Mary's thread"].[56]

In all probability, this text was jotted down prior to Leibniz's visit to Leeuwenhoek in Delft in 1676. But the sort of discoveries that the microscopists were making were already, like so many Mary's threads, floating in the air, and it is not at all surprising that Leibniz took notice of them.

The Specter of Parthenogenesis

Leibniz notices something close to parthenogenesis, or reproduction by budding, in a curious letter to Arnauld of 1687: "I dare not maintain that plants have no souls, nor life, nor any substantial form: since, although one part of a tree planted or grafted can produce a tree of the same kind, it is possible that there is in it a seminal part which already contains a new plant."[57] Yet he strictly denies that animals can reproduce by splitting in the same way that plants can on the grounds that animals have a complicated structure, such that not every part may be said to contain the principles required for the formation of the whole: "A twig of the plant is often capable of producing a new and complete plant, for which we see no analogy in the animals: thus we cannot say that the foot of an animal is an animal, in the way that it seems that each branch of a tree is a plant capable of flourishing on its own."[58]

Unbeknownst to Leibniz, however, Leeuwenhoek would fully accept the reproduction of animals through splitting. The Dutch microscropist describes this process in minute detail in a letter of December 1702, recounting his experiments of several decades earlier:

> [I saw] an animalcule coming out of the first animalcule, and when heretofore I saw such an animalcule attached to a larger one, I thought that a younger animalcule was attached accidentally to a larger one, but on closer observation I saw that it was a generation, for I observed that, while the last-mentioned animalcule, when first I saw it was an animalcule, had only four very small, short tentacles, after sixteen hours the animalcule had grown as to the size of its body and tentacles, and after four hours more I saw that it had left its mother's body.[59]

As we have seen above, in response to a question from Arnauld concerning the division of insects, Leibniz seems skeptical of the suggestion that both parts remain truly living. While Leibniz here passes up the opportunity to turn the question of parthenogenesis into one of philosophical significance, this passage is certainly interesting in that it indicates the widespread observation of division in the animal world prior to the eighteenth century, favoring the view that there was a long heritage of parthenogenetic experimentation, against the widespread argument that parthenogenesis went more or less unacknowledged prior to the eighteenth century.[60] It is at least true that parthenogenesis did not become the source of widespread philosophical speculation until the 1740s. It was Abraham Trembley, with his announcement of the discovery of reproduction by division in polyps, in May 1741, who brought parthenogenesis to the center of the scientific community's attention.[61] Having chopped a polyp into several small pieces, grafted bits of polyp onto other bits, and even turned what looked to be a whole polyp inside out, so that what was thought to be the creature's stomach quickly became its epidermis, Trembley reasonably concluded that there could be no sense in speaking of polyps as fixed, enduring, organized individuals.[62]

A short time after the freshwater polyp had become a common touchstone of natural science, the French naturalist and germ theorist Charles Bonnet wrote in his *Considérations sur les corps organisés* of 1762 (unaware, of course, of what Leibniz had written in the correspondence with Arnauld) that "the metaphysics of this great man [Leibniz] led him to suspect the existence of such a being as the polyp."[63] Bonnet would hypothesize that "the polyp's body is, so to speak, constituted by the repetition of an infinity of small Polyps, who are only waiting for favorable circumstances in order to come to the light of day."[64]

By the time Bonnet wrote this, the biologist and natural philosopher Pierre-Louis Moreau de Maupertuis had already appropriated the term "monad" and turned it into a physical atom endowed with a "perception élémentaire."[65] Within a few more years, in 1773, Müller would give the genus name *Monas* to a number of newly discovered species of infusorium.[66] And throughout the first half of the nineteenth century, C. G. Ehrenberg and other microbiologists introduced to the world a number of new *Monas* genera and species, including the *Cryptomonas* or *Panzermonade*, and the elusive *Monas minima*.[67] Ehrenberg revealingly describes members of the genus as "point-animals [*Punktthierchen*],"[68] while Müller defines "monad" in his work as a "Corpus punctiforme."[69] And of course no survey of the eighteenth-century physicalization of the monad would be complete without a mention of Kant's 1756 work, *Monadologia physica*. This title is striking, but as we are seeing here Kant was by no means alone in conceiving monads in this way. In the decades following Leibniz's death, monads were broadly reconceived after the model of the infinity of small polyps that made parthenogenesis possible. They had become living and physical building blocks of the natural world.

According to the canonical view of Leibniz's philosophy today, all these eighteenth-century thinkers would seem to have missed the point: the monad was meant to be an atom of substance, a metaphysical simple endowed with nothing but perception, and certainly not a tiny speck of living matter or a punctiform body. It was with this in mind that Jacques Roger wrote that "in general, the eighteenth century,"—by which Roger meant principally eighteenth-century natural scientists—"understood Leibniz's metaphysics poorly."[70] To be sure, physical monadologists entirely abandoned the distinction that Leibniz considered so crucial between "atoms of substance" on the one hand, from which bodies *result* but not from which bodies are *built*, and physical atoms on the other. Yet Bonnet does seem right to say that parthenogenesis may be seen as a sort of confirmation of Leibniz's model of organic body. For what else is the small polyp awaiting "favorable circumstances in order to come to the light of day," as Trembley writes, but a nested individual that, as a result of its currently being dominated by the principle of activity of the polyp of which it is an element, has yet to be fully activated?

The tremendous difference between the parthenogenetic model of organic body and Leibniz's model is that the polyp, as conceived in the eighteenth century, is not in any sense a unified corporeal substance. Leibniz can thus be seen as representing a halfway point between a certain widespread premodern conception of biological entities, which sought to give an account of the entity's unity or soul-based properties while by and large ignoring its microphysical make-up, and the modern conception, which would come to see the microphysical make-up as *all there is* to an animal, as the only feature of a living being that differentiates it from nonliving entities, while its unity would come to be seen as nothing more than a temporary, contingent supervenience upon the physical make-up. In this sense, we may say that Leibniz's theory, focusing as it does on unity and on microstructure, straddles the boundary between the old metaphysical picture of animals and the modern biological picture that emerged out of it.

By the mid-eighteenth century, a strict materialism would come to dominate, particularly in France but also to no small extent elsewhere in Europe, in the philosophical discussion of what a living being is. On this view, espoused in its most radical form by Julien Offray de La Mettrie in his *L'homme-machine* (1747), Claude Adrien Helvétius (the grandson of the discoverer of ipecac, discussed in chapter 1) in his *De l'esprit* (1758), Paul Henri d'Holbach in his *Système de la nature* (1770), or Denis Diderot in *Eléments de physiologie* (1784), animals, including humans, would come to be seen as mere clumpings of matter that, for a limited time, through a fortuitous arrangement of their parts, come to develop the capacity for sensation and motion, and, in some few cases, for self-awareness. On this materialist picture, there is no room for an ontological distinction between real, existent entities and phenomenal semi-entities. Leibniz's insistence on a soul-based principle of unity for the explanation of all organized, living matter, rather than taking spirit itself as a supervenient property of organized matter, would come to be viewed by materialists such as La Mettrie as unjustifiable speculation.[71] The living being would come for many in the eighteenth century to have no more reality than the reality of its parts. In other words, in Leibniz's terms, living beings would come to be seen in the eighteenth century as aggregates, or, in Robert Sleigh's terms, as divisible rather than just component-wise deconstructible.

Diderot explains in his *Eléments de physiologie of* 1784 that life consists in an arrangement of organs. Insofar as the organs can be separated from one another and, in some cases, continue living, whatever there is in the animal that might be called a "soul" is not indivisible. He asks, if "life remains in the organs separated from the body; where then is the soul? What becomes of its unity, its indivisibility?"[72] Insofar as ensouledness is for Diderot just the temporary capacity for motion and sensation, any division of an animal body that results in the deprivation of this capacity to one or both of the parts of the body constitutes an empirical demonstration of the possibility of the separation of the body from the soul. "A ligature of the nerves impedes all sensation, all movement," he writes, "a ligature can thus separate the soul from the body."[73]

In his 1784 work Diderot goes so far as to describe all animal reproduction as consisting in the division of one organ from another, as the passing on of life or ensouledness from one bit of living matter to another. This communication of life does not result in the coming into being of a new individual. For Diderot, generation consists in the rearrangement of matter, and, eventually, in the physical separation of this matter from the more massive source matter. He explains that "the generation of parts occurs little by little, and not suddenly, through the arrangement of parts, and not by development."[74] While in an earlier treatise Diderot had joked about humans reproducing by parthenogenesis, he later suggests that sexual generation may be nothing more than the separation of a quantity of living matter from another quantity. He writes that he is "tempted to assimilate the generation of man to that of the polyp that reproduces by means of division. The union of the man and the woman only gives rise to the production or the development of a new organ."[75]

For Leibniz, as we have seen, even if both halves of a bisected corporeal substance go on living, the corporeal substance itself has not been divided. It survives in only one of the halves, while the other half falls under the domination of a new, previously subordinate substantial form. Without germs or dominant monads, there is no question as to which half of a bisected worm or polyp (or human) remains the same creature that the whole had been prior to the bisection. On Diderot's interpretation of parthenogenesis, the whole prior to division was not really a whole at all, but rather, in Leibnizian terms, an aggregate. On this view, the whole animal functions as one, but has no more real unity than a team whose members may quit at any time. When a member quits, for example, or when a fetus separates from its mother, or when a bit of a worm is cut off from the rest of the worm, there is no question for Diderot as to which bit of living matter retains the soul, for soul is for him nothing more than the capacity of matter for sensation and motion. The presence of soul in living matter does not elevate this matter to the status of substance, as it does in Leibniz's corporeal-substance metaphysics. There is for Diderot no basis in an incorporeal principle for determining to what substance some bit of living matter belongs. Thus, for him, there is no better answer to the question, "which part of the bisected worm is the worm that was here prior to the bisection?" than to the question "which chunk of the cleaved block of marble is the block of marble that was here prior to its cleavage?"

Monads, Cells, and Worms

In the eighteenth century, then, Leibniz's monads become assimilated to microorganisms. But were microorganisms involved in his original invention of them? In the same measured tone earlier employed by Jacques Roger, Catherine Wilson has suggested that "we need to see the monads as to some extent modelled after the animalcula—they have perception and appetition, and can exist at very low degrees of awareness and general competence."[76] Wilson thinks that there are important differences between the middle-period metaphysics, in which Leibniz thought of all objects as aggregates of animalcules,[77] and the later metaphysics, in which Leibniz thought of objects encountered "in" space as "the representations of perceivers, each of whom experiences its own "world" as a more or less adequate version of the world perceived by God."[78] Yet, she notes, throughout the most mature, immaterialist period, Leibniz repeatedly falls back on a stock image of the world as akin to "a garden full of plants" or a "pond full of fish":

> Leibniz did not want to give that fish-pond, the most arresting image of the whole *Monadology*, up, and who can blame him? That it was apparently irreconcilable with his immaterial atomism troubles his modern commentators; Leibniz himself seemed to combine a confidence that his two systems really did converge with an anxiety about the details required to work this convergence out.[79]

One may agree with Wilson while nonetheless clarifying that the monads themselves, for Leibniz, are by no means basic building blocks in the way that cells are today held to be the building blocks of organisms. Leibniz's animalcula or worms were not conceived on the model of cells but rather as organic bodies with no lower limit to their composition, like a worm that might be split into infinitely many worms. Rather than holding that the monads can be seen to some extent as modeled after the animalcula, we might do better to say that it is the organic bodies of corporeal substances that are modeled after animalcula. Leibniz's central concern in developing his model of organic bodies, is to argue that any appearance of discreteness or self-containedness in a biological entity is only an appearance. The monad is unlike the animalcule to the extent that it is a truly simple and self-contained unity. The animalcule, in turn, is like the organic body in that neither is at all self-contained but both are always composed out of other organic bodies. As we have seen, the model of "animalcule" from which Leibniz draws inspiration is decidedly not that of a basic-level, cell-like organism. It is a "worm," which Leibniz seems to conceive, at least from the Arnauld correspondence on, as capable of surviving bisection, which is to say, in the terms of Leibnizian metaphysics, as capable of allowing this or that previously subordinate monad to rise to predominance as a result of changes in the structure of the organic body.

What is characteristic of the corporeal-substance metaphysics is not that Leibniz thinks of complex entities as being constituted out of a number of basic, cell-like, not-further-decomposable entities. Rather, Leibniz believes, along with many of the microscopists, that there is nothing fundamental or bottom-level about microorganisms at all. The lesson that enhanced perception taught was, first and foremost, a humbling one: one must never presume that one has arrived at the bottom level. An animalcule, like a horse or a man, is composed out of other animalcula, which are themselves composed out of other animalcula, and so on without end. When monads are introduced, in contrast, this is in large part so that there may be a lower limit to the analysis of things, even if this limit is immaterial rather than atomic in the traditional sense. The animalcula, then, are never basic, whereas the monads are so by definition.

The picture of bodily matter as lacking any basic building blocks is buttressed, rather than contradicted, by the subvisible world of animalcules described by the microscopists. Certainly, it is easy for us, today, to think that the opposite picture of matter would be inspired by such a discovery, in view of our common knowledge that there is a basic unit that constitutes living beings, namely, the cell. Yet it would be another century and a half before the cell would be isolated as the basic unit of the living being.[80] In the mid-seventeenth century, the astonishing implication of the microscope was that living nature seemed to lack a bottom limit in its composition. What had once been thought of as small and simple, the worms and insects visible to the naked eye, turned out to be, on closer inspection, fully outfitted with complex organs that function just as ours do. Any lower limit one might impose is only a result of the contingent fact that our optical organs are capable of detecting things only within a certain range of sizes. If the range were different, our conception of what is small, and our estimation of roughly how small the smallest living entities are, would also be different.

Why, then, is it hard to break free of the anachronistic idea that with his monads Leibniz had something like animalcula in mind, and with his animalcula, something like cells? Here, as perhaps elsewhere, we remain under the spell of earlier generations' agenda-laden readings of Leibniz. As Georges Canguilhem has observed, and indeed as we have already seen, by the end of the eighteenth century, "the term *monad* was frequently employed to designate the supposed [basic] element of the organism."[81] Leibniz could not have had anything like the cell in mind when he introduced the concept of monad at the beginning of his mature-period metaphysics any more than when he took an initial interest in microscopy, around 1669. It is true that Hooke speaks of "cells" in his influential *Micrographia*, but what he has in mind are empty spaces or pockets in certain materials he examined; thus for Hooke a "cell" is literally akin to the monk's small living space in a monastery from which it derives its name. When Leibniz appears to shift from talk of animalcules to talk of monads, this is not, as Wilson has described it, "a continuation of policy by other means."[82] Rather, the animalcule is never, for Leibniz, a basic building-block entity; it is always further divided into subordinate constituents. The monad, in contrast, is always a basic building-block entity, even if the bodies of corporeal substances are not literally built from them but rather result from them. Animalcules are infinitely divided and lack, qua organic bodies, any rock-bottom principles of their own; monads are simple and immaterial and yet are themselves the rock-bottom principles from which organic, animalcular bodies, indeed all bodies, result.

Leibniz, as we have seen, continues throughout his late period to speak of worms and other such animals, and these are never in competition with the monads that are supposed to come and replace them and to partially continue their middle-period work "by other means." Rather, these worms are the organic bodies of corporeal substances or "animals," and they are infinitely divisible (or, more precisely, deconstructible in Sleigh's sense) rather than being basic building blocks. Considered apart from the corporeal substance with which they are united, they are an infinite aggregate of smaller organic bodies; considered as a corporeal substance, they are an infinite union of dominated and dominating corporeal substances. In the end, corporeal substances are but the result of the primitive active and passive forces of monads, but it is for the infinitely deconstructible organic bodies of these corporeal substances that the animalcula or worms may be said to serve as an inspiration, and not for the monads that in the end underlie these bodies. Leibniz writes to Malebranche as early as 1679:

> There is even room to fear that there are no elements at all, everything being effectively divided to infinity in organic bodies. For if these microscopic animals are in turn composed of animals or plants or other heterogeneous bodies, and so on to infinity, it is apparent, that there would not be any elements.[83]

This letter is a harbinger of things to come, and indeed an early outlier of a line of explanation that fifteen or so years later Leibniz would begin to repeat with increasing frequency and with increasing explicitness as to the biological nature of the beings implicated in the constitution of larger organic bodies.

To return to the question with which we began this chapter, then, we may now be in a better position to answer the question: why the infinite nestedness? We may agree with Roger that Leibniz's theory of organic body is motivated by a desire to take account of the real. But we still must ask, why does "the real" come out looking precisely like *that*? The answer seems to have much to do with the state of microscopical and anatomical research in the scientific context out of which Leibniz's philosophy emerged.

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PART THREE

The Origins of Organic Form

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Chapter Five

THE DIVINE PREFORMATION OF ORGANIC BODIES

In chapter 3 we saw how Leibniz manages to account for the growth, development, and motion of animals by appealing to "material plastic natures" alone. Nevertheless, the question of the original formation of plants and animals, and other animal-like corporeal substances, remains. Ralph Cudworth had resorted to the doctrine of immaterial plastic natures because he had assumed that organic bodies did not exist prior to embryogenesis. Something therefore had to be introduced initially in order to bring living beings into existence. In this, Leibniz likens Cudworth's doctrine to that of those who believe that it is the soul that is responsible for making its own body: "I have no need to resort, as does Cudworth, to certain immaterial plastic natures, though I recall that Julius Scaliger and other Peripatetics, as well as certain adherents of van Helmont's doctrine of the archaeus believed that the soul makes its own body."[1] The soul does not make the body, for Leibniz, because the body is always already there. But how could Leibniz have believed such an improbable thing? And to what extent is this belief rooted in his interest in the science of animal generation?

It is clear that as early as the period of his major animal-economical texts, considered in chapter 2, Leibniz had developed an intense interest in the technical and empirical science of generation, quite apart from his emerging a priori commitments to the ungenerability of corporeal substances. Thus he writes to Gunther Schelhammer in December 1680, on the difficult problem of the causal relationship between intercourse and conception:

> Concerning the … seminal matter, it is to be investigated whether this is equally necessary to the generation of animals. Certainly, that the [seminal] matter in the testes is generally necessary is apparent from the example of eunuchs. Of the matter that comes from the prostate there is room for doubt. And truly the problem of highest importance of all in this argument is to discover why at times conception should occur, and at other times coitus should turn out to be in vain. That is, what are the true requisites of conception?[2]

In this correspondence Leibniz is interested not just in human conception but in reproduction across the animal kingdom. Thus in the letter just cited he goes on to ask "whether dogs that have been deprived of their spleen are sterile," and in a letter from September of the same year he notes that he has read "with much delight" those things that Schelhammer relates "concerning the genitals of moles [*talpae*]."[3] "Lower" animals with newly discovered genitals were important for empirical refutation of the view that such kinds generate only spontaneously, while eunuchs were important as a comparison class with "normal" men in the effort to understand what the requisites of conception are. But these empirical questions would give rise to other, more properly philosophical ones. For example, what is it in the fluids in ordinary cases of sexual reproduction that is imbued with the power of generation? What, moreover is the nature of this power? Does the fluid conceal some primordium that would reveal that what we call generation is not generation at all, but only, as Leibniz would put it, an entry into "the larger theater"?[4] In this chapter we will consider Leibniz's contribution to generation theory in its philosophical context as a central problem of natural philosophy as well as in the context of seventeenth-century empirical research.[5]

From Approximation of Eternity to Eternal Existence

In much of the popular literature on childbirth and midwifery from the late Middle Ages into the seventeenth century, a caricatured version of Aristotle's view of sexual reproduction as an "approximation of eternity" had become a commonplace. Apocryphal treatises "de secretis mulierum" and their vulgate translations proliferated throughout the thirteenth and fourteenth centuries and were attributed variously to Aristotle or to his medieval commentator, the philosopher and zoologist Albertus Magnus.[6] One late-coming contribution to this genre was that of François Mauriceau, who in the years between Descartes' mechanical epigenesis and Leibniz's preformation theory, wrote for a broad audience of surgeons, midwives, and other curious readers:

> It is a very great truth, and one recognized by all of us, that everything that is in this low world is subject to corruption, and in the end is constrained to suffer death. This is what obliged nature, provident and concerned for its own conservation, to give to each creature a certain desire to make itself eternal, which, not being able to be done in the individual, insofar as he is mortal, is done by an indispensable necessity through the propagation of forms and species.[7]

Although directed at a popular audience, Mauriceau's account of sexual reproduction well epitomizes the predominant premodern account of embryogenesis, according to which this process is governed by an immaterial principle of development that realizes form in matter to the extent possible or appropriate for a given kind of creature. This is a view that would continue to be defended explicitly by sophisticated theorists well into the seventeenth century, and that, as we will see, would continue to implicitly guide the accounts of embryogenesis of theorists who directed much of their energy toward denying the need for such an immaterial principle.

One seventeenth-century theorist who continued to explicitly defend such an account was William Harvey, the English Aristotelian and former student of the Padua school of medicine. For him, as he explains in the *De conceptione*, published as an appendix to the 1651 *Exercitationes de generatione animalium*,[8] the homonymy between biological and cognitive "conception" is more than just homonymy; he argues that what occurs in the uterus at conception is literally the same thing that happens when an idea is had in the brain.[9] Once the idea is formed in utero, it is then fashioned with the available material—the menstrual blood—into a creature resembling its progenitors. While the environment may play a role in the acquisition of particular traits, it does not have to, on Harvey's understanding, in order for the conceived offspring to come out more or less like its parents, since its development is guided ab initio by an idea of its parents' traits. Insofar as Harvey is able to rely on an internal, immaterial principle guiding the fetus toward a particular end, namely, that of being a particular sort of creature with particular traits, he is under no pressure to postulate external, efficient causes to account for species reproduction and trait acquisition. Harvey maintains that there is nothing corporeal left in the uterus after coition, and infers from this that fertilization must consist in the activation of an incorporeal principle of development. Thus, while justifying his position in terms of empirical evidence, Harvey remains faithful to a premodern conception of sexual generation.

Accounts of fetal development as an end- or idea-driven process were doomed to fall into disfavor in the seventeenth century. However, it would prove much harder to eradicate immaterial, guiding principles of development from embryological explanation than many modern thinkers would have liked. This is because, as the example of Harvey makes very clear, such principles would continue to appear indispensable in the explanation of organic phenomena long after physics, the study of inorganic bodies, had proved, for many, perfectly able to do without them. Leibniz, rather than deviating from his mechanist convictions and reintroducing plastic natures or some other immaterial principle of development, takes a different tack: for him, as for Malebranche, there can be no mechanical explanation of the coming-into-being of animals, yet both philosophers also believe that animal bodies can be explained in terms of mechanical causes to no less an extent than other entities in nature. There is no contradiction between the universality of mechanism, on the one hand, and the nonmechanicity of generation on the other, in Leibniz's view, insofar as animals are never generated at all, but have preexisted since the creation:

> Animals never having been formed naturally from an inorganic mass, mechanism is incapable of producing these infinitely varied organs anew, though it can take them by means of development and transformation from a preexisting organic body.[10]

Indeed, Leibniz is so committed to mechanism that he takes the evident impossibility of a mechanistic explanation of the generation of animals not as a refutation of mechanism, but, on the contrary, as strong evidence for the view that generation must not actually occur. It is only insofar as corporeal substances are never formed at all that Leibniz is able to agree with Cudworth that corporeal substances such as animals cannot be formed mechanically while maintaining nonetheless that whatever happens, happens mechanically:

> Plants and animals ... are never formed entirely anew. I am thus of the opinion of Mister Cudworth (whose excellent work for the most part pleases me very much) that the laws of mechanism alone would not be able to form an animal where there was nothing already organized; and I find that he is correct in opposing that which some of the ancients have imagined in this matter, and even what Monsieur des Cartes has imagined with his man, the generation of whom costs so little, but who resembles so little a true man.

In other words, what Descartes' embryology succeeds in accounting for is at best a mere machine, not a divine or natural machine, let alone an ensouled corporeal substance. Leibniz continues:

> And I strengthen this opinion of Mr. Cudworth in that I consider that matter, arranged by a divine wisdom, must be essentially organized throughout and thus that there are machines in the least parts of the machine to infinity.[11]

Leibniz's careful choice of words reveals the deep interconnection of his theory of organic body and his commitment to preformation: as against Descartes, mechanical laws alone could never account for the origins of a new natural being; yet, as against Cudworth, Leibniz wishes for his account to remain broadly compatible with traditional mechanism, so rather than invoking a force or principle in matter capable of bringing new organization into being where before it did not exist, instead Leibniz argues that it is simply of the nature of organic body to have no origin in time (other than at the Creation).

In his *Considerations on Vital Principles and Plastic Natures*, Leibniz remarks that he neither needs Cudworth's immaterial plastic natures, nor do they fulfill his needs since, as we have already seen, "this preformation and this infinitely complex organism" will do the job just as well. The material plastic nature consists for Leibniz in the organic body alone, which is infinitely complex. Because it is infinitely complex, no process of decomposition may ever take it out of existence, nor bring it into existence. It follows from this, Leibniz believes, that the organically embodied creature must always have existed, unless it was created miraculously directly by God, an intervention Leibniz refuses to invoke for the explanation of nature's ordinary operation. Since no organically embodied creature ever comes into existence, we do not need to appeal to plastic natures to account for coming-into-existence. He explains:

> I believe that not merely the soul but the whole animal subsists. Very exact observers have noted before now that it is doubtful that an entirely new animal is ever produced but that living animals as well as plants already exist in miniature in the seeds before conception. Assuming this doctrine to be true, we may reasonably conclude that what does not begin to live does not stop living either and that death, like generation, is only the transformation of the same animal, which is sometimes augmented and sometimes diminished. Thus, we discover the marvels of divine artifice even where they have never been thought of. For since the mechanisms of nature are mechanisms down to their smallest parts, they are indestructible, since smaller machines are enfolded in greater machines to infinity. Thus one finds oneself forced to maintain, at the same time, both the pre-existence of the soul with that of the animal and also the subsistence of the animal with that of the soul.[12]

While what Leibniz is emphasizing is the preexistence of the whole substantial animal, it is a necessary condition of such preexistence that there be an accompanying preformed organic body that is by definition infinitely complex, as we already saw in chapter 3, and therefore undecomposable. No sequence of cuts can bring it out of existence, and by the same token no sequence of juxtaposition of parts can bring it into existence. Thus the whole animal is not only component-wise deconstructible and substance-wise indivisible; it is also—to introduce two more cumbersome neologisms—component-wise supplementable and substance-wise ungenerable. Leibniz frequently emphasizes that it would go beyond the limits of the possibilities of mechanism to propose that an organic body could ever come into being where there was not one before: "The mechanism, incapable of producing *de novo* these infinitely diverse organs, can very well attain them from the development and transformation of a preexisting organic body."[13] In sum, Leibniz saves his own mechanism by opting for a preformationist account of generation.

Before proceeding any further it will be useful to make a terminological clarification, one that sets the present study at odds with recent scholarship. Preformation theory, as it is understood here, is the view that development consists merely in the expansion or unfolding of structures that exist prior to conception. Epigenesis, in contrast, holds that the development of the fetus proceeds through increasingly complex structures. Epigenesis has triumphed in modern developmental biology since the zygote is undifferentiated, and different types of cells, those of nerves, muscles, and such, develop only gradually as a result of conception. The debate between the epigenesists and preformationists became the central problem of embryology in the early modern period, at the moment when preformation gained new plausibility as a result of microscopic research on the primordia of living beings.

Most scholars, following the groundbreaking studies by Jacques Roger and Peter Bowler,[14] followed by the influential work of Andrew Pyle,[15] make a further conceptual distinction between *preformation* and *preexistence* theory. Only the latter view for these authors has it that all creatures must exist since the creation, *and* that generation is only the unfolding of what has always already existed. Preformation, in contrast, for them holds that the fetus is formed before conception at some particular time, but not necessarily by God, and perhaps even by some natural means.

Leibniz's theory involves not just some preexisting entity or other, but an entity with a particular organic *form*—at least in the mechanized sense of this notion in which Leibniz often understands it, as synonymous with "figure" or "structure"—and to speak of preformation rather than preexistence brings out more accurately this feature of Leibniz's theory. Preexistence, in contrast, could in principle describe a belief in disembodied souls in some "baby heaven" awaiting their descent into a bodily life at conception, a possibility that Leibniz is very concerned to rule out. François Duchesneau has rightly emphasized that what exactly it is that is preformed is a difficult question to answer, since, as we will see later in this chapter, Leibniz repeatedly emphasizes that a tremendous change, or metamorphosis, is required to bring the creature from its preexisting state into the larger theater. But there is one thing about which Leibniz could not be any clearer: there is no coming-into-being of creatures, and every creature always exists in an organically embodied form, supernaturally brought into being simultaneously with the rest of creation. The term that Leibniz uses to describe this view is "preformation" (or, more precisely, "divine preformation"), and not either preformation*ism* or preexistence. We shall follow Leibniz's usage here, in full recognition that it deviates from the distinction later made by Roger and Bowler.

Toward the end of the seventeenth century, preformation in one version or another enjoyed much greater currency than the opposing view, only to decline rather swiftly in the eighteenth century in the wake of the debates between Caspar Friedrich Wolff and Albrecht von Haller.[16] The popularity of the preformationist view in this period, whether "ovist" or "animalculist," was motivated not only by the evident limits of mechanical epigenesis but also by the century's discovery of subvisible organisms that might appear as promising candidates for the role of primordia.

Leibniz's preformation theory provides a model of animal bodies as machines, but these are a very peculiar sort of machines, to the extent that there is no possibility of manufacturing them. This is a distinction that makes an ontological difference. Descartes seems to have well understood as much and to have seen the success of his theory of the animal-machine as hanging upon his ability to successfully account for the origins of animals "in the same style as the rest, namely, by demonstrating effects from causes."[17] He could not provide such an account, and for precisely this reason, in retrospect, Descartes' embryology appears wildly speculative and ungrounded. Yet Descartes had believed that his own epigenetic account of embryogenesis through thermomechanical causes must be true for deep philosophical reasons, even if its details remained to be worked out.

The failures of early mechanists such as Descartes to provide such an account were often derided, and conception and embryogenesis were often explicitly cited, by later seventeenth-century philosophers who wished to reintroduce plastic natures, archaeus, formative virtues, and such, to account for the phenomena of conception and development. An amusing example of such a view of mechanist generation theory comes from John Ray, who writes in his *Wisdom of God Manifested in the Works of His Creation* of 1691, that generation

> is so admirable and unaccountable, that neither the Atheists nor Mechanick Philosophers have attempted to declare the manner and process of it; but have (as I noted before) very cautiously and prudently broke off their Systems of Natural Philosophy here, and left this Point untoucht; and those Accounts which some of them have attempted to give of the Formation of a few of the Parts, are so excessively absurd and ridiculous, that they need no other Confutation than *ha, ha, he*.[18]

Leibniz's doctrine of preformation might perhaps be seen as just such a prudent breaking off, though denial that true generation occurs is something very different from simple neglect of it. To replace generation with development and unfolding is, in a certain sense, to address "the manner and process of it." Nor could Leibniz be accused, though he remains a "Mechanick Philosopher," of offering an excessively speculative account. For, though he often claims that his account of generation is derived from a priori principles, Leibniz never hesitates to draw upon empirical evidence that he takes to corroborate his views.

"Seeing" versus "Thinking" in the Search for the Primordia of Life

Let us recall Leibniz's declaration, previously cited, of his preference for "a Leeuwenhoek" who tells him what he sees, over "a Cartesian" who tells him what he thinks. We might approach Leibniz's engagement with generation theory and its place within his philosophy as a whole by asking whether he comes to hold the theory he does as a result of "seeing" or "thinking." That is, we might ask whether Leibniz's generation theory is relatively more Leeuwenhoekian than Cartesian, or the reverse.

Views have changed over the course of Leibniz's reception history as to the relationship between empiricism and a priori commitments in Leibniz's generation theory.[19] In a curious polemical work dating from 1741, *Eine bescheidene Prüfung der Meinung von der Præexistentz oder dem Vorherseyn menschlicher Seelen in organischen Leibern* (A Conclusive Examination of the Opinion concerning the Preexistence of Human Souls in Organic Bodies), Johann Friedrich Bertram insists "that the proposed preexistence of human souls in organic bodies is nothing but a whimsically adopted poem."[20] He wonders:

> Why were so many millions of souls created so incredibly long ago by the Creator, without any purpose. … Were they all ready to be brought forth at the beginning of the world? … Did there not occur in the meantime a great drifting of the souls? Did not some wind blow them to and fro, some foot press them into the mud, some mouth grind them with its teeth, and was not a great, uncountable mass of human and cattle bodies consumed with food and drink? … Not to mention other enormous absurdities.[21]

Indeed, put in these terms preformation does seem rather absurd. Who could have been responsible for the promulgation of such a fairy tale in the modern era? Bertram thinks he knows: "The person who helped this opinion onto its feet … is the famous Herr von Leibniz, a man who is known well enough both for his broad erudition as well as for all sorts of peculiar and extravagant ideas."[22] Most peculiar and extravagant from Bertram's point of view is not the view that souls preexist, but rather that they exist in organic bodies; for him, Leibniz's theory of divine preformation is most offensive because it denies "the *immaterial* nature of our souls," and holds instead that the soul "is connected with a small, eel-shaped body [*Ahl-förmigen Cörper*]."[23]

Bertram is somewhat forgiving, identifying the source of Leibniz's absurd belief not in Leibniz's imagination alone but in the imagination of one of Leibniz's contemporaries:

> But (as we recall in the aim of excusing him) Herr von Leibniz would never have come to the fantastic concepts of his monads and little spirits, if the famous Leeuwenhoek in Holland hadn't discovered such strange things with the microscopes he invented.[24]

From this polemical work we see again that by looking to Leibniz's immediate successors, a picture of Leibniz emerges on which his philosophical views are forged out of direct engagement with empirical life science. It is certainly an exaggeration to say that Leibniz never would have come to his preformationism had he not encountered Leeuwenhoek. Yet the particular form that Leibniz's theory of divine preformation took is one that likely would not have been possible prior to the emergence of microscopic science.

As has been emphasized already, the relative successes of the emergence of mechanical natural philosophy look very different depending on whether one is considering the physical sciences or, instead, what would later come to be grouped together as the life sciences. Perhaps the most problematic subdomain of all the life sciences is generation theory, or the effort to account for the coming into being of new living beings. Indeed, with respect to the problems of generation theory, in an important sense the Aristotelians possessed much more powerful conceptual tools. As Mauriceau's late echo of their account attests, sexual reproduction fit perfectly into a broader cosmological scheme in which form and matter play their respective roles, and in which male and female reproductive principles are but instances of these all-encompassing roles. However, notwithstanding the empirical work of Galen (on the reproductive tracts of Barbary apes, rather than humans), for the most part ancient generation theory was based on "thinking" rather than "seeing." Indeed, until Harvey performed his methodical autopsies of deer in various stages of pregnancy, no one had directly, systematically observed the process of mammalian embryogenesis. For the first time in the latter half of the seventeenth century, then, it became necessary to make the thinking and the seeing that constituted generation theory match up. It is clear that as a result of the new possibility of coordinating thinking and seeing, many had begun to feel that new empirical discoveries had advanced generation theory beyond its earlier guesswork. Thus George Garden writes in the *Philosophical Transactions* of January 1691, on the subject of the generation of animals that "Mens Conjectures were … wide and unsatisfying upon this Head until this Age."[25]

Leibniz would certainly reject Bertram's claim that not only his theory of preformed organic bodies but also his theory of monads owes its origins to the discoveries of Leeuwenhoek. Leibniz explicitly claims on more than one occasion that his commitment to the doctrine of preformation comes not from any particular microscopical discovery, but from a decidedly philosophical source. As he explains to Burchard De Volder in a letter of June 20, 1703: "No entelechy ever lacks an organic body. As far as my consideration of these matters goes, things could not be otherwise; they are not derived from our ignorance of the formation of fetuses, but from higher principles."[26] He will later claim in the *Monadology* that his a posteriori reasonings about the eternal existence of organic bodies, which are "derived from experience," nonetheless "agree perfectly with my principles deduced *a priori*."[27] In other words, Leibniz is fully confident, or at least claims to be fully confident, that he would have come to believe in the doctrine of preformation no matter what the state of empirical science in his lifetime. Indeed, in an intriguing undated fragment published in the *Otium hanoveranum*, Leibniz criticizes Harvey for assuming that conception must result from a "spiritual radiation" simply because he was unable experimentally to determine the locus of it. Harvey cannot discover where conception occurs, Leibniz thinks, "because this [the process of conception itself] is disturbed by dissection. Whence, having discovered nothing, he imagined to himself that it occurs through spiritual radiation."[28] For Leibniz, the limitations on human intervention in the process of generation must not in themselves dictate what is to be deemed the superior theory of generation. Far from acknowledging that his own preformation has empirical roots, Leibniz criticizes epigenesis for allowing the circumstances of empirical investigation to be brought to bear in the theoretical account of conception.

This confidence may be seen as flowing from Leibniz's commitment to a version of the doctrine of *rationes seminales*, or seminal reasons. As Augustine explains this ancient doctrine:

> The being that thus appears has already been wholly created in the texture as it were of the material elements, but only emerges when the opportunity presents itself. For as mothers are pregnant with unborn offspring, so the world itself is pregnant with the causes of unborn beings, which are not created in it except from that highest essence, where nothing is either born or dies, begins to be or ceases to be.[29]

Leibniz describes his particular version of preformation as agreeing both with recent scientific discoveries as well as with religious doctrine:

> And since even the smallest insects reproduce by propagation of their kind, one must conclude the same to be true for these little seminal animals, that is, that they themselves come from smaller seminal animals, and thus have originated only with the world. This agrees well with Holy Scripture, which suggests that there were seeds in the beginning.[30]

Although he does not mention Augustine when directly discussing his own theory of preformation, Leibniz does credit the Church Father with recognizing that animals have an indivisible soul, and thus an indestructible one: "It is true that Augustine suppos[ed], according to the prejudice common to all men, that beasts have a soul. . . . He believed that the souls of beasts were effectively spiritual and indivisible."[31]

While Leibniz recognizes that Augustine was not opposed to the immortality of animals, he sees this belief as much more central in the thought of certain other philosophers: “I still maintain, as Plato already has and before him Pythagoras, who took this opinion from the Orient, that there is no soul that perishes, not even that of animals.”[32] At the same time, however, Leibniz is intent to distinguish his own doctrine of preformation from that of Pythagoras, who famously believed in the transmigration of souls. For Leibniz, the crucial difference between his view and Pythagoras’s is that Pythagoras argues only for the preexistence of souls, which might leave one body in order to enter another one, whereas Leibniz believes concretely that every creature is perpetually organically embodied, which is to say that there can be no transmigration, since no soul can ever depart entirely from the body in which it already finds itself. We will return to the differences between Leibniz’s theory and metempsychosis shortly.

The view that all things are contained in the world from creation finds a very early expression in Anaxagoras’s doctrine of *logoi spermatikoi*. For Anaxagoras, however, the notion primarily concerns the admixture of different elements within matter, and the potential extractability of any element from any other. In this respect, the Anaxagorean doctrine has important similarities to the theory of mixtures, briefly treated in chapter 1, that is associated with the school of “Latin pluralists” and that would, through Daniel Sennert’s theory of subordinate forms, perhaps come to have some influence on Leibniz’s mature theory of substance. In its Platonized, and subsequently Christianized and Latinized, form, the term *logos spermatikos*, if not the Anaxagorean doctrine itself, is transformed into *ratio seminalis*, a notion that is perhaps most closely associated with the Augustinian vision of the world, cited above, as “heavy” with the causes of things that have yet to come to be. However vivid the image of a pregnant world may be, Augustine gives no real account of the ontological status of things prior to the “proper opportunity for their appearance.” The fact that Augustine speaks in terms of “causes” suggests that he does not have actual preexisting things in mind at all, but is only claiming that God in his wisdom has created the world in such a way that each successive state of it follows in accordance with reason from its preceding states.

In sum, there are indeed ancient, philosophical precursors to Leibniz’s theory of preformation, and we must not see him as being entirely disingenuous when he claims that he would have found himself committed to it no matter what the state of technology and science in his era had been. But two scientific discoveries appear to inform Leibniz’s particular doctrine of preformation to the extent that we cannot talk about it as the same doctrine as, or as directly continuous with, ancient doctrines such as that of Augustine. One is insect metamorphosis, discovered by Jan Swammerdam,[33] and observed and written about extensively by Leeuwenhoek. The other is the discovery of microorganisms, which enabled Leibniz to pick out an actual bodily vehicle for the preexisting soul rather than letting the seed of the future animal or human remain a merely hypothetical entity or describing it vaguely as a seminal "cause" of a future, as-yet nonexistent entity. For a philosopher other than Leibniz, having such a vehicle might not be absolutely necessary, even if it would certainly help to make the philosophical theory of preformation much more empirically plausible. But for Leibniz, who believes for deep philosophical reasons that we have already considered that every created substance must be embodied, to the extent that embodiment is just a condition of the existence of substances, in order for preexistence to be a tenable theory this must be an *embodied* preexistence. In this respect, then, the discovery of preexisting seminal animalcules may be seen as helping to fill out an important part of Leibniz's mature account of substance.[34]

In the previous two chapters, we saw how Leibniz's otherwise Aristotelian conception of composite substance differs from that of Aristotle himself, as a result of the fact that Leibniz's conception is formed in a period in which the microstructure of organic bodies has become a central subject of inquiry in science. Similarly, we may say that Leibniz's theory of preformation differs from that of Augustine, in view of the fact that Leibniz's theory is formed after "the seeds of things" had become a central subject of scientific inquiry, and indeed at precisely the same time that the true seeds of things were being positively identified.

Observability and Probability

We have seen that Leibniz's generation theory derives not just from higher principles but also from his interest in empirical discoveries, not just from thinking but also from seeing. We have yet to consider what exactly was seen, or, perhaps better, what Leibniz and his contemporaries thought they were seeing. We should also consider, in this connection, how aware a theorist such as Leibniz may have been of the problems inherent in interpreting the newly observable rudiments of reproduction. That is, did Leibniz and his contemporaries believe that what they were observing spoke for itself, or did they sense that what the microscope had lain bare in their era could nonetheless serve to buttress any number of competing theories of generation? To adapt a phrase from Ian Hacking, did they ever ask themselves whether one really *sees* through a microscope?[35]

Caution in describing what one has observed was characteristic of most seventeenth-century thinkers seeking to corroborate their respective generation theories by means of empirical evidence. Most offered descriptions of embryonic development that were restricted only to comments on what they had seen.[36] Some researchers, such as Malpighi, are hard to classify as either preformationists or as epigenesists since they seldom have anything to report beyond what they have observed, and nobody, in the earliest years of preformation, had ever observed either a spermatozoon or a mammalian ovum.

Interestingly, the same cautious limitation of claims to the observable had also been characteristic of Harvey's epigenesis. He is a leading figure in the epigenesist tradition, insofar as his work on the chick embryo leads him to conclude that all animals develop into complex organisms from a uniform and undifferentiated primordium. Harvey believes that all living things, not just those born of oviparous mothers, start as eggs or egglike primordia, and that viviparous generation must be understood on analogy to the oviparous kind. Harvey identified the egg as the primordium of life and explained sexual reproduction and spontaneous generation in terms analogous to those of the reproduction of oviparous creatures. But he was unable to answer the question concerning the ultimate origins of the primordia of viviparous creatures, the discovery of the production of mammalian eggs in the ovaries having been made only two centuries later by Karl Ernst von Baer in 1827.[37]

Since Harvey could not find the mammalian egg, and since his method prevented him from commitment to any entity that cannot offer itself up to visual inspection, the English anatomist's suggestion that all things come from eggs remained, from his own point of view, merely speculative. The research on mammalian ovaries that his work inspired—particularly that of Regnier de Graaf, immortalized in female anatomy itself as the discoverer of the Graafian follicles, and of Malpighi—would gradually pave the way for ovist preformation, as a result of two factors: (i) the development from a uniform primordium into a complex organism came to be seen as inexplicable within the increasingly dominant mechanist natural philosophy of the day; and (ii) simultaneously, the possibility of microscopic yet nevertheless complex entities came to be seen as plausible as a result of microscopy. Harvey is an epigenesist to the extent that he believes conception sets into motion the development of a new, complexly structured creature out of homogeneous materials, but the concern he takes, along with nearly all of his contemporaries, to find the primordia of these reveals that "epigenesis" and "preformation" need to be thought of as describing positions on a continuum rather than two radically distinct, mutually exclusive options. This is especially the case in view of the general interpretative caution of the theorists describing the observable evidence.

A similar caution to that exercised by Malpighi and Harvey in their interpretation of observable data is also characteristic of Leibniz, who tends to speak of preformation as merely probable and as the theory that best conforms to the observable evidence. Thus in a 1701 letter to A. C. Gackenholtz, on botanical method, Leibniz writes:

> If this [account of plants] were attested by diligent observation, it would more solidly establish the acceptance of the doctrine of Kerckring and Leeuwenhoek, which always seemed to me most probable: namely, that something subtle, which was already organic, and which could be denoted by the name of "plant" or "animal," reaches the female's eggs from the male seed, and from here, as if transformed in its proper soil, develops into something more elaborate, a fetus, through [a process] that may be called generation.[38]

So "generation" is probably, though not certainly, just development into something more elaborate; it does not involve an addition to the list of existents. One may wonder why Leibniz, who seems compelled in view of his deep philosophical commitment to the indestructibility of corporeal substances to hold that there can be no true generation, would nonetheless use the cautious language of probability when discussing the empirical study of generation. The answer to this question probably has to do with a concern that no amount of empirical observation could resolve the deeper questions about generation, that generation science can only speak in terms of probability, even if one's metaphysical principles might favor one particular generation theory over another. Interestingly, then, Leibniz is willing to express certain commitment to preformation insofar as he is speaking of it as a doctrine that flows from higher, a priori principles, but only partial commitment to it insofar as he is treating it as an empirically grounded account of observable evidence. Leibniz's probabilism in the latter case seems to have to do with a more general commitment to the view that any empirical theory is at best probably true.

Leibniz and Leeuwenhoek

The observable evidence appears to have been interpreted very differently by different theorists depending upon the sex of the animal body that was the primary focus of investigation. This difference of interpretation gave rise to two opposed camps among the preformationists: the ovists maintaining that the primordium of future organisms preexists as an egg in the mother, and the animalculists believing that it preexists as a spermatozoon.

While Leibniz's preformation might derive from higher principles, one central detail of his version of the theory would only become possible in the mid-1670s as a result of the discovery of spermatozoa. Leibniz's mature version of the doctrine of preformation would come to hold that all corporeal substances came into existence at the creation of the universe, as living, embodied entities, and that, at least in the case of all vegetable and animal corporeal substances, these exist prior to what appears to be their coming-into-being in the form of seeds or spermatozoa.[39] Although Leibniz's chosen primordium, the spermatozoon, is vastly smaller than the mammalian ovum, Harvey's preferred source of the future animal, historical contingencies would promote the former beyond the status of mere theoretical entity and into the category of observables much earlier. In this respect, animalcular or spermatozoid preformationism was empirically a more well grounded theory in the seventeenth century.

We have already seen that from the very beginning of his career, the young Leibniz was interested in taking into account the findings of microscopical research in his reflections on the nature of generation. But the crucial piece of empirical information that would help him to develop his mature theory of generation would come only in 1676, with his exposure to the microscopic research of Antoni van Leeuwenhoek.

Catherine Wilson suggests that it was Leibniz's 1675 reading of Malebranche's *Search after Truth* that "showed [Leibniz] how the microscope fitted in with metaphysics. Malebranche saw preformation as a necessary correction to strict Cartesianism, which was epigenetical."[40] However, as we saw in the previous chapter, Leibniz's interest in microscopy reaches back at least as early as 1669, even if it was not until 1676, one year after reading Malebranche, that Leibniz looked through a microscope for the first time, on a visit to Leeuwenhoek in Delft. His conviction as to the fit between microscopy and metaphysics was evidently only strengthened, rather than conceived, at this moment. In time, Leibniz would come to believe that "a Leeuwenhoek" is preferable to "a Descartes," not just because Leibniz will prefer preformation to epigenesis, but also, more importantly, because it is Leeuwenhoek's cautious observation, as opposed to Descartes' wild speculation, that shows the way to the correct account of a problem such as the nature of generation.

The year 1676 was an eventful one for the still reasonably young Leibniz. Having just finished four years of intensive mathematical study under Christiaan Huygens in Paris, in early October he set out on a trip to England and the following month traveled on to Holland. Among the luminaries he had a chance to meet in England were the Royal Society's Henry Oldenburg and John Collins. After arriving in Amsterdam in mid-November, Leibniz then made the acquaintance of Swammerdam, the discoverer of insect metamorphosis, and also met with the controversial Spinoza. He managed to squeeze in yet another appointment during the Dutch leg of the journey, one that has, no doubt, prompted a good deal less speculation throughout the centuries than did his visit to the author of the *Ethics*. This other visit was to Leeuwenhoek, who honored Leibniz by giving him a brief demonstration of the uses of the microscope, and, we may speculate, briefing Leibniz on what had been his own most remarkable microscopic discovery to date: the spermatozoon.[41] This visit was motivated by a belief—one that can be traced back as early as 1669, and was evidently shared by Oldenburg, whom Leibniz had just visited in London, as well as by Huygens, who, again, had been Leibniz's mentor for the past four years—that the findings of the microscopists are of tremendous relevance to our understanding of the basic questions of metaphysics. Evidently, Leibniz was in no way let down in this belief by the visit to Leeuwenhoek.

A year or two prior to Leibniz's visit, according to Leeuwenhoek's recollections decades later, the Dutch microscopist had carried out research on the "animalcula in semine marium" (animalcules in the seed of males) of a number of animal species, including humans. According to Leeuwenhoek's variety of preformation, all future adult humans are contained within the testicles of their male ancestors, and the animal embryo is enveloped in microscopic form within the head of the spermatozoon. As Leeuwenhoek insists in a letter of 1678, "it is exclusively the male seed that forms the fetus and … all that the woman may contribute only serves to receive the seed and feed it."[42] Leeuwenhoek will later write in 1700, regarding his priority dispute with Nicolaas Hartsoeker over the discovery of spermatozoa and the development of the theory of animalcular preformation, that he, Leeuwenhoek, "did not only give the Royal Society an account of [spermatozoid preformation], by my letter of *Novemb*. 1677, but even 3 or 4 years before, at the request of Mr. *Oldenburg*, I had made an inquiry into those matters."[43] We can infer from this letter, unless Leeuwenhoek's memory is in error, that the Dutch microscopist was actively researching the function of spermatozoa and developing his own theory of animalcular preformation around 1674 or 1675, thus roughly one or two years before Leibniz's first visit to Leeuwenhoek in Holland in 1676.

Writing in April 1679 to Nehemiah Grew, Leeuwenhoek proudly takes credit for the solution of the mystery surrounding the function of the testicles:[44]

> As a result of my observations … I have no doubt but that yourself and the learned Philosophers will agree with me in stating that the testicles have been made for no other purpose than to furnish the little animals in them, and to keep them till they are ejected. … Also, those who have always tried to maintain that the animalcules were the product of putrefaction and did not serve for procreation will be defeated.[45]

Of course, one might believe in the importance of seminal vermicules for conception as part of that mysterious efficient cause of the epigenesists, without necessarily subscribing to the view that the human embryo is preformed in these vermicules. This is clearly not Leeuwenhoek's position. He maintains, like Leibniz, that "all creatures that are endowed with a moving or living Soul, depend upon … the moving or living animals that were made in the male seeds, in the beginning of creation."[46]

Leeuwenhoek offers a number of arguments for his view that the spermatozoa are but future animals in an extremely miniature form. The first of these arguments is based on his direct observation of plants enveloped within vegetable seeds, and the claim that of necessity the same envelopment must occur in animals. This claim rests on the assumption that animal "seed" functions exactly as does the seed of an apple tree. Leeuwenhoek notes that in the seed of an apple we can actually see the leaves and trunk in an extremely small, enveloped form. Why may we not then assert, he asks, "that in an Animalcule from the Male seed [*het Mannelijk zaad*] a whole Human being is enveloped and that all Animalcules from the Male sperm derive from the first Man that was created?"[47] In another letter to the Royal Society, Leeuwenhoek argues that the best evidence we have for animalcular preformation, in light of the difficulty of actually observing spermatozoa, comes from the observation of other microorganisms:

> It will seem strange to many, that cannot comprehend, how in an Animal of the Masculine Seed, that is so incomprehensively small, so great a Secret, as a Body of a Man doth comprehend, can be Locked up. But if we remember that there are Living Creatures in Waters, that we have many times seen come before our Eyes, that being of a Roundish Body, were no thicker then the thinest end of a Tayl of an Animal in the Masculine Seed.[48]

In a letter of August 1688, Leeuwenhoek cites the empirical evidence of the envelopment of plants within seeds and goes on to claim that it is in keeping with God's ordering of the universe at creation that animals be similarly enveloped. "God," he writes,

> Lord and Omniscient Maker of the Universe, makes no new Creatures [*nieuwe Schepsels*], but … He, Lord and Creator, has so ordered and made it from the beginning, that all well-made or full-grown Seeds of plants (although it may remain hidden from our eyes) are already created therein. … Which, thus happening in Plants, I assert, must necessarily take place also in the Male Seeds of all Animals [*de Mannelijke Zaaden van alle Dieren*].[49]

Leeuwenhoek explicitly rejects the caricatured view according to which the human fetus might be detected with a powerful microscope in the head of a spermatozoon. He sees this as a primitive conception of the preformationist theory, and ridicules the idea that human semen might be "full of small babies [*vol van kleijne kinderkens*]."[50] Leeuwenhoek argues instead that though the future human's organic body does actually exist in the spermatozoon, it must undergo a metamorphosis, just as do amphibians and insects, in order to become recognizable as a human baby: "Just as we have no reason to say that some worms, while they are still swimming in water, are flying creatures, though creatures with wings will eventually emerge from them … it would be equally wrong to assert that the little worms in the human sperm are small babies, even though a child is formed from such a small worm."[51]

Spermatozoid preformation would gain quite a bit of popularity by the end of the century. Nicolas Andry, for instance, to whom we were introduced in the previous chapter, writes in his *De la génération des vers dans le corps de l'homme* of 1700:

> It thus does not appear unreasonable to think that in one single spermatic worm there is an infinity of organized bodies capable of producing an infinity of animals: so that according to this thought, which could only appear bizarre to those who measure the wonders of the infinite power of God according to the ideas of their senses and of their imagination; one could say that in one single spermatic worm, there would be organized bodies capable of producing fetuses and children, for infinite centuries, always smaller and smaller in relation to one another.[52]

We saw in the previous chapter that Leibniz does not begin to explicitly identify corporeal substances as worms until the latter half of the 1690s, within a few years of Andry's treatise on worms in the human body. Claims concerning the status of spermatozoa as the vehicles of organic bodies, similarly, do not begin appearing in an explicit and unequivocal form in Leibniz's writings until 1695, with the *Système nouveau*. Duchesneau holds that as late as 1686 "Leibniz did not even exclude the possibility of an explanation of the formation of living beings by means of a mechanical epigenesis—or, more exactly, he had not yet decided between epigenesis and preformation."[53] Duchesneau is likely referring to Leibniz's first acknowledgment of Leeuwenhoek's theory of preformation in the correspondence with Antoine Arnauld. In this correspondence Leibniz first begins to claim that the organism preexists and that it continues existing after what is vulgarly called death. Characteristically for this correspondence, Leibniz invokes empirical microscopy somewhat tentatively as justification for his philosophical claims. As he writes in a letter of October 1687, evidently recalling his visits to Delft of more than a decade earlier:

> I learned some time ago that Monsieur Leeuwenhoek holds opinions very close to mine, in that he believes that even the largest animals arise through a kind of transformation. I do not venture either to approve or to reject the details of his opinion.[54]

There is, then, a period of at least ten years during which Leibniz likely knew of the discovery of spermatozoa without incorporating this knowledge in any significant way into his philosophy. There is, moreover, a period of around twenty years, from the visit to Holland to the publication of the *Système nouveau*,[55] between Leibniz's probable first discussions of the theory of spermatozoid preformation and his explicit localization of the preexisting soul within the spermatozoon in 1695. By the time of the *Principes de la nature et de la grace* of 1714, Leibniz is so convinced of the spermatozoid preexistence of all creatures, including humans, that he casually refers to humans in the state of preexistence as "human spermatic animals [*des animaux spermatiques humains*]."[56]

Duchesneau has also expressed some hesitance to describe Leibniz as a wholehearted animalcular preformationist. He writes that "Leibniz would draw some support for his own "philosophical position" on the envelopment and development of organisms from the then current doctrines and observations on germ preformation. But he generally avoided siding radically with either the ovist or the animalculist theory." Duchesneau concludes: "I would be reluctant to assimilate his position to Leeuwenhoek's whom he mostly admires for his technical skill, not for his theoretical views."[57] Yet perhaps when Leibniz says he prefers "a Leeuwenhoek" to "a Cartesian," we may take this to mean that, in his view, it is precisely through the sort of technical skill that Leeuwenhoek has mastered that one arrives at the correct theoretical views. Duchesneau takes the correspondence with Louis Bourguet from the years 1709 to 1716 to be most representative of Leibniz's views on the matter of preformation. In this correspondence, Leibniz openly refuses to take sides between the ovists and the spermists. In one letter, he is particularly careful to point out that he is not opposed to the claims of the physician Antonio Vallisneri, who had denied Leeuwenhoek's theory:

> M. Camerarius of Tübingen believed that the grain was like the ovary, and the pollen (though in the same plant) like the sperm of the male. But if this were true, the question would still remain whether the basis of the transformation of the preformed living being is in the ovary, following M. Vallisneri, or in the sperm, following Leeuwenhoek. For I maintain that there must always be a preformed living being, be it a plant or an animal, that is the basis of the transformation, and that this is the dominant Monad itself: no one is better suited to clarify this doubt than M. Vallisneri.[58]

Significantly however, as we learn from a footnote in the Gerhardt edition of this letter, Leibniz's original draft did not contain the above passage, and instead we find Leibniz more sympathetic to the animalculists than to Vallisneri:

> Up until now the Hypothesis of seminal Animals has seemed to me the most plausible. It also seemed attractive to M. Huygens, to M. Hartsoeker, and to others. What I say is meant neither to contradict M. Vallisneri, nor to prevent his judgment, which in my view has much weight, but to motivate him to clarify this important matter.[59]

Considering the agreement of this deleted passage of the letter to Bourguet with Leibniz's mature-period claims elsewhere concerning the embodiment of the preformed animal in the spermatozoon,[60] it appears likely that the view expressed in the correspondence with Bourguet is not the best expression of Leibniz's actual views concerning preformation, but instead that what Leibniz writes to Bourguet might rather be motivated by a concern not to offend a particular correspondent with what he would otherwise have wanted to write (and, even in this case, did write at first). As we have already seen, elsewhere Leibniz is much more open about his support for Leeuwenhoek's theory of preformation than he is in the Bourguet correspondence.

Leibniz sometimes speaks of Leeuwenhoek's work as mere confirmation of the conclusions to which reason would have led us without the aid of experimental science:

> Besides that which … M. Leeuwenhoek has observed of this, one could say that reason leads us there just as much as does experience, because there is nothing in mechanics that could make from an unformed mass a body endowed with an infinite number of organs, such as that of the animal.[61]

But as we have already seen, Leibniz also frequently relies on Leeuwenhoek's discoveries as one source of empirical grounding of a metaphysical theory that might otherwise appear rather outlandish. In short, Leeuwenhoek's work, though Leibniz might not have wanted to admit it, was a crucial support without which Leibniz likely would not have dared to make the claims he did. One detects a deep admiration for Leeuwenhoek on the part of Leibniz, almost a feeling of solidarity in an ideological struggle. In the *Entretiens de Philarète et d'Ariste* of around 1712–14, Leibniz, probably only half playfully, writes: "According to this Hypothesis [of ovist preformation] the male would hardly do anything more than the rain. But Mr. Leeuwenhoek has rehabilitated the masculine gender and the other sex has been degraded in turn."[62]

In sum, for Leibniz, right up through his most mature writings, it is necessary that no substance ever come into being, and that every substance always exist in an organically preformed body. From 1676 until very late, the spermatozoon discovered by Leeuwenhoek serves as the most likely candidate for this role of preexisting soul-bearer.

Leibniz, Swammerdam, and Monadic Metamorphosis

For Duchesneau, the fact that the preexisting entity bears no clear resemblance to the eventual creature is enough to feed a doubt as to whether Leibniz was really a preformationist at all, as even the great epigenesist Harvey would insist that every creature comes from some preexisting primordium. For our understanding of Leibniz's particular variety of preformation here, we need to turn our attention not to the empirical discoveries of Leeuwenhoek but to those of his countryman, Jan Swammerdam, whose name Leibniz consistently associates with the discovery of insect metamorphosis.[63]

For Leibniz, what is commonly known as the generation of animals is not just an augmentation of the preexisting organism but also "une grande transformation," as a result of which the spermatozoon becomes "un animal d'une autre espece."[64] It is only through this "revestement nouveau"[65] that the preformed creature is given "the means of nourishing itself and of growth, in order to pass into a larger theater [le moyen de se nourrir et de s'aggrandir, pour passer sur un plus grand theatre]."[66] In the *Nouveaux essais*, Leibniz writes tellingly of ancient theories of transmigration: "I do not believe that a person who would be certain that the soul of Heliogabalus existed in a pig wanted to say that *this* pig was a man, and the same man as Heliogabalus."[67] Individual identity runs more deeply than species membership, whether the individual in question is an insect that moves from the larval to the adult stage, or whether it is a man reincarnated as a pig (though Leibniz does not really believe in the latter possibility).

One example of species change that Leibniz does affirm is that of a standard-grade, preexisting monad into a human spirit at conception. For Leibniz, the difference between a human soul and an animal soul is that the former is a mind, a *mens* or *esprit*, and this means most importantly that it is capable of reasoning and is a suitable subject of reward and punishment. In some short works of the mid-1680s,[68] Leibniz worries that a preexisting spermatozoid human could not be considered human prior to conception, since if this were the case the vast majority of human lives would be wasted at conception, which is contrary to God's wisdom and grace. Indeed, the discovery of spermatozoa, on Leeuwenhoek's interpretation, meant that the biblical injunction against wasting seed would be literally impossible to follow: even in proper, marital intercourse, most of the seed comes to no use, and thus in this respect marital intercourse is scarcely different, morally, from onanism. But neither, for Leibniz, could a preexisting spermatozoon *become* a human being at conception; that is, neither could it somehow be promoted from the status of mere corporeal substance to the status of a human being with a mind. For, in Leibniz's view, in the texts of the mid-1680s, this would not constitute a transformation but a discontinuous rupture, the destruction of one entity and the creation of another. Thus, at least in this period, Leibniz does wish to excuse human beings from the process of preformation, the reality of which he otherwise accepts, and instead see the conception of a human being as a miraculous creation involving the intervention of God.

Leibniz would gradually come to change this view, however. In the *Système nouveau* of 1695, it is not clear that Leibniz wants to exclude humans from the process of preformation. In this work, Leibniz praises Swammerdam, Malpighi, and Leeuwenhoek as "the best observers of our time," who have "made it easier for me to admit that animals and all other organized substances have no beginning … and that their apparent generation is only a development, a kind of augmentation."[69] He does distinguish sharply between the ungenerability and incorruptibility of ordinary forms or brute souls on the one hand and human minds or rational souls on the other, which "have particular laws," placing them "above the upheavals of matter."[70] He maintains that "rational souls follow much higher laws, and are exempt from anything that might make them lose the quality of being citizens of the society of minds."[71] But nowhere in this text does he explicitly wish to exempt human individuals from embodied pre- and postexistence, and he seems to be careful to distinguish humans from animals in important respects while nonetheless not denying that pre- and postformation must hold of all created substances, even of human beings.

In the *Principes de la nature et de la grace* of 1714, in any case, there can be little question where Leibniz stands; there, as we have seen, he is so convinced of the spermatozoid preexistence of all animals, including humans, that he casually refers to humans in the state of preexistence as "human spermatic animals."[72] The broader context of this surprising description runs as follows:

> There are small animals in the seeds of large ones, which, through conception, assume new vestments that they appropriate for themselves, which give them the means to nourish themselves and grow in order to pass to a larger theater and to bring about the propagation of the large animal. It is true that the souls of the human spermatic animals are not rational and do not become rational until conception settles that these animals will have a human nature.[73]

So it is settled: no human souls are lost in ejaculation, since the soul is not human until conception; but transformation of a preexisting spermatozoid soul into a human soul does not consist, as Leibniz had earlier worried it would, in the simple destruction of one soul and the simultaneous creation of another. It is, rather, a transformation like any other, for instance, like that of a caterpillar into a butterfly.

Daniel C. Fouke has provided a clear analysis of the problem of how bare-level monads are promoted to the rank of rational beings in the course of human reproduction.[74] Fouke rightly argues that Leibniz is forced to deviate from his general account of the successive states of substances as unfolding spontaneously from its individual nature, describing the promotion to rationality as instead a rare instance of divine intervention in the natural order. One point that Fouke does not emphasize is that this deviation would not have been necessary had Leibniz not been fundamentally committed not just to some sort of preexistence but also specifically to preexistence in an organically embodied form. We have been arguing that the identification of the future human, like other future animals, with the spermatozoon was an important part of the need Leibniz perceived to develop an account of promotion to rationality at some moment after conception. Clearly, this need would not have been felt in the same way if the future human were conceived as a disembodied soul in a prebirth baby heaven. Spermatozoa as the bodily vehicle of future humans were both a solution to a problem Leibniz faced—given that every substance must be constantly embodied, where is the body of the preexisting human?—as well as the source of new problems, such as the condition of the future human prior to conception.

Theologically motivated exceptionalism vis-à-vis human beings should not diminish the significance of the impact of a theory such as preformation on Leibniz's thought. The great lengths to which he goes to explain how humans might be exempted from preformation drives home the point that, for him, in the ordinary course of nature nothing is generated ex nihilo; in order for humans to be so generated, it must be conceded that their generation violates this ordinary course. A high price to pay for theological correctness.

Leibniz, as already mentioned, frequently juxtaposes his own doctrine of metamorphosis to the ancient belief in reincarnation. What appears to us as death, he believes, is a mere transformation of the animal body, but not a departure of the soul from the body, into either a permanently disembodied state or into another body through metempsychosis:

> Thus not only souls, but even animals are ungenerable and imperishable, they are only developed, enveloped, returned, depleted, transformed; souls never leave their bodies, and never pass from one body to another body that is to them entirely new. There is thus no metempsychosis, but there is metamorphosis.[75]

Elsewhere Leibniz describes his theory of metamorphosis as "metensomatosis."[76] He explains that this term is a synonym of "transformation," which is of course the Latinized form of "metamorphosis." Here we use the term "metamorphosis" because it provides the clearest contrast with the original Pythagorean and Platonic doctrine, and because it suggests an analogy to processes in the natural world. It is, however, important to bear in mind that the term "metamorphosis" did not resonate in Leibniz's time as primarily an entomological term any more than the Latinate "transformation" does today. But this does not diminish the fact that it was an analogy to processes in the insect kingdom that Leibniz intended when employing the term "metamorphosis" in his account of what happens to the organism after death.

In the piece just cited in which Leibniz speaks of "metensomatosis," the *De natura mentis et corporis*, dated by the editors of the Academy Edition to between 1683 and 1686, we encounter the only occurrence in Leibniz's writing of the term "metensomatosis," used as a synonym of the generally preferred "metamorphosis." Here Leibniz writes:

> If we imagine some animal similar to a butterfly that is made out of a worm, and prior to that was of such a kind that the worm, in turn, was made from something else that was up until then very small, and thus again back to the beginning of the world, and where the progress of the animal into a worm is extinguished, or is pushed back into some non-sensible animalcule (nor am I speaking of those worms, that arise *per accidens* from members), with the soul likewise always remaining in all of them, there will indeed not be mere Metempsychosis in this *anima*, but indeed metensomatosis or transformation, and indeed it will not so much always be the soul [that remains], but likewise always the corporeal substance.[77]

Metensomatosis, then, is for the immortal corporeal substance what metempsychosis is for the immortal soul. This term is evidently not Leibniz's invention. In Goclenius's *Lexicon philosophicum* of 1613 we find an entry for "Metensomatosis, that is, transcorporation, for example, when the soul migrates from the human body into that of a cat."[78] Goclenius identifies this doctrine with the teachings of Zoroaster. As with the concept of the "organic," then, Leibniz is taking an already familiar, if obscure, term and radically reconceiving its meaning. "Organic" had been a synonym of "mechanical," and "metensomatosis" evidently a synonym of "metempsychosis"; Leibniz appropriates both of these terms and renders them not so much as synonyms of their respective related notions but as special cases.

In a letter to Arnauld of April 30, 1687, Leibniz explicitly mentions Leeuwenhoek's experiments with pepper water to corroborate his commitment to the metensomatosis of animal souls (described here as "metaschematismus"):

> We find that there is a prodigious quantity of animals in a drop of water imbued with pepper. … Now if these animals have souls, we would have to say of their souls what we can probably say of the animals themselves, namely, that they were already alive from the creation of the world. … The ancients were mistaken in introducing the transmigration of souls instead of the transformations of the same animal which always preserves the same soul; they put *metempsychoses pro metaschematismus*.[79]

As preformation satisfies both biblical and empirical demands, so, too, does the metamorphosis of the creature, including the human being, after death. Leibniz believes that the bodies of the blessed must accompany them into the afterlife and so requires a theory that will not permit the soul to become disembodied: "For why cannot the soul always retain a subtle body organized after its own manner, which could even someday resume the form of its visible body in the resurrection, since a glorified body is ascribed to the blessed?"[80] Leibniz writes that this doctrine conforms not only with religious teaching but also with the order of nature established through experience, "for the observations of very capable observers have convinced us that animals do not begin when they are popularly believed to begin. … And both order and reason demand that what has existed since the beginning should no more have an end."[81] If the origins of Leibniz's spermatozoid preformation can be traced in part back to Leeuwenhoek, it is Swammerdam who deserves the credit for the doctrine of metamorphosis. Thus Leibniz writes that he is indebted to Swammerdam for the discovery that "the silkworm and the butterfly are the same animal … the parts of the butterfly are already enveloped in the caterpillar."[82]

In contrast to his own doctrine of metamorphosis, Leibniz denounces metempsychosis as "le Dogme de Pythagore," and claims that he is "fort éloigné" from the Pythagorean view. But his explanation for why it is correct to view his own predictions concerning the afterlife as greatly distanced from that of Pythagoras amounts to an explanation of the great affinity of the two doctrines, the only difference being that Leibniz's version involves a physical as well as a spiritual aspect: "I am very far removed," he writes, "because I believe that not only the soul, but the same animal subsists as well."[83] In other words, it is the constant organic embodiment of the animal that ensures that its soul can never migrate from one body to another.

This constant organic embodiment, moreover, is comprehended by Leibniz as a consequence of preestablished harmony. In short, metamorphosis as opposed to metempsychosis is guaranteed by organic preformation. Preformation, moreover, is in turn guaranteed by preestablished harmony. Let us turn now to the connection between these latter two doctrines.

Preformation and Preestablished Harmony

Divine preformation is not just a necessary consequence of Leibniz's model of infinitely complex organic bodies but also of his adoption of the doctrine of preestablished harmony. Because there must always be a body "proportioned to the perceptions" of every simple being, and because simple beings cannot come into or go out of existence, it follows that every simple being has always existed in an organically embodied form. The preestablishment of harmonious perceptions and the preformation of organic bodies are of a pair.

Divine preformation, as we have already seen in chapter 3, plays a crucial role in Leibniz's rejection of Cudworth's immaterial plastic natures. In her summary of Leibniz's metaphysics, Cudworth's daughter, Damaris Masham, ascribes to Leibniz what she calls the "Principle of Uniformitie," correctly discerning the connectedness of the preformation on the one hand and the infinite complexity of the organic body on the other:

> All these Simple Beings you thinc have; always will have; and ever since they existed have had Organick Bodys, proportion'd to theire Perception. So that not onely after Death the Soul dos remain: but even the Animal also. … The same Principle of Uniformitie in the works of Nature … led you also to your Systeme of the Harmonie preestablish'd betweene substances.[84]

Although for the reasons just described there would appear to be a natural, perhaps necessary, fit between preformation and preestablished harmony, curiously it is in Malebranche's *Search after Truth* of 1676 that we find the most elaborate philosophical account of preformation. Malebranche is an occasionalist, and thus, some commentators argue, we should see the theory of preformation as best suited to the exigencies of this theory of causation. Malebranche writes:

> We ought to accept … that the bodies of every man and beast born till the end of time were perhaps produced at the creation of the world: I mean that the females of the original animals may have been created along with all those of the same species that they have begotten and that are to be begotten in the future.[85]

To be sure, preformation is compatible with occasionalism, but there is no good reason to believe that acceptance of the former doctrine would impel one to accept the latter. Leibniz did not see any reason either. Indeed, if Leibniz were to draw an association between occasionalism and any particular theory of generation, he would probably see occasionalism, which posits the continuous intervention of God in the world, as most similar to the theory of epigenesis, which posits a continuous creation of new beings by God. Cartesian epigenesis, underlain as it is by an ontology on which animals are nothing more than machines, would not require such perpetual recourse to miracles, since the formation of an animal-machine is not in any sense a coming-into-being of a new substance, but only a new articulation of matter. For Leibniz, however, for whom animals are always simultaneously machines *and* substances, a universal epigenesis would be offensive for precisely the same reason Malebranche's occasionalism is: it would require that God see to individual comings-into-being directly, when in fact these can be accounted for nonmiraculously in terms of the this-worldly unfolding of substances, all of which came into being simultaneously in the singular super-miracle of the Creation.

While an occasionalist such as Malebranche may coherently defend a theory of preformation, it is only a defender of preestablished mind-body concomitance[86] and preestablished intermonadic harmony who must, at risk of incoherence, defend such a view: if there is no preformed body, then it makes no sense to hold that the soul and body are in preestablished harmony with each other. Although Malebranche and Leibniz have differing accounts of causation, both see preformation as a means of remaining faithful mechanists in their respective accounts of animal generation.[87]

In sum, Malebranche defends preformation not because he is an occasionalist and sees occasionalism and preformation as of a pair, but because he is a mechanist and sees mechanism as incompatible with epigenesis. Leibniz, in turn, defends preformation both because he is a mechanist and because he is committed to the doctrine of preestablished harmony. Leibniz, like Malebranche, sees epigenesis as inexplicable in mechanical terms, and, unlike Malebranche, sees preformation as a necessary part of the doctrine of mind-body concomitance or preestablished harmony. On one possible understanding, preformation and preestablished harmony might be thought to be in tension with each other, to the extent that preformation might seem to depend upon some robustly conceived unity between an organic body and an immaterial principle, while preestablished harmony drives a wedge between body and the immaterial principle. But preformation requires no more union than what preestablished harmony affords: organic embodiment is a condition sine qua non of the existence of a substance, and even if this embodiment may, in the end, be traced back to a condition of simple substances that falls short of union with an independently existing body, nonetheless this does not mean that the immaterial principle's connection with the organic body is contingent or temporary. Inseparability does not imply metaphysical union.

In Leibniz's view the doctrines of preformation and of preestablished harmony are closely connected, insofar as the harmony of a soul with a body since the creation requires that there *be* such a body since the creation. It speaks for this close connection of the doctrine of animalcular preformation with the doctrine of preestablished harmony that Leeuwenhoek attempts to justify his commitment to preformation in a way that closely anticipates Leibniz's reasoning in defense of the doctrine of preestablished harmony. In a letter published in the *Philosophical Transactions* of August 1699, Leeuwenhoek presents a typical statement of his conviction that all humans existed as spermatozoa within the body of Adam:

> Now if we know which way the fish do increase, that it is not done but by intermixing of the Male and Female Seeds, and likewise we do know the great Mistery that is included in the small Seed of an Apple, why might not we then assert that in an Animal of the Masculine Seed of a Man, is locked up a whole Man, and that the Animals of the Seed are all descending from the first Created Man.

Leeuwenhoek is insistent on finding an interpretation of empirical evidence that does not require appeal to what, in his view, could only be explained by perpetual divine intervention, which Leeuwenhoek would consider miraculous:

> It being then that hitherto, nothing at all is come before me that can make me the least Scruple, to induce me to recede from my former opinion, and to receive an opinion to believe, or hold, that Animals should come forth of themselves, therefore I still remain of this my opinion, that out of the Animals of Masculine Seeds, come forth Animals of the same kind as they were Created in the beginning, and that as hitherto no truer Position is left. For if Animals could be born of themselves, which I should reckon to be a Miracle, then must not only every Minute, but every Second, Millions of Miracles be done, which is an opinion not to be received.[88]

For Leibniz, similarly, preestablished harmony is the only account of the relationship between mind and body that manages to avoid appealing to miracles. Leibniz repeats throughout his mature thought that the doctrine of preestablished harmony is superior to other competing doctrines because it

> excludes every concept of miracle from purely natural actions and makes things run their course in a regulated and intelligible manner. Instead of this, the common system has recourse to absolutely inexplicable influences, while in the system of occasional causes God is compelled at every moment, by a kind of general law and as if by compact, to change the natural course of the thought of the soul to adapt them to the impressions of the body and to interfere with the natural course of bodily movements in accordance with the volitions of the soul. This can only be explained by a perpetual miracle, whereas I explain the whole intelligently by the natures which God has established in things.[89]

The fact that Leeuwenhoek is interested only in refuting epigenesis, while Leibniz's primary interest is in refuting occasionalism, does not render the structural similarity of their respective arguments any less interesting. Leeuwenhoek is concerned to avoid the coming into existence of new animals that is posited by nonpreformationist accounts of generation. For Leeuwenhoek, such accounts include both epigenesis and spontaneous generation. Epigenetic generation, on Leeuwenhoek's view, can be seen as a special case of spontaneous generation: the new life is "spontaneously" brought into existence through sexual intercourse. How spontaneous generation of rats from bilge or eels from mud could occur is for Leeuwenhoek no greater a mystery than an entirely new coming-into-being that results from the entry of sperm into the womb. In the absence of a preformationist account, Leeuwenhoek believes that there are two possible ways in which one might attempt to explain animal generation: it can be explained either as the result of some inexplicable interaction of the male's and the female's material contributions, or it can be explained as the result of a direct intervention on the part of God.

Consider, now, Leibniz's explanation of the various possible relations between mind and body. He writes in the "Second Explanation" of the *Système nouveau* that the agreement or sympathy between the soul and the body will come about in one of three ways.

1. The "way of influence." This is the account of causation given by "common philosophy." However, since it is impossible to conceive of material particles or of immaterial qualities that can pass from soul to body or from body to soul, this view must be rejected.
2. The "way of assistance" or occasionalism. This account would make a deus ex machina intervene in a natural and ordinary matter where reason requires that God should help only in the way in which he concurs in all other natural things.
3. The way of "preestablished harmony," according to which God has made each of the substances from the beginning in such a way that each agrees with the other entirely as if they were mutually influenced or as if God were always "putting forth his hand."[90]

Now, for comparison, let us formulate in Leibnizian terms Leeuwenhoek's account of what he sees as the three possible ways in which generation could occur:

1. Sperm functions as the vehicle of a volatile salt or like spirit, impressing on the generative fluids of the female a certain *contactum vitale*. This account might be called the "way of influence": the sperm influences the material of the womb and brings a new being into existence. In Leeuwenhoek's view, such an account is untenable because it resorts to an inexplicable power of matter, sperm, to bring into existence a new living

soul, just as, for Leibniz, the commonsense theory of cause requires an unacceptable commitment to the inexplicable power of bodies to causally influence souls.[91]

2. If the way of influence is rejected, then it follows for Leeuwenhoek that, if "from immobile substances … a body came forth that was mobile, that would be a Miracle and its production would … be dependent on the Great Almighty creator."[92] This account might be called the "occasionalist theory of generation." Like Leibniz in his objection to occasionalism, Leeuwenhoek sees God's intervention for each instance of generation to be an untoward retreat into miracle, where a perfectly naturalistic explanation is available, namely:
3. "All creatures that are endowed with a moving or living Soul, depend upon their first generation; or to put it in a better way, they depend upon the moving or living animals that were made in the male seeds in the beginning of creation."[93]

On the basis of this comparison, we may discern a striking analogy between each of the prominent early modern theories of cause and a corresponding theory of animal generation:

Theory of cause	*Theory of generation*
Cartesian interactionism	Epigenesis
Occasionalism	Spontaneous generation
Preestablished harmony	Preformation

Of course, Malebranche is both a preformationist and an occasionalist, so it would be a mistake to suppose that there is something about preformation that forces one to prefer preestablished harmony. Nor is Malebranche a great defender of spontaneous generation. The point is simply that if we switch "generation" and "causation," we may say that in a sense Leibniz sees Malebranche's theory of causation as a sort of perpetual recourse to miracle or divine conception in the same way that one might see commitment to the reality of spontaneous generation as involving commitment to ubiquitous, daily miracles, wherever slime forms into a frog or dust into a mouse. This is not to say that preformation and preestablished harmony *must* go together, but only that Leibniz's reasoning in his rejection of competing theories of causation looks a great deal like Leeuwenhoek's reasoning in his rejection of competing theories of generation.

In Leeuwenhoek's adoption of preformation and Leibniz's of preformation and preestablished harmony, each had to consider three options. Either the current state of things is the result of an inexplicable influence of matter on other matter, or it is the result of God's perpetual intervention, or it is the result of the initial conditions set up by God at the beginning of the world. Leeuwenhoek saw the last option as most satisfactory in relation to the question of the origins of organisms; Leibniz saw the last option as the best explanation of both the origin of organisms and of the relation of the organism's body to its soul. Since Leibniz appears to have been aware of Leeuwenhoek's argument for preformation before he himself accepted preformation and before he developed his theory of mind-body concomitance (again, Leeuwenhoek's theory of preformation was in place by 1675, Leibniz met with Leeuwenhoek in 1676 and first ventured a preformationist theory in the correspondence with Arnauld a full decade later), it would not be careless to hypothesize an influence of the microscopist on the philosopher, both in the philosopher's acceptance of the doctrine of spermatozoid preformation and in some of his reasoning concerning the doctrine of preestablished harmony.

Leeuwenhoek directs most of his argumentative energy in defense of preformation against "Corn-dealers; Bakers, Millers, and those who cannot see past the end of their nose,"[94] obviously not people to whom Leibniz devoted a great deal of his philosophical attention. But the humble level on which Leeuwenhoek's argumentation was conducted should obscure neither the fact that his preformationist claim is exactly the same as Leibniz's—namely, that the spermatozoon is the bearer of the human soul—nor the fact that the two thinkers' arguments for this theory are very similar. Moreover, considering the similarity between Leeuwenhoek's argument for preformation and Leibniz's for preestablished harmony, perhaps these two doctrines should be conceived as more closely intertwined within Leibniz's thought than they have usually been thought to be.

Conclusion

Leibniz, as we have seen, leaves no room for spontaneity in the generation of animals. For an epigenesist such as Descartes, in the end sexual generation is on an ontological par with the purportedly spontaneous generation of bees from rotting carcasses or of frogs from pond scum: both proceed according to "minor laws" as a result of the rearrangement of matter. For Leibniz, in contrast, the possibility of a new creature coming into existence as a result of such a rearrangement appears absurd: insofar as an animal is organically embodied, and insofar as this organic body is infinitely complex (as was discussed at length in chapters 3 and 4), it follows that no entirely new creature, with an entirely new organic body, can ever come into existence. Neither biological parents nor Mother Nature is capable of bringing forth a body that would require infinitely many steps for its production, and so the only other possibility is that that body has always existed in harmonious concomitance with the soul of which it is the body. Indeed, since no substance has any influence on any other and every state of every body unfolds only from its own prior states, it stands to reason that Leibniz could not believe that the most significant change-of-state of an animal, its coming-into-being, would be something that could be brought about, in the case of sexual reproduction, by epigenetic causes, or, in the case of spontaneous generation, by natural causes such as the proper mixture of heat and moisture. Leibniz does not believe in intersubstantial causation at all, so a fortiori he must reject the generation of one substance as a result of the activity of another substance.

Does this mean that Leibniz eschews spontaneity? Not entirely. As we will see in the next chapter, while Leibniz's preformation theory compels him to reject spontaneous generation, and also compels him to see epigenetic reproduction, with Leeuwenhoek, as a sort of spontaneous generation, at the same time his theory of preestablished harmony, according to which all bodies and all souls are each, in their own way, automata, amounts to a sort of theory of *universal spontaneity*, according to which every state of every being unfolds according to the individual law or principle of that being. This doctrine is a well-known feature of Leibniz's thought, yet its full significance for his philosophy of biology and of generation has yet to be treated in detail.

Chapter Six

GAMES OF NATURE, THE EMERGENCE OF ORGANIC FORM, AND THE PROBLEM OF SPONTANEITY

Introduction

In his 1726 fiction, *Gulliver's Travels*, Jonathan Swift sends his hero, following the better-known sojourn in Lilliput, to a land of giants, in comparison with whom he is now as small as the Lilliputians had been to him. The king of this land is perplexed as to the origins of this "homunculus" and appoints his greatest scholars to conduct an inquiry. "They all agreed," the narrator relates, "that I could not be produced according to the regular laws of nature, because I was not framed with a capacity of preserving my life." After much debate, he goes on,

> they concluded that I was only *relplum scalcath*, which is interpreted literally, *lusus naturae*: a determination exactly agreeable to the modern philosophy of Europe, whose professors, disdaining the old evasion of *occult causes*, whereby the followers of Aristotle endeavour in vain to disguise their ignorance, have invented this wonderful solution of all difficulties, to the unspeakable advancement of human knowledge.[1]

While Swift ridicules the idea of *lusus naturae*, which is interpreted literally, "games of nature," as having failed to progress beyond premodern theories of the origins and causes of natural forms, in fact he does not quite give an accurate account of contemporary trends in modern philosophy, since by the time he is writing the appeal to games of nature has already largely gone out of fashion. One of its firmest opponents, until just ten years before the publication of Swift's satire, was none other than Leibniz.

The idea in question enjoyed its greatest currency in the sixteenth and seventeenth centuries and was generally deployed to explain unusual or aberrant productions of nature, not only reports of miniature men but, more commonly, such things as the supposed figures of Jesus or Mary in the side of a cliff or the medical abnormalities reported on by Jacques Bouquet in his letters to Leibniz from Padua (discussed in chapter 1). What is more, it, or a close variant of it, was just as often deployed to account not only for wondrous occurrences, but also for perfectly quotidian cases of the emergence of organic form.

Consider, to begin, the Renaissance Platonist Marsilio Ficino's vivid account of a number of natural phenomena, including, among other things, spontaneous generation and the influence of the maternal imagination upon the development of traits in the fetus. Ficino asks rhetorically: "From the beginning of any thing that is to be generated, do not celestial influences bestow wonderful gifts in the concoction of the matter and its final coming together?" Spontaneous generation, then, is for him nothing other than what occurs when the rays of the heavens concoct suitably disposed matter into complex organisms. Thus Ficino goes on to ask: "Do not innumerable frogs and similar animals often, when the face of the heavens favors it, leap forth out of the sand in a moment? Such is the power of the heavens in well-disposed material." Ficino adduces a number of other earthly phenomena that involve the influence of the powers of vision and imagination, making the case that, a fortiori, celestial rays have the power to influence the form of earthly things. He maintains that "the immense size, power, and motion of celestial things brings it about that all the rays of all the stars penetrate in a moment the mass of the earth." These rays even penetrate all the way to the center of the earth. "By the rays' intensity, the material of the earth there—being dry and far from any moisture—is immediately kindled and once kindled, is vaporized and dispersed through channels in all directions and blows out both flame and sulfur." He describes this fire as "very dark," and "like a flame without light," using the same vivid phrase that, as we have seen, Descartes would later echo in describing the "fire" that burns in the heart at the moment the fetus is quickened. Ficino continues: "Finally, diverse powers come into being in the combinations of rays with each other of one sort or another, here and there … instantly with an emission of rays forces are imprinted in images, and divers forces from a different emission."[2]

Consider, in turn, the sixteenth-century Dominican Antoine Goudin's account of the origins of fossils. In his *Philosophy, Following the Principles of Saint Thomas*, he argues that there are both efficient and final causes at work in the earth's production of rocks that resemble animals or parts of animals. Their efficient cause is a sort of cooking brought about by exhalations from the depth of the earth that makes the strata where fossils are found into a furnace of sorts. Their final cause, in turn, is

> a certain force earth itself possesses variously, following the different places in which the mixed body is formed. This force, similar to the maternal bosom from which animals arise, assuredly plays a great role in the formation of these bodies; this is why, according to Aristotle and Saint Thomas, earth and water furnish to everything arising from the bowels of the earth their

> matter and bosom, as would a mother, while heaven and the stars fulfill the office of the father, who imparts the form.[3]

For Goudin, a male formative principle exercises its influence over the maternal matter of the earth and thereby gives rise to forms in earth that resemble living beings. A fossil is simply a "spontaneously" generated creature whose form is imposed in the wrong sort of material—stone, say, rather than pliable mud—and so is unable to live and move as an animal does, even if it partakes of animal form.

Thus we see that the question of the origins of fossils is intimately connected to the question of spontaneous generation, which in turn is assimilated, by Ficino among many others, to the process of trait acquisition in fetal development. All of these are cases of nature's productive capacity, which is conceived along the lines of traditional accounts of sexual generation as the imposition of form upon matter. Those instances of this sort of productivity that appear to happen exceptionally—as, for example, in the case of monstrous species, or the appearance of animal-like traits in human infants, or the appearance of organic forms in a geological substratum, as in the case of fossils—are picked out as games of nature, but these are only the most noteworthy instances of a much more diffuse, indeed universal, natural generativity.

One might suppose that mechanist natural philosophers would shy away from the view that nature, in itself, is able to generate any of the things described by Ficino and Goudin. After all, their model of generation had been based on the sort of basic conceptual division between form and matter that the mechanists would come to eschew. Yet, remarkably, the sort of explanations to which these premechanist thinkers appealed continued to play an important role in the seventeenth century in accounting for the causes of the emergence of organic order, whether in a pond, in the side of a cliff, or even in the particular traits of a child's face. Leibniz, with his firm insistence that "nature does not play," would perhaps be more successful than any of his predecessors or contemporaries in moving beyond the sort of explanation favored by Ficino. Even Leibniz, however, does not exclude, for example, the power of the faculty of the imagination in embryogenesis, and to the extent that he does succeed in eschewing this and similar powers, interesting problems arise as to the place of spontaneity in Leibniz's natural philosophy.[4]

In this chapter we will look at three distinct cases of natural generativity: (i) the influence of the maternal imagination in fetal development, (ii) spontaneous generation, and (iii) the origins of paleontological forms. We will be considering Leibniz's position in the history of attempts to account for the emergence of organic order in three broad classes of entity: embryos, worms, and fossils. Insofar as these classes are not generally seen today as giving rise to the same kind of questions, in this chapter, more so than in the others, we shall have to stray for long periods from Leibniz and into the broader context of these natural-philosophical questions in order to properly understand the full rationale of Leibniz's strategies in answering them.

Imagination, Trait Acquisition, and the Doctrine of Marks and Traces

As early as the *Directiones* of 1671, Leibniz expresses a cautious openness to the possibility of influence of the imagination on the states of the body. He neither accepts it nor rejects it, but instead proposes that "tests should be set up to determine what the powers of the imagination and the belief[s] of the patient are capable of bringing about. To this end physicians should be given the art and the means to convince the patient of all manner of things."[5] He writes more than three decades later in the *Nouveaux essais* of 1704 with considerably more certainty about the special case of the maternal imagination: "It can happen that a female brings an animal into the world that seems to derive from another species, and that the imagination of the mother alone has caused this irregularity."[6]

What now are the reasons for the endurance of interest in this doctrine, dismissed by some scholars as a mere "wives' tale,"[7] in the philosophy of Leibniz? Does it do important work in the context of his theory of generation, or does it occur in his writings, as it were, vestigially? In order to adequately answer this question, it will be useful to consider the role it played in the philosophy of a number of his contemporaries. As we will see, the theory plays a vastly less important role in Leibniz's thought than in that of other mechanist philosophers, and this, it will be suggested, is for the deep reason that it is incompatible with his doctrine of preestablished harmony.

The imagination theory, while in some sense helping its defenders to avoid the now off-limits forces of Aristotelian natural philosophy, in another sense allows these forces to continue on in a different guise. It might be suggested that the transformation the general account of heredity undergoes from the ancient to the early modern period effectively shadows the better-known transformation of the concept of idea. Just as we witness a transformation of this latter concept—which originally described real entities in the world or beyond it that inform the world and make individual beings the sort of beings they are—into a concept that describes mental entities had by individual thinking subjects in the act of thought, so too we witness a migration of the responsibility for heredity from the form of humanity or bovinity, once thought to direct the individual human or cow fetus's gestation, to the mother's own, individual imagination. Indeed, from the Renaissance into the early modern period, the role of the imagination in the inheritance of traits (hereafter, "the imagination theory") was most often conceptualized as just another causal force in nature rather than a deviation from nature's ordinary course.[8]

Interestingly, many sixteenth-century authors appeal to the imagination theory while making a conscious effort to dissociate it from magic. Pietro Pomponazzi claims in his 1567 *De naturalium effectuum admirandorum causis* (On the Causes of Admirable Natural Effects) that the power of imagination can be used to cure the illnesses of others and implies that it can also be used, should one wish, to bring illness to the healthy. Only the latter goal is pursued by "old sorcerers [vetulis fascinantibus],"[9] while the former is just good medical practice. This same distinction between the legitimate imagination theory and the spurious practices of old sorcerers such as chiromancy is sustained into the seventeenth century; as Lynn Thorndike notes, physiognomy, broadly construed in the early modern period to include the imagination theory, "is to be accounted for by the fact that, while other forms of divination, including for many even judicial astrology, were condemned as superstitious, it was regarded as having a natural basis."[10]

Even Paracelsus, seldom one to feel the corrective prick of Occam's razor, seeks to place the imagination theory on a firm and respectable footing relative to other evidently more speculative theories such as judicial astrology. In the *De natura rerum* of 1537 Paracelsus claims that birth defects are to be attributed to the degree of the zodiac rising on the Eastern horizon at the time of birth: "I have observed many … monstrous signs, in men as well as in women, all of which should be regarded as monstrous signs of occult ascendants with evil influence. Hence the proverb: 'the more crooked, the more wicked; lame limbs, lame deeds.' For these are signs of vices and seldom signify anything good." Thus, birth defects are signs of vice, and this vice is traceable to the positions of the stars. But, Paracelsus continues, "Often these monstrous signs come from the stars of people's minds, which … ascend and descend in accordance with the individual's fantasy, mode of thinking, and imagination. Thus, often women give birth to monsters or to children marked with signs while they are still in the womb, because the women have been subject to fears or terrors, and feed on these in their imagination."[11] For Paracelsus, imagination moves in to explain given effects when astrological explanation seems far-fetched; from his point of view the explanation in terms of the power of the imagination is preferable, in view of its evident naturalism, to the explanation in terms of the power of the stars.

Leibniz, at least in the *Directiones* of 1671, believes that neither power should be dismissed out of hand, even if both should be subjected to further scrutiny. We have already seen (in chapter 1) his recommendation in that work that tests be set up to determine the power of the imagination upon the body. Elsewhere in the same work, Leibniz advises that "attention should be paid to astrological effects: whether for example it is true what they say, that if a woman gives birth during a (solar) eclipse, she and the child will die, and other things in this sort of tradition."[12]

Many premechanist thinkers had been interested in appealing to the power of the imagination over the developing fetus primarily in order to explain games of nature in a narrow sense, that is, instances of abnormal fetal development in which nature is, so to speak, dirempted from its usual course. In the seventeenth century, in contrast, this same power came to be invoked in the course of explaining the ordinary process of trait acquisition and in the course of explaining what happens, as Aristotle says, "always or for the most part."[13] This transformation may be seen in part as the natural consequence of the banishment of final and formal causes from scientific explanation. For an Aristotelian there is an independent formative power guiding the fetus, a power with which the mother's imagination might interfere; indeed, for Aristotle the mother's role in reproduction is in a sense *always* interference, for it is her material causation that impedes the perfect numerical reproduction of the father. In the later Aristotelian tradition, the restriction of the mother's role to pure material causation recedes, yet the possibility of her imagination playing a formative role is still seen as a deviation from the ordinary course of reproduction. In the Coimbran Aristotle commentaries, the imagination is held to "occasionally [make] the formative faculty wander from its target, and imprints upon the fetus absurd or alien figures."[14] For the Coimbrans there was a proper, innate formative faculty that guided the ordinary development of the fetus, and the mother's imaginative faculty could, in moments of distress or excitement, interfere with the normal formation of the fetus: the one formative faculty could get in the way of the other one, while the natural process was the development of the new natural being from internal forces. The influence of the external maternal imagination was thus unnatural or aberrant. In mechanist embryology, by contrast, the fetus had no innate formative faculty of its own: it was entirely formed by the impact of external forces, including the maternal imagination, now nominally reconceived as a purely physiological force. In other words, in the sixteenth century, the imagination theory was convenient, primarily in the explanation of aberrations; in the seventeenth century, deprived of formal and final causes in the account of organic growth, it was not so much convenient as necessary in the explanation of the regular course of sexual reproduction.

At least one mechanical natural philosopher, as we will see, would observe that without such a power of the maternal imagination one would not only be unable to account for the inheritance of particular variable traits, one would also be left unable to explain ordinary species reproduction. While mechanists could be reasonably confident that inorganic natural phenomena, and perhaps even "the formation of the fetus in general," might soon be explained in terms of matter in motion alone, such limited means seemed utterly insufficient when attention was turned to the seemingly irreducibly complex process by which, as Aristotle had put it, like begets like, and a mechanist account of this phenomenon, such as that offered by Descartes, comes out looking like a fantastic exercise in wishful thinking.

For roughly sixteen years, from 1632 to 1648, Descartes appears to have been frustrated by the evident intractability of animal generation and fetal development within the constraints of mechanism. In the *Discours de la méthode* he acknowledges that he is simply too ignorant to explain these "in the same style as the rest, namely, by demonstrating effects from causes, and showing from what sort of seeds, and in what manner, nature must produce them."[15] Yet eventually he manages to produce something of a treatise on the formation of animals, even if incomplete, as a component of his *Description du corps humain*, first published posthumously in 1664. In this work, Descartes begins by describing the initial action of the two parental seeds upon each other, how they, as a result of their heat, "serve as a leaven to each other" (an instance of fermentation, discussed already in chapter 2), which ultimately causes some particles "to gather toward some part of the space that contains them; and, expanding there, they press on the others that surround them, which begins to form the heart."[16]

In the *Description* Descartes has remarkably little to say about the subsequent acquisition of particular traits, save for a rather elaborate account of sexual differentiation, according to which every fetus sends forth its sexual organ in the direction of the mother's navel, so that if the child is facing toward her back, the "penis" will thrust inward and so result in a girl, while if the child is facing forward it will thrust out and yield a boy. This account raises interesting questions. Mechanism renders even sexual dimorphism something of a mystery: if there is no longer a matter/form dichotomy onto which the male/female one may be mapped, then why is there not simply universal parthenogenesis instead of distinctly sexual reproduction?[17]

Beyond the problem of sexual differentiation, Descartes also attempts an account of more specific traits. Thus, for example, he adopts the common view that facial hair is a result of "dryness" in the body and explains that "the dryness of males results from the transpiration of spirits through the testes."[18] But what about even more specific traits, not, say, the presence or absence of facial hair, but that hair's color and texture? What about the exact pigment of the skin, the modality of the earlobes, attached or unattached, or the color of the eyes? Here, Descartes' account of the development of fetuses is at its most inadequate. There is, it would seem, only a hint of a solution, and it is to be found in scattered comments, later more fully developed by other mechanist philosophers, concerning the formative power of the mother's imagination.

In a letter of January 29, 1640, Descartes writes to Lazare Meyssonnier (whom he has accused of being misled by astrology, chiromancy, and other stupidities in a letter of the same day to Marin Mersenne)[19] that he is suspicious of the fable according to which the urine of a man who has been bitten by a rabid dog contains "effigies of little dogs." But, he continues, if it actually does happen, this phenomenon should be no less difficult to explain than the causes of "those marks that children receive as a result of the desires [*envies*] of their mothers."[20] A few months later, he writes to Mersenne, who had worried that such marks might be damaging to Descartes' account of mind-body interaction, that there is nothing at all so strange about *marques d'envie*, and he now maintains that there is nothing impossible about the claim concerning the effects of a rabid dog bite.[21]

In his published works, Descartes makes two references to the *marques d'envie* that interest Mersenne. One is in *La dioptrique*: "I could even demonstrate to you, moreover, how sometimes [the image] can pass from [the pineal gland] through the arteries of a pregnant woman into certain parts of the child that she carries in her womb, and how it forms its markings there, which cause such astonishment among the learned."[22] And again in *L'homme*, in almost exactly these words: "I could add something here about how the traces of [the mother's] ideas pass through the arteries to the heart, and thus radiate throughout the blood; and about how they can sometimes even be caused by certain actions of the mother to be imprinted on the limbs of the child being formed in the womb."[23]

Malebranche, for his part, will make a very significant addition to the history of the mechanist appropriation of the imagination theory: he maintains that without it there would be no possibility of accounting for species reproduction within a mechanist framework. Thus he writes in the *Search after Truth* of 1676:

> It is true that this communication between the brain of the mother and that of her child sometimes has bad results when the mother allows herself to be overwhelmed by some violent passion. Nevertheless, it seems to me that without this communication, women and animals could not easily bring forth young of the same species. For although one can give some explanation of the formation of the fetus in general, as Descartes has tried successfully enough, nevertheless it is very difficult, without this communication of the mother's brain with the child's to explain why a mare does not give birth to a calf, or a chicken lay an egg containing a partridge or some bird of a new species.[24]

Malebranche begins his discussion of the subject with the usual sensationalist anecdotes about defects; his chosen example is of a child born with bones broken in exactly the same places where a publicly executed criminal—whose execution the pregnant woman had the misfortune to witness—had had his own bones broken. He also tells us that women with excessive cravings give birth not only "to deformed infants but also fruits they have wanted to eat, such as apples, pears, grapes, and other similar things."[25] These things happen, he explains, because

> infants in their mothers' womb, whose bodies are not yet fully formed and who are, by themselves, in the most extreme state of weakness and need that can be conceived, must also be united with their mother in the closest imaginable way. And although their soul be separated from their mother's, their body is not at all detached from hers, and we should therefore conclude that they have the same sensations and passions.[26]

The "flow of spirits," Malebranche explains, "excited by the image of the desired fruit, expanding rapidly in a tiny body, is capable of changing its shape because of its softness."[27] The infants become like the things for which their mother has communicated to them a desire. But the mother, since her body is not soft enough to take on the figure of the things she imagines, remains unchanged.

Malebranche, as we have seen, like Leibniz, supports a preformationist version of animal generation, though for Malebranche all future animals are contained not in the spermatozoa of their male ancestors but in the ova (still a strictly hypothetical entity in the seventeenth century) of their female ancestors. All human beings were contained *in ovo* in our first mother, Eve, and are passed down matrilineally, so to speak, egg contained within egg, until the egg is given its chance to enter what Leibniz would call "the larger theater" by developing into a fetus after being stimulated along this path by the father's contribution. In Malebranche, then, the great challenge becomes just the opposite of the one faced by Aristotle: how to account, not for resemblance to the mother's side, but rather for the acquisition of paternal traits. But Malebranche has at least some means of accounting for resemblance to the father, or to paternal relatives known to the mother, that Aristotle lacked: paternal resemblance results from the mother's having an idea of the father.

Malebranche's conviction that the formative power of the maternal imagination is required to form an embryo into a member of the particular species to which its parents belong suggests that, in his view, the preexisting egg is not really, strictly speaking, preformed, since until it begins the period of gestation it lacks even a minimal amount of "form," in the old sense of the word: it lacks that in virtue of which it might be said to belong to one species rather than another. Andrew Pyle, observing this problem in Malebranche, asks, "Can there be organisms that don't belong to any species?"[28] As Pyle rightly notes, Malebranche does seem to retract his claim, cited above, that without the imagination theory we could not account for the production by members of a species of members of the same species. Malebranche writes:

> I do not deny that God could have disposed all things necessary for the propagation of the species throughout infinite ages in a manner so precise and regular that mothers would never abort, but would always give birth to children of the same size and colour or, in a word, so similar that they would be taken for one another, without this communication of which we have just spoken.[29]

On this account, then, the preexisting seed does not have to *become* a member of a species. It always already is one; indeed, it is an exact copy of all other unborn members of its species, and, it becomes differentiated from them through specific traits, if not generic traits, through the influence of the maternal imagination. The imagination, that is, is responsible for a goat's becoming speckled, but not for a preexisting seed's becoming a goat. There is, however, no obvious reason to prefer this statement to the statement that immediately precedes it in the *Search after Truth*, that we have just cited above, in which Malebranche explicitly affirms that it would be *impossible* to explain how animals give birth to other animals of the same species without recourse to the imagination theory.

Scholars have generally supposed that the imagination was at most thought to break into the process of fetal development on rare occasions and disrupt the otherwise strictly mechanical process. Yet there is much textual evidence that the maternal imagination does not disrupt a normal process but is *itself* part of this process; as Descartes says, the mother is the "formative agent of all of the exterior members [formatrix omnium membrorum exteriorum]," regularly communicating images to the fetus through the umbilical arteries that serve to shape and imprint its visible body. This, however, is not, at least from the point of view of a mechanist like Descartes, the intervention in an otherwise physical process of the mental. For images, too, are physical things on his account.

In sum, the role of the maternal imagination in fetal development was adaptable across different ontologies and did not necessarily imply commitment to nonnatural or immaterial forces. And in this respect the maternal imagination provides a useful illustration of a general rule that should guide our interpretation of the nature of seventeenth-century scientific parsimony: while it is true that many natural philosophers sought to pare down the list of *forces* at work in nature, there is no a priori way for the historian to tell which *phenomena* were associated with which forces. In other words, a thinker such as Descartes could have a radically minimalist ontology of forces but still remain committed to phenomena that others might explain in terms of the forces he rejects, and that would themselves subsequently be abandoned in the history of science.

Leibniz, for his part, will be intent on arguing that soul activity can have no role in the formation or the maintenance of the body. The fact that he would so much as consider adopting the doctrine of maternal influence in his own writings, as in the passages cited above, is particularly interesting, in view of his frequent insistence that the soul in no way may be seen as having the responsibility for "making the body." As he writes in his polemic against G. E. Stahl, speaking of Ralph Cudworth and others,

> they were mistaken who believed that there would be in the soul, building its own body (or in I-know-not-what other factory supervisor), such a wisdom and power that it could contrive and produce the divine machine of the animal. For the outcome of the artifice is owed to divine preformation."[29]

In a sense, the imagination theory transfers the role of the "supervisor" from the developing fetus to the mother on whom it depends for its development. But what need might Leibniz in particular have of this theory? Does it simply enter his work as a result of passive incorporation of ideas that are, as it were, in the air? One possible and very unexpected point of entry into his thought may be a doctrine ordinarily associated with his logic. In 1686, Leibniz presents his well-known "doctrine of marks and traces" in the *Discourse on Metaphysics*:

> There are from all time in the soul of Alexander traces of everything that has happened to him and marks of everything that will happen to him and even traces of all that happens in the universe, though only God can know them all.[31]

Now one certainly would not want to say that here Leibniz consciously or unconsciously intends to connect the doctrine of marks and traces with embryological considerations. Yet the extent to which his description of concept containment parallels his own accounts elsewhere—as well as the accounts of others, of the way in which fetuses come to acquire traits—is worth noting. Thirteen years earlier, in the *Search*, Malebranche would claim both that the human fetus inherits from the mother physical traits as a result of her "violent passions" and that similar violent passions of the first parents have left physical traces on the brains of all subsequent generations. He writes that sin is communicated from one generation to the next as a result of "very profound traces from the impression of sensible objects" in our first parents, "which they may well then have communicated to their children."[32] Elsewhere in the same work, Malebranche writes that "many children carry on their faces *marks or traces* of the idea that struck their mother."[33] It is evident that for Malebranche the "biological" question of the inheritance of traits on the one hand, and on the other the moral and theological problem of the transmission of original sin, are of a pair.

Such an association was indeed widespread in the seventeenth century. As recent ground-breaking work by Richard T. W. Arthur discusses, according to the primarily Lutheran doctrine of traducianism, which Leibniz is known to have held in his youth, original sin is transmitted to children directly from the souls of the parents, and so on back to Adam.[34] Thus Leibniz writes to Lambert van Velthuysen in a letter of May 1671, mostly promoting his recently composed *Hypothesis physica nova*:

> I explain by means of this body, in which a mind is implanted, that mind can multiply itself, without new creation, *per traducem*. … Nor do I think traduction is despised by certain theologians except insofar as it seems to imply corporeality and divisibility, and thus mortality. That it does not is shown with as much clarity as sunshine by the very nature of indivisibles. Once this is supposed, it is at least more rational to concede human propagation to be natural than needlessly to invoke God to perform the perpetual miracle of new creation.[35]

In Daniel Sennert, whose theory of subordinate forms, as we have seen in previous chapters, bears important similarities to Leibniz's model of nested individuality, traduction is identified explicitly as a notion borrowed from botany, namely, from the grafting of plants:

> For example, in trees, in which the seminal force is diffused throughout the whole body, if some part is cut off, and that of some other tree is inserted, the soul of the tree from which the shoot was cut is communicated into the other tree: in the same way, when the soul is conveyed with the semen of animals into the female uterus, so finally from this semen endowed with its own soul the complete animal emerges.[36]

For Sennert, the theological question of the origins of souls and the "biological" question of the origins of bodies receive one and the same answer. In the context of Leibniz's philosophy, if we recall that the soul and the body are for him, as it were, two automata running along parallel tracks, then we may perhaps see traducianism as an earlier anticipation, in accounting for the origins of souls, of the parallel account of the origins of bodies that he would later offer by way of the theory of preformation.[37]

Malebranche's *Search* was published while Leibniz was still in Paris, and from the year of its publication Leibniz grappled with Malebranche's ideas concerning occasionalism and preformation.[38] We may assume that prior to its appearance in the *Discourse*, Leibniz was already familiar with the doctrine of marks and traces in the literal, physical sense in which Malebranche intends it. Catherine Wilson has pointed out that it is often thought that Leibniz's doctrine of concept containment originated in Leibniz's logic, in his belief that a proposition is true in virtue of the containment of the predicate in the subject. However, she points out, we need to distinguish sharply between the concept containment theory of truth and the doctrine of marks and traces. While the former remains ontologically neutral as to the subject of the proposition, since, for example, Caesar's future actions can be contained in the notion of Caesar no matter what kind of thing Caesar is, the doctrine of marks and traces requires that Caesar "must be a substance of a certain type."[39] Namely, Caesar must be the sort of substance on which marks and traces might appear for inspection by an infinitely perceptive eye. The concept containment theory of truth and the doctrine of marks and traces are in many respects analogous to each other, and they are both about substances. But the former is a logical doctrine concerning concepts, while the latter is a doctrine literally about potentially visible properties of the primordia of things. We might be tempted to understand this parallelism as flowing directly from the doctrine of mind-body concomitance, understood as a subdoctrine of preestablished harmony: because every state of a simple substance is always accompanied by a bodily state through which it is explicated, it follows that every predicate contained within the complete concept of an individual substance must have some bodily mark corresponding to it. To be clear, this is not to say that Leibniz thinks of the doctrine of marks and traces as an embryological doctrine, but only that it follows from his commitment (i) to the constant organic embodiment of every substance; and (ii) to the bodily expression of everything contained within that substance's complete concept, that he is also committed to the view that every developing fetus will have external marks that report, so to speak, the various states of its soul.

As already suggested, what likely prevents Leibniz from adopting the explicitly embryological doctrine of the influence of the maternal imagination that had so occupied Descartes and Malebranche is his commitment to preestablished harmony, and so to the denial of any influence of any sort of external forces upon the body of a developing fetus. For Leibniz, even if we were to think of marks and traces in an embryological sense, as the bodily expression in the embryo of states of the embryo's soul, still the marks and traces could not be a record of the history of influences upon the body by external forces. Leibniz's particular doctrine, according to which the marks are always already there in the preformed individual, rather than being seared in at some point in the course of development, obviates the need to give an account of the role of imagination in fetal development.

In the polemic against Stahl of 1709–10, the Halle physician draws heavily on the theory of maternal imagination as support for his own anti-Leibnizian commitment to the real influence of the soul upon the body. Here Leibniz does avow that "it often happens that excessively violent passions of the soul excite great bodily motions, and that the affects of pregnant women manifest themselves in a very remarkable fashion in the formation of the fetus." Yet he maintains that ultimately this excitation can be cashed out in metaphysical rigor in such a way as to avoid any mention of real mind-body causation. In reality, Leibniz continues, "the soul does not change the laws of the motions and formations of the body," yet since there is "a correspondence and agreement" between the mother's soul and the womb, in the case of the formation of the fetus, "we rightly assign this change to the soul, when the state is evident in it from which the corporeal mutation follows."[40] In other words, Leibniz retains the theory of the influence of the maternal imagination, as a sort of "as if" doctrine, even though he recognizes that in metaphysical rigor it violates his causal theory.

Leibniz's cashing out of the doctrine here, it is interesting to note, is remarkably similar to other attempts to gloss causation[41] in a way that saves the traditional manner of talking about the interaction of substances even while denying its possibility at a deeper metaphysical level. In the end, the traits that emerge from the "violent passion" of the mother were already enfolded in the fetus, and before that in the spermatozoon, from the beginning of time. The traits unfold harmoniously with the successive states of the mother, but if one had looked hard enough before this unfolding occurred, one would have found distinct bodily "marks." The fetus is an automaton, which is to say that every state of it can follow only from its prior states. Another way of putting this is to say that every state of it arises spontaneously or from within.

Such a conception of spontaneity will prove to be important for our understanding of a number of other domains of Leibniz's natural philosophy as well. Let us turn, in the following section, to the problem of spontaneous generation before moving on in the subsequent section to the question of the origins of fossils.

"An Alteration of Man, a Generation of Worm": From Spontaneous Generation to Heterogenesis

The influence of the maternal imagination on the developing fetus is one traditional way in which form has often been thought to be imposed on matter through the activity of some sort of mindlike principle. Another is the variety of generation we call "spontaneous." Indeed, any comprehensive account of the history of spontaneous generation would need to contend with the fact that for most of the history of this theory generation is not "spontaneous" at all, in the sense of "coming out of nowhere," but rather involves the imposition of form in matter as a result of influx from the intelligent celestial bodies. Such generation may nonetheless count as "spontaneous" in that the forms produced are not produced in any law-like or regular way: there is no regular connection between the form of a barnacle or frog on the one hand and the form of the celestial bodies on the other. On the standard account of spontaneous generation going back to Aristotle, what sort of creature one ends up with is simply a result of the relative proportions of heat and moisture. Nonetheless, in spontaneous generation so understood, as in sexual generation, there is a sort of parent contributing the matter and another contributing the form, and the principle difference is simply that the progenitors are not biological beings, but rather celestial intelligences and terrestrial matter.

Like Ficino before him, the Cambridge Platonist Henry More explicitly describes "spontaneous" generation as resulting from a sort of celestial influx, while also identifying the influence of the mother's imagination on the developing fetus as simply another instance of the same widespread generative power in nature. In *The Immortality of the Soul* of 1659, More maintains that the sun and the stars are the "most Intellectual Beings in the world," and that these have

> filled the whole Earth with vital Motion, raising innumerable sorts of Flowers, Herbs and Trees out of the ground. These have also generated the several Kinds of living Creatures. These have filled the Seas with Fishes, the Fields with Beasts, and the Aire with Fowles; the Terrestrial matter being as easily formed into the living shapes of these several Animals by the powerful impress of the Imagination of the Sun and Stars, as the Embryo in the womb is marked by the strong fancy of his Mother that bears him.[42]

In the same work More argues for a sympathy between earthly and astral bodies as a consequence of their mutual subjection to the "Spirit of Nature." The universal spirit, More maintains, "is ready to change his own Activity and the yielding Matter into any mode and shape indifferently as the occasion engages him, and so to prepare an edifice, at least the more rude strokes and delineaments thereof, for any Specifick Soul whatsoever, and in any place where the Matter will yield to his operations."[43]

This sort of account of spontaneous generation—as imposition of a form from without, whose particular mode and shape remains free of the like-begets-like principle that governs sexual generation—seems to meet its demise at roughly the same time that the theory of sexual generation is transformed, from one of imposition of form by a paternal agent, into either a purely thermomechanical process (Descartes) or the triggering of some primordium (both ovist and animalculist preformation theory). In other words, the generation of frogs from cosmic rays falls out of favor not as a direct result of experimental refutations of spontaneous generation, such as Francesco Redi's famous 1668 study on maggots, but because the rays had been thought to play a role too analogous to the formal, active principle once attributed to semen but increasingly seen as superfluous. At this point, spontaneous generation comes to be accounted for in terms of heterogenesis, that is, as purely a consequence of putrefaction. According to the theory of heterogenesis, new organisms are not developed out of previously formless matter, but are rather merely the by-products of the decay—that is, the loss of functional unity once explained by the inherence of a form—of dead organisms. As is clear from the previous chapter, before Leibniz had developed his doctrine of preformation, and likely before he could have learned of Redi's experiments, he had already come to understand "spontaneous" generation as heterogenesis. This is perfectly compatible with preformation, since the worms that arise out of a decaying body are just newly independent corporeal substances that had previously been subordinated to the greater individual within which they were nested.

There were many important factors in the rise of heterogenetic accounts of nonsexual generation. One of these was skeptical libertinism, which relished the possibility that biological kinds, including human beings, have earthly, rather than divine, origins, and that the multifarious life forms we see around us are but the result of chance. In the sixteenth century, Girolamo Cardano and Julius Caesar Scaliger both entertained the possibility that the corpses of large animals could produce new, "perfect" animals or animals that traditionally had been thought to come into being only through the cycle of like begetting like. The libertines even suggested that human beings could arise from such a process.

According to the historian Giuliano Gliozzi, in his monumental study of early modern theories of racial difference, many of the defenders of human spontaneous generation in the sixteenth century were Paduans, and it is reasonable to assume that in that environment they were heavily immersed in Aristotelian biology. Among the more prominent and controversial of these was Lucilio Vanini, whom Gliozzi sees as "connecting the polygeneticism expressed in sixteenth-century naturalism with the version that would take on new forms in the milieux of French libertinism in the first half of the seventeenth."[44] Since there is no upper limit to how much putrescent matter could collect in a bog or mud bank, Vanini argued that the upper boundary for the size, if not the nobility, of a spontaneously generated organism was set largely by environmental circumstances (just as had been the case for Aristotle), in particular, by the extent of the concentration of putrescent matter on the one hand, and the heat of the sun causing it to transform into new life-forms on the other. Repeating a prejudice that goes back at least to Herodotus, Vanini presumed that the environmental circumstances ideal for the spontaneous generation of large animals, as well as of new animal kinds, were most likely to arise in Africa (*ex Africa semper aliquid novi*, ran the oft-repeated motto).

Vanini is not the only libertine to discern the connection between spontaneous generation and natural origins for humanity. Some, such as François de La Mothe Le Vayer, believed that it is only by appeal to spontaneous generation that we can explain the variety of humanoid, yet evidently soulless, creatures thought to dwell at the edges of the known world. As he writes, "nature is capable of producing on her own—without man's falling into execrable bestiality—animals that resemble us to such an extent that they force us to say that sometimes there is a greater difference from one man to another than between us and them."[45] La Mothe Le Vayer claims that this is not so hard to conceive if we are willing to draw on the authority of many ancient and medieval authorities, among them Plato,[46] Aristotle, Epicurus, Lucretius, and Avicenna, who all acknowledged that "the Earth had [earlier] produced us from herself as [she does] the animals."[47] La Mothe Le Vayer does not simply repeat the heterogenetic theory of the sixteenth-century naturalists; instead, he offers a developmental account according to which "men did not come into being originally in the perfect state in which we see them."[48]

The fact that in the Christian tradition, as opposed to the Aristotelian, the first man is born from the earth is worth some reflection. On the face of it, this should not count as an instance of *spontaneous* generation, since after all Adam is supernaturally created by a God who has a clear idea of what he is creating. In other words, Adam's creation admits of teleological explanation. With respect to later medieval, Renaissance, and early modern ideas about earthborn creatures, the distinction between these creatures' mode of generation and that of Adam is not so clear, since they, too, are seen as being generated as a consequence of heavenly or astral influx into terrestrial matter. Of course, the Christian God is meant to be "heavenly" only in a figurative sense, yet God's role in the first generation of human and animal species bears a remarkable resemblance to medieval and early modern ideas about the celestial "fertilization" of terrestrial matter. The standard nineteenth- and twentieth-century triumphalist accounts of spontaneous generation generally leave out the role of the sun and other heavenly bodies, yet these are almost always invoked by those seeking to define this mode of generation, even critically, in the era in which it was still an option.

In the *De generatione animalium*, Aristotle mentions, without much explanation, that the *pneuma* in animal semen is "analogous" to the material of the stars.[49] As one commentator notes, while Aristotle did not mean by this that the *pneuma* originated from the ether, we do find this view springing up in the later Aristotelian tradition.[50] Avicenna describes the *pneuma* as a "virtus informativa" not just analogous to but in fact of the same kind as the virtue of the heavenly bodies.[51] Throughout Scholastic philosophy, there is a common presumption that the formative power at work in nature in general is but a different manifestation of the formative faculty traditionally held to govern biological growth and development. This formative power filters down from the celestial to the terrestrial sphere, and in this respect we may say that in all cases of natural growth and development, including the emergence of fossils and crystals as well as of "spontaneously" generated organisms, there is an agent whose role is analogous to the father's in sexual generation, namely, the heavens.

But, again, this picture of spontaneous generation begins to change with sixteenth-century naturalism and then more radically with the double effect of seventeenth-century mechanism and libertinism. Cartesian embryology, like libertine theories of spontaneous generation, consists in the denial that generation takes place in a broader cosmological context. It is the result of minor causes: an animal fetus for Descartes is nothing ontologically over and above the clots of blood that serve to constitute it, just as a Nile-born ox is for Vanini nothing over and above the sludge from which it emerges.

Where, now, does Leibniz stand with respect to the ontological implications of the various accounts of spontaneous generation?

Leibniz had a clear if transitory early interest in the possibility of a role for the stars in biological growth and development. It is mostly in the very early *Directiones* of 1671 that we see him considering the possibility of such a phenomenon. He would, however, eventually reject even the possibility of such a role while continuing to believe in the reality of the influence of the imagination on fetal development: a phenomenon that, as we have just seen, was held by many thinkers, including Ficino and More, to be one manifestation of the very same force through which the celestial bodies were held to influence biological processes. Rather than adopting a theory of astral influx to account for spontaneous generation, the young Leibniz would gravitate toward a sort of heterogenesis, according to which new creatures arise not from the imposition of form by the stars on suitably disposed matter but rather through the corruption of older forms and the emergence of newer ones out of these.[52]

Leibniz's early model for such an understanding of the generation of insects and worms is evidently the Jesuit scientist Athanasius Kircher.[53] "Every living thing," Kircher writes in his *Scrutinium physico-medicum contagiosae luis, quae pestis dicitur* (Physico-Medical Investigation of the Contagious Pestilence, Which Is Called Plague) of 1658,

> produces from its own decay some congruous animal and different from all others. This we have proved by actual experiment for species of different herbs, and it is true for grain quickened into winged worms. It is just as certain among animals whether highly organized or simple. A dead and rotting ox is quickened into bees. … Horses living and dead produce wasps and beetles which for food then suck the blood of the animals that gave them life, to their great annoyance. Human beings (as well as some brutes) generate bedbugs, lice and fleas, which are thus as intimate companions provided by nature to draw off corrupted blood. A dead body, foul with decay, becomes a nursery for worms. Remains of insects, when they rot, produce animals of a similar nature.[54]

Elsewhere in the *Scrutinium* Kircher reveals the experimental basis of his conclusions:

> Air, Water, and earth teem with innumerable insects capable of ocular demonstration. Everyone knows that decomposing bodies breed worms, but only since the wonderful discovery of the smicroscope [*sic*] has it been known that every putrid body swarms with innumerable vermicules, a statement which I should not have believed had I not tested its truth by experiments during many years.[55]

Although most of Kircher's theories would fall into disrepute, by the middle of the century heterogenesis would prevail over celestial influx as the preferred account of spontaneous generation.[56] Leibniz's early interest in this account of the generation of insects and worms is thus not exceptional, but if we see it as one of the important elements in the eventual emergence of his theory of nested individuality (treated at length in chapter 4), then we may conclude that Leibniz, unlike many of the other supporters of heterogenesis, would see its important implications for key philosophical notions such as substance and individuality.

In his famous 1669 letter to Jakob Thomasius (which Michel Fichant identifies as the young Leibniz's "lettre-programme,"[57] a veritable manifesto), already cited in chapter 4, Leibniz indicates that microscopy is relevant to his thinking about the natural world and signals that it has revealed a sort of universal heterogenesis, not just of creatures ordinarily seen as biological but of such elements as rust as well. The purpose of Leibniz's letter, specifically, is to show off the ease with which he is able to reconcile the true teaching of Aristotle with the mechanism of the moderns. He begins with the fairly extreme revisionist claim that form in the original Aristotelian sense of "form" can be understood in terms of figure. With this out of the way, he continues: "It remains for us to come to change." He acknowledges that the moderns account for all change in terms of local motion and tries to make sense of Aristotle's four-part analysis of cause—that is, into generation and corruption, increase and decrease, alteration, and change of place—in light of the moderns' simplified analysis. The outcome of his observations in this matter is that the four-part analysis is worth retaining, at least for conceptual purposes, but that strictly speaking, as he writes, "all changes can be explained by motion." His choice of examples is telling:

> I observe in advance that numerically one and the same change may be the generation of one being and the alteration of another; for example, since we know that putrefaction consists in little worms invisible to the naked eye, any putrid infection is an alteration of man, a generation of worm. Hooke shows similarly in his *Micrographia* that iron rust is a minute forest which has sprung up; to rust is therefore an alteration of iron but a generation of little bushes.[58]

Nearly the same observation is made in the *Theoria motus concreti* two years later, where Leibniz argues that the death of living bodies "is invasion by worms, dependent on an invisible fructification."[59] Leibniz speaks of invasion as though the worms are coming from outside, but he also describes the worms as "fructifying" within the body, that is, growing up aboriginally, as it were, out of the physical matter of the dying body. Here death is only relative: while it forces one corporeal substance to retreat to "the smaller theater,"[60] it also simultaneously permits countless other corporeal substances to move to the larger theater, to act directly in accordance with their substantial programs rather than subordinately as nested individuals within the greater corporeal substance's body.

Having explained in the Thomasius letter why he believes that form is nothing but figure, Leibniz goes on to explain that the other basic problem of Aristotelian metaphysics, generation, is not motion but rather *the end of motion*:

> It is no objection that generation occurs in an instant while motion involves succession, for generation is not motion but the end of motion; the motion is already finished at that instant, for a certain figure is produced or generated at the very last instant of motion, as a circle is produced in the final moment of a revolving motion.[61]

Leibniz appears to be voicing acceptance here of already widespread views, evident in both Kircher and Hooke, according to which: (i) living creatures are generated from the environment, not ex nihilo, as the theory of spontaneous generation is often taken to hold, but rather from some preexisting material, the alteration of which brings about what we call "generation," but which can be explained in terms of change of place alone, along perfectly mechanistic lines; (ii) there is no fundamental division between the mineral and the vegetable, or, more generally, between the organic and the inorganic; (iii) animal bodies contain the preexisting material, the alteration of which can bring about the generation of new creatures. Putrid infections do not necessarily come from without but can just as easily come from a change of conditions within the body.

Biological theories of heterogenesis may also be traced in part back to chemical theories of subordinate forms. As we have already seen, Leibniz's shift to the organic model of the body involves a transition from his early animal-economical view, to a view that might be called "chemical Aristotelian," which has its roots in medieval alchemy, and which, in Leibniz's own century, is vigorously defended by Sennert. On this view, each body, in addition to its dominant substantial form, contains numerous, actual subordinate forms rather than just the potentiality to give rise to these forms when corrupted or altered. In this connection, William Newman notes a very interesting feature of medieval chemical theories: for the chemists as for the large majority of natural philosophers prior to the modern period, "worms could be seen as a normal decomposition product of such materials as cheese and flesh. Hence the worms were potentially present (*in potentia*) in a given sample of cheese or flesh, but they were not, of course, actually present (*in actu*) in the cheese or flesh before those substances became rotten."[62] As Newman explains, for a natural philosopher such as the sixteenth-century chemist Thomas Erastus—who believed that metals can be resolved into oils, waters, and so on, but nonetheless that this does not require that the metals are composed of these things *in actu*—the implausibility of the body's actual composition out of worms served as an analogical argument against the chemical theory of the actual composition of metals out of nonmetallic components. For Erastus, a chemist "who states that the normal decomposition products of metals are always present *in actu* within the undecomposed metals is making a claim tantamount to the absurd view that cheese and flesh are made of worms."[63]

As we have seen, however, for Leibniz the example of the body and the worms would only have served to strengthen the anti-Erastean, chemical view that subordinate forms reside in bodies. The worms in the body are indeed there *in actu*. In fact, on Leibniz's model of organic body, the very suggestion of spontaneous *generation* cannot come up: the appearance of worms in a rotting cadaver is only the appearance in the "larger theater" of what was already there. Leibniz's theory is thus a sort of heterogenetic account of nonsexual generation, according to which generation is the transformation of rotting biomatter into new creatures. The one tremendous difference is that, for Leibniz, when the worms emerge, this is not strictly speaking any sort of genesis at all. One could thus say that whether some change counts as generation or as alteration is for Leibniz a relative question.

Leibnizian heterogenesis is thus starkly different from classical accounts of spontaneous generation: it is neither spontaneous nor is it generation. It is rather more like libertine accounts than the accounts that would take a broad range of natural phenomena to be the result of the imposition of form by some natural or cosmic formative principle. For Leibniz though, unlike for the libertines, it is not motivated by any sympathy for the scandalous idea that human beings might, like worms, be earthborn. Instead, it is motivated by Leibniz's firm commitment to the perpetual organic preformation of all corporeal substances and by his model of nested individuality, according to which these organically preformed corporeal substances conspire in the constitution of one another's organic bodies.

Another natural phenomenon taken by many of Leibniz's predecessors and contemporaries to involve the imposition of form on matter by some supernatural or cosmic generative principle is the production of fossils. Accounting for these objects was a task Leibniz took very seriously, and here most of all we see just how thoroughgoing was his opposition to natural spontaneity, understood as the arising of a new state of created substances undetermined by their prior states.

Geogony and the Problem of Fossils

The speculative sciences of origins in general, and paleontology in particular, complicate our image of early modern science, for since the nineteenth century it has been widely accepted that the sciences that deal with a nonrepeatable past, insusceptible to experimental confirmation, are epistemologically less well founded than sciences such as mechanical physics that are concerned with what bodies do always and everywhere, or what hypothetical bodies would do under hypothetical circumstances. There has also been a tendency, as we have already emphasized, to place the sciences of life further down on the scientific hierarchy than mathematized physics. As we saw in the introduction, Pierre Duhem understands this priority of the one science over the other as resulting from the fact that physics is a "mature science," to the extent that it seeks to interpret causal relations in terms of an abstract symbolic system, while anatomy, for example, is only a "causal theory," to the extent that it seeks to explain bare facts in terms of everyday reasoning. From this perspective, paleontology is doubly degraded, for it is interested in the reconstruction of a buried and unrepeatable past by means of traces of formerly living creatures, back to which one refers by the most ordinary causal reasoning at one's disposal.

Leibniz's own paleontology is embedded within a much more fundamental debate in early modern natural philosophy concerning the ontology and origins of natural beings and concerning the faculty of the imagination and its role in the generation of forms, the nature and frequency of miracles, and the epistemological limits of any effort to reconstruct events that have been buried in the distant past. His greatest contribution to the history of geology, what we think of as the *Protogaea*, is largely the result of C. L. Scheidt's christening of an unfinished manuscript of Leibniz that he, Scheidt, published in 1749. What Leibniz himself refers to as his "Protogaea" is not the work that today bears that name but rather a one-page text published in the *Acta Eruditorum* of 1693.[64] Leibniz's original title for the manuscript eventually published by Scheidt was *De ortu et antiquissimo statu rerum naturalium in regionibus Brunsvic.-Luneb. Dissertatio* (Dissertation on the Origin and the Most Ancient State of the Natural Things in the Braunschweig-Lüneburg Regions).[65] This title in turn echoes that of a 1665 work by Hermann Conring, *De antiquissimo statu Helmestadii et viciniae coniecturae* (Conjectures on the Most Ancient Condition of Helmstedt and Vicinity).[66]

What came to be known as Leibniz's *Protogaea* was written between 1691 and 1693, like the short text published in the *Acta Eruditorum*. The longer work was supposed to serve as the first part of his history of the Guelf family, the ancient lineage that would give rise to the house of Brunswick, of which Leibniz was the secretary and official historian. Leibniz averred that in order to write this history with adequate depth, it would be necessary, so to speak, to begin at the beginning, which is to say to describe the formation of the earth, the oceans, the continents, and the mountains. He was procrastinating, of course, and in the end he succeeded in *not* completing the task of writing the more recent history he had been assigned until 1714, at which point his employer, the Elector of Hanover, having just been crowned King George I of England, punished him for his tardiness by leaving him behind in Hanover to finish it. The history of the Guelfs picked up speed at this point, but by now Leibniz was too old, and when he died two years later, he left only fragmentary pieces of it completed.

At first glance, the *Protogaea* seems best categorized as a contribution to the variety of writing that may be called "cosmography," of which the most prominent examples in the seventeenth century were the works of Steno,[67] Kircher, and Thomas Burnet, and also, notably, the third and fourth parts of Descartes' *Principia philosophiae*. Leibniz describes his project as a "natural geography" whose aim is "to describe the diverse kinds of terrain and their stratification in different regions." He explains that this new science will, if done correctly, serve to corroborate the account of Creation familiar from scripture, though in the end he is careful to leave biblical exegesis alone as an autonomous discipline:

> These conjectures concerning the infancy of the globe appear plausible, and contain the seeds of a new science that could be called natural geography. But we do not have the pretention of establishing this science, but rather only of making an initial attempt. And without boasting of the agreement that seems to exist between our opinions and the holy scriptures, we will defer to the judgment of those whose task it is to interpret them. And although the vestiges of the primitive world offer uniform indications to us in the present state of things, we do not doubt but that our descendants will judge still better in these matters than we.[68]

Yet Leibniz's goals in this work are at least in part much more concrete than the general description he gives of it as "natural geography" reveals. If there is a grain of truth in Leibniz's affirmation that his account of the origins of the earth are relevant to his history of the Guelf lineage, this is because the part of the earth to which he devotes the most attention, namely, the Harz Mountains, belongs to the current house of Brunswick, and is in fact, in view of its rich silver deposits, an important source of its operating revenue. At the time of writing what we call the *Protogaea*, Leibniz had recently spent the better part of five years in that region attempting to construct a hydraulic and wind-driven system for generating sufficient energy to excavate the entirety of his employer's holdings in the Harz.

What we call the *Protogaea* represents the confluence of two of Leibniz's long-standing interests: geogony and mineralogy, the one arising from deep natural-philosophical concerns that Leibniz shares with earlier philosophers such as Descartes, the other flowing from practical concerns, most notably having to do with the economic profit to be derived from a well-informed approach to mineral extraction. As for mineralogy, as early as 1682, four years after his first visit to the Harz Mountains, Leibniz expresses a wish to write a treatise on minerals.[69] In that same year, Leibniz also publishes the *Denkschrift betr. die allgemeine Verbesserung des Bergbaues im Harz* (Memorandum concerning the General Improvement of Mining in the Harz), which is a very detailed and thorough analysis of many aspects of the practice of mining, including scientific, economical, and legal ones.[70]

In the *Protogaea*, the practical questions of the sort that had been the principle focus of the *Denkschrift* intermingle with extremely speculative aims,[71] aims that are difficult to understand if we do not grasp the importance of speculative cosmogony as a component of seventeenth-century physics. As, for example, parts III and IV of Descartes' *Principia* show, before (and during) the Newtonian revolution—which by mathematizing physics made the objects of its study tractable *sub specie aeternitatis*—it was important for natural philosophers to give not just an explanation of the causes of the motion of bodies but also of their origins.[72] As early as the *Hypothesis physica nova* of 1671, in fact, Leibniz is interested in accounting for the current state of the world in part by appeal to the conditions of its formation.

Certain observations Leibniz makes in the *Protogaea* indicate that he is not entirely ignorant of the epistemological problems intrinsic to the project of scientifically explaining events and processes buried in the past. Indeed, these are problems that threaten the scientificity not just of paleontology but also of archaeology, historical linguistics, toponymy, and the *historia civilis* in which Leibniz was naturally inclined, and professionally obligated, to take an interest. He seems, though, to have believed that the evidence that fossils provide must be considered together with what we would today call chemistry, fluid dynamics, stratigraphy, and so on, in order to arrive at a plausible explanation, at a sort of "consilience of inductions," to use William Whewell's expression, concerning the origins of fossils. While speculative, Leibniz's contribution to earth science is remarkable for the effort he makes to remain grounded in the demonstrable.

It is not surprising that the sciences that treat the past, to the extent that they are speculative and undemonstrable, in the seventeenth century easily incorporated mythological elements and tended to rely, in a greater measure than, say, ballistics or hydrology, on the authority of sacred scripture. Descartes' *Le monde* is radical in its complete naturalism in the description it offers of the formation of planets, including our own, without any reference to the biblical account of genesis. But Descartes expresses his prudence in a different way: he describes his "world" as an imaginary one and his geogony as a sort of fable. Leibniz, true to his conciliatory spirit, prefers to argue for the harmony of faith and reason and even to reject empirical data when they appear to conflict with the authority of scripture, as, for example, in his reaction to the theory of adaptation (which will be treated in detail in chapter 7):

> There are those who take the liberty to make conjectures, to the point of imagining that in the past, when the ocean covered everything, the animals that today inhabit the earth were aquatic, until the moment when their descendants departed from their first home. But this is not in agreement with the holy scriptures, which it is impious to contradict.[72]

Some commentators see the account of cosmogony given in the *Protogaea* as compatible with materialism. George MacDonald Ross believes that Leibniz "implicitly admits the looseness of the connection between his account and that in the Bible" when he writes:

> But heat or internal motion comes from fire, or light, that is, a highly rarefied permeating spirit. And thus we arrive at a cause of motion, which is where the Holy Scripture also takes up the beginning of cosmogony. So the earliest stage in the formation of things which can be reached by human knowledge, whether by reasoning or by the teaching and tradition of Holy Scripture, is the separation of light and darkness, that is, of active and passive beings; the second stage is the mutual separation of passive beings, that is, the segregation of liquids from dry things.[74]

"In short," MacDonald Ross concludes, "throughout his life Leibniz believed it was possible to give a purely materialistic account of the early development of the universe, with only passing reference to the Bible, and none at all to his monadological metaphysics."[75] But the separateness of the kingdoms of nature and grace on the one hand and the activity of immaterial monads on the other is something quite distinct from materialism. From Leibniz's perspective, there would simply be no reason to drop down to the monadological level in order to accomplish what he sets out to do in the *Protogaea*. As for compatibility with scripture, all the evidence suggests, at least in this passage, that Leibniz finds the geogonical account given in Genesis to be very useful for his admittedly more detailed approach to the study of the earth.

That said, it is undeniable that certain data were more difficult than others to accommodate within a scripturally based interpretation. One very important difference between Leibniz's earliest observations on the formation of geographical features and the account he gives in the text of the early 1690s that we call the *Protogaea*, may be characterized in terms of the demise of spontaneity. In an important undated manuscript discovered by Claudine Cohen, most likely from the mid-1670s, Leibniz gives a very different account of the origins of fossils than the one that would become familiar from the *Protogaea*:

> I can hardly believe that the bones … that are sometimes found in the fields, or that one finds while digging in the earth, are always the remains of true giants. Likewise, I can hardly believe that the stones of Malta [i.e., glossopetrae, or sharks' teeth], which are commonly called serpent tongues … are the teeth of fish and that the shells that are found so far from the sea are certain signs [*marques*] that the sea once covered these places, that she left these shells when she retreated, and that they were subsequently petrified. If this is so, the earth must be much older than the Bible indicates; but I propose by means of a rational process of reasoning to show that this is not the answer. What I believe is that these shapes of animals and shells are usually nothing more than a game of nature: in other words, that they were created independently and have no relation to animals. For it is a fact that stones grow and take on many odd shapes; for proof of this we have only to look at the stones that the R. P. Kircher accumulated in his *Mundus subterraneus*.[76]

Here Leibniz evidently does believe that fossils are a result of nature's spontaneous capacity to throw forth organic forms. An analysis of the terminology and the content of this text places it very early in his career, likely no later than 1671, by which time, as we saw already in chapter 5, Leibniz had begun to shy away from Kircher's rather florid claims. If we compare this text to Leibniz's observations on, for example, the power of the stars in the course of earthly affairs, his lack of cautious skepticism regarding Kircher's already controversial theory is surprising. In any case, we know that whatever the precise date of this text, it expresses a view Leibniz would not hold for long. By the time of the *Protogaea* one of Leibniz's most basic convictions would be that nature, as he puts it, does not play.

According to the account of fossils as games of nature, there is a formative or creative faculty in nature that produces the forms of animals in inorganic substrata; it is a sort of superfluous fertility in nature that projects semblances of animals onto rocks or into sediments, simply because it possesses an overabundance of this formative principle and needs to let off steam, as it were, in discharging it without producing real animals in so doing. On this account, if the "spontaneous" generation of animals happens when nature's (or the celestial bodies') formative principle is projected into suitably disposed matter, then fossils, in turn, are generated when the same principle is projected into matter, such as rock, that is not so disposed. The belief that fossils are in some way *lusus naturae* is thus the product of a conception of the generation of *all* forms in nature on analogy to the generation of animals. It relies on the view that formative principles or seeds, on analogy to the semen of animals, are distributed throughout nature and that everything in nature develops from these principles. A fish produced in stone, on such a view, would be the result of the form of a fish developing out of a formative principle in the wrong kind of material substratum. The result is the semblance of a fish, but one that had never been initially caused by the presence of a real fish. It would be the misfiring of an endlessly productive nature, thrown up gratuitously as a sort of game.

For Leibniz, as we have seen, the generation of organic bodies can be explained entirely in terms of the unfolding and development of preformed corporeal substances, and this development, as well as any other change in the organic body, can be derived, as Leibniz puts it, from the vegetative structure of the body alone. Thus he cannot, in his mature writings, be in agreement with Kircher on the question of fossils, and indeed he denounces the Jesuit's account of their origins as a fairy tale. But he also cannot accept Descartes' (superficially fictional) account, according to which the formation of planetary systems, continents, and ultimately organic bodies as well is only a chance result of the initial conditions of the cosmos in conformity with certain minimal laws of nature. Leibniz would hope to find a sort of golden mean between these, according to which everything happens mechanically in nature, even as everything that happens mechanically evidences the divine wisdom behind the Creation. Thus he hopes to defend what we would today call a theory of "intelligent design," without for that taking recourse to intelligent or spiritual principles subordinate to God that would be responsible for the emergence of organic structure—whether living or fossilized—in the world. His project in the *Protogaea* thus overlaps, as Cohen and Wakefield have rightly noted, with that of the *Theodicy*, written two decades later. There, Leibniz describes God's justice in creating this best of all possible worlds in the following terms:

> Perhaps the crust [of the earth] formed by cooling, which had great cavities beneath it, fell, so that we are now only living upon ruins … and several floods and inundations have left sediments, of which we find traces and vestiges, which lead us to see that the ocean was in those places that are now the most distant from it. But these revolutions finally stopped, and the globe took the form that we see. Moses insinuates these great changes in few words: the separation of the light from the shadows indicates the fusion caused by fire; the separation of the moist and the dry tells of the effects of floods. But who does not see that these cataclysms [*désordres*] served to bring things to where they are at present, that we owe to them our riches and our commodities, and that it is by means of them that the globe has been readied to be cultivated by our tending. These disorders [*désordres*] have passed over into order.[77]

Physicotheology, nascent capitalism, the protestant work ethic: all are encrusted in the geological strata of our earth. Leibniz's stratigraphic account of God's providence may be seen—in certain respects—as a continuation of certain deep-seated ideas about the implantation of the seeds of emerging forms in terrestrial matter. For many in the seventeenth century, the intelligent principle that governs the emergence of new organic forms is not one that is imposed from above by the stars, but rather one that is imbricated in terrestrial matter in the form of seeds. Thus Kircher explains in his *Mundus subterraneus* of 1665: "God created everything at once. Everything is found hidden in matter that will be produced in the nature of bodies and of material substances." Although the divine architect created nothing de novo other than matter and the human soul, nonetheless all forms that emerge after the creation are only "developments" made possible by the formative virtue in the seeds, which has existed since the Creation.

For Kircher, it is by means of such seeds that crystals, animals, and fossils alike can be explained. As for the last of these, Kircher believes that fossils are only "prodigious images" generated wherever nature projects a form without having selected a material substratum well-disposed to facilitate that form's survival as a living being. To use Leibnizian terminology, a fossil for Kircher is an organic body that never comes together with a corporeal substance, whereas, for Leibniz, every organic body is always the organic body *of* a corporeal substance. Leibniz's theory of fossils might be understood as a special application of his general theory of the constant organic embodiment of corporeal substances. That is to say that for Leibniz, wherever there is an infinitely integrated structure, there is a living being, and wherever there is a trace or vestige of such an infinitely integrated structure, one may suppose that there was a living being that made it.

For him, therefore, those who believe that fossils are products of nature's formative power alone "allow themselves to be seduced by the fairy tales … of Kircher and Becher, and other authors as vain as they are credulous, who have written of the wonderful games of nature and of her formative power."[78] Leibniz does acknowledge that there are some productions of nature whose origin cannot be determined with certainty. Thus, as concerns ambergris (which as it happens is a hardened, mucous excretion from certain types of whale), "there is not enough of it to determine whether it arises from the mineral, vegetable, or animal kingdom."[79] But ambergris, unlike fossils, is a mass rather than a structure. And Leibniz believes that only organic beings can give rise to organic structures.

In the *Protogaea* Leibniz relates several examples of fossils that he himself has seen in the Harz Mountains:

> I have seen many marine animals, such as the shark, the herring, the lamprey, and this latter sometimes stuck beneath the herring. Looking at these phenomena, most observers are content to say that they are games of nature, a term that is devoid of meaning, and they present to us these ichthyomorphous stones as an example of the undeniable capriciousness of nature's genius [*rerum genii*], hoping by this to solve all the difficulties and to prove that nature, this great fabricator, imitates, as if playing, the teeth and bones of animals, shells, and serpents.[80]

Leibniz notes that the defenders of this sort of explanation often find not only images of animals but also of the face of Christ, of the Virgin, or—the Protestant variant—the face of Martin Luther. "So they believe," he writes, "that they have discovered Christ and Moses in the cave at Baumann, Apollo and the muses in veins of agate, the Pope and Luther in the stone at Eisleben."[81] He relates a story of the miners of the Harz Mountains who even found the figure of a little man in silver, "of the length of a finger, wearing a miner's clothing, and carrying a tray full of metal" (the difference between such a homunculus and Swift's example of a supposed game of nature with which we began is that the little man in silver, unlike the little man in flesh and blood, has been formed in the wrong sort of matter, a matter that does not permit it to move about and act as a real man). Leibniz shrewdly explains that "Christians and miners" are predisposed to perceive those things that are naturally present to their minds. In such cases, "art comes to the aid of nature," which is to say that the imagination imposes forms where they are not to be found in the matter itself.

But there is a tremendous difference for Leibniz between the fortuitous products of chance and the remains of the organic bodies of corporeal substances. Leibniz is ready to admit that it is possible that the figures of living beings or of particular human beings "which deviate but little from reality" might be produced, "but never to the point that they could be mistaken for the works of Scopas."[82] Chance can never copy exactly, and thus those who argue that the resemblance of a stone to Christ is no less verisimilar than an ichthyomorphous stone run the risk of appearing foolish after a more thorough examination:

> But it is to be feared that such poorly measured blows will fall back upon their author, and that an argument drawn from such a perfect resemblance will only prove the contrary of what it was meant to establish. There is such a relationship between these supposed simulacra and real fish, their fins and scales are reproduced with so much precision, and the great number of these images in one place is so great, that we can only suppose a manifest and constant cause, rather than a game or chance, or I-don't-know-what generative ideas: the inane words of the philosophers.[83]

Leibniz never denies the possibility of miracles. But for him they must occur with utmost infrequency if there is to be any sense at all in calling them miraculous. Thus, for example, as we have seen, he criticizes Malebranche's occasionalism on the grounds that the latter would have God intervening at every moment in every event in the world; but if this were the case, Leibniz thinks, there would be nothing to distinguish transubstantiation or the incarnation of Christ, for example, from the most banal events imaginable, such as my own digestion of a meal of untransubstantiated bread. For this reason, Leibniz is staunchly opposed to popular miracles as well: in the case of a weak resemblance of a stone to Christ or of a piece of silver to a miner, the cause can only be attributed to the observer's power to impose the form by means of the imagination.

In the case of stronger resemblances, whose verisimilitude is strengthened rather than weakened by closer investigation, the resemblance is due to the fact that it is not an *image* at all, but rather a *vestige*, which is to say the real thing, transformed by time. The fossil, thus, is no more a work of artifice than was the natural machine from which it is left over.[83]4It is clear that in the *Protogaea* Leibniz wishes to explicitly bring his theory of organic preformation and his rejection of plastic natures, developed elsewhere and with other concerns in mind, to bear on the debate as to the nature and origins of fossils. In section XVIII, for example, he repeats in the harshest of terms his denunciation of the theory of plastic natures or forces residing in matter:

> I often notice that the more attentive one is in observing nature, the more familiar one becomes with its phenomena, and the more one is disposed, also, to accept our opinion. And the most talented men rightly believe that the vestiges of animals and the debris of various other bodies were submerged, and they do not allow themselves to be easily persuaded that organic bodies without antecedents, without a destination, without a germ, are born, outside of all the laws of nature, as a result of I-don't-know-what plastic force, in the bosom of lime or of stone: these useless matrices.[84]

By "matrices," Leibniz clearly wishes to suggest not just "matrix" but also "uterus," which was commonly denoted by this term. The point is thus to suggest that the earth, unlike a living (female) animal body, is "useless" for the purpose of gestation. According to Leibniz, the formation of crystals, by contrast with that of animals and plants, can be exhaustively analyzed in terms of "external contiguity," that is to say in terms of the regular repetition of radial and polygonal shapes. The forms of fish or plants in stone could never be reduced in the same way to geometrical motifs. Thus Leibniz continues:

> [In the case of organic forms] it is not at all a matter of certain radial bodies and of regular polygons as we see in crystals, garnet, and other gems and fluors, as well as in various other minerals, no more than the figures shaped by hexagonal snow, by beehives, in vitriol and aluminum, by common salt and nitre ... it is not at all a matter of all that geometry of inanimate nature, which can be easily understood by the juxtaposition of parts, as in crystallization.[86]

Leibniz denies that it is necessary to take recourse to any process of "gestation" for minerals. He would hope to assimilate the process of mineralogenesis not to embryogenesis but to the construction of artificial machines: in both cases, the thing comes into being through juxtaposition of parts. The crucial distinction is thus not between the "natural" and the "artificial," but rather between organic entities on the one hand and, on the other, anything that can be exhaustively understood in terms of the geometrical relations of its parts, including crystals as well as machines. Significantly, for entities of the latter sort, a crucial marker of their ontological distinction from organic beings is that they may at least in principle be produced by art. Living beings, in contrast, could never be generated in an alchemical furnace or by any other technological means. With the exception of living beings, then, nature and art are not categorically different from each other: "Nature, in effect, is nothing other than an *ars magna*, and we do not always distinguish clearly what is fabricated [*factitia*] from what is natural."[87]

These distinctions might be graphically summarized as follows:

	Clock	*Crystal*	*Fetus*	*Fossil*
Generated by	*Human art*	*Mechanical process of repetition of externally contiguous forms*	*Preformation*	*A once-living animal (thus, ultimately, through preformation).*
Comprehensible through study of generation in other domains?	Yes	Yes	No	No
Development influenced by imagination?	Yes	No	Yes	Development of the animal it once was, yes; development of the fossil after animal's death, no.
Infinitely complex?	No	No	Yes	Infinitely fine-grained detail, but lacking the infinitely complex *structure* of the animal of which it was once the body.

Thus, Leibniz makes an effort to distinguish between the process of formation of minerals and crystals and that of biological entities. One of the essential differences between mineralogenesis and embryogenesis is that the former process can be entirely reproduced by human art in an experimental context. Human beings are capable of creating on a small scale what nature does on an immense one: nature, Leibniz writes, "who has mountains as her alembics, and volcanoes as her furnaces."[88] When it comes to what we think of as biological generation, in contrast, our experiments are useless: the homunculus created in the laboratory is only a part of alchemical legend, not of real experiment. It is in this connection that Leibniz has occasion to strongly deny that minerals "gestate" in the earth. At the same time, he is eager to identify the structure and production of minerals with artificial mechanical processes.

Leibniz sets off gestating things—embryos of biological entities—from both mineral and technological entities. Biological entities are the things that cannot be reproduced in alchemical furnaces, unlike the products of geological processes. Geological and technological processes are, further, related to each other to the extent that both provide, or are capable of providing, a means for understanding the other. The volcano can be adequately simulated in a furnace, for example. Biological processes, in turn, are distinguished from both geological and technological ones in view of the infinite complexity of the entities they produce. These latter are distinguished from geological processes as well by the fact that, in the formation of living entities, as we have seen, the imagination can play a formative role: embryogenesis is the only subdomain of nature in which at least apparently spontaneous changes remain acceptable, while "spontaneous" generation in contrast has been reduced to a sort of heterogenesis that is not really genesis at all. The generation of fossils, in turn, in contrast with that of minerals and of the traits of living beings, in no way involves imitation or the projection of an image. Fossils are, rather, only vestiges or remains of real entities.

The idea that fossils are a result of *lusus naturae* is in the end a vestige of a conception of the generation of all natural forms on analogy to the generation of animals. It depends upon the hypothesis of formative principles distributed throughout nature, and upon the view that everything in nature develops from these principles. A fish produced in stone, from this point of view, would be the result of an ichthyoid formative principle that happens to trigger the process of formation in a material substratum that is not suitable for the production of a full-fledged fish capable of swimming, breathing through gills, and so on. For Leibniz, as we will see more fully in the next chapter, such a frozen fish, a fish without any sort of fishy activity in it, can be no fish at all, since what makes a substance the sort of substance it is, is precisely its activity. Nature could not produce, in his view, an entirely useless or end-less fish, and so the form of a fish frozen in stone cannot be a direct product of nature but only an indirect vestige of nature's productivity. Nature, in other words, does not play.

Conclusion: From *lusus naturae* to *Spieltrieb*

One lesson to derive from the study of Leibniz's engagement with the areas of natural philosophy treated in this chapter is that we must be careful to distinguish between two very different notions of spontaneity in interpreting Leibniz's philosophy. One takes spontaneity, in the original Latin sense of "spontaneus," as equivalent to the Greek *automatos*, that is, the state of being determined only by one's intrinsic properties, which is to say, in Leibnizian terms, the absence of extrinsic denominations.[89] As is well known, this sort of spontaneity is central to Leibniz's philosophical project. There is another sense of spontaneity, that of being entirely undetermined by prior conditions, either intrinsic or extrinsic, and of arising from the free activity of some mind or mindlike power, influencing the course of material nature without in turn being governed by its laws. As we have seen in this chapter, this variety of spontaneity was often adduced in the explanation in the early modern period of a variety of instances of the emergence of order in biological nature, and it is a variety of spontaneity that Leibniz categorically eschews. In the case of trait acquisition, Leibniz translates the influence of the maternal imagination into the terms of his system of preestablished harmony; in the case of spontaneous generation, Leibniz provides an alternative account in terms of heterogenesis; and in the case of fossils, Leibniz rejects the explanation of them as games of nature in favor of an account that treats them as vestiges of real organic bodies.

Interestingly, over the course of the eighteenth century, this latter notion of spontaneity will make a complete transit from natural philosophy to aesthetics. Art, Friedrich Schiller writes in the second of his 1794 *Letters on the Aesthetic Education of Man*, is the "son of liberty," and it longs to receive its law not from the "indigence of matter" but from the necessary conditions of spirit. For Schiller, at the beginning of a man's life he is treated by nature no differently from the rest of its creatures. But what makes a man a man, Schiller maintains, is that he possesses the power to return, guided by reason, along the steps that nature has earlier obliged him to take, and "of transforming the work of blind compulsion into a work of free choice, and of elevating physical necessity into moral necessity."[90] The human faculty that makes this transformation possible is nothing other than the *Spieltrieb*, or "play-drive," the very tendency that Leibniz had sought to expel from nature. At the heart of German

Idealism, then, we find the idea that it is exactly the *lusus* that distinguishes man ontologically from nature in its rigid determination. One could propose—though this proposal will surely have to be developed elsewhere—that the roots of modern aesthetic theory lead directly back to crucial developments in the early modern philosophy of nature. The circumscription of precisely what nature is capable of in the seventeenth century has its echo a century later in the Idealist account of what man is capable of in his liberty and independence from nature. In one way or another, spontaneity, in the sense not of self-determination but of play, will find its place.

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PART FOUR

Species

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Chapter Seven

THE NATURE AND BOUNDARIES OF BIOLOGICAL SPECIES

Biological Species and the Question of Leibniz's Nominalism

The problem of species has long been familiar to analytic philosophers interested in Leibniz. Particularly in the treatment Leibniz offers of the problem in his *Nouveaux essais sur l'entendement humain* of 1704—a comprehensive response to John Locke's *Essay concerning Human Understanding* of 1690—the problem has been understood principally as one in metaphysics and the philosophy of language: how it is, namely, that the meanings we give to words can be determined to capture the real natures of the things in the world that these words are purported to denote. What has been comparatively less studied is the problem of the determination of the boundaries of what we today would call "biological" species in Locke and Leibniz and the way in which this narrower problem gives rise for them to domain-specific problems that do not come up in connection with their respective investigations of the "species" of triangles, gold, or artifacts.

In the first part of this chapter we will see that Leibniz's analysis of the nature and boundaries of biological species is very different from his now well-known nominalist account of the species of, for example, mathematical objects, and even of ordinary physical objects.[1] With respect to plants and animals Leibniz positions himself squarely in the species-fixist camp, like his contemporary John Ray, the English naturalist who insists unequivocally that "the number of true species in nature is fixed and limited and, as we may reasonably believe, constant and unchangeable from the first creation to the present day."[2] Leibniz, like Ray, believes that all species were formed at the Creation and will remain fixed for all time, notwithstanding his simultaneous belief in the possibility of tremendous morphological change in a species over time and even of tremendous morphological change or "transformation" over the course of an individual creature's life.

Whatever Leibniz's views with respect to other ontological domains, such as that of mathematical objects, being a biological species fixist, Leibniz, we will see, is *eo ipso* a species realist, not a nominalist, at least if we understand nominalism as the view that groupings of individuals are arbitrary and not based on real shared kindhood; and realism, minimally, as the view that groupings *are* based on real, shared kind membership, rather than as the perhaps stronger view that kindhood is derived from the objective existence of a universal external to individuals in which these individuals participate. To believe that there is real kindhood requires at least the view that there are *universalia in rebus* in the sense often attributed to Aristotle. Leibniz's nonnominalist account of biological species membership certainly does not take recourse to external, "Platonic" universals but could not get by without some presumption of a universal kind-membership inhering in the individual biological entities themselves.

Surprisingly, Leibniz maintains his species realism notwithstanding his well-known commitment to the principle of plenitude or to an infinite hierarchy of beings. In order for there to be a biological species between any two given species, there must be such a thing as species. For Leibniz, these are not species, moreover, in the sense in which Thomas Aquinas had understood the species of angels: that is, as singletons or sets occupied by only one member. Rather, a biological species is multiply instantiated, and to be a member of the same species as another creature is to share in the same line of descent from the same ancestors as that other creature. A biological species is for Leibniz a relatively isolated reproductive community, all of whose members may be said to be members of the same species not in virtue of any morphological resemblances (though they generally have these as well) but rather in virtue of shared origins.

This account of species, while starkly different from Aristotle's, is one that came by the sixteenth century to be associated with Aristotle's biology and that emerged out of the combined impact of the exigencies of the new science of taxonomy, particularly botanical taxonomy, together with a new tendency in scriptural interpretation to read Genesis as describing the original, true, and regrettably lost system of classifying living kinds.[3] Leibniz is very much of his time, a contemporary of John Ray and a taxonomical thinker squarely in the line of development that extends from Andrea Cesalpino in the sixteenth century to Linnaeus in the eighteenth.

Adam's Language and Noah's Ark

An important part of the story of the emergence of modern species fixism, though one that cannot detain us for long here, has to do with developments in the history of scriptural interpretation. Many sixteenth-century naturalists came to believe that Adam's legendary ability to discern essences was recoverable, and indeed would be recovered by their own research.[4] To cite one of many examples, in his *Neu Kreutterbuch* (New Book of Herbs) of 1577 Hieronymus Bock writes that "it is … clear and undeniable that Adam, as the first-created, did not only clearly and correctly understand all of Earth's creation through the pouring in [to him] of divine power and wisdom, but also named every creature with its correct name."[5] There is a remarkable similarity between reflections such as those of Bock on the one hand and those we find in texts on the biblical languages on the other.

As we will see later in this chapter, Leibniz's interest in finding and classifying paleontological kinds is for him of a pair with his lifelong interest in the tracing of the linguistic histories of nations, and he brings an antiquarian zeal to both of these projects. But while he is ardently fixist with respect to animal kinds, living or extinct, he is also, so to speak, a staunch evolutionist with respect to language. For this reason, Leibniz is skeptical of the very idea of a primordial Adamic language that would give the true names of things. He believes instead that many languages, including Hebrew but also German, have something "primitive" about them, in the sense that the names for things are rooted in natural sounds associated with them. But beyond this there is nothing particularly primordial about any language, scriptural or national.

As already mentioned, for Ray the number of species was fixed once and for all, and variation within a species, much as for today's "creation scientists," could never lead to transmutation. Thus he writes in a 1696 text:

> Differences that issue from the same seed, be it in an isolated plant or in an entire species, are accidental and not the signs of a specific character. … The same is true of the animal world … the number of species in nature is certain and determined: *God rested on the sixth day, interrupting his great work*—that is, the creation of new species.

Although species are eternal, for Ray their essences are unknowable:

> The correct and philosophical division of any genus is by essential differences. But the essences of things are unknown to us. Thus, in place of these essential characters, characteristic accidents should be used … [that] join together plants that are similar, and agree in primary parts, or in total external aspect, and which separate those that differ in these respects. … The essences of things are wholly unknown to us. Since all our knowledge derives from sensation, we know nothing of things that are outside us except through the power that they have to affect our senses in some particular way, and by the mediation of these impressions to cause a particular image to arise in the intellect. If the essences of things are immaterial forms, it is admitted by everyone that these are not encountered in any sensible means.[6]

Ray believes that species are "Ideas" in the divine mind, and denies any true transmutation, admitting only what we might describe as microevolution or intraspecies phenotypic drift. He maintains that biological kinds "are not transmutable, and the forms and essences of these are either certain specific principles, that is, certain very small particles of matter, distinct from all others, and naturally indivisible, or certain specific seminal reasons enclosed by means of an appropriate vehicle."[7]

The ontology and epistemology of biological kinds defended by Ray would prove a difficult pair to sustain together. If essences cannot be known, then one might reasonably protest that we have no good reason to think there are such things. In contrast to Ray, many others, influenced by currents of thought as diverse as Epicureanism, Baconianism, and Skepticism, would come to sense the tension between the skeptical epistemology and the realist ontology that Ray hoped to rope together. John Locke's nominalism, to cite an important figure in the emergence of Leibniz's mature views on species, may be seen in large part as a consequence of the evident inability of biological taxonomy to adequately reflect the complexity of its object of study.[8] Locke discerns a deep theoretical as well as an empirical problem. If essences are wholly unknown to us, as Ray acknowledges, then how do we justify our classificatory systems except as arbitrary reflections of our narrow priorities? That is the theoretical problem. The empirical problem is this: if species, whose essences are unknown to us, are set down for all eternity at the creation, how do we account for the abundant cases nature appears to present to us of overlap and hybridity? How do we account for what John Dupré would later describe as the ineradicable "disorder of things"?[9]

Early modern nominalism partially maps onto what is today sometimes referred to as "species antirealism" in the philosophy of biology.[10] According to this latter doctrine, because what we think of as species are but snapshots in time of various, ever-evolving lines of descent, there can be no justification for treating biological species as real natural kinds. Today's antirealism is strongly motivated by evolutionary theory (though, to be sure, many evolutionists remain realists), which takes animal species out of the class of relatively stable, fixed entities, like the elements on the periodic table, and historicizes them, placing them more on a par with, say, nation-states or car models. The nominalism associated with, for example, Locke, has something of a different focus: it is not concerned with whether some kind has a changing history or is fixed and unchanging. Rather, it is motivated by the recognition of the impossibility of ever getting, by empirical means, to the real essence of a thing. The only sort of essence that may now be spoken of is the nominal essence, which may be determined in view of the *powers* a thing has or the way it enters into relations with things outside it. Thus, for Locke, in an important sense biological species do not present any particular problems that do not also arise in the case of, say, the elements.

Yet it would be difficult not to notice that Locke is relatively more preoccupied with the status of biological species than with other purported natural kinds,[11] particularly with human beings and those primates most closely resembling them. Indeed, at times he appears to believe that the best empirical evidence in favor of his nominalism comes from what he takes to be the common natural phenomenon of cross-species reproduction. "I once saw a Creature," he maintains,

> that was the Issue of a Cat and a Rat, and had the plain Marks of both about it; wherein Nature appear'd to have followed the Pattern of neither sort alone, but to have jumbled them both together. To which, he that shall add the monstrous Productions, that are so frequently to be met with in Nature, will find it hard, even in the race of Animals to determine by the Pedigree of what Species every Animal's issue is; and be at a loss about the real Essence, which he thinks certainly conveyed by Generation, and has alone a right to the specifick name.[12]

When, as was discussed in chapter 6, reproduction was conceived by premodern science as the imparting of a form that endows the offspring with some real essence, there was little problem in accounting for the ontological status of species, or in asserting with certainty the membership of an individual within a species. The mechanization of embryogenesis, which is to say first and foremost the removal from this process of a role for a formal principle, effectively put all species on the endangered list, so to speak, and threatened to give us only a world of individuals. This is precisely what Malebranche feared, as we saw in chapter 6, when he adopted the imagination theory "to explain why a mare does not give birth to a calf, or a chicken lay an egg containing a partridge or some bird of a new species."[13] Yet what Malebranche feared, Locke would soon celebrate.

Nathaniel Highmore, to cite another revealing example, confirms the point that, for many, purely mechanistic embryogenesis threatened to bring about a crisis in the traditional understanding of species. In criticizing Kenelm Digby's strict mechanist account of generation in terms of the operations of "external accidents" working upon intrinsically inert particles, Highmore wonders, assuming that there is "nothing else to give a figure to Plants, but ascending and descending, of light and heavy parts,"

> whence should that variety arise in the fashion of those ascending and descending parts: the weight of the parts should carry them directly downwards, as the lightness doth upwards; and so all roots should descend in one continued round, but long, lump: what then makes some spherical, other

> stretching out infinite numbers of hairy threds; some directly downwards, others parallel to the superficies.[14]

In short, mechanism might be able to account for generation in general but not for the generation of all the diverse kinds of creature. Here, the example concerns plants, yet, as Highmore goes on to note, "the formation of Animals affords us little lesse perplexity."[15]

As we have already seen, Descartes denied the end-directedness of natural phenomena, including embryogenesis; but it would not be until the second half of the seventeenth century that the link between this denial and the tenuousness of species would be made explicit: the end-blindness of nature now means that the tendency of horses to beget horses is no more natural than the occasional cat-rat, ape-man, mule, or monstrous *mola*. Even if Descartes never faced up to the problem, for Locke mechanism cannot but militate in the direction of antiessentialism; in the domain of science with which we are concerned, this means that the revolution in embryology that brought about the abolition of formative faculties also brought about a crisis in the concept of biological species. For Locke, the mechanist ontology underlies the theory of classification. As Michael Ayers has noted, Locke's mechanism holds that all changes in nature are just changes of degree—anything that is not an atom is infinitely malleable.[16] This means, among other things, that the difference between two horses on the one hand and a horse and a zebra on the other does not give us any instruction as to how to go about classifying. Thus, horses are grouped together, and zebras are excluded, but this is a pragmatic decision, not one dictated by reality. We classify in a manner dictated by differences that matter to us, and this is an appropriate approach to classification because differences between things come about not as a result of differing essences but only of rearrangements of atoms.

Leibniz's response to Locke's position would be both innovative and conservative. His ultimate concern would be to hold onto the reality of biological species while acknowledging the difficulties Locke discerns in coming to know the true natures of things and in establishing the true criteria for grouping *similar* things as separate instantiations of the *same* thing. Leibniz would ultimately come to adopt a fairly nominalist view of the objects in certain ontological domains (indeed, the ontological domains that have tended to garner most of the attention of historians of philosophy). But for him, in contrast with Locke, biological species do present a number of particular problems that are not there in the case of, for example, gold or mercury, let alone of mathematical objects, and therefore require a separate analysis. Let us turn now to Leibniz's analysis of biological species.

Transformism, Gradationism, and Nominalism

As we have already seen, for Leibniz identity runs deeper than kind-membership. As shown by the examples, already considered in chapter 5, of Heliogabalus's reincarnation as a pig, of insect metamorphosis, and of the promotion of a bare monad to spirit at conception, for Leibniz an individual can change from one kind to another, while (other than in a few passages that we shall consider shortly) a kind itself cannot change into another kind. Leibniz writes in the *Nouveaux essais*, for example, "there are kinds or species to which an individual could not (naturally, at least) cease to belong, once that individual has already belonged to it, whatever revolutions may come to pass in nature. But there are kinds or species that are (I admit) accidental for the individuals that belong to them, and they may cease to be of that kind."[17] But which are the species that an individual cannot leave behind, which are the accidental ones, and what accounts for the difference? The view that an individual can pass through various species is sometimes called "transformism," and it is particularly widespread among Platonically inclined philosophers of the early modern period. These thinkers tend to see individuals as the bearers of essences, and they take these essences to be so durable that they could survive even the transition of the individual from one species to another. Some features of early modern transformism may be traced in part to the discovery of microorganic life, together, perhaps, with the resurrection or continuation of ancient ideas about change, best captured poetically in Ovid's *Metamorphoses*. To cite one example, Anne Conway argues in her *Principles of the Most Ancient and Modern Philosophy*, published posthumously in 1690, that all creatures are mutable in respect of their natures, and even that "the justice of God gloriously appears in the transmutation of things from one species to another."[18] This transmutation is not substantial but only modal, in the sense that while changing the species or nature of the creature, the essence remains the same, which is to say for Conway that it remains the *same* creature through its various species transmutations. A creature's species, then, would appear to be just a stage of it. As Leibniz explains similarly in a letter to Thomas Burnet: "I maintain that there must always be a preformed living being, be it a plant or an animal, that is the basis of the transformation, and that the same dominant monad must be there."[19]

Conway takes insect metamorphosis as confirmation of transformation as a general principle of nature and includes as instances of the same principle at work a number of rather unexpected phenomena, including "spontaneous" generation: "Among animals, worms change into flies, and beasts and fish that feed on beasts and fish of another species change into their nature and species. And does not rotting matter, or body of earth and water, produce animals without any previous seed of those animals[?]" While transformation is generally described in terms of the striving of creatures toward, or falling away from, God, Conway also sees this process as, at least sometimes, influenced by environmental factors: "Just as wheat and barley can change into each other and in fact often do so, which is well known to farmers in many countries, especially in Hungary where, if barley is sown, wheat grows. And in other more barren places, and especially in rocky places such as are found in Germany, if wheat is sown, barley grows instead, and in other places barley becomes plain grass."[20]

Leibniz seems to assume that the transformations of individuals will unfold in a relatively stable way in virtue of the kind of thing they are, and will remain, across their transformations. That is, caterpillars regularly transform into butterflies, but not into fish, and this in virtue of the fact that they are in all their stages preformed descendants of a biological kind that includes all the members of, for example, *Morpho menelaus*. In this respect, as we already saw in the previous chapter, Leibniz is a very conventional defender of heterogenesis in that he, like Athanasius Kircher and others, seems to believe that there are clear rules governing which kind of creature can be transformed into what, as for example in the case of what was sometimes called "taurogenesis," in which a rotting ox carcass gives rise to bees, but never any other variety of insect.

Transformism, then, is nothing like a Lamarckian account of change in lineages as a consequence of the change of individuals in response to their environment. Conway and Leibniz both believe that what transforms over time are not lineages but rather individual creatures, which are immortal, and that these transformations happen for reasons that have more to do with the creature's relative spiritual "excellence" or worthiness than with natural factors. For Conway and Leibniz both, transformism is of a pair with what might be called "gradationism," the view that there is a "chain of being" extending from the "lowest" creatures (worms and such) at the bottom to angels and then to God at the top, with human beings the highest in the chain among earthly creatures.[21] This conception of the order of nature is rigidly hierarchical, and a creature's position in the hierarchy is determined by one criterion, its perfection, which is to say the degree of its likeness to God. Leibniz's particular version of the chain of being has it not just that there is a hierarchy of kinds, but indeed that between any two kinds on this hierarchy there must be an intermediary kind. Yet the infinite gradations of species of varying degrees of excellence need not push in favor of a nominalist interpretation of Leibniz's theory of biological kinds, since, again, in order for there to be a kind between any two given kinds there must at the very least be such things as kinds. Although the hierarchy is conceived as a continuum, nonetheless it must have some abrupt breaks, since some of the characteristics that define species, notably reason, are all-or-nothing affairs. Either you possess reason or you do not, and to open up the possibility that reason could be possessed in greater or lesser degrees is to open up the possibility that human beings are nothing special among natural beings, that nonhuman apes, for example, could possess in some degree what humans possess more perfectly, and indeed what makes them human.

The principle of the plenitude of natural kinds is therefore not entirely analogous to the principle of continuity that describes, for example, geometrical lines or the set of real numbers, since in the latter case it is key that there are no real elements composing a continuous line, whereas there *are* real, multiply instantiated kinds within the hierarchy of kinds. We should therefore not be too tempted to see Leibniz's commitment to the principle of plenitude as strengthening the case for his nominalism, since in fact he holds that the belief in a kind between any two kinds does not exclude the possibility of real, abrupt breaks. The scale of beings may more correctly be said to be dense than continuous, in the modern mathematical sense of having actual discrete units between any two given units.

Botanical Method and the Conventional Nature of Classification

One compelling ground for ascribing biological nominalism to Leibniz may be the extent to which he seems to agree with Locke about the difficulty of getting to the characteristics that truly mark off one kind of being from another—to its "real essence," in Locke's terms. Thus, for example, Leibniz writes in an important letter to A. C. Gackenholtz of April 23, 1701 (see Appendix 5), that there is always a variety of ways to classify in any domain of science. Citing his own *De arte combinatoria*, of 1666, which he proudly mentions having written as an "adolescent," Leibniz notes that in any domain "the genera of any determinate number of inferior species correspond to the combinations of things, so that it is understood that there are as many combinations of things as there are kinds of species." He notes that philosophers and jurisconsults have studied the variety of moral virtues by considering the different ways of subdividing them. Yet in these cases, as in the case of biological kinds, "since there is an immense variety in the great number of combinations and in the various ways of separating them, it is apparent that, if the method is to be of any use, the more useful comparisons will be preferred; as also for the sake of aiding the memory, a method that is more detailed and more commodious may be preferred."[22] Classification is then arbitrary and based on what interests the classifier. Yet it is important to bear in mind that here Leibniz is concerned with the classification of species into higher genera and not of individuals into species. Since Leibniz is working in a preevolutionary context, the classification into higher taxa can have nothing to do with charting lines of descent or with kinship. Indeed, since there are no real kinship relations among species, it might be thought that classifying into higher kinds can only be based on criteria that are initially chosen in view of some special human concern or other. Yet Leibniz believes that one can discern *real* "analogies" or "resemblances"[23] among species, even if these do not come from shared descent.

Presumably, this reality derives from the proximity of the blueprints of two species in God's mind at the Creation. The taxonomic grouping of several species into a genus, then, should ideally reflect this proximity, even if it is difficult to pick out the right morphological features in virtue of which two species may be said to be objectively close. Some plants have similar roots but very different flowers; other plants might resemble one another in their flowers but have a very different root structure. Leibniz notes that the current fashion in botany is to prefer classification based on flower morphology, and he is skeptical but not entirely dismissive of this approach, for reasons we will consider shortly.

Leibniz notes in the same letter to Gackenholtz that in botany divisions are generally made either with respect to the particular usefulness of the plant for human beings, or with respect to the plant's morphological features. Both of these criteria are accessible, Leibniz notes, without any particular grasp of the "interior" nature of the plant. But, he goes on, there is no reason to despair of not being able to access this interior nature, since as a result of the work of Jungius, Malpighi, Hooke, Swammerdam, and Leeuwenhoek, "soon we will arrive at something more profound" in our study of plants.[24] He concedes that classification with respect to the flowering part of the plant may be more profound than any other morphological criteria, since "there is in fact a very great connection between the flowers and the generation of the plant; and it is above all useful to find the variety of principles in generation; which Aristotle himself saw when he undertook to trace the variety of animals back to this capital point."[25] Leibniz repeats in an undated text published a few years after his death in the *Otium hanoveranum* that botany must not be limited to the study of the medicinal effects of plants, but must extend, most importantly, to the study of their reproduction: "Botanists are complacent in the mere noting of plants and their virtues. Few take an interest in the growing of plants for the purpose of the propagation and conservation of seeds."[26] While one must consider multiple ways of classifying, ultimately it is the flowers, as the part most closely connected with generation, that serve as the best indicator of species.

For Leibniz, there is nothing wrong with employing multiple systems of classification. Indeed, the more the better, as each one may help to reveal something new about the structure and nature of the entities in question. What is more, a perfectly acceptable principle of classification might for Leibniz be simply pedagogical, where entities are placed together not in virtue of any real belief in their kinship, but only because, so arranged, it may be easier to learn their names. Leibniz does not see anything wrong with this. Yet in the end the study of the flowering part—by which Leibniz means not the petals of a flower but the reproductive parts enclosed by the flower—is (probably) going to be the most revealing about the true nature of the plant.

He sums up all of these points in a rich passage of the *Nouveaux essais*. The modern botanists, he maintains,

> believe that the distinctions taken from the forms of the flowers best approximate the natural order. But here as well they find much difficulty, and it would be relevant to make comparisons and arrangements not only according to one criterion, such as the one I just mentioned, which is taken from the flowers and which is perhaps the most fitting up until now for a system that is tolerable and commodious for those who are learning, but also according to other criteria taken from other parts and conditions of plant: each criterion of comparison warrants its own separate Tables [of classification]; without which we will allow to escape our attention many subordinate genera, and many comparisons, distinctions, and useful observations. … The more one follows the arrangements and conditions that are there required, the more one approximates the natural order. This is why, if the conjecture of certain notable people turns out to be correct, that there is in the plant, besides the known *grain* or the seed that is analogous [*qui repond à*] to the egg of the animal, another seed that could be called masculine, that is to say a powder (*pollen*, which is very often visible, although perhaps sometimes invisible, like the grain itself of certain plants), which the wind or other usual accidents spreads so as to join it with the grain which comes sometimes from the same plant, and still other times (as is the case with hemp) from a neighboring plant of the same species, which by consequence will be analogous to the male, although perhaps the female is never entirely deprived of this same *pollen*.

Leibniz believes that by paying attention to these generative elements within the flowers, eventually we will be able to come to the "natural divisions" of botany, that is, to a classification of plant kinds that maps onto the real differences between species:

> If (I say) this turns out to be true, and if the manner of generation of plants came to be better known, I do not doubt at all that the varieties that we

> would discern would provide a criterion for very natural divisions. And if we had the penetration of some superior intellects and knew things well enough, perhaps we would find there attributes fixed for each species, common to all of its individuals and always subsisting in the same organic living being, whatever alterations or transformations might befall it, as in the best known of physical species, which is the human, reason is such a fixed attribute, which pertains to each individual and always inseparably, even if one cannot always perceive it.[27]

In Leibniz's account of the importance of the reproductive parts of plants for determining their true natures, the perpetual motion of reproduction, or self-propagation through the generation of offspring (from preformed primordia, of course), lies at the heart of the account of what it is that makes a biological entity the kind of entity it is. That is, he believes we should study the reproductive parts of flowers if we want to know what kind of plant we are dealing with, since it is in large part through reproduction—rather than, say, the growth of thorns—that the perpetual motion machine that is the plant perpetuates itself, or, in other words, keeps its species in existence.

This account agrees with the theory of species realism and species fixism that, rightly or wrongly, came in the early modern period to be attributed to Aristotle. On this account species membership is determined exclusively through lines of descent: to be a member of a kind is to be descended from the original parents of this kind. In the lengthy passage just cited, Leibniz acknowledges the strength of the theory of species membership that sees this membership as rooted in descent from common parents alone. He maintains that because an animal is a machine of perpetual motion in part in virtue of its capacity for self-reproduction, classification of species in terms of their generative systems is less arbitrary than any other taxonomy based on the comparison of morphological features. Creatures are the creatures they are in virtue of their being generated from like creatures, and they bear real relations to members of other species in virtue of resemblances of their generative systems. This is what Kant would later call "the unity of the generative power,"[28] that is, the inclusion of a group of scattered individuals in the same kind in view of their shared ancestry.

The Domain Specificity of Leibnizian Nominalism

In the *Nouveaux essais*, Leibniz expresses agreement with the principle, defended by Ray and others, that shared species membership may be determined by looking at lineages of shared decent. As he writes, in cases of doubt, "generation or race"—a curious synonymy to which we will return later in this chapter—"gives at least a very strong presumption" as to the creature's species membership.[29] Whatever views he might hold as to the reality of mathematical or other kinds, with respect to biological species "it is the nature of things that ordinarily fixes the limits of species."[30] In effect, the nominalism that we might wish, along with Benson Mates and others, to attribute to Leibniz with respect to mathematical objects, and perhaps even to physical objects, cannot be extended as far as biological entities. For, as Leibniz explains very clearly in the *Nouveaux essais*, different meanings attach to the notion of species depending upon the ontological domain in which it is being applied. Leibniz writes: "There is some ambiguity in the term *species* or *being of a different species*; which is the cause of all these confusions. … We can understand species either mathematically or physically. In mathematical rigor the slightest difference that brings it about that two things are not entirely similar, brings it about that they are *of different species*."[31] He goes on to consider the differing cases of three different kinds of mathematical object: the circle, the ellipse, and the oval. There is only one species of circle, since all circles resemble one another perfectly. There are infinite species of ellipses, but only one genus, since in all ellipses the ratio of the focus and the apex differs only with respect to size. In ovals with three foci, finally, there are infinitely many species *and* genera.

Now, in physical entities, since no two ever resemble each other perfectly, it follows that by the same criteria as those employed with respect to mathematical entities, every individual entity is isolated from every other with respect to species. Moreover, since every physical entity is constantly changing, no individual thing ever perfectly resembles *itself*, and thus "men laying down the physical species do not adopt such a rigorous stance and it depends on them to say whether a mass that they can themselves make to return to its original form remains in their view the same *species*. Thus we say that water, gold, quicksilver, common salt remain the same and are only disguised as a result of ordinary changes."[32] However, the criteria for plants and animals are not arbitrary in this way. Leibniz continues: "But in organic bodies or in the species of plants and animals we define the species through generation, so that this similar being, which comes or could come from the same origin or seed, will be of the same species."[33] In contrast with mathematical identities, and in contrast with ordinary physical entities, the criteria for establishing sameness, or sufficient sameness to be included in the same species, are not based on arbitrary or subjective concerns of the person who classifies living beings but on the objective fact that all the members of the same species of living beings have the same origin.

For Leibniz the animal is not *just* a machine of perpetual self-nutrition and self-reproduction, as we saw in chapter 2. It also has its own "special office" (*officium*) that makes it a member of the species to which it belongs. In contrast to Locke, and indeed to Ray, Leibniz believes that we may eventually come to know the special offices of all animals.[34] He acknowledges that outside of the human species—of which we know that all members have the special office of contemplation not by study of human morphology but through direct experience—our knowledge is limited. Yet he also believes that any limitations here may in principle be overcome.

In the *Corpus hominis* of the early 1680s, Leibniz asserts explicitly that "machines do not have a species," but here he clearly means only machines in the common sense. Animals are for him those machines that *do* have a species, which is discernible in their trademark activity, and which is maintained through their motion and reproduction. It is of the essence of a squirrel to dance or jump, so a squirrel is, essentially, a dancing or jumping machine. The need to see this trademark activity in order to grasp the true nature of the species is one reason why ethology must be included along with anatomy and physiology in any adequate science of animal economy. In the letter to Gackenholtz of 1701, Leibniz makes this very clear. Plants and animals, he writes, "and, in a word, organic bodies produced by nature, are machines able to perform certain offices, which they do in part through their individual nutrition, in part through the propagation of their species, and finally also through their very perfection, that which each one brings about through its special office." Leibniz goes on from here to make explicit what that "special office" is in human beings: a human being is "a machine for the perpetuation of contemplation," just as a squirrel is a machine for the perpetuation of dancing or jumping.[35] Leibniz had already written similarly, in the *Specimen inventorum de admirandis naturae generalis arcanis* (Specimen of Discoveries concerning Admirable Secrets of a General Nature) of around 1688: "Therefore it is well enough that souls be given to brutes, especially as the bodies of brutes are not made for ratiocination, but rather are destined to various functions; thus the silkworm is made for weaving, the bee for making honey, and others to other functions through which everything in the world may be distinguished."[36]

How can Leibniz be so sure that we are capable of coming to know the *real* special office of a creature and not just some feature that is phenomenally salient from a human point of view? The short answer is one that extends far beyond the bounds of his philosophy of biology and into his physicotheology and theodicy: Leibniz believes the various species of animals were created *for us* in the first place. Their special offices are special principally for us, but at the same time, in Leibniz's anthropocentric world, an animal's being-for-us, so to speak, is its being *tout court*. Coming to know it through its salient features is the same thing as coming to know it. In this respect, Leibniz simply ignores the epistemological problem that served as the engine of doubt in Locke's nominalism and indeed in so much modern philosophy. At least with respect to knowledge of biological kinds, Leibniz remains a very premodern philosopher, one who believes that God simply would not place us in a world of essences from which we are cut off by some epistemic gap.

Leibniz continues in the 1701 letter to Gackenholtz:

> In other bodies [besides the human body], the whole purpose of nature has not been adequately explored by us. However, it is not at all doubtful that a great part of its purpose lies in human usage, which is to say auxiliaries that aid in our contemplation, or, which is the same, that excite in us admiration of the divine wisdom.[37]

This belief, while theological, has important epistemological consequences. One is that, for Leibniz, in contrast with Locke, real essences can be known; indeed, the real essence of a species is that feature that serves both as a sign to humans of God's wisdom and as the very reason why God created it in the first place. A natural-philosophical consequence is that, in order to hold to the view that creatures are designed for the very purpose of disclosing to us God's wisdom, Leibniz must ipso facto also hold that creatures are *designed*, that is, that their organs were formed for the execution of some function rather than that functions are executed by animals because they happen to have the right organs. Leibniz beseeches his readers already in the *Discourse on Metaphysics* of 1686 to "keep away from the phrases of certain extremely pretentious minds who say that we see because it happens that we have eyes and not that eyes were made for seeing."[38] One of these pretentious minds may be Spinoza, who in the Appendix to Part I of the *Ethics* argues adamantly that we chew because we happen to have teeth, rather than that we were given teeth in order to chew. Other likely culprits here are the various neo-Epicureans of Leibniz's day who were keen to resurrect the Lucretian account of the origins of species out of fortuitous arrangements of atoms.

As we have seen, an animal is a quasi-perpetual-motion machine with a species. It differs from the ideal perpetual-motion machine both in that it has a species and in that it requires constant refueling in order to exist. It differs from ordinary machines or "organica artificialia" in that it is both self-sustaining and self-reproducing. As we already saw in chapter 2, Leibniz berates other mechanists who dream in vain of a perpetual-motion machine in the stricter sense of a machine that requires no fuel at all:

> In order that men should obtain this durability of action in their machines, they now add to them a quasi-perpetual machine that is made by nature, which is of course man himself, the pilot, who repairs what is weakened or broken down in time, who applies an external force, bringing agents together with patients … or in some other way conserves the power of the Machine.[39]

In other words, artificial machines are only able to continue running because a certain kind of natural machine—a human being—tends to them by bringing them new fuel. But natural machines require no such attendance. And even if the individual animal will eventually cease functioning, in death it is still capable of a sort of perpetuity to the extent that it is capable of reproduction. Put two clocks in a room together and you will never get a third, little clock out of them; put two (appropriately selected) dogs together, and you might. This is not just a difference in the degree of complexity of the tasks that the different kinds of machine can accomplish; it is a difference that places the dog in a separate ontological class. A species of plant or animal, on Leibniz's understanding, is that transmission of properties across generations, which, as Leibniz puts it in his polemic against G. E. Stahl of 1709–10, are like so many links in a chain.[40] Leibniz writes that mating and reproduction prove the divine coordination of things, in that an individual substance requires something outside of itself, provided by divine wisdom, in order to fulfill its ends. "We have recognized a great difference between machines and aggregates or masses," he writes,

> insofar as machines have their effects and their ends by virtue of their own structure, while the ends and the effects of aggregates are born of a series of struggles, thus of the meeting of diverse machines; for, even if it follows a divine predestination, this meeting manifests more or less clearly its coordination with [the divine predestination]. Thus the worm labors on its own in the sole aim of producing silk; however, in order for another silkworm to be born, there must also be the union of the male and the female, and thus the combination of a single animal with a foreign element; for this combination shows more clearly its coordination with divine wisdom.[41]

Ultimately, the end of every natural machine is reproduction, but there must also be a subordinate end in order for there to be a clear fact of the matter as to what is being reproduced. Silkworms give rise to silk-producing machines; spiders, to web-making machines; humans, to contemplating machines, and the endurance of this trademark activity or *officium* is precisely the condition of a thing's being the sort of thing it is at all. Ordinary machines may not have a species, but hydraulico-pneumatico-pyrotechnical machines of quasi-perpetual motion are no ordinary machines.

Morphological Deviation and the Problem of Monsters

Biological species membership, as we have been seeing, is for Leibniz an all-or-nothing affair determined by descent from the same parents, and wide morphological variation does not have as a result greater or lesser membership in a species. Deviation from the type standard does not for Leibniz yield dogs, for example, that are any less canine than their more perfect relatives. Another way of putting this is that, for Leibniz, monstrosity is not the result of deviation from the morphological standard. Leibniz would agree neither with Aristotle, for whom widespread morphological falling-short of the species standard brings about a sort of universal monstrosity, nor with many of his own early modern contemporaries, for whom gross morphological deformation could disqualify some offspring from membership in the same species as its parents. For Leibniz, species membership is determined rigidly by the species membership of the parents, and this remains the case even when the offspring is so deformed as to resemble its parents barely or not at all. What matters is that the offspring have the special office, and this is something that is, broadly speaking, ethological rather than morphological, that is, something that has to do with the principle of activity of the creature, which is rooted in its interior nature rather than in any external markings.

Indeed, for Leibniz it is often the prevention of an animal from doing what it naturally does, in accordance with its special office, that leads to its deformation. Thus in the *Journal des Sçavans* of July 5, 1677, Leibniz recounts the story of a goat with deformed horns, an "extraordinary coiffure," as he puts it, suspected by some to be a living representative of the unicorn species.[42]

Leibniz explains that, in fact, this deformation is only a consequence of the restriction of the goat's movement in its early life:

> I do not know whether the frustration that he felt in seeing himself deprived of his freedom could have contributed [to his condition]; for you know what the stories teach us, that a great sadness or worry has been able in one night to change the color of a prisoner's hair, and to make a young man look like an old one. Physicians make still more extraordinary observations, which are more related to the coiffure or the excrescence we are dealing with here, a substance that is not very hard, but that one can nonetheless rightly call the *rudimentum cornuum*, since it is from this substance that the horns are formed. … The physical cause of this excrescence could be attributed to the fact that the aqueous humor of this animal could not be dissipated as soon as it was attached, as it ordinarily is by the heat of this sort of animal that is accumulated in their bounding, leaping, and running, this great humidity mixed with the juice, the volatile salt that forms the

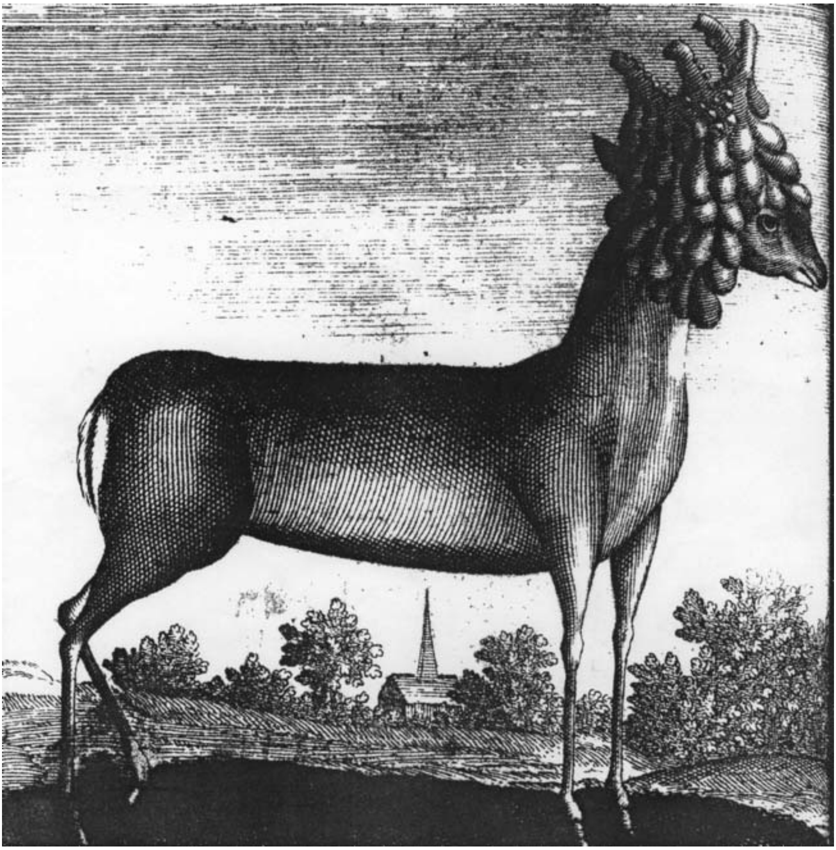

Figure 7.1 "A Goat with a Very Extraordinary Coiffure," from the *Journal des Sçavans*, July 5, 1677. From the Gallica database of the Bibliothèque Nationale de France.

> horns, attracted the matter downward by its heaviness, and made it soft, and of a colder temperament.[43]

In other words, morphology cannot be separated from ethology: an animal has the form it has *because* it has the principle of activity that it has. To be an animal of a certain kind is to have a certain principle of activity that in normal ecological circumstances will give rise to a normal representative of the species. But an abnormal representative is no less a member of the species than one that has developed in a nurturing milieu; Leibniz's coiffed goat is every bit a goat. Deformations are thus in no way "wonders" but rather only a consequence of the interruption of the normal developmental process. As for human beings, Leibniz frequently distinguishes between the "interior nature" and the "exterior marks" of a creature,[44] and consistently offers reason as the trait that separates us from animals. Under normal circumstances, the interior nature will be legible in the exterior marks, but these marks need not be there in order for the creature to be the sort of creature it is.

In Leibniz's account of the unusual goat we see many themes familiar from other writings on physiology and animal economy from the 1670s and 1680s. In particular, Leibniz continues to display a pronounced interest in excrescences, as he had in the *Directiones* of 1671. The formation of excrescences, Leibniz believes, is influenced by behavior as well as by emotion: if the animal's motion is confined, and if, for example, as a result of its confinement it is made sad and lethargic, then its horns will develop differently than under normal circumstances. In this way, not just ethology but even psychology is relevant to the study of physiology. It is worth noting here, if only in passing, that Leibniz does not find anything contradictory about offering psychological explanations in relation to animals: for him, to identify animals as machines is in no way to deny that they may also be the appropriate objects of psychological study. It is also interesting to note that Leibniz takes the curiosity of the goat as an opportunity for the application of general physiological principles. As has already been mentioned, recent scholars[45] have emphasized that the rise of seventeenth-century science brought with it a shift in the perception of "wonders," or natural rarities, from portents, broadly speaking, to opportunities for further discovery. Leibniz's explanation of this particular rarity in terms of the purely mechanical consequences of the failure of the aqueous humor to dissipate shows very clearly that his approach to abnormal physiology lies squarely within the modern frame of reference.

Under normal circumstances the interior nature of an animal will be legible in the exterior marks, but these marks need not be there in order for the creature to be the sort of creature it is. The interior nature determines the activity of the creature, and the exterior features are a sort of reflection or—to deploy a well-known term from the Leibnizian lexicon—a sort of *unfolding* of this interior nature. Given the fact that Leibniz's metaphysics of substance is a metaphysics fundamentally rooted in activity, it is appropriate that in his analysis of one particular kind of substance—namely, the kind we would today call "biological entities"—the reality and nature of the substance should be grounded in what they do, what they are created to do, and not in how they look.

Leibniz notes that externally dissimilar features can easily give the false impression of divergent species membership, and warns that "the mixture of figures is not always a sign of the mixture of kinds."[46] He relates the story of a badly disfigured child whose suitability for baptism was debated by the local clergy. In the end, the child was baptized and declared a person *par provision*, that is, until such a time as his precise species membership could be established. "Here is a child," Leibniz comments, "who was very close to being excluded from the human species simply because of his form."[47] Leibniz argues, along lines already familiar from the *Directiones* of 1671, that outward disfigurement cannot be a sign of the absence of a rational soul for the same reason that physiognomy is a predictively bankrupt science: "One would not be able to give a reason … why a face that is a bit longer, or a flat nose … could not coexist … with a soul."[48] The body may in the end be, for Leibniz, the unfolding of the soul, but this does not mean that external traits may be treated as gauges of the soul's capacity. Leibniz's firm commitment to the view that morphology can reveal nothing of soul-based capacities, and that it is these capacities that determine species membership, will be important for his argument, treated in the following section, against the possibility of ape-human kinship, as also, more generally, against the possibility of evolution.

Design, Diversity, and the Specter of Evolution

Charles Darwin observes in his 1871 work *The Descent of Man, and Selection in Relation to Sex* that once a naturalistic account of the generation of animals is admitted, creationism loses its footing and it becomes possible to think of entire species as having natural origins: "I am aware that the conclusions arrived at in this work," he writes,

> will be denounced by some as highly irreligious; but he who denounces them is bound to shew why it is more irreligious to explain the origin of man by descent from some lower form, through the laws of variation and natural selection, than to explain the birth of the individual through the laws of ordinary reproduction. The birth both of the species and of the individual are equally parts of that grand sequence of events, which our minds refuse to accept as the result of blind chance.[49]

Was now the danger to the species concept, inherent in reproduction from minor causes, apparent in the centuries preceding Darwin? Aristotle had a satisfactory way of explaining a wide range of natural phenomena: all natural things are a combination of matter and form; there are all sorts of ways some particular form can come to inhere in some suitably receptive matter, among these sexual generation, solar concoction, and such. In all cases, form separates itself from matter to the extent possible in imitation of the purely formal divine, and thus the more noble organisms—those capable of reuniting through self-motion to copulate when necessary—will be separated out into male and female. But with the matter-form metaphysics gone, there is no clear reason why there should remain either dimorphism in sexually generating species or regular species reproduction—what in earlier days could have been described as formal replication—among the males and females of a species.

Before Descartes, a Scholastic Aristotelian might have argued that eels and barnacles are mere rearrangements of matter that do not require any transmission of form, and that these thus differ fundamentally from horses and men, whose generation is also always *reproduction*. But effectively Descartes insisted that horses and men are generated as Aristotle conceded eels and barnacles must be, namely, by what Descartes called "minor causes." Leibniz, as we have seen, avoids the account of generation in terms of minor causes by denying that generation sensu stricto happens at all. Accordingly, he is able to preserve clear species boundaries: for Leibniz a creature is a member of species *x* if its parents were members of *x*, and we can be sure of shared species membership from parent to offspring because the offspring already existed as a preformed primordium within the body of the male parent. As we will see, Leibniz also believes in the possibility of what today would be called "microevolution": morphological change within a species over time, and thus even his preformation theory of generation does not entirely circumvent the possibility of environmentally triggered mutation. Yet for Leibniz even men with the similitude of beasts remain essentially men, a view he will develop over the course of his debate with Locke about species, and which, as we will see at the end of the present chapter, will serve as a cornerstone of his universalist anthropology.

The Fossil Evidence for Morphological Change

Leibniz was sharply aware of the fast-growing evidence that the species currently walking the earth may not be exactly the same as those that lived long ago. At times, the paleontological evidence led Leibniz to propose what looks like a theory of speciation through descent from ancestors of a different species. "There has been found at Tonna, near Gotha in Thuringia," he writes in a letter to Burnett de Kemney of 1696,

> some parts of a skeleton that is by all appearances that of an elephant. Some local doctors wanted to maintain that it was a production of the earth, a *lusus naturae*. They consulted me; I said that I do not doubt at all but that it is *ex regno animali*, and if it is not from an elephant, it is nonetheless from a similar animal [*d'un animal analogique*], either that elephants or similar animals [*animaux approchans*] have lived previously in those lands, or that

> there were amphibious marine animals of the nature of the elephant, when a great part of the earth was still submerged. For species can be greatly changed by the span of time, as by the interval of space, as is well witnessed by the differences between our animals and those of America.[50]

He complains again in the same year of "the physicians at Gotha, Doctors Rabe and Bachof and others, [who] still wish to uphold the view that the remains of the elephantiform animal at Tonna are games of nature."[51]

But if the remains are not games of nature, then what are they? How could one account for their presence in such a way as to avoid both the Scylla of evolution and the Charybdis of the spontaneous production of organic forms that have no representatives among real animal kinds? Leibniz's approach is to deny that there must be actual transformation of one species into another even if species themselves can be greatly changed. With the trailblazers of modern taxonomy, Leibniz believes that species membership is rooted in descent, or, in other words, that the kind of creature a creature is, is determined exhaustively by the kind of creatures its parents were. But this is not to say that there cannot be variation, even great variation, in a species over time, as when sea-dwelling, elephant-like animals take to the land, or vice versa. The elephantiform marine mammal's remains strongly suggested to Leibniz that offspring could be radically unlike their ancestors, and prima facie this fact threatened to weaken the like-begets-like principle to which he was attached. His strategy for maintaining this principle in the face of paleontological diversity was to hold that change over great lengths of time does not diminish the reality of species at any given time; and he does not seem worried about the potential incompatibility of the claim that, for example, as long as there are squirrels there will be dancing machines, with the possibility that someday the descendants of squirrels will be aquatic, and thus (synchronized?) swimmers rather than dancers.

Nowhere does Leibniz engage with the problem of species extinction—and relatedly, with the possibility of species change—more extensively than in that work of his that we have come to call the *Protogaea*. Even though Leibniz sticks to his strategy of describing morphological change as change *within* a species rather than change from one species *into* another, some commentators have discerned a burgeoning theory of evolution in this text. Horst Bredekamp, for example, cites the following passage as evidence of such a theory: "Once, when the ocean covered everything, the animals that today live on land were aquatic animals, and then they gradually became, with the retreat of this element, amphibians, and ultimately moved away, in their successive generations, from their original home. … But such a view contradicts the holy authors, from whom it is sinful to deviate."[52] But Bredekamp's citation does not tell the full story. In fact, Leibniz is clear that he is not even tempted by the thought of evolution, and not just for reasons of theological correctness. Here is the full passage from the *B* edition of the *Protogaea*:[53]

> There are those, I realize, who go so far as to propose that the animals that today inhabit the earth were aquatic, that they became amphibious as the waters retired, and that their descendants eventually abandoned their primitive dwellings. But beyond the fact that these opinions are in opposition to the holy Scripture, from which we should not deviate, *the hypothesis itself offers a number of unavoidable difficulties*.[54]

What were these difficulties? Around the time of the *Protogaea*'s composition, a few years prior to the discovery of the Thuringian mammoth, Leibniz becomes intensely interested in the spate of discoveries, in regions as far apart as Mexico and Russia, of fossilized mammoth skeletons. These remains were problematic both because they were vastly larger than the teeth and bones of known elephants and because they were appearing in regions that in Leibniz's day were no longer inhabited by elephants of any size. Leibniz reasons as follows: "We can assume either that these animals were once more widely distributed across the globe than today, because their own nature or the nature of the soil has changed, or that they have been carried very far from their homeland by the strength of the waters."[55] Leibniz seems aware here of the inherent epistemological difficulties in making determinations as to the differences between the variety of past species and those of today. Simply finding an unfamiliar skeleton neither proves that it is the skeleton of an extinct species, nor, still less, that current species are descended from it. Indeed, determining paleontological species necessarily involves different criteria from those ordinarily deployed for living species: since we only have fragments of them, and these fragments are not capable of reproducing, the criterion of interfertility, or the determination of species membership in terms of the like-begets-like principle, cannot be employed. Instead, one must look to morphological criteria alone. Yet, as we have seen in the previous section, Leibniz does not believe that morphology is in general the best guide to determining true species membership.[56]

Because Leibniz believes (i) that morphology without consideration of the causal chain of generation cannot be a reliable guide for the classification of species, and (ii) that there are actually infinitely many species in nature, and between any two given species there is a third, intermediary species (even if it shares ancestral links to neither), it is certainly not surprising that he finds the fragmentary evidence of the known paleontological record, in which skeletal morphology is all one has to go on, insufficient for determining the past existence of now-extinct species, let alone as to the ancestral connection between past species and present ones. Even our knowledge of present species, to the extent that it is based on morphology, is deemed by Leibniz to be provisional. He writes in the *Nouveaux essais*, for example:

> Perhaps at some time or in some place in the universe, the species of animals are or were or will be more subject to change than they are at present among us, and many animals that have something of the cat in them, like the lion, the tiger, and the lynx, could have been of one single race and now could be new subdivisions of the ancient species of cats. Thus I come back continually to what I've said more than once, that our determinations of physical species are provisional and proportional to our knowledge.[57]

Here again the amount of change Leibniz admits does not extend beyond the degree of microevolutionary adaptation any "creation scientist" today would admit. In this passage there is no evidence that Leibniz takes the "subdivisions" of a "race" to be distinct species, since nowhere does Leibniz assert here that lynxes, lions, and such, are reproductively isolated from one another. Significantly, elsewhere in the *Nouveaux essais* Leibniz mentions different breeds or "races" of dog that are sufficiently different in size and shape to raise the question of species difference. Leibniz responds in this case, as in the case of the giant cats, that they are evidently descended from a common ancestor, and all likely have the same "interior nature."[58] Similarly, while Leibniz reports of an unnamed traveler who maintained that "les Negres, les Chinois, et enfin les Américains" were all of different "races" from one another, and all of them from the Europeans. Leibniz insists that since "we know the essential interior of man, that is, reason," there is no ground for believing that what we today call "racial" differences, based as they are on "exterior marks" or morphology, could ever amount to species differences. We will return to Leibniz's theory of racial difference toward the end of this chapter.

Change over great lengths of time does not diminish the reality of species at any given time, and radically altered morphology does not fundamentally alter the special office of the creature. Presumably, in the case of the lion and its fellow felines, as long as there are large, wild cats there will be growling, meat-eating animals (or whatever Leibniz imagines their special office is), and Leibniz is not concerned to attribute to the tiger, the lion, and the lynx a special office in each case, notwithstanding the morphological diversity among these three subdivisions. Species membership, again, is an all-or-nothing affair determined by descent from the same parents, and wide morphological variation does not give rise, as a result, to greater or lesser membership in a species.

Language, Organic Function, and Adaptation

Leibniz, as we have seen, believes in the deliberate design of the organs that make up an organic body, even if much of what he writes seems to suggest that creatures have the morphology they have as a result of the influence of environmental circumstances and behavior over time. To the extent that organs are designed in accordance with divine wisdom, there is an assumption of a direct correspondence between anatomy and capacities, that is, between what the animal is capable of doing and how it is constructed. Yet Leibniz also concedes that animals may have organs designed for functions that are no longer regularly performed by that species, or that animals may on occasion be able to execute functions with organs that could not have been designed for these functions. Nowhere does the possibility of such a discrepancy between organs and functions, between what an animal is designed for and what it does, loom larger than in the question of animal language.

There is a fine line in seventeenth-century natural philosophy between the view that animals are an instantiation of rationality in their design, on the one hand, and on the other hand the view that animals *themselves* possess reason. That animal rationality was a position defended by libertines is well known; what has not been noted as often is that many believed that if we are to deny full rationality to animals, we must find some difference in their anatomy or design that would account for their diminished capacity for thinking, or indeed speaking. Marin Cureau de la Chambre, to cite one prominent example, argues that the rationality of animal actions—the fact that they do what is best for them in concrete circumstances—is evidence that they possess the faculty of reason:

> We must conclude, [that there is] is a faculty born with [animals], which ought to be of an order as elevated, as its effects are excellent, and which consequently acts with a great knowledge. If it be so, who will not have cause to believe, that actions whose successes are so well ordered, which have so well regulated a progress and a concatenation, which so justly ties together the means with their ends, must needs be enlightened by Reason.[59]

Cureau de la Chambre bases this claim in part on the purported empirical evidence that there is nothing in animal anatomy that could be seen as underlying any fundamental difference in respective mental capacities:

> Porphyrius, Plutarch, Raymondus Sebondus, for whom also Montaigne in his Essays hath written an Apology, were all of the same opinion with our Author, and if you will have the reasons of these and other learned men, why they have allowed Reason to Beasts, take these in brief. That most Animals

> have organs fit, and faculties like ours; In Anatomy the very cells of their brain nothing different.[60]

In the 1650s, the Baconian philosopher, John Bulwer, had argued the contrary view, that we could be certain of the absence of a soul in apes, in view of their anatomical difference from us. "Indeed, the bodies of other Creatures," he writes, "are not capable of mans soule, because they are not of that Fabrick, temper, and constitution, if they were capable; yet, for want of fit Organs the soule could not exercise her actions."[61] In 1672 Thomas Willis similarly identifies the complexity of human action and deliberation with the elaborately folded surface of the human brain:

> Those Gyrations or Turnings about in [the brains of] four footed beasts are fewer, and in some, as in a Cat, they are found to certain figure and order: wherefore this Brute thinks on, or remembers scarce any thing but what the instincts and needs of Nature suggest. In the lesser four-footed beasts, also in Fowls and Fishes, the superficies of the brain being plain and even, wants all cranklings and turnings about: wherefore these sort of Animals comprehend or learn by imitation fewer things.[62]

For Willis, as for Bulwer, there are sufficient physiological markers of a profound difference between humans and animals to assure us of our unique place in nature without having to leave the bounds of empirical science and engage in metaphysical disputations about the possession of a soul. Along the same lines as these thinkers, Spinoza famously went so far as to maintain that the mind *just is* the idea of the body, and that higher cognition is the direct correlate, under the attribute of thought, of bodily capability under the attribute of extension.

Leibniz carves out a moderate view in relation to these thinkers. He does not believe that every anatomical feature must be the correlate of some mental capacity (except, perhaps, in metaphysical rigor). Instead, he believes that it is the animal's activity that is the reflection of divine wisdom, and, secondarily, that this activity may be better facilitated by a certain conformation of the organs. For Leibniz, as we have seen, every species has its special office, and this office is in some way or other written into the body, though not in as direct a manner as for Spinoza or Willis. In some cases Leibniz thinks that animals may have the proper conformation of organs to do things that do not belong to their special office. For example, in the *Histoire de le l'académie des sciences* of 1706, we read the following report:

> Without a guarantee such as that of Mr. Leibniz, who was an eyewitness, we would not dare to report that near Zeitz, in Meißen, there is a dog that speaks. It is a peasant's dog, of the most common figure, and of a medium size. A small child heard it pushing out some sounds that he believed to

> resemble German words, and from that he got the idea to teach it to speak. The master, who had nothing better to do, spared neither his time nor his efforts, and fortunately the disciple had dispositions that it would have been difficult to find in another. Finally after some years the dog knew how to pronounce approximately thirty words, among which are *Thé, Caffé, Chocolat, Assemblée,* French words that passed into German without any change. It is worth noting that the dog was already three years old when it began its schooling. It only speaks as an echo, that is to say, after its master has pronounced a word, and it seems that it only repeats the words by force, and in spite of itself, although it is not at all mistreated. Again, Mr. Leibniz saw it and heard it.[63]

At least since Aristotle the idea of talking animals (if not Francophone animals) was associated with prephilosophical or mythical ideas about nature: Aristotle insists in the *Politics*, for example, that "Man is the only animal that has the gift of speech" (I.2), and with this lays down what would be a nearly universal commitment of subsequent philosophy. Richard Serjeantson traces the reception of Aristotle's view in the sixteenth and seventeenth centuries in such figures as Kenelm Digby, Vossius, and John Ray, noting that "an unsuitable anatomy … was one of the principal reasons for denying animals the capacity for articulate speech. They were widely taken to lack the right equipment of palate, larynx, tongue, lips. … For this reason … the miraculous constitution of the human speech organs served as a powerful proof in natural theology."[64]

But *why* are the brutes mute? Is it that they could not possibly have anything to say, or is it simply a contingent fact about their physiology that their limp tongues do not permit them to communicate what they are nonetheless thinking? Could the exceptional case of a talking dog reveal the thought that is always hidden in the canine body, usually unable to be expressed as a result of the unsuitable conformation of the canine vocal organs? We may be certain that Descartes would have taken the case Leibniz reports on, as well as the case discussed in Gabriel Naudé's 1648 edition of Rorarius's *Quod animalia bruta saepe ratione utantur melius homine* (That Brute Animals Often Make Better Use of Reason Than Men), with which he was likely familiar, as one of mere imitation rather than true speech. In a letter to Henry More of April 15, 1649, Descartes writes: "I think that even in us all the motions of our limbs which accompany our passions are caused not by the soul but simply by the machinery of the body. The wagging of a dog's tail is only a movement accompanying a passion, and so is to be sharply distinguished, in my view, from speech, which alone shows the thought hidden in the body."[65] Perhaps nowhere is Leibniz more anti-Cartesian than in his views on the interior lives of animals. As he writes in a text of the early to mid-1680s:

> I fear the opinion of the Cartesians will eventually be refuted by experience if men were to take greater pains in teaching animals. Descartes, writing to More, correctly asserts that he knows demonstratively that all the actions of beasts are able to be explained without invoking souls, so that the contrary cannot be demonstrated, but this needs to be understood according to metaphysical rigour, by which this cannot be demonstrated in relation to men.[66]

In other words, though God could have created the world such that he and Leibniz were the only existing beings, short of this possibility there is no greater evidence for the real, independent, substantial existence of other human beings than there is for that of animals. Nonetheless, as we have seen, Leibniz's report from Meißen tells of a case of mere imitation. Leibniz disagrees with Descartes that true speech is the only shibboleth for discerning mental activity in another being while nonetheless maintaining that speech is the exclusive office of human beings, the only species that, in addition to being a sort of embodiment of God's reason, is also itself capable of exercising the faculty of reason.

Whether dogs possess a degree of reason or not, their species difference from human beings is clear to all. Other creatures, however, were not so easy to place squarely on the other side of an ontological divide from human beings, and here as well the question of language played a very important role.

The Specter of Ape-Human Kinship: Leibniz, Locke, and the Impact of Edward Tyson's Orang-Outang

There are creatures in the world, Locke announces in his *Essay concerning Human Understanding*, that "have shapes like ours, but are hairy, and want Language, and Reason." He also identifies people among us, "that have perfectly our shape, but want Reason, and some of them Language too." He goes on to describe ever more unlikely beasts: "There are Creatures, as 'tis said … that with Language, and Reason, and a shape in other Things agreeing with ours, have hairy Tails." There are, he goes on, "others where the Males have no Beards, and others where the Females have." He infers from these oddities that the discrete reality of the human species cannot be maintained. "If it be asked," he reasons,

> whether these be all Men, or no, all of humane Species; 'tis plain, the Question refers only to the nominal Essence: For those of them to whom the definition of the Word Man, or the complex Idea signified by that Name, agrees are Men, and the other not. But if the Enquiry be made concerning the supposed real Essence; and whether the internal Constitution and Forme of these several Creatures be specifically different, it is wholly impossible for us to answer.[67]

In his response to Locke in the *Nouveaux essais*, Leibniz also takes up the problem of the "Orang-Outang" (which is to say, in the nomenclature Leibniz adopts from Edward Tyson, a chimpanzee, or perhaps a bonobo) and speculates as to what this creature might mean for our understanding of human uniqueness:

> Few theologians would be bold enough right away and unconditionally to baptize an animal that has a human figure but that lacks the appearance of reason, if it were found as a baby in the wild, and a priest of the Roman Church would perhaps say conditionally, *if you are human, I baptize you*.

Leibniz is evidently taking a cue from Augustine, who in *The City of God* writes similarly: "Whoever is anywhere born a man, that is, a rational mortal animal, no matter what unusual appearance … or how peculiar in some part they are human, descended from Adam."[68] For Leibniz, as for Augustine, morphological deviance has nothing to do with the possession of that special office of humanity, the contemplative rational soul, and this even in the case in which the morphology is so distorted as to conceal from outside observers whether the creature in question is human or not. Leibniz continues:

> It would not be known if it is of the human race, and if a rational soul lodges within, and this could be the case of the *Orang-Outang*, an ape that is outwardly so similar to a man, of which Tulpius speaks from his own experience, and whose anatomy has been published by a learned Physician.[69]

The learned physician in question, though he goes unnamed, is none other than Edward Tyson, who published his anatomical study, *Orang-Outang, sive, Homo sylvestris, Or, the Anatomy of a Pygmie, compared with that of a Monkey, an Ape, and a Man*, in 1699, and who by the time Leibniz wrote the *Nouveaux essais* had far surpassed his predecessor Nicolaus Tulpius as the most thorough and influential investigator of primate anatomy and of the boundary between human beings and their nearest ancestors. Although it does not seem that by 1704 (or later) Leibniz has read Tyson directly, and indeed in the *Nouveaux essais* he does not appear able to recall Tyson's name, nonetheless the very mention of this recent work shows just how present the "orang-outang" was in debates about human nature at the turn of the eighteenth century. It is clear that Leibniz was at least familiar with one of the more important arguments of Tyson's *Orang-Outang* by 1704, and that he deploys this argument in his response to Locke's 1690 essay, written nine years before the *Orang-Outang* had been published. With this in mind, let us have a brief look at the work of Tyson in order to better understand its impact on Leibniz.

Tyson is a staunch realist about biological species, unlike contemporaries such as Locke. He believes that the boundaries between species are fixed and eternal, and that at higher orders of taxa there are clear criteria that separate one from the other. Tyson thinks that we may properly place a given natural being in the animal kingdom, between "the Vegetable and Angelick" in virtue of the presence of a stomach and intestines, "for all Animals have these Parts; and all that have them, are Animals."[70] The gradations are many and minute from the plants to the angels, but nonetheless they are, for him, really there. "'Tis a true Remark," he writes, "which we cannot make without Admiration: That from Minerals, to Plants; from Plants, to Animals; and from Animals, to Men; the Transition is so gradual, that there appears a very great Similitude, as well between the meanest Plant, and some Minerals; as between the lowest Rank of Men, and the highest kind of Animals."[71] Tyson on occasion suggests that resemblances between species may be accounted for in terms of common lineage, or "relationship" in the robust sense of evolutionary theory. Indeed, he seems positively to affirm adaptation in the case of porpoises,[72] of which he also did an anatomical study some eighteen years before his study of the chimpanzee:

> The structure of the viscera and inward parts have so great an Analogy and resemblance to those of Quadrupeds, that we find them here almost the same. The greatest difference from them seems to be in the external shape, and wanting feet. But here too we observed that when the skin and flesh were taken off, the fore-fins did very well represent an Arm … the Tayle too does very well supply the defect of feet both in swimming as also leaping in the water, as if both hinder feet were colligated into one.[73]

Tyson's use of "as if" may be telling. In general, he seems to believe, like Leibniz, that climatic and environmental influence can alter traits within members of a species, but that this can never lead to speciation. Commenting on the proverb that "Africa always produces something new," a capacity Pliny and other authors attribute to climate, Tyson caustically comments that "'tis not the heat of the Country, but the warm and fertile Imagination of these Historians, that has been more productive of [new, monstrous species] than Africa it self."[74]

In any case, the purported relationship between porpoises and quadrupeds is one matter, that between men and apes quite another. All the same, Tyson cannot help but acknowledge the resemblance between human and ape bodies. When writing about apes, Tyson is very concerned to turn back the trend in his contemporaries' thinking toward blurring the line between themselves and men. But the fact that he feels compelled to enter into this battle at all might be taken to show that to think about apes and men as having shared ancestry was, if offensive to Tyson's sense of human dignity, nevertheless possible. Indeed, for Tyson there is so much evidence for human-ape kinship that in the end the only way he is able to secure this fundamental difference, while acknowledging physiological similarities, is by locating human uniqueness in something altogether unconnected to physiology:

> The Organs in Animal Bodies are only a regular Compages of Pipes and Vessels, for the Fluids to pass through, and are passive. What actuates them, are the Humours and Fluids: and Animal Life consists in their due and regular motion in this Organical Body. But those Nobler Faculties in the Mind of Man, must certainly have a higher Principle; and Matter organized could never produce them; for why else, where the Organ is the same, should not the Actions be the same too? And if all depended on the Organ, not only our Pygmie, but other Brutes likewise, would be too near akin to us. … In truth Man is part a Brute, part an Angel; and is that Link in the Creation, that joyns them both together.[75]

It is not, then, the ape that is of a "middle nature" between the rational and the animal, for that notch in the scale of being is occupied by man himself. Rather, the ape is a brute sui generis, it is wholly a brute, but one that is remarkably able to simulate, both in its anatomy and in its behavior, the ensouled human being. Tyson tellingly says that in its physical resemblance to humans, and not just in its learned behavior, "the Orang-Outang imitates a Man."[76] The human being, in turn, is the true missing link, the creature that truly, rather than just by way of simulation, straddles the boundary between the animal and the angelic. This difference between apes and humans is one that, for Tyson, cannot be observed and established empirically. In this respect, Tyson differs from a number of his predecessors and contemporaries who had rather less knowledge of anatomy than he did and who were able accordingly to presume that human distinctness can, as it were, be read off of human anatomy.

Tyson explicitly sees the view that apes are capable of language as atheistic and as a "romance of antiquity."[77] He shares in the majority view, attributed by Serjeantson to Vossius, Digby, and others, of animal language in the early modern period. Yet his own account of ape anatomy in the region of the mouth and throat poses a serious explanatory problem for him. Tyson is very clearly worried about the particular physiological likeness of apes and humans in the region responsible, at least in humans, for the production of speech:

> As to the Larynx in our Pygmie … I found the whole Structure of this Part exactly as 'tis in Man. … And if there was any further advantage for the forming of Speech, I can't but think our Pygmie had it. But upon the best Enquiry, I was never informed, that it attempted any thing that way. Tho' Birds

> have been taught to imitate Humane Voice, and to pronounce Words and Sentences, yet Quadrupeds never; neither has this Quadru-manous Species of Animals, that so nearly approaches the Structure of Mankind, abating the Romances of Antiquity concerning them.

Tyson explicitly accounts for all reported instances of teaching animals to speak as mere imitation, and not as indicative of any conscious activity. He goes on to write of the larynx that

> Anaxagoras, Aristotle, and Galen have thought [it] to be the Organ which Nature has given to Man, as to the wisest of all Animals; for want perhaps of this Reflection: For the Ape is found provided by Nature of all those marvellous Organs of Speech with so much exactness … that there is no reason to think, that Agents do perform such and such actions, because they are found with Organs proper thereunto; for, according to these Philosophers, Apes should speak, seeing that they have the Instruments necessary for Speech.[78]

Then why are they not speaking? Tyson repeats his conviction, noted above, that the only explanation lies in the fact that anatomy is not, to borrow a phrase, destiny, that one cannot infer from the organs a creature has what it will be able to do:

> From what is generally received, viz. That the Brain is reputed the more immediate Seat of the Soul it self; one would be apt to think, that since there is so great a disparity between the Soul of a Man, and a Brute, the Organ likewise in which 'tis placed should be very different too. Yet by comparing the Brain of our Pygmie with that of a Man; and with the greatest exactness, observing each Part in both; it was very surprising to me to find so great a resemblance of the one to the other, that nothing could be more. … Since therefore in all respects the Brain of our Pygmie does so exactly resemble a Man's, I might here make the same Reflection the Parisians did upon the Organs of Speech, That there is no reason to think, that Agents do perform such and such Actions, because they are found with Organs proper thereunto: for then our Pygmie might be really a Man.[79]

But this is an odd sort of reasoning, particularly in view of the fact that, as concerns bipedalism, Tyson is perfectly willing to reason that the ape is capable of this simply because "'tis sufficiently provided in all respects to walk erect."[80] Why does sufficient provision translate into a capability in the one case but not in the other?

This is not the place to work out interpretative quandaries arising from Tyson's study, so let us instead turn to Leibniz's views on the possibility of ape language. In chapter 1 of Part III of the *Nouveaux essais*, "On Words," Leibniz has his counterpart Théophile observe: "As concerns *organs*, apes evidently have those required to form speech just as much as we do, and nonetheless we do not find in them the slightest endeavor to speak. Thus they lack something that is invisible."[81] The source of this argument is clear: it comes, whether directly or indirectly, from Tyson. Indeed, the *Nouveaux essais* reveal a preoccupation with "orang-outangs" that Locke could not have felt in writing the *Essay* fourteen years earlier, again, nine years before the publication of Tyson's *Orang-Outang*. Yet this is a curious point to pick up from Tyson, for it shows the design argument at its weakest. If speech is an outward sign of reason, and apes have the organs of speech, but not the capacity to speak, then how can Leibniz, or Tyson, remain committed to the natural-theological argument that a creature's organs are created for some purpose and thus are revelatory of divine wisdom?

One possible response to this question is that Leibniz is repeating Tyson's argument without putting all that much thought into its implications for his general commitment to intelligent design. Another is that here Leibniz believes, as many in the late eighteenth century would after him, that it is the circumstances of the ape's social life that prevent it from speaking, and not any innate inability. Thus, for example, James Burnet, Lord Monboddo, argues in 1773 that the great apes are "a barbarous nation, which has not yet learned the use of speech." He argues that since, as Tyson has shown, they possess the organs necessary to speak, what prevents them is only that they have never been educated, just as "men, living as the Orang Outangs do, upon the natural fruits of the earth, with few or no arts, are not in a situation that is proper for the invention of language."[82] A similar suspicion underlying Leibniz's invocation of the ape in the *Nouveaux essais* would square very well both with his observation elsewhere in the same work that apes should be baptized *just in case* they have a rational soul, as well as with Leibniz's observation in the article on the coiffed goat that living in an impoverished environment can bring it about that a creature is not able to exercise all of its inborn capacities.

What is clear, in any case, is that Leibniz shares with Tyson an equally realistic view of the divisions between species, even if he seems more inclined to allow that the orang-outang falls on our side of the division rather than on the side of the animals. Leibniz believes with Tyson, and against Locke, that species are set down once and for all by God, and that there can be no overlap between them (though curiously, both Leibniz and Tyson seem to deviate from this general principle in the case of marine mammals). For Leibniz, it may ultimately be impossible to know whether an orang-outang possesses a rational soul or not. If it does, then it is wholly a human being, deserving of baptism and suitable for salvation, no matter how different it looks from a "normal" human being. For Leibniz there is a fact of the matter as to whether an ape is a man, or not, and this fact of the matter has to do with what Locke would call the "real essence" and what Leibniz sometimes calls the "interior nature." There is for the author of the *Nouveaux essais* a clear criterion for distinguishing men from apes, even if it may be difficult to discern in practice on which side of the dividing line a given creature falls. For Locke, in contrast, there is continuity between the ape and the human realms, not least as a result of supposed cross-species fertility, and any question we may ask about whether some creature is a man or not has only to do with criteria for membership among humans that we happen to set, but that may not in the end have to do with real essences.

Leibniz believes that the orang-outang, or *Homo sylvestris*, is in fact a *Homo*, which is to say that it participates entirely in humanity, which in turn is to say that it is rational. He further believes that this justifies claiming that we know its real essence and also claims that it renders the creature's morphological differences from us irrelevant:

> I believe that in the case of human beings we have a definition that is real and nominal at the same time. For nothing could be more internal to human beings than reason, and ordinarily it makes itself known clearly. That is why the beard and the tail [of an ape] are not to be considered when accompanied by it. A *homo sylvestris* [*homme sylvestre*], though hairy, will make himself known.[83]

Here, then, Leibniz is claiming that there is not so much continuity between the orang-outang and the human, as that there is fully shared species membership. Ordinarily reason makes itself known in humans, but for whatever reason (here Leibniz is silent) it has retreated from the surface in these mute and hairy *homines*. Yet their hairiness and other simian features are for Leibniz no grounds for denying that the orangutan is every bit a rational creature. Orang-outang and humans look alike not because they are related species, but because they are the *same* species.

The Problem of Human Diversity

Parallel to the developments we have already considered in geology and paleontology, in the early modern period significant new ethnographic evidence was rapidly being accumulated that seemed to conflict with the biblical account of origins. On the one hand, new discoveries, particularly in the Americas, made it increasingly difficult to believe that enough time had elapsed from the biblical creation for human beings to have wandered so far from the presumably Near Eastern Garden of Eden and to change so much with respect to physical appearance. On the other hand, increasing awareness of the technological achievements of other civilizations, particularly those of the Chinese, made it increasingly difficult to believe that the revealed truth of Christianity gave Europeans any greater access to scientific truth than their pagan neighbors enjoyed. Interest was also piqued by the fact that some cultures, such as the Chinese, the ancient Persians, and the Mexicans, had alternative chronologies of world history that placed the origin much further back than the Old Testament would have it. In view of these problems, certain thinkers advocated a doctrine of multiple creations and held that revealed scripture was only of relevance for those created from Adam and Eve. This doctrine, often called "polygenesis," was an important impetus to the rise of theories of racial difference in the late seventeenth century.

For the most part, early modern thinkers stuck by the principle that, as Edward Tyson puts it in the *Orang-Outang*: "between human and non-human there is nothing in between [inter hominem et non-hominem medium non datur],"[84] while taking "human" to designate all and only descendants of Adam. Leibniz is squarely in the camp of the majority of moderates on the question of human cultural and phenotypic diversity. For him, "racial" difference is a mere superficial layer of individuals, concealing but not diminishing their underlying commonality.

This is his mature view, anyway, and there is at least one early text that might seem to contradict the account of Leibniz's anthropology as presupposing full equality among human beings. In an audacious proposal of 1671, titled *Modus instituendi novam militiam invictam qua subjugari possit orbis terrarum, facilis executio tenenti Aegyptum, vel habenti coloniam americanam* (A Method for Instituting a New, Invincible Militia That Can Subjugate the Entire Earth, Easily Seize Control over Egypt, or Establish American Colonies), written as an addendum to his better known *Consilium Aegyptiacum*, Leibniz sketches out a plan for training a new army of warrior slaves:

> A certain island of Africa, such as Madagascar, shall be selected, and all the inhabitants shall be ordered to leave. Visitors from elsewhere shall be turned away, or in any event it will be decreed that they only be permitted to stay in the harbor for the purpose of obtaining water. To this island slaves captured from all over the barbarian world will be brought, and from all of the wild coastal regions of Africa, Arabia, New Guinea, etc. To this end Ethiopians, Nigritians, Angolans, Caribbeans, Canadians, and Hurons fit the bill, without discrimination. What a lovely bunch of semi-beasts! But so that this mass of men may be shaped in any way desired, it is useful only to take boys up to around the age of twelve.[85]

Leibniz goes on to propose that prisoners be segregated according to language, which for him is the same as segregation by race or genus. In this way, unable to communicate with any warriors beyond their own small squadron, the warriors will be unable to plan an insurrection. Even in this text, however, Leibniz is not interested in seizing future warriors on the basis of perceived racial differences. He is interested in seizing boys from beyond the pale of Christendom and *making* them into semi-beasts. This is, no doubt, brutal, but there is no indication of a belief in the biological position of the barbarians to be seized as taxonomically somewhere between humans and animals.

In a few other texts Leibniz gives some indication of having developed views on the concept of "race." In notes on a text by Wilkins taken at some point between 1677 and 1686, Leibniz lists the terms *Race*, *genus*, *Geschlecht*, and *series generationum* as synonyms, also defining genealogy as the "explication of this series." These definitions might be more significant than they first appear. In the earlier *Modus instituendi*, Leibniz had referred to the Ethiopians, Canadians, and others, variously as *gentia* and as *genera*. Does this mean that each group constitutes a generative unity, which is to say that each group is reproductively isolated? Certainly not: throughout his life Leibniz remains committed on Christian grounds to a monogenetic account of human origins. Even in the *Modus instituendi*, the barbarians are to be captured and enslaved not as subhumans but simply as non-Christians.[86] A generational series, then, is something quite distinct from an isolated reproductive community. Nonetheless, as biologists today know full well, interfertility *in potentia* does not necessarily lead to offspring: for many subspecies of a given species, it is enough that a given creature have slightly different markings on its feathers than another, for example, in order to turn both parties off from the prospect of mating. In the *Modus instituendi* Leibniz appears to take Ethiopians, Canadians, and Europeans to be in much the same situation: relatively reproductively isolated because mutually uninterested, even if biologically the same, and descended from the same first ancestors.

Another reproductively isolated community is constituted by the European nobility, with its complicated rules governing the political union of families through marriage. And here we come back to the Guelf history, discussed briefly in the previous chapter, and Leibniz's inclusion in it of a survey of the dominion's geographical features as well as of the riches that could be extracted from these. Leibniz's real task in writing the history of his employer, the task for which what came to be known as the *Protogaea* was but a preface, was to establish the ancient connection between the Guelf family and the Este family, a lineage which in his day exercised great power and held substantial territory in northern Italy. This task was ultimately one of genealogy, which is to say of the explication of a generational series. In this connection, we might suppose that Leibniz's official task of writing a *historia civilis* of his employer's family could have been understood, by him if not necessarily by his employer, as part of a larger project of *historia naturalis* that would include, for example, contributions to botanical method or taxonomy.

Generational series are at the root of political power as well as natural order. Such series may be sustained by the interbreeding members of a species, but there are other examples of such series, and in no case does Leibniz appear to believe that what keeps the series in existence is what we would think of as reproductive isolation in a biological sense. An individual may breed outside of its group whether that group is conceived in terms of its nobility, in terms of ethnicity, or in terms of zoological similarity. In short, if there is some minimal evidence that Leibniz conceives of ethnic or racial groups as, in some sense, real kinds, there is a great deal of evidence that he conceives of the Guelf-Este family, among others, in just the same way, namely, as a generational series. There does not seem to be any evidence that he thinks of these series as "natural kinds" in the sense with which we are familiar (the kinds such that, in picking them out, we are carving nature at its joints). In the end the only thing that is natural in this way is for him the species, and this is something in which all the subgroups constituting generational series—whether lynxes among the great cats, or Hurons or Guelfs among humans—participate equally.

This all suggests that Leibniz's proposal in the *Modus instituendi*, while politically outrageous, does not seem to be based on anything like an essentialistic account of human racial difference. Yet some authors, in a hurry to associate Leibniz's colonial ambitions with racism in our own contemporary sense, have argued for a different view. For example, Peter Fenves writes that Leibniz's name "is often found in lists of those who were early proponents of a racial system of human classification." Fenves maintains that "Leibniz concurs with—and gives credence to—the novel representation of supranational distinctions that François Bernier first proposes in his essay 'A New Division of the Earth, by the Different Species or Races of Man,'" which was published in the *Journal des Sçavans* of 1684.[87] Indeed, it is clear that Leibniz read this issue of the *Journal*, even if it did not make enough of an impression on him for him to retain Bernier's name in his memory. In a letter thirteen years later to the pioneering Swedish Slavist J. G. Sparwenfeld, Leibniz writes: "If it is true that the Kalmuks as well as the Moguls and Tartars of China depend on the Grand Lama in matters of religion, it is possible that this says something about the relation among their languages and the origin of these peoples. It is simply that the size and constitution of their body is so different among them." Here, Leibniz seems surprised that bodily morphology should be expected by anyone to correspond to linguistic kinship among different groups, since Leibniz believes that language is far more important than "race" for determining ancestral relations. Nonetheless, he is aware of the interest in "racial" classification of others:

> I remember reading somewhere (but I cannot recall where) [evidently a reference to Bernier's article] that a certain voyager divided human beings into certain tribes, races, or classes. He assigned a particular race to the Lapps and Samoyeds, a certain to the Chinese and neighboring peoples; another to the Negroes, still another to the Cafres or Hottentots. In America there is a marvelous difference between the Galibis or Caribbeans, for example, who have a great deal of value and just as much spirit, and those of Paraguay, who seem to be children or youths all their lives. This does not prevent all human beings who inhabit the globe from being all of the same race, which has been altered by the different climates, as we see animals and plants changing their nature and becoming better or degenerating.[88]

In the *Otium hanoveranum*, the early compilation of Leibniz's texts edited by Joachim Friedrich Feller, we find another text consisting in a nearly exact Latin paraphrase of the contents of Bernier's "Nouvelle division."[89] The text is interspersed with misspelled Italian expressions, motivating the conjecture that Leibniz composed it during his Italian voyage of 1689–90[90] for a colleague who could read no French, and amused himself in doing so by trying out his own elementary Italian skills. It is clear that Leibniz's reasons for writing it fall short of assertion of the truth of its claims. Yet later, the pioneering physical anthropologist Johann Friedrich Blumenbach would incorporate elements from the *Otium hanoveranum* into his *De generis humani varietate nativa* (On the Innate Variety of the Human Race) of 1795, evidently failing to recognize that Leibniz is not stating his own views but rather summarizing those of Bernier. Thus, the identification of Leibniz as a seminal thinker in the history of racial science appears to result from a simple mistaking of indirect statement for direct. For Leibniz, it is historical linguistics and not the study of morphological differences that will give us insight into the true lineages of the various human groups. As he concludes in the text just cited, adding his own view to the long summary of Bernier's system: "I should like for the regions [of the world] to be divided according to languages, and for this to be noted on maps."[91]

Fenves also takes the *Modus instituendi* of 1671 as a significant statement of Leibniz's views on race. But in addition to its evident status as a bit of juvenilia, and in addition to the political circumstances of the text's composition—namely, as an addendum to the *Consilium aegyptiacum* of the same year, in which the young Leibniz was attempting to impress Louis XIV—it is, again, not at all clear that even here Leibniz thinks of humanity as divided up into anything that corresponds to the modern, which is to say Blumenbachian, notion of race.

In any case, as Leibniz grows older his commitment to the biological and spiritual equality of all human beings grows more pronounced. By the time of the *Nouveaux essais*, for reasons that Leibniz himself sees as rooted in his Christian, universalist anthropology, the philosopher positions himself squarely against those, like the racist polygenesists (if not like Isaac La Peyrère, the seventeenth-century founder of polygenesis, himself), who would adopt a theory of the separate creation of different human populations and who would make the case that those created independently of the descendants of Adam and Eve are not truly human. Richard Popkin maintains that Leibniz did not seem to be interested in the historical, chronological, anthropological questions that provided the ammunition for the pre-Adamite theory (that is, the prevailing version of polygenesis in the seventeenth century, according to which there were separately created human beings living before Adam's creation). Leibniz was, Popkin writes,

> very much concerned to discuss other theologies outside of Christianity in terms of their ideological content, but not their differing claims about the facts of human history [. . .] His efforts to unite the churches within Christendom, and then to unite them with Islam and Chinese religion, did not involve finding common historical ground, but rather common metaphysical and moral ground.[92]

Yet we know from scattered passages that Leibniz was a committed monogenesist, and that he believed that human phenotypic diversity is a consequence of environmental influence over time. Thus he notes in a text from the *Otium hanoveranum* that all of humanity must belong to the same species, even if "they have been changed by different climates just as we see that animals and plants change their nature, in becoming better or degenerating."[93] For Leibniz, then, there is only one origin for human beings, and subsequently the boundaries of the human species must remain rigidly fixed. In this respect, Leibniz may be described as a moderate degenerationist who believes that human diversity can be accounted for in terms of environmental pressures over time in different habitats.

One of the great ironies of early modern ethnography is that it was the religious and creationist worldview that spoke in favor of common origins for all humanity, while the abandonment of the need to interpret human diversity in scriptural terms easily led to polygenesis. Polygenesis, and the corollary belief in the essential difference between different groups, would enjoy its most widespread success in the context of nineteenth-century American slavery. The fact that this account of human diversity remains controversial in the seventeenth century may be traced in part to the enduring imperative in the period to stay faithful in speaking of origins to the traditional religious conception of humanity, according to which human beings are created in the image of God and are in this respect absolutely distinct among natural beings, and according to which all human beings, in virtue of this God-likeness, are, notwithstanding physical differences, equal.

Appendix 1

DIRECTIONS PERTAINING TO THE INSTITUTION OF MEDICINE (1671)

LH III 1, 3, folio 1–9. Originally written in German. Previously published in German in a critical edition by Fritz Hartmann and Matthias Krüger (*Studia Leibnitiana Sonderheft* 8, no. 1 [1976]: 40–68). Numeration added.

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1. One must have instruments for precisely investigating the urine and the pulse, since these are generally signs of a man's condition. For the urine nothing is better than a good single-lens microscope, for this will reveal thousands of things that otherwise are not found in the urine, and [so] one will quickly arrive at rules that surpass all previous ones.

2. The blood that is let with leeches should likewise be examined. The pulse should only be felt by even the least of physicians when their hands have attained the perfection of noticing all differences, as Galen remarks. To this end it will be useful if the wonderful thoughts that the famous Marcus Marci[1] has written in his *Sphygmica* should be brought into practice.

3. The urine and blood can also be tested by weighing, distilling, clarifying, with and without fire, and in other ways, particularly when one is in doubt.

4. Tests are to be conducted with sputum as well as with blood and urine, and even more than with blood, since it is easier to obtain. And I believe that from the saliva much can be concluded as to a man's constitution, as also from the urine, and that from the anatomy of the sputum the causes are to be found as to why one man enjoys eating one thing, another man something else. One could clarify the sputum by dissolving it in clear spring water, etc. As also with urine, one can let it form into crystals, mix certain solvents or reactive agents into it, etc., from which colors will appear that will enable one to judge as to a man's constitution.

5. Next a general examination of people should be established, by means of static medicine, as was put into a system of rules by Sanctorius only after thirty years of experiments.[2] This should then be brought together, advanced, and made appropriate to all particular facts. One

could also establish experiments in elastic medicine as to the increase or decrease of the strengths of a man, as in the drawing of a bow or the distance one is able to throw something, but ideally in the long span of a certain task, as in walking, pulling something, etc.; nevertheless the best thing is for the doctor to have experience, for which it is not worthwhile to carry out an exhaustive investigation.

6. To the observation of the pulse belongs the observation of the warmth and coldness of the hands by an exact, much improved thermometer. For some men have naturally warm hands, some naturally cold, more or less according to their constitutions.

7. The thermometer must however be improved, both according to P. Eschinardi's[3] recollection, as well as according to the proposal in England to create a circular thermometer, as the *History* of the [Royal] Society relates.

8. Further tests could be conducted on a man by giving him a bath, so that that which washes off of him could be anatomized and examined. The breath could also be examined by reducing it into a dried residue. Every man must pay attention as concerns his own sweat. The sweat can be collected and its degree of salinity, etc., examined.

9. There should be certain people in the republic who have developed their [sense of] smell, touch, taste, etc., to perfection, so that they might be able to examine any suspicious things. Each office should have a doctor, a surgeon, a pharmacist, and still other people affiliated with it, available at a low cost. A cook should be expert at distinguishing all things on the basis of their taste and smell, and should be examined with respect to this [skill]. A barber should be expert in [the sense of] touch; there must be people who have brought their ability in sensing by touch up to a point that they can do everything the blind man about whom Mister Boyle writes accomplished. This is all possible.

10. From the clarity, strength, purity, etc. of a man's speech, one can also draw medical consequences.

11. One must procure all previously established cases and medico-physical observations. These should be brought together from all authors, and brought into order according to the degree of their plausibility. Then they should all be tested as soon as possible. Some of them can be tested whenever one chooses, and in these cases they should be tested right away. Some of them, for example the remedies for certain illnesses, can be tested only when the occasion presents itself. Thus it should be brought about that everywhere there is a catalog of the patients in a given region, with all of the details of their illnesses. Now, if one has guidelines for the tests at one's disposal, one can conduct the tests right away. But they should not be dangerous, for otherwise they would spell the patient's doom.

12. Everywhere, people should be called together and made to understand the following: whoever is in the position to describe a remedy in more or less comprehensive detail, and to make this description plausible, shall be honored. The governing doctor [*Der Medicus des Amts*], who brings together so many wonderful things, shall also be honored. Every doctor and chemist shall always keep a journal describing all of his labors. Above all, those things that old ladies and market criers relate concerning medicinal plants [*simplicia*] should be brought together.

13. All patients who die in the hospital should be anatomized, and it would be good if most people could be anatomized. All anatomies should be conducted in a different manner, as Steno prescribes in his *Anatomica cerebri*. As much as possible should be known about the "natural history" of the person who is anatomized, and then all of his humors, etc., should be examined, the pancreatic juice, the bile, etc. [It should be determined] whether the juice is more acidic or saline, and which colors result from the gall or from the other parts with the *lignum nephriticum*. In the autopsy all the smallest details should be drawn, all the ducts and passages should be tested with colored liquids poured into them, all sorts of ligatures should be applied. A means of coagulating the blood should be sought, after the manner of Bilsius,[4] so that it does not hinder the autopsy. A liquid needs to be sought that would eat away the flesh, while leaving all the ducts intact, so that everything could be investigated very exactly. The human body should be investigated in all its details to the most precise degree, so as to always have, so to speak, a living anatomy in view. This would be much better than the illustrations of Copenhagen and Helmstedt.

14. One should inquire how it is that liquids that have been drunk arrive so quickly in the bladder, as one experiences in the drinking of acid water, and perhaps also how the lead balls mentioned in the English *Transactions* could travel through the digestive tract.

15. Very precise lists of questions must be given to all physicians, by means of which they should examine their patients. Indeed, once these have been printed, every competent man will be able to examine himself and to write up his own natural history.

16. In order to conduct experiments on the nature and motion of flatulence, air should be pushed into the body, or drawn out of it.

17. Many universities, and also inquisitive private physicians, must be solicited for projects for universal inquiry.

18. In order to determine whether the signs of the hand and so on have a certain power, one would have to make prints of the hands of many people whose actions are known to us. This could easily be done if their hands were covered in a liquid, with the prominent part being wiped off, printing that which lies beneath the lines [of the hand]. Mey's medical

chiromancy is also worth mentioning.[5] In order to determine whether there is something [of value] in the astrological tradition and in the principles of Ptolemy, one must also inquire and set up experiments.

19. Rules should be prescribed to people as to their behavior with respect to eating and drinking. Everything should be eaten chopped up into little pieces. Different diets should be tried with different people. For example, one man should be given primarily dairy products; another should be permitted to drink only warm beverages; another should be permitted to eat only what is lifeless; and so on. Some should have everything together. One should pay attention to the conditions of members of religious orders, who usually have a common way of living with respect to diet and other things, and one should determine the consequences of this. It should be tested whether there is a benefit to a man who eats animals that have, up to a certain amount, been fattened with hay, or other animals, etc.

20. All sorts of means should be tested on various men to see whether, by the application of the proper art, they may be made old, so as to derive a preferable model [of aging]. Along with Mr. Charas,[6] the causes of natural death should be investigated, in order to find the means of prolonging life.

21. People should be examined with the highest degree of exactness in order to determine what they enjoy eating or drinking, and what not, as well as the degree of enjoyment. One should also pay attention to what sort of musical tone may be delightful to someone, as for those who have been bitten by the tarantula.[7] Indeed, according to Plato's *Republic*,[8] a change of music changes the Republic. Everyone must pay attention so as to determine what it is in the world that brings him the most joy.

22. Bills of mortality must be brought to the greatest possible perfection, and must be made not only in the large cities, but also everywhere in the countryside. And the difference of climates, of the soils, of the air, etc., should be precisely noted: in this way many admirable things will result. Certain people should then be contracted to make inductions and observations from these. Attention should be paid to astrological effects: whether, for example, it is true what they say, that if a woman gives birth during a (solar) eclipse, she and the child will die, and other things in this sort of tradition. One should study the rules of the authors of calendars concerning bathing and bloodletting—rules these authors have applied to the moon and to the signs of the zodiac—according to the methods proposed by Kepler, Campanella, Trew, and other learned men.

23. All the medicinal plants of the whole world should be brought together and multiplied in our regions so that they can be examined without any doubt. The examinations of simple elements must proceed in such a way that we first exhaust all of their sensible qualities, and of each of these that we determine to the extent possible its degree. Then we

must, to the extent possible, treat them directly by pressing, percolating, etc., distilling with air or with fire, and then mixing them with solvents and reactive agents. And then we must also combine all of their qualities and note their degrees. It will be especially worthwhile to test the colors of all things against the touchstone of *lignum nephriticum*.[9]

24. One must above all determine the manner and pathway by means of which taste functions.

25. We must investigate whether there are solvents only for sweet things [*dulcia*], or whether for acidic or saline things, and we must also find the degrees [of acidity, etc.].

26. One should also pay attention to whether something truthful may by drawn from the signatures of things: where this is the case, this will be a perspicuous proof of providence.

27. Countless anatomies should be performed on animals, living as well as dead.

28. One should begin to pay more attention to the illnesses of animals than has been done up until now, for just as Steno correctly says that we have learned all of today's anatomy from animals, so too could we learn the whole of pathology from them, for we may cut them open when and how we please. And the Republic would pay the individual who gives his animal over to the common good. In general we pay attention almost exclusively to the illnesses of horses, ignoring those of other animals. We can also test therapeutic methods on animals easily and safely, particularly when we will have begun to better understand their illnesses. We can test medicines [*arzneyen*] on animals when we please, and from this make a conclusion according to its analogy [*proportione*] to human beings. We cannot make such tests on humans.

29. Regular visits of inspection to the pharmacies should be set up, and we must pay attention both to what Bartholin has written against the apothecaries, as well as to what has resulted from the disputes in England between the apothecaries and the physicians.

30. The amount of time for the production of urine from drinking, or of excrement from eating, should be precisely observed, which will happen more quickly in one man than in another.

31. One should pay attention to how much the natural stimuli and indications should be believed, as when nature indicates vomiting by means of a brief retching sensation, or damage to a vein by means of loss of blood. Likewise to what extent the natural appetite is to be followed or not followed when it comes to eating this or that, sleeping, etc. And as it is well known so complete a symmetry is found in the parts in the human body, even though it is in no man perfect in every way, such deviations [*evagationes*] should be noted, and tests should be made to determine whether something can be concluded about the constitution of the body.

And if, as Wren, Hooke, and others propose, a history of the climate is composed, or, as I often proposed, calendars of past years are made, everyone should note in very fine detail what changes he has noticed in himself. And in particular the best notes could be made by those who are always used to living their life in the same way, such as farmers or members of religious orders.

32. Tests should be made to determine what would happen if a man were continually nourished with water, or with water and bread, etc., and what would be the uses of a consistently simple and regular diet.

33. From the figure of the hair of a person all sorts of useful conclusions can without doubt be made. Of the nose and other [parts] I do not wish to say.

34. It is to be tested whether the antimonachale (antimonium crudum)[10] is useful to people as well as to horses and pigs, when it is introduced by degrees as a cure. NB

35. There are certain agreements and communications among the members of the body, as a living person himself experiences, but that cannot be found in dead bodies. Thus, for example, everyone knows the connection that the genitals and the sole of the foot have with the head. Rubbing the sole of the foot a little brings about the same sensation in the head. Similarly, experiments should be instituted for other [connections between parts]. And it may be that it is also in accordance with reason, that the parts of the body that have a constant proportion between them also have more sympathy with one another.

36. An effort must be made to create a number of new aphorisms. Whoever comes up with a new aphorism that was previously unknown and that is fitting in most cases should get a certain prize. The same should hold for whoever is able to find a solid reason for already known aphorisms, the reason of which had not been discovered before. In this connection see Claudius Campensius[,] Mr. De la Chambre, Antimus—i.e., Honoré Fabri—and others on the aphorisms of Hippocrates. Not to mention the new aphorisms added by Laurentius Scholzius,[11] etc.

37. Tests should also be set up to determine what the powers of the imagination and the belief[s] of the patient are capable of bringing about. To this end physicians should be given the art and the means to convince the patient of all manner of things. One must, in particular, find, by reasoning, the communications of the external members with the internal ones. In this way already a great deal could be done by means of external applications.

38. I do not doubt that liquors may be found that, injected with a syringe, will dissolve bladder stones, and also < … > take away the gouty calculuses. If this method is followed and everything is encouraged, in ten years we will have more things brought together.

39. Take note of where rubbing is felt most strongly, on the sole of the foot, on the head, and so on. One feels certain pains most strongly at the top of the head, when one presses hard. Here or nearby is the beginning of the nerves.

40. Bitter things are good against fevers. Acidic things are good against the plague.

41. Whether those people are of the same humor, who have the same sort of deviations of the symmetry of certain parts from [their] ordinary symmetry.

42. One should test all sorts of liquors injected into the blood. One should not cease to make tests involving the transfusion of the blood, at least in animals, as in England a weak horse was made strong again by the use of fresh sheep's blood. One should make tests with different sorts of baths, for all baths are in a certain sense in the category of infusion through the pores.

43. Likewise with various sorts of oils for unction, and with those that are put on the head or on other external parts. Likewise, one should study a number of modifications of the respiration, brought about by the variety of air drawn in.

44. Likewise, various effects should be tested of various liquids injected by enema into the anus or into the genitalia with a syringe. One could, likewise, apply ventouses in such a way that the full cup that has been removed is replaced right away with another one that is filled with liquor, which will then be taken up by the body. One could, likewise, apply something full of a certain liquor to the skin, and then apply cups (with or without incision) to the same area, so that it could better penetrate into the body. With cups applied in various places one is best able to detect the agreement of the parts.

45. One could not only inject liquids into the blood, but could also incorporate dry bodies into it. One could first temper the blood that is to be transfused with various infusions or compressions according to one's wishes.

46. There is no better way to strengthen worn-down vessels (if this is the cause of a natural death) than by means of certain kinds of bath.

47. The most exact histories are to be written of all those who have lived for a long time. See in this connection Meybomius on the long-lived.[12] Likewise the history is to be noted of all those who endure something out of the ordinary, such as apoplexy, epilepsy, etc.

48. A certain number of the best foods should be established, and a certain form of the ways of living, according to each man's temperament. For because of the infinity of kinds [of food], one must try to reduce them to a little, since we see that the oldest and most healthy people enjoy foods but little. Foods and diet should also be prescribed that are useful to all temperaments.

49. The entire pharmacy should be reduced to a few principal kinds, as Danus Ludovicus has proposed,[13] and every village should have such a pharmacy.

50. As the Bartholomites have the convention [*Institutum*] of having their seminars and also their parishes, so, similarly, should every village have two men, an old one and a young one, who are physicians [*physici*] or doctors [*Medici*], and they should be changed regularly. The doctors should be retained not by the patient, but only by the Republic. Indeed, it must be forbidden to the doctors to accept gifts, so that all possible considerations will cease, and every man will be treated with the same industriousness. For this reason, they must be made to take oaths. They must be supported by the Republic, together with their family members. It would be best if the available orders were applied to them. For members of religious orders are disinterested. Orders that were founded for this reason would be the best means one could hope for of advancing the Christian religion.

51. We see that mathematics has done so much in China; much more would be done [by introducing] medicine and physic, for these are indispensable to all men. Through the missions one could bring together all of the secret and simple remedies of the world.

52. Particularly when he is disinterested, a doctor has a general approach with all people.

53. A given thoroughfare or neighborhood of a populous city should, in addition to its pastors, also have its own doctors. To this end however there should also be superintendents and superintendents general.

54. The institution of medicine should be organized in orders after the example of the church. A certain sort of confession should be required, which, however, people would do with pleasure. So that the confessions are more effective, and more general, lists of questions should be prescribed to people, just as we have confessional booklets that list a thousand different sins that could be imagined, so that no one forgets anything. There should be different times of year during which every person performs his medical confession, and says everything, and sketches out the preceding period, [including] anything that he will consider with even a little anxiety. Everyone should, however, be free to have additional confessionals. And just as in sacred matters one is free to have an additional father confessor, who is not of the [same] parish, so too the same thing should happen here, [namely,] that there be certain free doctors who are bound to no parish and so can be chosen when one wishes. And in the case of emergency the private father confessor should communicate with the ordinary one. When confessing to the ordinary father confessor one should repeat everything that one confessed to the private confessor. As in the case of the penance that is prescribed in the spiritual confession,

so too here a rule should be established for determining what should be done. For spiritual father confessors as well should prescribe not only satisfactions and reparations for a given damage but also rules for the future. The rules or satisfactions of the medical father confessor should consist not so much in prescriptions as in rules of diet, just as those of the spiritual father confessor consist more in certain useful deeds that are prescribed, than, for example, in the praying of a certain number of Ave Marias or Our Fathers. Spiritual and medical father confessors should communicate with one another, but in such a way that neither should in the least reveal to the other something that could be compromising to the patient. The medical father confessor should be nearly so firmly bound by the duty of silence as the spiritual father confessor in every matter that could be compromising to the patient. Spiritual father confessors should be given instructions concerning certain techniques and questions, by means of which one will be able to distinguish the different humors of men, so that not just the affects in general can be found, but also so that their degrees and combinations can be found somewhat more precisely, which will then provide a remarkable light by which the doctor can determine the patient's temperament. At the same time, the spiritual father confessor will be greatly served in being able to recognize the passions through the determination of the temperament.

55. I take it as a punishment from God that [until now] we have been so blind and have not applied the thousandth part of our cares to such crucial matters. I can even say that we have almost as much to bemoan in due proportion to our indolence in natural matters as in sacred ones. And that we men with the highest degree of preposterousness not only neglect our beatitude—which is no wonder, given that we have never seen anyone who is yet blessed or damned—, but also our health. Indeed, we see daily the terrible martyrdom that is inflicted, already in this life, on those who care more for their possessions than for their own body (not to mention their soul).

56. It would be necessary for me to bring together all of the exclamations, exhortations, and advice, and all that can be found among the preachers and orators, sufficiently powerful for the excitation of the affects, in order to forewarn us of our ignorance. But I hope to have contact with people who grasp such things sufficiently, even when one says them in few words. And in this connection I am given reason for great hope both by the design of the English [Royal] Society in matters of mechanics, as well as by the instruction in political matters that is given to the *maîtres des requêtes*, so that it will be recognized that a similar design is most necessary in medical matters.

57. One must charge the pharmacists in all regions with the task of bringing together the registers of the plague and of health. Verulamius's[14]

incremental tables of the sciences. The history of life and death, Sanctorius's method for avoiding all errors in medicine.

58. [It should be determined] whether a diet is to be imposed, so that it does many things at once by combining some things at the same time, for example music and smells; other things separately, for example music and sleep.

59. [It should be determined] whether a means can be found for judging mechanically whether a man is stronger or weaker, such as weighing, the use of purgatives, etc.

60. Since I consider that taste is the best instrument for determining the nature of things, all means must be sought, by which men could arrive at a sense of taste that is subtle to the highest degree. Now it is known that men who only drink water are so subtle in their sense of taste that they can distinguish one water from another by its taste, which others cannot do. Therefore certain men should be fed with almost tasteless food, such as water and bread, or with meal prepared in the Tartar style.[15] Since they could also distinguish among things that are held to be tasteless by other men, they will distinguish the different tastes much more subtly. Related to this are also the arts of the wine traders, by means of which one can attain a pure sense of taste. One should always have a taste of water before trying anything else. If one harmonizes the observations of taste with a certain instrument, such as the *menstruum salinum*, one could then use this instrument in place of the sense of taste. Just as, once one knows that a water has been salted, he can determining the degree of salinity from the water's weight without needing to taste it. There must [also] be certain men in the Republic who are refined in the sense of smell, certain in the sense of touch, as in the case of Boyle's blind man. Such divisions of men are more needed than divisions of handiworkers.

61. Books should be published frequently that get people excited about real things, and should be distributed among the people in many languages. Vives, Bacon, and the Cartesian method, for example, should be presented to children in the schools in good time.

62. The Turks are in the habit of using opium in order to bring about cheerfulness, that is, they believe that it brings about an extraordinary color in the face, and revives a man's soul, so that whoever has once made use of it will always find it a source of delight. See Soranzo's *Ottomanno* p. 2 n. 49 p.m.[16]

63. One can distinguish natures and temperaments by means of music: one person enjoys one song, another enjoys another, and thus it would be good to make thorough observations on tarantulas, those who have been bitten by them.[17] Every doctor, by virtue of his duty, should be required to write down every notable circumstance he sees or hears of, and in particular those cases that he observes himself. It is indeed the opin-

ion that Hippocrates laid the foundation of his science in the Temple of Aesculapius, which was on the island of Cos in his home country, which today is called Longa. Those who had recovered from their illnesses were registered in that very place, and the remedies, by means of which they recovered, were noted down. Hippocrates abridged these somewhat and left them to his successors, so that the science still remains, although the temple burned long ago. Since so few particular observations have given us so much light, indeed have preserved rational medicine, why then have we become so blind that we have not more universally set up such [a science], with more energy and method. We would certainly learn more in a hundred years than was learned from Hippocrates on, up until the beginning of this century, indeed not even in a hundred years, but in ten.

64. All patients who die from hospital infections should be opened up, even if only at the place of their illness. What does not seem regrettable for great lords should also not be regrettable for private individuals.

65. That the spleen produces a sour or sharp material is shown by the example of a child who coughed constantly, without ejecting anything. When he was opened after his death, the spleen was too small, while the lungs and the liver were too large. Thus the material that belongs in the spleen went over into these organs.

66. Ways should be found of arriving ever closer to the most interior parts of a living body. Through the injection of clysters, and through the ducts and the throat, certain means have already been found, as also the *phlegmagogum* of the traveling physician, described in the *Ephemerid. Med.*, as also through the cutting of stones, of rupture, through the plugging of the cataract, Burrh's restitution of the humors of the eye, finally, the opening of veins and transfusion; of things taken in through the stomach I will not speak. Now means should be found, further, of reaching the interior of man, as the sword-swallower has done.

67. For all conditions a means should be found of putting a man into a deep sleep that will not harm him, and in which he feels nothing, and from which he could be easily awakened, as when a crocus flower or a strong odor, etc., is used to counteract opium. Then one should strive to learn the art of cutting in such a way as to wound only the parts that can easily grow back together, and those that are able to heal again when the person awakens, with his necessary motion being saved.

68. [It should be determined] whether a means could be found of easily cleansing the stomach of morbid discharge, by means of vomiting whenever one should wish as well as by means of swallowing something that is connected to a string, which can then be pulled out again, as with twine, but which would clear out the stomach.

69. All manner of ills of the body are either in the fluid or in the solid parts. In the fluid parts, that is, the spirits (if there are any), or the blood.

Spirits can be corroborated by means of odors, the blood both with other means and with infusions. But by means of food and drink the bile, the saliva, and the pancreatic juice can be increased or diminished in proportion. There is in the fluid either a deficit in it, or an abundance of it, or a motion in it that is inappropriate, or an inappropriate location, either an insertion into it from outside, or an alteration. Alteration occurs so long as it is exceedingly liquid, or exceedingly dense, or exceedingly hot, or exceedingly cold; a certain change of color, odor, or taste is involved. Hence it is fitting that certain men who are disposed to it explore, with the greatest exactitude, the tastes of those things that are ejected, but above all of the sputum, to which the man himself should attend most exactly. Similarly, judgments can be made from the taste of milk and of blood in various states.

70. [One must determine what is an] unhealthy quantity, as in dropsy, and abundance or plethora in the blood, [as also] an inappropriate place in extravasation, as in pleurisy. Note that many problems occur together, that is, that one thing arises from another. For example, motion from alteration, or alteration from abundance and from place. In solid parts in turn [there may be] either an excessive magnitude or dearth, or confinement; or [there may be] excessively soft substance, or hard, or spongy, etc.; or tense or compressed, heavy or light; from there pus, resolution, color, odor, taste, or something heterogeneous which is inserted.

71. The means are to be established by which one may diagnose where the patient's problem is located. Often the physicians do not believe the person who tells them what part is affected by the illness, but the truth will be confirmed too late by the result. Sometimes, however, the reverse is the case. A sick person does not indicate the true locus of pain; there is indeed a certain deception, as in vision and sound, so in pain as well as in touch, concerning the place to be indicated, but it could perhaps be that this deception as well, as in vision and sound, can be reduced to certain reasons and rules, whence often it should be possible to conjecture perfectly concerning the affected place in the sick person. Indeed, from these very reflections and collisions and sympathies of the pains, the cause will be able to be gathered.

72. Bellini, if I am not mistaken, has begun to mathematize in medicine, and also Steno, as nearly everyone does.

73. The rites of all peoples concerning such things should be collected. From books of itineraries, everything should be collected that pertains to medicine.

74. There are certain minutiae which are most worthy to be observed, and which are capable of conserving a man throughout his life, for example, to write and to read standing in an elevated place, against catarrhs of the head; moderate motion, against pleurisy; frequent urination preserves

a man from gall stones. [One should] eat and drink frequently, and a small amount each time. [One should] avoid drinking before sleep. Thus Lower in *De corde* [says that] one should strip oneself somewhat and cool down during the night when one gets up to unburden the bladder, and exercise the whole body. One should continually mix heat with cold by sustaining a cool breeze. All things should be alternated if possible.

75. The first policy should be to bring together the policies and plans of many other people. In this way my plan will be the originator of others. There are innumerable people who could well provide such a thing, but they are not called upon by others, nor by themselves, to do so.

Appendix 2

THE ANIMAL MACHINE

LH III 5, 12, 1 page, double sided. Critical edition in Pasini, *Corpo e funzioni cognitive in Leibniz*, 1996.

October 3, 1677

In any machine there must be a principle of motion. I hold that this arises in the animal from an already preexisting motion, as in an already vibrating pendulum, or from the chyle which, already mixed with the blood, brings about fermentation. For the chyle derived from the lacteous veins into the subclaviar and axillary veins is propulsed from there into the right ventricle of the heart, and in this way is mixed with the blood. This mixture of the chyle that has been reduced into blood with the fresh chyle brings about a powerful effervescence, like the mixing of wine that has already stopped fermenting with the juice freshly pressed from a grape (consider the way in which Burr's universal pomade is made). It is just in this way that butter is easily made if something of the butyric liquor that has already been prepared is left in the vessel when the new butter is poured in. This effervescence renews and conserves the motion that already exists in the blood and that arises from earlier nourishment, or from the initial nourishment of the mother. This movement would without doubt be extinguished unless a new impetus were to arrive, just as the pendulum continues to exercise a very considerable accumulated force if it receives new, even weak, impulsions. In oscillating clocks, then, a small force maintains, with the same intensity, the very strong impulsion received in the beginning, and even a very large body could be lifted little by little by the intervention of a weak pendulum: thus motion and heat, or the fervor of the blood, once they are engendered are sustained by new, small supplements. The reason of which is that motion is not lost, except insofar as it is dispersed by friction.

The heart, moreover, whether as a result of a new fermentation, or of a habit adopted by the mother and conserved for a long time, sends the blood impregnated by the new chyle from the right ventricle through the arterial vein [i.e., the pulmonary artery] to the lungs. From there it flows through the venous artery [i.e., the pulmonary vein] to the left ventricle of the heart; its speed is now very great, on account of the narrowness of the vessels, if they are compared with other, larger ones, and altogether with all of the blood vessels of the body considered as a totality, by means of which the blood flows toward the left ventricle of the heart, as I've said. Moreover, the blood that impetuously escapes from these narrow ducts manifests its spontaneity and dilates the ventricle of the heart in which it expands: and this is diastole. But the heart, since it is in a certain sense a powerful muscle, returning to its proper state as if by resilience, powerfully expels the blood toward all the parts of the body (while the valves and the new blood that comes in obstruct its return to the lungs): thus is systole produced. The blood, moreover, expelled into the arteries, presses very hard upon all the parts of the body against which it is pressed; these parts, like inflated balls, repulse the blood in reforming themselves, and since, because of the valvules, the blood cannot return by the route by which it came, it is forced to go into the veins. It is thus brought back into its circuit in passing through the right ventricle and, from there through the lungs to the left ventricle. Moreover, when such a quantity of blood moves through the lungs at such a speed, it is necessary that the air in them rarefies; as before it was somewhat more dense, the superfluous part must be expelled. But the ambient air in which animals move in turn rushes into the place filled with more rarefied air than are the lungs, and is in turn expelled. The viscera thus become so accustomed to this reciprocation that they easily carry it through to completion, and that they are led to it, as if by their own impetus, even if this was in fact just preserved from prior actions. Nevertheless, the conflict between the external air that is irrupting and the internal heat that expels it compresses the sanguiferous vessels of the lungs and facilitates the expulsion of blood coming from the right ventricle of the heart and loaded with new chyle. This process, at this very high speed, serves above all to refill the left ventricle and in the meantime to thoroughly process the chyle during its passage through the lungs in order to convert it into blood. And it could be believed that the air contained in the diaphragm also performs a certain action in return by means of its resilience and contributes in this way to the conservation of motion. And this indeed seems definitively to be the machine of the body, by which its motion is maintained. Nothing else is to be mixed into this description; similarly, the description of motion in a mill-house is one thing, while the description of its various applications for extracting oil, crushing grain, splitting timber, which may be brought about by the work of this mill, is another. For the same first motion [of the animal machine] is able to bring about, depending on the diversity of the passages, the propulsion of the chyle from the stomach into the lacteous and subclavial veins, or the peristaltic motion of the intestines, or the secretion of excrements. All of these operations are to be explained separately once the reason of the first motion is understood, or, which is the same, that of Life. From which it may be understood to what extent the Anatomists stray from the true method of describing a machine, for no better reason than that they have ignored the true economy of animal motion.

Appendix 3

THE HUMAN BODY, LIKE THAT OF ANY ANIMAL, IS A SORT OF MACHINE (1680–86)

LH III, 1, 2, 1–2, one folded folio page, 4 columns. Previously published in a critical edition in Pasini 1996, and in Mahrenholtz 1987 (text only, plus German translation). Date: 1680–83 (watermark conclusively dated by Potsdam catalog to 1680; some terminology suggests a later date of composition, possibly as late as 1686).

1. The description of a machine is best approached through its final cause.

The human body, like the body of any animal, is a sort of machine. Any machine, moreover, is best defined in terms of its final cause, so that in the description of the parts it is therefore apparent in what way each of them is coordinated with the others for the intended use. Thus one who is to describe a given clock will say that it is a Machine made to display equal divisions of time, and therefore the function of a clock hand lies in its uniform motion for some period of time; and, further, he will say that for this motion a motive force is required, which arises from weight or from *elastrum*;[1] further, he will say that an impediment is required in order that the force should not be exercised suddenly (which may arise equally in the wheels as in the obstacle that moves back and forth); to such an extent, finally, he will say that a rule of uniformity is required, which is obtained in the first place from the elastic coil, or from the oscillations of some body, either heavy or elastic, or even from a certain period we have described elsewhere.[2]

2. The aim of nature in the animals it produces seems to have been to conserve, as much as possible, and with respect to its particular species, a machine of Perpetual Motion in the universe.

Though it is difficult, moreover, to determine the ends of things and the purpose of nature before the event, after something has been carried through to the end it is possible to determine what nature wished to do from what it did do. Wherefore if we wish to bring together into one whole everything that nature aimed at insofar as is permitted to the admirable artifice of Animals, and to establish a sufficiently simple concept, which contains all the rest by means of consequences, we should say: *the Bodies of Animals* are *Machines of perpetual motion*, or, to put it more clearly, they are machines comparable to a certain fixed and singular species of perpetual organic motion that is always maintained in the world. Thus for as long as there are spiders there will be weaving machines, for as long as there are bees there will be honey-producing machines, and for as long as there are squirrels there will be dancing machines. Thus the aim of nature when it produces an animal is a perpetual-motion machine, as against the aim of the mechanists, who are seeking after perpetual motion by a useless labor, in order to obtain something like an animal that it is not necessary to feed. On the other hand, this, our definition of the animal, may appear to resemble an enigma. Indeed, if it be asked, what is a machine of perpetual motion? not everyone will at once guess that the Animal is what it had in mind. It is nevertheless not for this reason to be rejected; often indeed this very thing happens in these definitions—which are not nominal but real or causal—whenever they are, evidently, sought from causes not immediately forthcoming. It is thus apparent in what way, moreover, from this singular notion the entire composition of the animal follows straightaway (it is on the other hand granted that plants conserve their species while nevertheless lacking any notable motion, and machines do not have a species).

3. For this perpetual motion it will have been necessary that the animal conserve its forces; that it be brought to those things that are fitting to this end, and that it avoid their contraries; that it be so constituted as to judge of the difference; and finally that it be able to propagate its species.

In any Machine not only is a proper structuring of the parts needed, but also a motive force. And as the parts do not so much come into contact with external ones, but rather with one another reciprocally—which is called "friction"—a certain durability is required of them, which is obtained now through their firmness, now indeed through their frequent renewal. Neither indeed, since the motive force be always finite, is a purely Mechanical perpetual motion possible, hence for the continuation of the machine an external restitution of the power of motion is needed. Further, in order that men should obtain this durability of action in their machines, they now add to them a quasi-perpetual machine that is made by nature, which is of course man himself, the pilot, who repairs what is weakened or broken down in time, who applies an external force, bringing agents together with patients, or indeed attracts the weight or *Elastrum* itself, or in some other way conserves the power of the Machine. Nature moreover brings it about that her Machine is able to do this very thing on its own, that is, that it be able now to be nourished, whereby worn-down parts and forces are renewed, now to be itself moved toward the nutriments that are to be obtained and toward other means of sustaining its functions, as well as [away from] impediments that are to be avoided; now, finally, that it be warned by internal and external things, and that it be prompted toward the fitting motion. As, to be sure, many external things may arise, all of which it is impossible for such a Machine to avoid without the singular care of a superior providence, for that reason in order that nature look after eternity—and since it is not able easily to conserve the individual, at least it conserves the species of the Machine and of its mechanical motion to the extent possible—it contrives a way in which Machines are able to produce others of a nature similar to themselves; and therefore through nature's end, we have at once the origin of three *functions*, to wit, *vital*, *animal*, and *genital*.[3]

4. The first mover in this machine is something analogous to a flame or to the Sun or a fixed star, from which there arises an ebullition that feeds itself.

With a view to what is to be taught, we now imagine the thing to be within our power, and that it is up to us to construct, by the art of Prometheus, an animal machine. We will indeed easily observe, the function of the first mover in the machine is entrusted to nothing explored by us more suitably than [to] what is similar to a flame, in which once it is kindled, for as long as motion endures moderate nutrition and ventilation with air will not be lacking, especially since with sufficiently great force the flame is able to attract air equally as well as nutriment; which is shown as concerns nutrition by Cardano's lamps,[4] and as concerns air by the registers of furnaces.[5] We will make use therefore either of a flame, or of any other thing bearing an analogy to a flame to this extent at least, that it arouses a boiling in fluid and always feeds upon the new matter that is attracted. It is evident furthermore what sort of thing the fixed Stars or the Sun bring about in the World: and what is needed is not light, nor even any heat, but only the matter for an enduring battle, which cannot obtain without the influx of new matter. Certain Chemists promise perennial motion in vitro, to which they include a certain most strong liquor together with a matter to be devoured; it is nevertheless necessary that, once the reaction is completed, it be exhausted in due time.

5. Experiment confirms this with respect to pyropus,[6] *the motion of the heart and of the blood, and respiration.*

By experiment, as well equally as by the agreement of authors, it is evident that there is, moreover, something in animals similar to a flame, or, if you please, to the Sun or to a fixed Star, and of course not to mention a certain newly discovered *pyropus* or nearly perpetual corporeal light furnished from the liquor of the human body, which through motion brings about a most violent fire; of course it is manifest to the senses themselves that in many animals there occurs a great heat, at least around the heart, although it be well known that cold ebullitions are produced, for us any ebullition will suffice. There circulates through the vessels of the body moreover a certain liquor that is called "blood," which boils with so much force as to expand exceedingly the capacity of the heart, which brings it about furthermore that the heart, not without a cooling impetus toward dilating, as *elastica* are accustomed to bringing about, again contracts itself by nearly the same force by which the heart was dilated through the *tonus* of its parenchyma[7] (for the heart is muscular and fibrous),[8] and in turn expels the blood, by another route nevertheless, since the valvule is blocking the return along the route by which it entered. For which reason, moreover, it is plausible that by motion a new ebullition is prompted, just as we see things that are agitated or placed in a hot place boiling more forcefully. And while it is granted that the seat of effervescence is in the heart, it nonetheless is easily communicated to the whole body by the blood vessels, just as [when] we attempt to heat an enormous cask of wine with a small fire, if the fire be applied through a small copper utensil, connected with the vessel through a tube. Seeing moreover that in any ebullition there is an excessive dilatation, the vapor is nevertheless not expelled, but rather it is necessary that it in turn be pushed along, whence arises respiration, indeed in all exceedingly great efficient [causes] there is a certain reciprocation of restitutions such as we note in oscillating pendula, or in vibrating chords. And ventilated furnaces exhibit a certain parallel to respiration, whenever they are thus tempered so that by turns they now attract air, and now expel smoke through the same aperture.

6. *The agreement of Authors; and in what way ebullition happens in most cases.*

We also have the agreement of the authorities: many indeed think that it is the Hot in the body that is fed by the humid; some appeal to the little flame in the heart, others to the fire without light,[9] a certain I-know-not-what analogous to the elements of the stars, as much as [to say] that in reality everything is a flame; some say it is a certain fermentation, some that it is innumerable little explosions comparable to gunpowder: we think that in all of these a moderate and enduring boiling obtains, which is fed by a circulating matter that grows more and more rarefied and is also restored little by little. Indeed, in all liquid bodies—where there are contained heterogeneous bodies, diverse with respect to degree of density, dilatable, variously mixed with condensable bodies, and contained by bonds—there is ebullition, as they are thus liberated so that they may act upon one another; of this we have said much in our *Hypothesis*.[10] This is indeed true, so that even glasses, and indeed fused metals and metals reduced to a liquid state, should themselves at length boil intensely; but ebullition endures the longest when from the beginning it is not everywhere equal, but rather, with the first parts having been consumed, the neighboring parts are little by little attracted to the seat of the ebullition, or by the circulation that is brought about, all of the parts are subject to enter into the fire little by little, such as we see happening in a flame, and as remains hidden from us in the body of an animal. We will thus rightly assert that an animal is not only a Hydraulico-Pneumatic machine, but also in a certain respect a Pyrotechnic one.[11]

7. Movement of the animal from one place to another, for which the animal has flesh and bones.

Yet to obtain perpetuity it does not suffice to have a Liquor on which the ebullition feeds for some time, for however great is the capacity of the lamp, which at any rate must be fairly small, the oil will soon be consumed: a lamp is therefore required for our Machine, which will seek out for itself and pour its own oil; or indeed, if it now lights upon no ready oil, it will know how to obtain this from olives that it gathers;[12] in reality, an animal is indeed such a machine. As therefore the entire Machine must be moved with respect to place, it is necessary that the liquid be included within the firm part or the vessel, and from there it is necessary that the liquor be able to move the vessel itself in which it is contained, as indeed at length the enclosed vessels are ruptured by ebullition if they do not swell up. They are able moreover to extract something from the swelling; thus with one part inactive and restrained, another part will be moved forward, whence if done by alternations a progression arises. It is however necessary that the force of ebullition be superior to the weight of the body; the whole can indeed be thrust forth by a part that has been pushed into something that offers resistance, as comes to pass in leaping, swimming, and flying. Whence it is fitting that the hard parts be interwoven with the soft ones, and that the hard ones themselves be disposed to various motions through their various joints. These hard parts are called *bones* in animals, while the soft parts both convey, renew, and purify the boiling liquor, as well as removing that most subtle vapor that arises therefrom and by whose motion they swell, whence the *flesh* that is composed by the vessels and separating sieves of both the liquors as well as of the vapors or spirits.

8. How the animal may be incited to acting by external and internal objects; and of the organs of the senses.

As moreover the vessels of the spirits, and of course the nerves and membranes and the adhering muscles, variously press upon one another through the force of the spirits that inflate the vessels and are sent out and moved by the boiling of the blood, at length everything is arranged in equilibrium; neither are they able to grow more inflated, nor are they able to be pressed more [by] those most closely bordering them, which should come to pass moreover when several vesicles [are] confusedly pressing upon one another in a single closed space, from a single blow of a bellows through flexible tubes (similar to those that are now occasionally used for the water that is sprayed during fires). I [thus] comprehend that they simultaneously swell up and mutually press upon one another. When to be sure a certain inequality has arisen from an external or an internal cause, which happens when an animal's senses are aroused, thereupon the entire force of the breath pushes either toward a restitution or, when it cannot do this, toward an offsetting of very short duration, which, since often, on account of the structure or the present location of the parts, cannot be obtained without tremendous upheaval. Hence at length there arises from a small cause a great *motion in the animal*, since the cause of motion is always at hand to the thing to be moved, and awaits release, just as is the case when someone opens a faucet and enables the water's exit, or releases a tense bow, or lights gunpowder: he does not in fact apply a force, but rather takes away an impediment.

9. In this way [arise] Sense and Appetite, and the Union between the Soul and the Body; and in what way the Soul is entirely in every part.

It is well known furthermore in what way an animal's force is entirely in the whole and entirely in any given part, which, however obscure it appeared hitherto, nevertheless now, with our explanation duly considered, is easily discovered. Take for instance the vesicles inflated by a bellows, described above; thereafter, once all are arranged in equilibrium, so that one be not able to yield more to the other, any given vesicle will receive all of the force of the blowing, and indeed if it has less tenacity in one small part of the membrane than the total force of the blowing, this vesicle will rupture from the total force of the blowing that is applied. And whoever indeed wishes to compress one vesicle will experience all of the force that had dilated the bellows offering resistance to him. Since moreover we will at length demonstrate [that] force is one thing, motion quite another, and motion indeed inheres in an extended mass, while motive force inheres in a certain other subject, which is called in common bodies the substantial form, in living bodies the Soul, in Man the Mind, whence in animals the origin of *sense* as well as *appetite*, *and the union of the soul and the body*, and the way in which either the Soul acts in the body, or is acted upon by the body, will be able to be explained with unexpected clarity. What has been bestowed to the human Mind, from which there follows an immortality conjoined with memory (as indeed whoever [agrees] to accept immortality without reminiscence has nothing much to look forward to) we will discuss in another place.

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Unattached marginalia on manuscript page 1:

Since it is exceedingly difficult for us to explain the efficient cause or the mode of generation, we are oft times able to make use of the final cause, for nothing is without a certain effect. And this effect is the end of the cause. Nature need not have a particular design; it is sufficient in any case that it was not disposed to some other outcome, and that out of infinite vain attempts only the good combinations should have followed, since the author of all of nature guides everything to perfection.

Unattached marginalia on manuscript page 3:

(See Bartholin's *Anatomia*, Book 2, chap. 6, p. 383,[13] where he undertakes to show that it is the pulsific faculty at work here, which [is] nothing other than the elastic force.)

Whence the reason of the phenomenon that confuses the Anatomists is rendered, [namely], why the pulse is fairly equal although the influx of blood be unequal, since evidently any given elastic bodies upon which pressure is exerted so that they move swiftly or slowly, nevertheless always restore the same speed, inasmuch as their tone permits them, whence indeed the isochronism of vibrations, and the quality of sound has elsewhere been described by us. For which reason with a relaxed tone, so that on account of [one's] debilitated condition during fevers the pulse can be weaker although the influx of blood is made faster, wherefore the pulsific faculty of the heart, which indeed nowadays distinguished Anatomists nevertheless defend,[14] is nothing other than the elastic force.

Appendix 4

ON WRITING THE NEW ELEMENTS OF MEDICINE (1682–83)

LH III 1, 1, ff. 1–3. Previously published in a critical edition in Pasini, *Corpo e funzioni cognitive in Leibniz*, 1996.

I am of the opinion that no one has yet written the *Medical Institutions* that I desire; yet I believe that today a learned doctor could easily write them. They would be as useful for teaching, exercising, and developing the art as a torch brought into a dark place.

It is evident that the human body is a machine disposed by its author or inventor to certain functions. And thus to write medicine is nothing other than to prescribe to a mechanic a method by which he will be able to conserve the machine that has been entrusted to his care, so that it should continue to operate correctly, like the precepts that are typically given to the custodians of those hydraulic machines by means of which water is dispensed throughout an entire city.

In any Machine one must consider both its functions or ends, as well as its manner of operating, or by which means the author of the machine achieved its end. And therefore we should take care lest we imagine a machine that would by chance fulfill these same functions, but nevertheless not by the same means, since the precepts governing the conservation of this imaginary machine were different from the laws governing the true machine. Thus it is not surprising that certain new philosophers, with whose very ingenious thoughts about human beings we are familiar, have contributed little to the advancement of medicine, since they have sketched out their man more from the intellect than from experience.

The primary function of a human being is perception, but the secondary function (which exists for the sake of the first) is to procure perceptions. The advancement of human perfection consists in the same measure in the advancement of these functions. And anything that is helpful to perception or to the faculty of procuring perceptions is agreeable; anything that impedes them is disagreeable.

The organs of sense exist for the sake of perception; and the organs of motion exist for the sake of procuring perceptions, which is to say for action. Both should be conserved in operation, or in the constant capacity for operation, which is brought about now by the removal of impediments, now by the increase of facilitating conditions. And the greatest increase is nutrition itself, seeing that the same individual particles cannot be conserved, but continually vanish.

The manner by which sensation is brought about can therefore be described through a separate consideration than the manner by which Motion, or the procuring of sensation, is brought about. It will be supposed, of course, that the object and the organs have been disposed in such a way as to sense; one could give an account on which there were in a human being no faculty of procuring for himself any perceptions, just as whoever is sleeping deeply has perceptions, but does not procure them for himself. From here it could be explained in what way perceptions excite in us the desire to procure other perceptions. We must thus describe the manner in which we are able to dispose the organs of sense as well as the objects in such a way that a certain perception arises in us. And this entire process may be understood even if nutrition is not yet understood, since it does not depend on it. Thus we sometimes see in those who are burdened by atrophy, or who cannot hold down their food, that sense and motion nevertheless endure for a sufficient length of time. Finally, therefore, this method would bring it about that the organs of nutrition would be revealed to be organs that are necessary not to present functioning, but only to future functioning. As for the organs of generation, they can be described as organs of motion by which an agreeable perception is procured, for nature brings it about that action the action of generation in animals be conjoined with the greatest pleasure.

In truth, insofar as our medicine is more concerned with the functions of nutrition than with those of voluntary movement, and more with those of voluntary movement than of sensation, and insofar as it is able to imagine a machine capable of nutrition, but deprived of sensation and of animal motion, it is thus easier to explain how we nourish ourselves than how we perceive and act. Ultimately, with respect to the manner in which the aliments serve to generate the parts we require in order to exercise the functions of the sensitive soul, it will be preferable to inquire first into those parts that are in a certain respect held in common even with plants, than into those that are proper to animals.

This method is analytic, moreover, when we investigate the means or the organs of any given function and the mode of their operating, and thus arrive at an acquaintance with the body through its parts. Once this task is completed, we will come back to synthesis, and we will describe all of the parts coordinated into one, and the first motor of motion and the liquid and solid instruments of motion, and their connection, and ultimately the entire economy of the animal, particularly when we will have learned by means of analysis the organs of each function, that often the very same organ can be devoted to several functions, just as in machines the wisdom of their maker shines through most of all when many effects are brought about by limited means.

In order to spell out this synthesis, we must consider what the ancients already had the wisdom to observe, that all of the parts of our body can be distinguished into what contains, what is contained, and what is an agent of impetus, which is to say into veins, humors, and spirits, and consequently our body is a hydraulico-pneumatico-pyrobolic machine. Now humors are contained in the vessels, but a spirit that penetrates, agitates, and moves everything is also diffused by the vessels, which is like the rays of the sun or a flame or even like an ignited cannon, or like other explosives of the sort we observe in fermentations and reactions (for all of this goes back to the fact that undoubtedly the perturbed ether tends to reestablish itself).

That in our bodies there are spirits—that is, a rapidly moving, imperceptible matter—is demonstrated not only from the circulation of the blood, but also from the members whose motion provides enough force for us to be able to suddenly lift great weights. This cannot be attributed to the structure of the machine, for machines raising great weights by means of forces, raise them slowly, while animals do it quite swiftly, from which it follows that they have a great force in them. Now it is clear that the members do not have a visible principle of motion, and even that the extravascular liquors do not cease to pursue their motion even when they have been perceptibly changed, from which it follows that the motor in our bodies is insensible. That there is in contrast a certain continuous fluid diffused throughout the whole body, from which it can be understood, that all things that are in contact with any given part of our bodies can easily be sensed. Once this spirit is set into a great internal motion, moreover, it does not lose force, but nor does it bring it about or communicate it to another, unless heavier bodies are immersed in it, or resist it, whereupon it will have a great force upon them; and when it is restrained from every side, if perchance an outlet toward somewhere else becomes available, it expends all of its force toward that place; from which it is apparent in what way by a slight exertion we exercise a great force: for to bring this force about it is not necessary to bring this force about in us, but only to direct it. Moreover, the spirit requires an aliment, as a flame requires oil; it requires air, which is to say it must respire, and moreover that it must also eliminate what it dissipates, and neither is it of importance that the blood of all animals is warm to our touch, for indeed we are not able to detect all luminous things, nor all things that effervescence makes warm, by our senses. And we know that a phosphorescent body, when it is deprived of air, gradually ceases to give off light, until such time as it is able to respire again.

It is not at all doubtful, therefore, that our life consists in something resembling a flame, which is found not so much in the heart as in all of the parts. That we should be the less astonished, we must know that a flame of this sort or a motive spirit is found in all bodies, that the force that it exerts comes from fermentations and other reactions or conflicts, that this spirit, once set in the appropriate motion, maintains the fluidity of water, but that, when it is more weakly agitated by the ambient bodies, the water freezes. In the same way, in us the spirit also receives its agitation from the ambient ether, with which it communicates in all places by means of small openings. The same spirit also easily conserves motion, for, in view of its divisibility, the obstacle that is opposed to a part of the body does not obstruct the motion of all of the other parts, from which it arises that soon, when the obstacle has been suppressed, the motion is communicated to that very part that had been obstructed.

Whenever the motion of this spirituous matter is disturbed, there arises in the liquid a certain ebullition, whose species is either fermentation, when one body is involved, or reaction, when two opposing bodies are mixed. Now the number of ebullitions of this sort in our body must be great, arising either when diverse humors are mixed with one another or when new aliments or new air are mixed into the contents that are already there.

I would thus suppose that a reaction arises when bile is mixed into the blood, for if a few drops of bile—even cold bile—are mixed into the blood outside of the vessels that has already coagulated and is turning dark, it will become a bit fluid and reddish. For indeed the blood is like oil, and the bile like sulfur, as sulfurs are easily dissolved by the oils that correspond to them, if alkalis have already been added (in fact there is in bile, just as in blood, a volatile alkali or urinous salt). As it is plausible that new aliments react with the blood confected from aliments already taken, for the bodies that are opposed to one another while also having a certain affinity are the ones that react most intensely, especially because +-------+ and the matters saturated by the bile somewhat earlier in the jejunum penetrate exactly from there into the blood.

It is not necessary initially to investigate the origin of the blood; indeed, it suffices that both the blood and its motion be communicated from the mother, for example, that the respiration of the mother is also beneficial to the infant; the blood is moved in the heart, veins, and arteries; it is dispersed in the arteries from the heart to the extremities [*membra*]; in the veins it returns from the extremities to the heart; it is filtered in the liver, where the bile is deposited, carried from the gall bladder into the jejunum through its own duct, where it saturates the chyle coming from the stomach, and with it returns to the blood in the subclavial veins.

In the extremities the blood deposits the lymph, which in turn is moved along in its own vessels, which are called "lymphatic." It comes with the blood in the arteries from the heart but does not return to the heart with the blood through the veins. A part of the lymph serves for nutrition, the rest moves through the lymphatic vessels. The lymphatic vessels pass through the glands, which are like nodes or shallow basins in which the filtered lymph is transformed and acquires a new nature. Among these glands, the pancreas is distinctive, as it is a gland that is agglomerated out of many simple (or clotted) glands; in the pancreas a subacidic lymph, which is called pancreatic juice, is produced; this lymph is more easily transformed by air than the lymph that is found in other parts. Saliva is also a particular sort of lymph, which undoubtedly contributes much to digestion in the stomach. The seminal vessels also belong to this category, the semen being composed partly from the lymph and partly from the blood. For the blood deposits both urine and blood in the kidneys, into which lymph is in turn mixed in the testes. It appears that the brain and the marrow are stagnant, condensed lymph. It is certain that bones are perforated by various vessels; it remains to be seen whether arteries or veins deposit something there, and whether the lymphatic vessels convey lymph there and bring it back from there.

As lymph is quite close to being a nutritive juice, it is clear that it responds to nature's intention and that the blood, deposing its heterogeneous components and consuming its sulfur as if by a flame in the course of its continual trajectory through the heart, transforms little by little into lymph. For, given all the sulfur that it has lost in passing through the heart and in being propulsed through the arteries, it is lymph ridden of sulfur that is deposited, once it cools down, in the extremities. The blood however, still saturated with the sulfur, yet still mobile, is carried to the heart by the veins.

The blood carried with the lymph to the thin vessels dispersed throughout the flesh is dissipated by sweat, after which these vessels, once again cooled down, absorb new matter coming from the blood: they purge the blood of it. This is why sweating is almost a panacea and stands almost alone in its usefulness for illnesses. +-------+ Matter is carried away by the sweat or by imperceptible perspiration in order to make room for new deposits. I understand completely that attraction whose origin is a certain initial impetus. +-------+.

All medicines operate either after the manner of aliments or of poisons. The former operate by degrees and insensibly, the latter by a great and sudden force. This is why the latter are not to be tried unless we require immediate aid.

The method of treating illnesses is twofold. One method is analytic, in view of the symptoms; the other is synthetic, in view of the causes. It must be considered that all symptoms are simple illnesses, for functions are always damaged by them. But since, when one function is damaged, it damages several others along with it, it can often be concluded that there is a single cause of multiple symptoms. If the damage done to the function is not perceptible in itself, then it is not deemed to be a symptom. The method of treating by symptoms would be infinite if we wished to enumerate all of their combinations. There are certain signs of a good constitution, and of a bad one, which cannot be called symptoms, such as color, urine, what is pleasing and what is injurious. One must teach true analysis, that is, the art of studying signs, on the one hand, and on the other of inferring the illness from the signs. Synthesis should be taught after having presented a model of analysis, that is, a model of the general method of treatment, which is to pathological synthesis what algebra is to the elements of geometry.

Appendix 5

ON BOTANICAL METHOD (1701)

Originally published as "G.W.L. Epistola responsoria de Methodo Botanica ad Dissertationem A.C.G. Medici eximii [G. W. Leibniz's Letter in Response to the Dissertation on Botanical Method of the Outstanding Physician A. C. Gakenholz]," in *Monatlicher Auszug*, April 1701, VIII S.68–80; reprint, Kortholt 4, 83–194; Dutens II ii, 169–72. LBr 293, Bl. 5–6; Ritterkatalog: A:52443; B:34667 in response to 52441; 52442.

Alexander Christian Gakenholz (also Gackenholtz, Geckenholz) was a physician and botanist from Celle, near Hanover. He submitted his doctoral dissertation, titled *Disputatio medica inauguralis de Hydrope* (Inaugural Medical Dissertation on Dropsy), to the faculty of medicine at Utrecht in 1698, and later went on to write, among other works, the *Progymnasma botanicum de vegetabilium praestantia* (Hamm, 1706). He wrote a letter to Leibniz, concerning mathematical questions, as early as 1694 (see A III vi, 229–32).

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I. On the optimal method of classifying plants. II. On the optimal method of classifying in general. III. On the method of classifying of recent botanists. IV. On the function of plants. V. On a different method of classifying plants. VI. On Joachim Jungius's method. VII. On comparisons of plants not to be made only on the basis of their flowers. VIII. IX. X. On various important criteria in distinguishing plants. XI. On promoting the advancement of medicine, and on Ramazzini's and Hoffmann's achievements in this.

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I. I have well received your letter, which testifies to a knowledge and experience that are uncommon, as well as to the affection you show for me. I wanted to respond immediately, first of all in order to thank you and second of all in order to explain my thoughts on certain points at somewhat greater length. Clearly drawing arguments from facts, you corroborate my opinion by showing, by the example of the roots I had mentioned, which are capable of a great variety, that we should not be obliged to classify plants from their flowers alone. To the differentia that you mention could be added the juices of certain roots. And in this category it could be recorded that the genus of camphor, as they say, is obtained from the root of the cinnamon tree. Certainly, I do not disapprove of the ingenious diligence of eminent men in botany, who have found a method of classifying plants from their flowers more convenient than former ones; however, I wanted it to be considered that from a single principle of division the matter is not resolved, and that the secrets of the botanical doctrine are not sufficiently explained by this one method.

II. Indeed, as I already showed as an adolescent, a long time ago, in a little book called *On the Combinatorial Art* of the year 1666, combinations of things according to set numbers afford a correspondence with the genera of so many inferior species, so that it may be understood that there are as many genera of species as there are combinations of things. For example, let there be four inferior species, or species presumed to be inferior, beyond which it is not possible to subdivide any further: *a*, *b*, *c*, *d*. There will be the following genera: one, the highest, combining all of them *a b c d*; there will be genera of the second order, coming next to the sum of four and combining only three of the species, namely *a*, *b*, and *c*, or *b*, *c*, and *d*, or, finally, *b*, *c*, and *d*; and in consequence the four genera will (by designating each one by the three species which it alone combines) *abc*, *abd*, *acd*, *bcd*. The genera of the third order (in this place), nearest to the inferior species and combining two of them, are six in number, namely *ab*, *ac*, *ad*, *bc*, *bd*, *cd*. Whence again it arises, according to a single mode of dividing and subdividing, namely by dichotomies (which indeed, when it can be employed, is the most perfect mode of division), that not all subaltern genera can be obtained. For example, if you proceed as follows:

abcd or abcd a bcd ab cd b cd a b c d cd,

by the prior mode you will not have subaltern genera other than, at the second level, a single *bcd* (combining all and only *b*, *c*, *d*); and at the penultimate or third level, a single *cd* (or that which combines all and only *c* and *d*). Other genera will escape your attention. By the latter mode you will lose all of the second-level genera; from the third level you will obtain only two, while there are four others, which are omitted by these modes. Other people, establishing other processes of division, will bring forth new results. No one will bring forth all results by a single method of dividing. This brings it about that the combinatorial method (which in fact includes multiple divisions) is more fecund than the common method of division (which is content with a single division). Hence, various philosophers and jurisconsults, by various modes of subdividing, have tracked down various human appetites, or various species of moral virtues, or of laws, or other notions of such kind; and everyone has noted something of use in his own method of considering and dividing. Since in truth in a great number of species the variety of combinations and of the diverse methods of division is immense, it is clearly necessary for the art of method that the more useful comparisons be preferred, and that a method that is more evident and commodious be selected for assisting the memory. Thus dichotomy by way of opposing differentia came out among the first for the purpose of discovery and recording.

III. Transferring these general precepts of the art of meditation into the present matter, I do not so much condemn the recent botanists' effort to assist memory by any method of dividing into classes that they judge the more suitable. I sooner praise their approach, as long as they do not adhere to it too rigidly and almost uniquely. Although, in advance of knowing the interior constitution of these machines of nature, no accurate method can be instituted, nonetheless a certain substitute method may be employed for the sake of our comprehension and progress in theory. In our effort to bring into order the works of nature, we resemble this methodical man from the ranks of the Ramists, who, ignoring the demonstrations, wished to classify the geometrical figures. This man, estimating everything from its external aspect and lacking experience of the causes, would give a certain superficial, and I would say impoverished, treatment of geometry; and nevertheless he should be praised for his diligence, and for being useful to those who are incapable of anything more. Such is our own activity, as it is, in the three kingdoms of nature.

IV. Plants, animals, and, if I may say it in a word, organic bodies that are produced by nature, are machines fitted for the perpetuation of certain functions; they bring about this perpetuation through the propagation of the species, as well as through the nourishment of the individual, as well, finally, as through the accomplishment of these operations which it is the special function of each to assume. And indeed it is manifest that the human body is a machine suited for the perpetuation of contemplation. In all other bodies we have not sufficiently explored the full extent of the ends of nature. It is however not at all doubtful that a great part of nature's ends are purported to serve for human use, that is, to facilitate contemplation, or, what is the same, to excite in us the admiration of divine wisdom. And thus whatever can be derived from plants or produced for the uses of humans must be included among the ends [of nature], and we must above all explain by what mechanisms they tend to that fulfillment. That this reason for botanical investigation should not be neglected in setting the principles of it is thus made evident.

V. Of course, as in geometry, the theoretical part is one thing—and this in turn is dual: either Euclidean, which demonstratively explains the causes of figures and the properties deriving from these; or Ramist, which divides the classes of configurations and the obvious properties according to the external aspect [*specie*]—, and another thing is practical geometry, which develops uses; and this in turn is dual: namely, either more esoteric or more popular. Thus plants or animals can be divided either theoretically, according to certain sensible differentia, or indeed practically, according to human usage; and both of these methods are more popular when the inner aspects are not in sight. Although I do not despair but that we will be able to come to something more profound, both theoretically—if men duly followed the endeavors of Jungius, Malpighi, Hooke, Swammerdam, and Leeuwenhoek with a dedication greater than what, to my surprise, is presently done—as well as in medical practice, if, where our instinct and sense do not suffice (for we have lost a good part of this natural instinct of ours which a physician advocates in a little book of his written in French, because of our artificial way of life, unless one believes that barbarians should be consulted as still nearer to their origin in Mother Nature), the sense and instinct of other animals may be invoked in an auxiliary fashion. For indeed it is very probable that whatever plants are pleasing for the nourishment of the same insect (of other animals I shall say nothing now) are of a cognate nature and possess similar properties.

VI. Further, in this theoretical part (I omit now the practical distinctions that are inferred from sensual, mechanical, alimentary, or medical uses), although I support an ordering into classes according to one certain criterion that is widely variable, I would reckon that other criteria for ordering and comparing plants should not be neglected. Joachim Jungius, who flourished in the century that just ended, a man who is to be counted among the most learned of his century, in his posthumous *Isagoge Phytoscopia*, which is but a small record of his lost meditations, elegantly taught to discern, and to express with apt names, the figures of leaves, since he saw that in these nature descended to the greatest varieties and those most suited for drawing distinctions. Now, I aver, learned men transfer this method with some success to the leaves of flowers, for it is with the flowers that the generation of plants is most closely connected, and it is above all useful to discover variety in the principles of generation, as indeed Aristotle understood when he undertook to relate the varieties of animals mainly by means of this criterion.

VII. But the comparison of animals is conducted more usefully also with a view to other parts, as comparative anatomy shows, to such a degree that in the lungs or organs of respiration a connection has been discovered between plants themselves and animals, as well as a certain continuity [*series*] and a kind of transition from plants to large animals by way of intermediary insects, if I may so call them, according to what

Swammerdam advises. Thus it can easily be understood that the comparisons of plants themselves should be instituted not only on the basis of the flowers, but also on the basis of most other major parts taken separately. It is not as though, on the basis of any single criterion, a complete distribution of all species should be undertaken: this would take up too much space in a textbook of *Institutions* (although in a book of *Pandects* it should be preferred). But this should be done in order that no useful comparison or combination be rashly neglected.

VIII. And these could be like corollaries of a certain primary ordering that will be of use in the future to lovers of botany, because it is necessary that plants, as you well remind us, be distinguished according to features other than the flowers, which are not always visible. I mentioned the root to you as an example, which is the primary instrument of nutrition, and which is always visible and in nearly all plants, as you rightly note, with the possible exception of those plants which, swimming in water, constitute with their orbicular leaves a vegetation under the name of duckweed, though even in these an analogue (of the root) might not be lacking. Further, the structure of the whole plant should not be neglected either, from which first arises the division into trees, bushes, and grasses. Coming to the parts of the plant, what a multitude of criteria for division are to be found there, either in the solid parts, as in the roots (of which I have already spoken to you), the trunk (its interior and its bark), the leaves (either of the plant or of the flower), the fruit (in which the seeds are discovered), and in other solid parts; or in the fluid parts, such as the marrow, the water that flows out, the resin, and, finally, in the humid substance that is pressed out, or, more precisely, in the odor or vapor that is emitted; meanwhile different plants are chiefly distinguished by different parts that they contain or to which they give rise; some by the flower, others by the root, others by the bark, some by the sap, etc. And there is none of those parts from which a certain comparison could not be drawn with wide application throughout the vegetable kingdom. If one point of comparison should be discovered to be analogous to another, this would provide much light.

IX. It pertains to the structure of the whole that very often from the prevalent part we name the whole plant a root or a flower, either because the function of the part that gives the name is more important, or because its mass or form is more preeminent, so that they are more usefully placed in a single genus and enumerated under a single heading. How many are the species included under the single name "grass," in all of which there is something that imitates the genus of grains? How many are the species of reeds, in which the stalk predominates? Why do we not group together the plants that yield berries in the same way that we do the grain-yielding ones? Why not in the same way the whole genus of ferns? In jurisprudence there are certain primary dispositions of the matters according to the various genera of moral persons—real, personal—, and nevertheless, from these diverse genera, common ones are usefully abstracted by the mind, as when the doctrine of conditions arising from wills and contracts is reduced to one genus, which happens by establishing proper criteria concerning the interpretations of acts, the times, the places, the various things and persons juridically treated, the privileges of churches, women, and soldiers, and the other innumerable topics which provide arguments for academic dissertations. Similarly, it is more relevant concerning nature that it be considered in all aspects, that all manners of comparison be instituted, since the investigation of it is more difficult than that of civil matters.

X. Moreover, new comparisons of plants, which will be of great importance, will be provided by new observations (if they are further confirmed) concerning the imitation of a double sex in plants, on which Rudolph Jacob Camerarius, a man most eminent among those who are curious about nature, has begun to work most assiduously, and which recently the young Mr. D. Burckhard, a recognized expert in these matters, who wrote me a learned letter about this, decided to further investigate. For they look in the very subtle pollen of flowers for the analogy of the male seed, and deny that anything of this sort is lacking in any plant, even if it is not always perceived by the naked eye; capsules are present for receiving the pollen that are to be compared to the female ovary; a stylus or something analogous, like the vagina of the uterus, emerges from the capsule. From the flower, which the heat of the sun has opened, the pollen, through the aid of a blowing wind, would transfer and apply to the highest tip of the stylus. From the grains of pollen, something spirituous would lead to the ovary and then, if I may say so, penetrate the pod and fecundate the eggs or the seeds therein; a strong indication of that process is provided by the fact that no generation follows when the pollen is prematurely removed. If this is further attested by diligent observation, it will corroborate a conciliation between the doctrines of Kerckring and Leeuwenhoek, a conciliation that always seemed to me most probable: namely, that something subtle, which was already organic, and which could already be denoted by the name of plant or animal, reaches the female's eggs from the male seed, and there, as if transformed in its proper soil and made to grow by feeding, develops into a fetus, through a process that may be called generation. In such an operation of nature, learned men report that plants behave quite differently. For commonly both semina are produced in the same flower and stalk, sometimes in distinct branches of the same plant, as in the hazel and the walnut trees; and sometimes different male and female plants have to be joined, which happens in hemp. Indeed, with the male part removed by force, the female plant never brings forward the semen responsible for generation, nor the prolific fruit. There is moreover much variety both in the receptacles and the figures of the pollen, as well as in the ovarian capsules and in the seeds contained there, and in the measures of the stylus or the vagina of the uterus, not to mention the figures both of the grain of pollen as well as of the eggs, commonly referred to as semen. Whence you see to which extent the field of comparison of plants is opened up, as certainly of great importance, even if reached to a lesser degree, and less extensive in our narrow experience than the field of what is disclosed in the figure of flowers.

XI. Besides, the numerous suggestions you cautiously provide in your letter to me concerning the improvement of medicine show no less your ability to judge than your knowledge of the art; these suggestions shall concern me less, who in the art of medicine—than which none is more excellent or difficult—can avail myself of neither that ability nor that knowledge. Nor do I interfere with these studies beyond what those outside of it are capable of. You know indeed that it pertains eminently to the activity of those who are engaged in civil affairs to have some measure of the health of the citizens. And thus formerly I urged Ramazzini, and now the celebrated Hoffmann, to pursue that investigation most useful to the human race: the natural history of the climate. For a number of years Ramazzini provided a Physico-Medical History, with one year dedicated to me (out of that kindness he is endowed with) and while he had been remiss in the most recent years, he wrote to me last year that he would soon publish all of them in a single volume. But in the year 1700 of the common era (which is to say in the secular sense the last of the century) Hoffmann most recently gave me, in a little book dedicated to me (which is an expression of his benevolence), a meteorological description that was at once an epidemiological one, admirably observing (beyond the variations of the barometer and the thermometer) the widest range of mutations of storms and of the wind (in which the essential of it is to be found) and from there which changes follow in human bodies and, if I may say, in the manner and condition of the illnesses. If these are continued and established in several places, with distinguished men exchanging information and with observations being compiled, not only shall we progress in understanding illnesses that proceed in singular and not yet investigated fashion, but a vast thesaurus of the most beautiful observations will soon be compiled, which will be of much use to the human race, so that I know nothing next to the practice of virtue that can be professed to be more pious and in agreement with Christian charity.

Nor do I doubt that you, as well as the distinguished men with whom you are in contact, will contribute their share to the common good. And in fact it is not required that, as did those two men whom I mentioned for establishing and initiating that practice, each one should compose entire volumes, but rather each should bring out a maximum of available and notable facts. It is not a great affair to have a barometer, a thermometer, or an anemometer, and to repeatedly cast one's eyes upon them, noting the smallest mutations of these instruments and of the air, or for these notations to make use of someone else's labor who would not lack diligence (for intelligence is needed for noting as well as using notations), or to enquire about the plants and animals in that year, but it is to relate everything to the effects upon the human body and to the use of the art (as you yourself do in a praiseworthy manner). Farewell and favor [me in friendship]. Sent from Hanover, April 23, 1701

NOTES

Introduction

1. See Michał Hanov, *Geologia, biologia, phytologia generalis et dendrologia*, in vol. 3 of *Gesammelte Werke* (Halle, 1766).

2. Steven Shapin, *The Scientific Revolution* (Chicago: University of Chicago Press, 1996), 185.

3. See, in particular, Pierre Duhem, *La théorie physique: Son objet, sa structure* (Paris: Marcel Rivière, 1914).

4. See Lorraine Daston and Peter Galison, *Objectivity* (New York: Zone Books, 2007).

5. G VI, 618.

6. G II, 270.

7. Daniel Garber, "Leibniz and the Foundations of Physics: The Middle Years," in *The Natural Philosophy of Leibniz*, ed. K. Okruhlik and J. R. Brown (Dordrecht: Reidel, 1985), 27–130.

8. André Robinet, *Architectonique disjonctive, automates systémiques et idéalité transcendentale dans l'oeuvre de G. W. Leibniz* (Paris: G. Vrin, 1986).

9. Catherine Wilson, "Leibniz and the Animalcula," in *Studies in Seventeenth-Century European Philosophy*, ed. M. A. Steward (Oxford: Clarendon Press, 1997), 153–76, at 174.

10. See Glenn A. Hartz, *Leibniz's Final System: Monads, Matter, and Animals* (London: Routledge, 2007). See also the very plausible argument of Glenn A. Hartz and Catherine Wilson, "Ideas and Animals: The Hard Problem of Leibniz's Metaphysics," *Studia Leibnitiana* 37 (2005): 1–19.

11. Michel Fichant, "Les machines de la nature," *Studia Leibnitiana* 35, no. 1 (2003): 1–28.

12. Pauline Phemister, *Leibniz and the Natural World: Activity, Passivity, and Corporeal Substances in Leibniz's Philosophy* (Dordrecht: Springer, 2005). For a thorough discussion of this work, see Justin E. H. Smith, "Review of Phemister, *Leibniz and the Natural World*," *Leibniz Review* 16 (2006): 73–84. Peter Loptson has recently offered what he calls an "epiphenomenalist" account of the Leibnizian world of bodies according to which bodies are real and causally separate from monads, while also being perfectly coordinated with them. This is a variety of compatibilism but rather far in spirit from the one outlined by Phemister, to the extent that Phemister wants to bring the different ontological levels in Leibniz's thought together rather than characterizing them as autonomous. See Peter Loptson, "Was Leibniz an Idealist?" *Philosophy* 74 (1999): 361–85. See also Peter Loptson and Richard T. W. Arthur, "Leibniz's Body Realism: Two Interpretations," *Leibniz Review* 16 (2006): 1–42.

13. G IV, 390.

14. Of course, there is also a crucially important Platonic component in Leibniz's philosophy. This component has been thoroughly studied by other scholars, including, recently, Christia Mercer, *Leibniz's Metaphysics: Its Origins and Development* (Cambridge: Cambridge University Press, 2001).

15. Montgomery Furth, "Aristotle's Biological Universe: An Overview," in *Philosophical Issues in Aristotle's Biology* ed. Allan Gotthelf and James G. Lennox (Cambridge: Cambridge University Press, 1985), 21–52, at 24.

16. James G. Lennox, "Putting Philosophy of Science to the Test: The Case of Aristotle's Biology," in *Aristotle's Philosophy of Biology: Studies in the Origins of Life Science* (Cambridge: Cambridge University Press, 2000), 98–109.

17. James G. Lennox, "Nature Does Nothing in Vain," in ibid., 205–24, at 222f.

18. G VI 543f.

19. On this, see particularly Stephen Gaukroger, *Descartes' System of Natural Philosophy* (Cambridge: Cambridge University Press, 2002).

20. It is this feature of the Leibnizian model of the animal body that has, of course, inspired the title of this book. A similarly titled book, on living bodies and automata in Descartes, Leibniz, La Mettrie, and Kant, was published some years ago in German. See Alex Sutter, *Göttliche Maschinen: Die Automaten für Lebendiges bei Descartes, Leibniz, La Mettrie und Kant* (Bodenheim: Athenaeum Verlag, 1989).

21. AT V, 278–79.

22. Dennis Des Chene, *Spirits and Clocks: Machine and Organism in Descartes* (Ithaca NY: Cornell University Press, 2001), 121. The question of vestigial or latent teleology in mechanism has generated a good deal of secondary literature. Some interesting recent contributions to this include Alison Simmons, "Sensible Ends: Latent Teleology in Descartes' Account of Sensation," *Journal of the History of Philosophy* 39 (2001): 49–75; Lisa Shapiro, "The Health of the Body-Machine? or, Seventeenth-Century Mechanism and the Concept of Health," *Perspectives on Science* 11, no. 4 (2003): 421–42.

23. Ibid.

24. Ibid., 45.

25. As an anonymous referee reminds, however, Descartes' letters concerning the Utrecht quarrel to Henrius Regius and Gisbertus Voetius, beginning in 1641, do bring out Descartes' more developed views on species and on the reproduction of kinds much more than any of his other work, published or not. See for example AT III, 371–74; AT III, 460–62.

26. AT XI 254f.

27. Descartes, *Primae cogitationes circa generationem animalium*, in AT XI 516–28. Certain radical schools of ancient materialism aside, it is a novel claim of mechanism that vitality is a corporeal phenomenon like any other. But Descartes is by no means the first to identify vitality with the beating of the heart, and so to see it as the primordial organ. Indeed, he shares this assessment of its importance with many whose other physiological precepts he would abhor. For example, in the thirteenth century Giles of Rome sees the heart as analogous in the individual to the role of the "first mover" in the cosmos: "Just as in the whole visible universe there has to be something that does not cease from motion, and which is

the source of the motion of other things, so in animals the heart is always moving *secundum dyastolen et systolen*, i.e., according to dilation and constriction, by impelling and drawing. From this motion arises motion in all the other members. So the heart is formed first in the embryo, is the first to live and the last to die" (cited in M. A. Hewson, *Giles of Rome and the Medieval Theory of Conception: A Study of the* De formatione corporis humani in utero [London: Athlone Press, 1975], 157f.).

28. AT XI, 516–28.

29. *De corpore* 15.2. George MacDonald Ross's article, "Leibniz's Debt to Hobbes" (in *Leibniz and the English-Speaking World*, ed. Pauline Phemister and Stuart Brown [Dordrecht: Springer, 2004], 19–34), has been very helpful for illuminating the full extent of the similarity between Hobbes's theory of animal motion and Leibniz's early model of animal economy. See also Catherine Wilson, "Motion, Sensation, and the Infinite: The Lasting Impression of Hobbes on Leibniz," *British Journal for the History of Philosophy* 5, no. 2 (1997): 339–51; Howard Bernstein, "Conatus, Hobbes, and the Young Leibniz," *Studies in History and Philosophy of Science* 11 (1980): 25–37; Ursula Goldenbaum, "Hobbes and Spinoza as the Heroes of the Young Leibniz; Leibniz as Belonging to the Modern," paper delivered at the conference *The Young Leibniz* (Rice University, Houston, Texas, 2003).

30. Thomas Hobbes, *Leviathan*, Parts I and II, ed. A. P. Martinich (London: Blackwell, 2005), 40.

31. G VII, 273.

32. See, for example, James G. Lennox, "Putting Philosophy of Science to the Test: The Case of Aristotle's Biology," in *Philosophy of Science Association*, ed. Micky Forbes, David Hull, and R. M. Burian, vol. 2, 1994 (East Lansing, MI: Philosophy of Science Association, 1996).

Chapter 1
"Que les philosophes medicinassent"

1. Some literature has appeared in the last several years on Leibniz's contribution to medicine, but little of it has been concerned to place Leibniz's interest within the context of his interest in, broadly speaking, the natural-philosophical study of the structure, motion, and generation of living things and the metaphysical study of substance and individual. See, for example, F. Hartmann and M. Kruger, "Methoden ärztlicher Wissenschaft bei Leibniz," in *Akten des II. Internationalen Leibniz-Kongresses, Hannover, 17.–22. Juli 1972*, 4 vols. (Wiesbaden: F. Steiner, 1973–), 235–47; Marion Mahrenholtz, "Leibniz' Literaturquellen zu einigen frühen Texten medizinischen Inhalts," *Studia Leibnitiana Supplementa,* vol. 27, *Leibniz' Auseinandersetzung mit Vorgängern und Zeitgenossen*, ed. Ingrid Marchlewitz and Albert Heinekamp (Stuttgart: Franz Steiner Verlag, 1990), 350–57; Achim Trunk, "An Early Concept of G. W. Leibniz Regarding Medicine," in *The Global and the Local: The History of Science and the Cultural Integration of Europe*, ed. M. Kokowski. Proceedings of the Second ICESHS (Krakow, September 6–9, 2006), 373–78.

2. AT VI 62, 15–20. For an excellent treatment of Descartes' views on, and contribution to, medicine, see Vincent Aucante, *La philosophie médicale chez Descartes* (Paris: Presses Universitaires de France, 2004). An interesting, if less comprehensive, earlier work on this topic is Richard Burnett Carter's *Descartes' Medical Philosophy: The Organic Solution to the Mind-Body Problem* (Baltimore: Johns Hopkins University Press, 1983). Many recent authors have also treated Descartes' notion of health, but only in the narrow context of the question of whether his philosophy involves a continued commitment to teleology, and not out of any direct interest, such as Aucante's, for Descartes' philosophy of medicine.

3. G IV 275. See also Marie-Noëlle Dumas, *La pensée de la vie chez Leibniz* (Paris: Vrin, 1976), 2–3; Ferdinand Alquié, *La découverte métaphysique de l'homme chez Descartes* (Paris: Presses Universitaires de France, 1950).

4. G IV 316.

5. See, in particular, Aucante, *La philosophie médicale de Descartes*, chap. 1.

6. LH III 1, 1.

7. OH 115.

8. See, for example, Leibniz's undated letter to Peter the Great, in Ger'e, No. 244, § 15.

9. FdC VII, 243.

10. A VI iii 87.

11. Gaspare Aselli (1581–1626), a Paduan anatomist, and discoverer of the "lacteal vessels."

12. Olaus Rudbeck (1630–1702), a Swedish anatomist and one of the first to describe the lymphatic system.

13. Leibniz most likely has in mind Benjamin ben Immanuel Mustaphia, alias Dionysius, a Spanish Jewish physician based for a time in Amsterdam and the author of the *Sacro-Medicae Sententiae ex Bibliis* of 1640.

14. Caspar (1560–1624) and Jean (1541–1613) Bauhin were both influential Swiss botanists. Caspar in particular played an important role in developing a binomial taxonomic system for classifying plants. As we will see in chapter 7, plant taxonomy would remain a focus of interest for Leibniz at least into the first decade of the eighteenth century. Evidently, in this text of 1671, Leibniz is comfortable including these Swiss brothers among the great "German" contributors to medicine and related fields.

15. A IV i 543–52, 546.

16. *Journal des Sçavans*, August 1677, 190–91. For a thorough account of Leibniz's relations with Krafft, see H. Peters, *Leibniz als Chemiker*, in *Archiv für die Geschichte der Naturwissenschaften und Technik*, VII (1916), which includes an edition of their correspondence.

17. See MK 68; GM IV 497–98.

18. *Journal des Sçavans*, February 1681, 46. Leibniz had written on the same subject in a letter to Schelhammer of May 23, 1680. See also Ravier 48.

19. On which, see, in particular, Vera Keller, "Drebbel's Living Instruments, Harmann's Microcosm, and Libavius's Thelesmos: Epistemic Machines before Descartes," *History of Science* 48 (2010): 39–74.

20. Dutens II 2, 108–10.

21. Nearly a decade later, Leibniz publishes anonymously the review of Johann Bernoulli's "Dissertatio Chymico-Physica de Effervescentia et Fermentatione nova Hypothesi fundata, cum descriptione alicujus perpetui mobilis pure artificialis," in the *Acta Eruditorum* of February 1691. This review reveals, if little else, a continued interest in these questions into the 1690s. Beyond this, it is noteworthy that Leibniz pays particular attention in this review to what he identifies as animal economy. He writes that the author "observes, following Bartholin's *Act. Med.*, p. 2, obs. 70, that the predominance of antimony with sublimate of mercury, mixed well and narrowly compressed, heats up and emits a vapor, and he is familiar with this one example of a solid effervescing with a solid. He disputes Borelli, who maintained in his *De Mot. Anim.*, p. 2, pr. 29, that dilated parts contained in what is being distilled will in turn soon vanish; as is confirmed by experiments however, the air emitted from ferments does not vanish, but instead can be collected" (65). Although this is just a review and does not contain any evident statement of Leibniz's own ideas, it is of note for the continuity, with respect to the authors cited and questions addressed, with the texts of a decade earlier.

22. G VII, 504.

23. Pertz I, 4, 266f.

24. See George MacDonald Ross, "Leibniz and Alchemy," *Studia Leibnitiana Sonderheft* 7 (1978): 166–77, repr. R. S. Woolhouse, ed., *Gottfried Wilhelm Leibniz: Critical Assessments*, IV (New York: Routledge, 1994), 502–14; George MacDonald Ross, "Okkulte Strömungen im 17. Jahrhundert," translated into German by Andreas Beriger, in J.-P. Schobinger, ed., *Friedrich Ueberwegs Grundriss der Geschichte der Philosophie*, Reihe 5, 17 (Basel: Schwabe, 1998), 196–224.

25. Cited in MacDonald Ross, "Leibniz and Alchemy," 508.

26. OH 417.

27. MK 85.

28. MK 86.

29. A VI i 279.

30. See, for example, Lawrence M. Principe and William R. Newman, "Some Problems with the Historiography of Alchemy," in *Secrets of Nature: Astrology and Alchemy in Early Modern Europe*, ed. William R. Newman and Anthony Grafton (Cambridge, MA: MIT Press, 2001), 385–431. On Boyle's debt to alchemy, see Principe, *The Aspiring Adept: Robert Boyle and His Alchemical Quest* (Princeton, NJ: Princeton University Press, 1998); on Sennert's, see William R. Newman, *Atoms and Alchemy: Chymistry and the Experimental Origins of the Scientific Revolution* (Chicago: University of Chicago Press, 2006). To designate the broad swath of shared techniques, presumptions, and aims of these two subsequently separated endeavors, Principe and Newman have taken to using "chymistry" as a neologistic umbrella term for *either* alchemy *or* chemistry.

31. On the influence of Sennert, see, in particular, Richard T. W. Arthur, "The Enigma of Leibniz's Atomism," *Oxford Studies in Early Modern Philosophy* 1 (2003): 183–227, at 203; Andreas Blank, "Sennert and Leibniz on Animate Atoms," in *Machines of Nature and Corporeal Substances in Leibniz*, ed. Justin E. H. Smith and Ohad Nachtomy (Springer, 2011).

32. Arthur, "The Enigma of Leibniz's Atomism," 203.

33. Daniel Sennert, *Thirteen Books of Natural Philosophy* (London: P. Cole, 1659), 458. See also Julius Caesar Scaliger, *Exotericarum exercitationum liber XV. De subtilitate, ad Hieronymum Cardanum* (Paris: Vascovani, 1557).

34. Blank, "Sennert and Leibniz on Animate Atoms."

35. See Appendix 1 for a complete translation of this text.

36. In personal correspondence.

37. LH III 1, 3; Appendix 1, 66.

38. LH III 1, 3; Appendix 1, 67.

39. LH III 1, 3; Appendix 1, 28.

40. LH III 1, 3; Appendix 1, 13.

41. Ibid.

42. LH III 1, 3; Appendix 1, 8.

43. Walter Charleton, *Natural History of Nutrition, Life, and Voluntary Motion* (London: Printed for Henry Herringman, 1659), 2–3.

44. LH III 1, 3; Appendix 1, 33.

45. LH III 1, 3; Appendix 1, 22.

46. This point has been made in rather greater detail by other authors. See, in particular, Keith Hutchison, "What Happened to Occult Qualities in the Scientific Revolution?" *Isis* 73 (1982): 233–53.

47. LH III 1, 3; Appendix 1, 37.

48. See Descartes' *Primae cogitationes circa generationem animalium* (Amsterdam, 1701), 11.

49. LH III 1, 3; Appendix 1, 37.

50. LH III 1, 3; Appendix 1, 50. "Denn ordens personen sind dis-interessirt."

51. LH III 1, 3; Appendix 1, 53.

52. LH III 1, 3; Appendix 1, 54. Here it is interesting to note the choice Leibniz makes as to which words should be capitalized, and which not, in a German language that as yet had no explicit rules.

53. LH III 1, 3; Appendix 1, 54.

54. LH III 1, 1.

55. Klopp VIII, letter cxxxv, to Thomas Burnet, 85; G III 220.

56. See LH III 4, 3a Bl. 1.

57. See Justin E. H. Smith, "The Body-Machine in Leibniz's Early Medical and Physiological Writings: A Selection of Texts with Commentary," *Leibniz Review* 17 (2007): 141–79.

58. An alembic is the upper part of a sort of still, used in alchemy, consisting in two "retorts" or spherical vessels connected by a narrow passage.

59. Smith, "The Body-Machine in Leibniz's Early Physiological and Medical Writings," 170.

60. Ibid.

61. *Misc. Acad. Nat. Cur.*, 1695–96, decuria 3, iii (app.) pp. 1–22; republished in Dutens II 2, 110–19.

62. Leibniz writes of Helvétius in a letter to Schelhammer of 1715: "Helvétius brought out a little book in which he purports to promise more noble and more exquisite remedies for the majority of illnesses. He is thus an Empiric, though at present the greater part of medicine is still not empirical. And few are those

matters for which certain reasons, in a domain that is so hidden, have been sufficiently established." He adds some of his own views on the medical application of purgatives, a topic evidently still of great interest to him twenty years after the treatise on ipecacuanha: "I consider that purgations are often useful, not in the way that many believe, whereby the corrupt elements are ejected, but rather in quickening the lethargic nature by its own instruments, and in such a way almost that vomiting is useful in apoplexy. I submit these, my very audacious conjectures, to your judgment" (Dutens II 2, 73).

63. MK 132; Pertz I 4, 177. "Nachmittag gegen 3 Uhr war bey der Hitze in den intestinis tenuibus, wie einstmalen, ein Kleines Grimmen, gleich wie nach einer eingenommenen Purgation. Vielleicht weil ich Mittag Garley getruncken."

64. MK 132.

65. Ibid.

66. In a letter to Louis Bourguet of 1714, Leibniz famously writes: "I despise almost nothing—except judiciary astrology" (G III 562). Some authors (e.g., Elster, *Leibniz et la formation de l'esprit capitaliste* [Paris: Auber Montaigne, 1975]) have taken this statement to represent a firm opposition to astrology throughout Leibniz's career. It would be more correct to characterize it as Leibniz's late-life estrangement from a practice that earlier he had approached, not with enthusiasm, but as one possible source among many of scientific knowledge.

67. Dan Garber first suggested this parallel to me.

68. Dutens II 2, 111.

69. Ibid.

70. In English in the original. Leibniz is evidently referring to the work of the English economist and epidemiologist William Petty, who had conducted a quantitative study of the impact of the 1665 London plague. See *The Economic Writings of Sir William Petty, Together with the Observations upon Bills of Mortality, More Probably by Captain John Graunt*, ed. Charles Henry Hull, 2 vols. (Cambridge: Cambridge University Press, 1899). For an interesting study of Leibniz's interest in demographics and epidemiology, see Jean-Marc Rohrbasser and Jacques Veron, "Leibniz et les raisonnements sur la vie humaine," in *Etudes et enquêtes historiques* (Paris: Institut National d'Études Démographiques, 2001).

71. "Extrait d'une lettre sur la maniére de perfectionner la Médecine," Dutens II 2, 162.

72. Guhrauer B II, 458. "[Er] sagt, er wolle dergestalt *Medicinische Calender* machen, aber nicht, wie die Astrologen, vorher, sondern wenn das Jahr umb."

73. Ramazzini's most noted work was his *De morbis artificium diatriba* (Diatribe concerning the Illnesses of Workers) of 1700, which is widely recognized as the first treatise ever on occupational medicine. This field is inherently concerned with the approach to the study of health that considers data from large population samples.

74. Müller and Krönert report that in July 26, 1691 "Leibniz brings Bernardo Ramazzini to the attention of the president of the Academia naturae curiosorum Leopoldina, the Nuremberg physician Johann Georg Volckamer (d. 1693), and succeeds in making the compendium of statistics on illness, 'De constitutione anni 1690 ac de rurali epidemia' an annex to the *Ephemeridae* of the Academy for 1691" (MK 112; Ravier 263).

75. MK 40; Cat. Crit. 3 N. 1179, 2.
76. Klopp 10, 346–50; MK 176.
77. Klopp 10, 350–53; MK 176.
78. Bernoulli's medical works, and Leibniz's reaction to them, will be treated briefly in the next chapter.
79. A III vi, 570.
80. A III vi, 124–32,124f.
81. A III vi, 762–63.
82. In a letter of Leibniz to Denis Papin of December 2, 1697 (A III vii, 418), for example, Leibniz describes the usefulness of sulfur and vitriol for combating scurvy, and also in passing reveals an enduring interest in international affairs as well as an interest, first evidenced in 1671 (see his *Modus instituendi novam militiam invictam*, A IV i, 408–10, discussed briefly in chapter 7 below), in the problem seafarers have in obtaining fresh water. He writes: "I would think that the effect of the acidic liquors of sulfur and of vitriol hardly differ the one from the other. And although ordinarily the mechanical usages are of more benefit than those in medicine, nonetheless the latter deserve to be more highly regarded. I even believe that they would be of considerable profit here, if the spirit of sulfur, employed to correct and conserve the water on ships, were also resistant to the illness of scurvy. In this case, if the English had had some [spirit of sulfur] recently, when the Spanish refused to give them fresh water in Havana, not as many of them would have died."
83. A III vi, 302.
84. Ibid. "Voila ce que J'ay vuë et que Je puis affirmer ayant moy mesme aydé l'inciseur anathomique à la dissection de ces deux corps, c'est peut estre Trop abuser de votre pattience monsieur."
85. A III vi 395.
86. See Lorraine Daston and Katharine Park, *Wonders and the Order of Nature, 1150–1750* (New York: Zone Books, 1998).
87. For a comprehensive treatment of this topic, see W. F. Bynum and Vivian Nutton, eds., *Theories of Fever from Antiquity to the Enlightenment* (London: The Wellcome Institute, 1981).
88. See Hermann Boerhaave, *Institutiones medicae* (Leiden, 1708).
89. Thomas Willis, *De Febribus* in *Opera Omnia* (Lyon, 1676), 65.
90. LH III 5, 111–12.
91. Ekkehard Görlich, *Leibniz als Mensch und Kranker* (Hanover, 1987), 128.
92. Dutens II, 2, 72.
93. A comprehensive analysis of the Leibniz-Stahl controversy is offered by L. H. Rather and J. B. Frerichs in "The Leibniz-Stahl Controversy—I. Leibniz's Opening Objections to the *Theoria medica vera*," *Clio Medica* 3 (1968): 21–40; "The Leibniz-Stahl Controversy—II. Stahl's Survey of the Principal Points of Doubt," *Clio Medica* 5 (1970): 53–67. See also Paul Hoffman's very helpful "La controverse entre Leibniz et Stahl sur la nature de l'âme," *Studies on Voltaire and the Eighteenth Century* 199 (1981): 237–49; Jean-Pierre Coutard, *Le vivant chez Leibniz* (Paris: L'Harmattan, 2007), particularly 304–33.
94. The full text will be published in a critical edition in Reihe VIII of the Akademie Edition, as well, separately, as in a bilingual scholarly edition prepared by François Duchesneau and the present author. Sarah Carvallo has done a bi-

lingual (French-Latin) edition of a part of the controversy. See Carvallo, *Stahl-Leibniz: Controverse sur la vie, l'organisme et le mixte* (Paris: Vrin, 2004). Unfortunately, however, Carvallo's edition leaves out Stahl's own "Observations," offering us only Leibniz's first round of thirty-one *animadversions,* or "doubts," and then his thirty-one replies to Stahl's observations.

95. NO Ad XI, 3, 158.

96. NO Ad XXIV, 216.

97. Dutens II 2, 111.

98. Görlich, *Leibniz als Mensch und Kranker*, 126–28.

99. Kant, *Vorlesungen über Ethik* 27:459, cited from Kant, *Lectures on Ethics*, trans. Louis Infield (New York: Harper and Row, 1963), 239; see also *Kritik der praktischen Vernunft* 5:160. The legend may have some shred of truth to it, however. We know that Leibniz was intensely interested in the art of silk production. According to Nicholas Rescher, Leibniz raised his own silkworms from the beginning of his period in Hanover (Nicholas Rescher, *On Leibniz* [Pittsburgh: University of Pittsburgh Press, 2003], 187), and as late as 1716 Leibniz would write to Bourguet urgently asking him to send him silkworm eggs from Italy (G III 590). As Maria Rosa Antognazza notes, Leibniz hoped to use silkworms to generate revenue for the Berlin Academy of Sciences, and in 1707 he obtained a monopoly for the production of silk in Prussia. It is not unlikely that he was very solicitous of the well-being of the creatures on which this industry depended. See Maria Rosa Antognazza, *Leibniz: An Intellectual Biography* (Cambridge: Cambridge University Press, 2008), 463; see also MK 180.

100. LH III 1, 3; Appendix 1, 28.

101. Anita Guerrini, *Experimenting with Humans and Animals: From Galen to Animal Rights* (Baltimore: Johns Hopkins University Press, 2003), 37.

102. For a more lengthy account of these and similar experiments, see Anita Guerrini, "The Ethics of Animal Experimentation in Seventeenth-Century England," *Journal of the History of Ideas* 50 (1989): 391–407.

103. LH III 1, 3; Appendix 1, 42. "Man mus nicht aufhohren Proben, mit transfusione sanguinis zu thuen, zum wenigsten in thieren, wie denn in England ein mattes pferd durch frisches Hamels-blut wieder kräftig worden."

104. Richard Lower, *Tractatus de corde. Item de motu & colore sanguinis et chyli in eum transitu* (Amsterdam: Daniel Elzevirius, 1669), 182.

105. Ibid., 200.

106. Ibid., 203.

107. He may well be referring to the work of Carlo Ruini, *Anatomia del cauallo, infermità, et suoi rimedii: Opera nuoua, degna di qualsivoglia prencipe, & caualiere, & molto necessaria aà filosofi, medici, cauallerizzi, & marescalchi* (Venice: F. Prati, 1618), or to one of the numerous editions of Laurentius Rusius's *Hippiatria sive marescalia* (Paris: C. Wechel, 1532).

108. Notes on Henry More's *The Immortality of the Soul*, 1677–78(?), A VI iv 1679.

109. A VI iv 1369.

110. John Cottingham has argued against the caricatured view of Descartes as completely indifferent to the suffering of animals. See his "A Brute to the Brutes? Descartes' Treatment of Animals," *Philosophy* 53 (1978): 551–61.

111. A VI iv 1488–89.

112. LH III 1, 1.
113. A II i 860–61.
114. GM 641. For an interesting account of Huygens's own views on animals and their moral status, see Nathaniel Wolloch, "Christiaan Huygens's Attitude toward Animals," *Journal of the History of Ideas* 61, no. 3 (2000): 415–32.
115. NO Animadversio XXII(b), 16–17.
116. NO Ad IX, 152–53.
117. NO Ad X, 155. "Itaque reipublicae interest nihil omitti, quod ad spem futuri progressus facere possit."
118. G III 507–8.
119. Cited in Charles E. Raven, *John Ray, Naturalist: His Life and Works* (Cambridge: Cambridge University Press, 1950), 375.
120. A IV i, 408–10.

Chapter 2
The "Hydraulico-Pneumatico-Pyrotechnical Machine of Quasi-Perpetual Motion"

1. Obtaining great effects from slight motions, without violating mechanical laws, will be an important component of Leibniz's physiological account of the origins of animal motion, as we will see in our treatment of the *Machina animalis* of 1677 and of the *Corpus hominis* of 1682–83, both examined below.
2. A IV i, 562–68. In an interesting article, Horst Bredekamp argues for the importance of the ideas about shadow theater and projection developed in this text for Leibniz's later perspectivalist theory of monads. See Bredekamp, "*Kunstkammer*, Play-Palace, Shadow Theatre: Three Thought Loci by Gottfried Wilhelm Leibniz," in *Collection, Laboratory, Theater: Scenes of Knowledge in the 17th Century*, ed. Helmar Schramm, Ludger Schwarte, and Jan Lazardig (Berlin; New York: De Gruyter, 2005), 266–82.
3. Jon Elster, *Leibniz et la formation de l'esprit capitaliste* (Paris: Aubier, 1975), 80.
4. Leibniz comments on this text in a note dated by the Academy editors to between summer 1678, and the end of 1682 (A VI iv, 1783–84). The spate of occurrences of this term in other texts of the same period corroborates their dating.
5. Walter Charleton, *Oeconomia animalis novis in medicina hypothesibus superstructa et mechanice explicata* (London: R. Danielis, 1659).
6. Cornelis van Hogelande, *Cogitationes sive de Dei existentia* (Amsterdam: Ludovicus Elzevirius, 1646).
7. This is a term Leibniz uses in an undated letter to Peter the Great on the division of the sciences, in which he defines "pneumatics" as the investigation of pure spirits. See Ger'e, No. 244, § XV.
8. For a fine overview of Leibniz's natural-scientific writings of the Paris period, which includes the *Drôle de pensée* and which immediately precedes the appearance of the notion of animal economy in Leibniz's work, see Hans-Jürgen Hess, "Die unveröffentlichten naturwissenschaftlichen und technischen Arbeiten von G. W. Leibniz aus der Zeit seines Parisaufenthaltes. Eine Kurzcharacteristik,"

in *Leibniz à Paris, 1672–1676*, ed. G.-W.-Leibniz Gesellschaft and Centre national de recherche scientifique (Wiesbaden: Steiner), vol. I, 183–217.

9. LH III 1, 1.

10. As François Duchesneau explains, to describe the animal body as a hydraulico-pneumatico-pyriac machine (the variant we find in the polemic with Stahl), is to hold that "the organism appears as a combination of dynamic microprocesses for which agents of impetus should be identified: this might be done by means of the chemical reactions that correspond to their specific functional properties." See his "Leibniz vs. Stahl on the Operation of Machines of Nature," in *Machines of Nature and Corporeal Substances in Leibniz*, ed. Justin E. H. Smith and Ohad Nachtomy (Springer, 2011).

11. See, in particular, Antonio Clericuzio, *Elements, Principles, and Corpuscles: A Study of Atomism and Chemistry in the Seventeenth Century* (Dordrecht: Kluwer Academic, 2000).

12. Please see Appendix 2 for a complete translation of this text.

13. LH III 5, 12.

14. Ibid.

15. G VI 609.

16. These are in fact a special kind of lymph vessel known as "lacteals." They are not veins. They were discovered by the Paduan anatomist Gaspare Aselli, who was mentioned in the *Bedenken*, a 1671 text discussed briefly in the previous chapter.

17. Enrico Pasini, *Corpo e funzioni cognitive in Leibniz* (Milan: FrancoAngeli, 1996), 110–11. Pasini also notes, "The comparison with the fermentation of wine, which belongs to the Galenic tradition (*De usu partium*, I 4, iii) is taken up by Descartes in *L'homme* in connection with the transformation of the chyle into blood, … and in the *Discours de la méthode* in connection with the heat of the heart. … Another contribution of Descartes' is the attribution of the movement of the heart to the fermentation due to the mixture in the heart of the blood that has just arrived there with the blood remaining from the prior diastoles. Nonetheless, Descartes attributes greater importance to the effect of dilatation that is produced by the heat of the fermentation than to the agitation caused by the fermentation itself" (*Corpo e funzioni cognitive in Leibniz*, 110–11). See also Jan van Gijn, "Franciscus Sylvius (1614–1672)," *Journal of Neurology* 248, no. 10 (2001): 915–16.

18. Please see Appendix 3 for a complete translation of this text.

19. Boyle, *Works* 10, 540. On the influence of the English chemist on Leibniz, see Leroy Loemker, "Boyle and Leibniz," *Journal of the History of Ideas* 16 (1955): 22–43.

20. Pasini writes on the roots of Leibniz's three-part neologism: "Hydraulico-pneumatic machines are those such that, to the techniques for constructing hydraulic machines, such as fountains, are added the use of air pressure, as in vacuum pumps; pyrotechnical or pyrobolic machines are those in which fire is involved in varying degrees, and thus are connected to metallurgy, as in the *Pirotechnia* of Biringuccio (1540), to bombs and to explosives in general, to the production of heat, though substantially the field of application of pyrotechnics ends up corresponding … to chemical reactions. Leibniz, with his neologism, wishes

to emphasize the dynamic character which imbues the animal machine with its active principle, whether this is a matter of effervescence, which, as was said, was capable of producing heat and ebullition, or of a fire without light as Descartes had already maintained, or, finally, of little explosions similar to those of gunpowder" (*Corpo e funzioni cognitive in Leibniz*, 119).

21. Kaspar Schott, *Mechanica Hydraulico-pneumatica, Qua Praeterquam quod Aquei Elementi natura, proprietas, vis matrix, atque occultus cum aere conflictus, a primis fundamentis demonstratur; omnis quoque generis Experimenta Hydraulico-pneumatica recluduntur; & absoluta Machinarum aqua & aere animandarum ratio ac methodus praescribitur* (Würzburg, 1657), preface, no page numbers.

22. Ibid., italics added.

23. See Marie Boas, "Hero's *Pneumatica*: A Study of Its Transmission and Influence," *Isis* 40, no. 1 (1949).

24. For a comprehensive account of this distinction, see Dennis Des Chene, *Spirits and Clocks: Machine and Organism in Descartes* (Ithaca, NY: Cornell University Press, 2001).

25. LH III 1, 2, § 1.

26. LH III, 1, 2, § 2. Pasini (in personal conversation) recommends the alternative translation of "saltatrices" as "jumping" rather than "dancing."

27. Leibniz's most famous conflict with a contemporary concerning this issue was with Joachim Becher, who was so infuriated by Leibniz's dismissal of his purported invention that he is inspired in his *Närrische Weisheit und weise Narrheit* (Ignorant Wisdom and Wise Ignorance) of 1680 to ridicule Leibniz's inventions at great length, including Leibniz's supposed plan to invent a carriage that could travel from Amsterdam to Hanover in six hours. See A I iii, 278; Gerland 119; MK 69. In March 1683, Leibniz gives his own account to the Landgraf Ernst concerning the value of Becher's supposed invention: "This man is well enough known through his exaggerations, which are mixed with black malice. One need only read his books in order to be convinced of this. … He set upon me because I stood in the way of a certain alchemical swindle he had planned. … What he says about the six-hour journey of the wagon from Hanover to Amsterdam belongs to his invention. … For one would have to lose one's reason in order to have ever thought of such a thing" (A I iii, 278).

28. A I 2, 90.

29. See, for example, Vera Keller, "Drebbel's Living Instruments, Harmann's Microcosm, and Libavius's Thelesmos: Epistemic Machines before Descartes," *History of Science* 48 (2010): 39–74.

30. In the *Essais de dynamique* of 1695 (FdC I, 653), Leibniz strongly denies the possibility of a perpetual-motion machine in the usual sense by the following reasoning: "If the substitution of one force for another gives rise to perpetual mechanical motion, or an effect which is greater than its cause, then the two forces are clearly unequal; and the one that was substituted for the other must be the more powerful, since it produced something greater. I take it to be certain that nature never substitutes unequal forces for each other, and that the complete effect is always equal in power to the total cause."

31. Antonio Nunziante has also pinpointed these two properties as constituting Leibniz's notion of life throughout, at least, the 1680s. See his "'Corpus

vivens est automaton sui perpetuativum ex naturae instituto.' Some Remarks on Leibniz's Distinction between 'Machina naturalis' and 'Organica artificialia,'" in *Individuals, Minds, and Bodies: Themes from Leibniz*, ed. M. Carrara, A. M. Nunziante, and G. Tomasi (Stuttgart: Franz Steiner Verlag, 2004), 203–16.

32. LH III 1, 2, § 3.

33. LH III 1, 2, § 7.

34. In the *Corpus hominis* Leibniz also suggests that the source of the heat may be "pyropus," a sort of "artificial fire," which he describes at greater length in the course of contrasting it with *aqua fumans* in a 1680 letter to Schelhammer as follows: "*Aqua fumans* (insofar as I see it), whose first invention is wrongly attributed to Kunckel, has nothing in common with light or durable artificial fire. For to those who had *aqua fumans* the composition of this *pyropus* was unknown. What the Jesuit communicated to you, I do not know: [but] this is certain, this artificial and, so to speak, cold fire is drawn from urine. This fire, which I described in a poem, is not something else, if you consider the origin and perfection of the thing. … By strong friction and much motion it is possible to produce the fire only if it is mixed in with gunpowder. But the light is communicated to bodies by the lightest rubbing. I am in the habit of calling this *pyropus*. It is namely a fiery gem, which, if I may say, you should fear to handle in the darkness, [and] which shines like amber" (September 14, 1680; Kortholt 173f.; Dutens II 2, 165).

35. LH III 1, 2, § 4.

36. Jean Fernel, *Physiologia*, ed. John M. Forrester and John Henry (Philadelphia: American Philosophical Society, 2003). Book IV ("De spiritibus et innato caldo"), chap. 1 ("Calorem quendam in nobis cunctisque viventibus inesse, eumque divinium"), 256–58.

37. See AT VI 46, 7–8.

38. Leibniz uses the term "nescio quid" here, as frequently elsewhere, not to express irony, but rather generality. He wishes to say that there is something analogous to the stars, without having to go into the details of this analogy.

39. This last sentence is one of the hardest in the manuscript to decipher, and likely for that reason Mahrenholtz misreads it as asserting that an animal *is* a hydraulico-pneumatic machine (Marion Mahrenholtz, "Leibniz' Literaturquellen zu einigen frühen Texten medizinischen Inhalts," 353). The Latin reads: "Plerique enim Calidum in corpore animalis statuunt, quod humido alatur; nonnulli flammulam cordis adhibent; alii ignem lucentem, <quidam nescio quid analogum elementi stellarum, quale quod revera omnis est flamma,> quidam fermentationem, nonnulli displosiunculas innumerabiles ad pulveris pyrii instar: nos quod in his omnibus reperitur ebullitionem moderatam et durabilem, quae <a> materia circulata magisque ac magis rarefacta, et paulatim etiam instaurata, alatur. … Animal ergo esse machinam non tantum Hydraulico-Pneumaticam, sed et quodammodo Pyrotechnicam merito dicemus."

40. See, in particular, Ernst Wilhelm Kämmerer, *Das Leib-Seele-Geist Problem bei Paracelsus und einigen Autoren des 17. Jahrhunderts* (Wiesbaden: Franz Steiner Verlag, 1971).

41. NO 9. The passage reads in full: "So that therefore the Archaeus should not be sought after except in the soul and in the corporeal spirits that are in agreement with it, nor do we need some plastic or hylarchic principle, nor vari-

ous princes or little kinglets in the bodily parts like the cardianax, gastrianax, and other such ones."

42. See, in particular, Agostino Nifo, *Expositiones in omnes libros De historia animalium, De partibus animalium et earum causis ac De generatione animalium* (Venice, 1546). For a thorough study of Nifo's thought, see Edward P. Mahoney, *Two Aristotelians of the Italian Renaissance: Nicoletto Vernia and Agostino Nifo* (Aldershot, UK: Ashgate, 2000).

43. Pierre Gassendi, *Syntagma*, 2, 345a; cited in Antonia LoLordo, *Pierre Gassendi and the Birth of Early Modern Philosophy* (Cambridge: Cambridge University Press, 2006), 205–6.

44. The most important *direct* influence on Leibniz's theory appears to come from Sylvius's *Praxeos medicae idea nova* of 1671. Sylvius is sometimes credited as the founder of the theory of fermentation as the basic chemical process in living bodies.

45. Walter Charleton, *Natural History of Nutrition, Life, and Voluntary Motion* (London: Printed for Henry Herringman, 1659), preface.

46. Ibid., 2–3.

47. Charleton, *Natural History of Nutrition, Life, and Voluntary Motion*, 17.

48. Stephen Gaukroger, *Descartes's System of Natural Philosophy* (Cambridge: Cambridge University Press, 2002), 194.

49. Rudolphus Goclenius, *Lexicon Philosophicum* (Hildesheim: Georg Olms Verlag, 1980), 783. "Nutriri proprie dicitur id, quod in se ipso aliquid recipit ad suam ipsius conservationem corporalem."

50. LH III 1, 1.

51. On this, see in particular Vincent Aucante, *La philosophie médicale de Descartes* (Paris: Presses Universitaires de France, 2004).

52. For a comprehensive survey of this history, see Antonio Clericuzio, "Chemistry of Life: Ferments and Fermentation in 17th-Century Iatrochemistry," *Med. Secoli* 15, no. 2 (2003): 227–45. See also Clericuzio, *Elements, Principles, and Corpuscles*.

53. Betty Jo Teeter Dobbs, *The Janus Face of Genius: The Role of Alchemy in Newton's Thought* (Cambridge: Cambridge University Press, 1991), 49.

54. Ibid., 48.

55. Willis, *De Fermentatione*, chap. 1, 1, in *Opera Omnia* (Lyon, 1676).

56. Ibid.

57. Ibid., chap. 3, 12.

58. Ibid., 12–13.

59. NO Animadversio XIII, 13.

60. Thomas Willis, *De anima brutorum, quae hominis vitalis ac sensitiva est*, in *Opera Omnia,* chap. 2, 7.

61. Willis, *De anima brutorum*, chap. 1, 3–4.

62. See Appendix 4 for a complete translation.

63. As Pasini notes, in the *De scribendis* "the rhythm of the deduction is more certain and more accelerated than in the *Corpus hominis* of the same era—perhaps as a result of the nature of the program of elaborating the theoretical elements of medicine announced in the beginning of the text—which gives to the text a more abstract and schematic tone, but also, at least at the beginning, a more compact structure" (*Corpo e funzioni cognitive in Leibniz*, 117).

64. It is possible that in the *Corpus hominis* manuscript as well, "pyrotechnic" should be read as "pyrobolic."

65. LH III 1, 1.

66. Ibid.

67. Psychopyrism, though, did have its defenders. See Richard Baxter, *Of the Nature of Spirits: Especially Mans Soul. In a placid Collation with the Learned Dr. Henry More* (London, 1682).

68. Pasini, *Corpo e funzioni cognitive in Leibniz*, 116–17.

69. This succinct account of Bernoulli's theory owes much to Raphaële Andrault, "Mathématiser la médecine," presented at the conference, "Leibniz and the Empirical Sciences," Orotava, Spain, February, 2009.

70. In personal conversation and correspondence.

71. See, for example, GM III/2, 884.

72. Dutens II 2, 91.

73. Bernoulli writes to Leibniz on April 8, 1711, making explicit his disagreement with Steno: "Steno thought that it is not certain nerves, but rather the muscles themselves that are contracted by means of crispation [*crispationem*], and this without access to new material: I preferred rather to say, with Borelli, Willis, Majorvius, and others, that the contraction of the muscles proceeds through a certain inflation, resulting from effervescence or ebullition, of the spirituous juice together with the blood that is coming in, just as I explained this at length in my own *Dissertation on the Motion of the Muscles*" (GM III/2, 872–73).

74. Leibniz to Bernoulli, February 10, 1711, GM III/2, 864. "I will readily agree with Steno that the nerves act by a certain contraction [*crispationem*]. Yet this very contraction, if I am not mistaken, cannot be explained unless by appeal to a fluid that passes through the nerves."

75. GM III/2 884f. "Many things in organic bodies appear to consist in perpetual, imperceptible vibrations, which mutually restrain each other when we appear to be at rest. Thus in truth the matter leads back to the elastic force. I suspect that memory itself consists in the perdurance of vibrations. … Thus we have no need of the fluid that is called 'animal spirits', unless we trace it back to this elastic force itself."

76. See Robert Boyle, *New Experiments Physico-Mechanicall, Touching the Spring of the Air, and Its Effects* (London, 1660), I, Experiment 1. On Boyle's influence, See Pasini, *Corpo e funzioni cognitive in Leibniz*, 123.

77. LH III 1, 2, § 5.

78. See Johann Bernoulli, *On the Mechanics of the Movement of the Muscles* (1694), ed. and trans. Paul Maquet (Philadelphia: Transactions of the American Philosophical Society, 1997), § 20.

79. See, in particular, François Duchesneau, *La physiologie des Lumières. Empirisme, modèles et théories* (The Hague: Nijhoff, 1982), 32–64.

80. Leibniz writes to Bernoulli in December, 1710: "Baglivi, the Italian physician, denies … that the animal spirits contribute to the motion of the muscles, which he supposes to be contracted by a certain crispation; Steno held a similar opinion."

81. See Giorgio Baglivi's *Specimen quatuor librorum de fibra motrice et morbosa*, in *Opera omnia medico-practica et anatomica*, 7th ed. (Leiden: Sumptibus Anisson and Joannis Posuel, 1710), 237–394. Duchesneau sees Baglivi's work

as an important anticipation of that of Albrecht von Haller. See also N. Zurak, "Nervous System in the Fibrillar Theory of Giorgio Baglivi," *Med Secoli* 12, no. 1 (2000): 147–58; N. G. Mihali, "Re-Evaluation of the Epistemic Foundation of Baglivi's Medical Doctrine and His Anatomic-Physiological Theory," *Lijec Vjen* 131, nos. 1–2 (2009): 40–41.

82. NO Animadversio XIII, 13.

83. NO Animadversio XVIII, 15.

84. . NO Animadversio XIII, 13. "Et dici potest corpus nostrum non tantum machinam hydraulico-pneumaticam, sed et pyriam esse."

85. NO Ad XII (2), 161.

86. NO Ad XIII, 162.

87. NO Ad XV (1), 163.

88. NO 2.

89. NO Ad I, 135–36.

90. NO Animadversio IX, 11.

91. This is a view attributed by Cicero to Chrysippus in his *De natura deorum*: "It would take too long to praise the qualities with which the mule and the ass are endowed—for mankind, of course. And the pig? What else is it but food? It has a soul, Chrysippus says, in order to keep it from rotting; the soul takes the place of salt, for it is destined to serve as nourishment for man" (*De natura deorum* II, 64).

92. NO Animadversio VIII, 11.

93. NO Animadversio IX, 11.

94. NO Animadversio XV, 14.

95. NO Ad IX, 152.

96. NO Ad XVI (2), 165. "Corpus non posse sic actuari ab anima, ut leges mechanicae corporum vel minimum violentur."

97. François Duchesneau, *Les modèles du vivant de Descartes à Leibniz* (Paris: Vrin, 1998), 336.

98. NO Animadversio XXVI, 18.

99. NO Ad XXIX (1), 221.

100. NO, 3.

101. NO Ad XXI, 175–76.

102. Ibid.

103. NO Ad XXIX, 221.

104. NO Animadversio XXX, 19.

105. NO Ad XXI (1), 176.

106. NO 6–7.

Chapter 3
Organic Bodies, Part I: Nature and Structure

1. NO, Preamble, no page numbers given. "Omnis organismus revera sit mechanismus, sed exquisitior."

2. Montgomery Furth, "Aristotle's Biological Universe: An Overview," in *Philosophical Issues in Aristotle's Biology* ed. Allan Gotthelf and James G. Lennox (Cambridge: Cambridge University Press, 1985), 24.

3. See Catherine Wilson, *The Invisible World* (Princeton, NJ: Princeton University Press, 1995), 181–83.

4. *De generatione animalium* I, 715.

5. François Duchesneau, *Les modèles du vivant de Descartes à Leibniz* (Paris: Vrin, 1998), 199.

6. Ibid., 199–200.

7. Cited in Duchesneau, *Les modèles du vivant*, 202; Marcello Malpighi, *Opere scelte di Marcello Malpighi,* ed. Luigi Belloni (Turin: Unione Tipografico-Editrice Torinese, 1968), 512–13.

8. Wilson, *Invisible World*, 13.

9. Garber, "Leibniz and the Foundations of Physics: The Middle Years," in *The Natural Philosophy of Leibniz*, ed. K. Okruhlik and J. R. Brown (Dordrecht: Reidel, 1985), 89.

10. For an exhaustive account of the role of derivative force in Leibniz's dynamics, Pauline Phemister, *Leibniz and the Natural World: Activity, Passivity, and Corporeal Substances in Leibniz's Philosophy* (Dordrecht: Springer, 2005).

11. LH III 1, 2 § 9.

12. See, for example, Dutens II 1, 260.

13. An earlier version of this section of the present chapter appeared as Justin E. H. Smith, "'A Mere Organical Body Like a Clock?' Organic Body and the Problem of Idealism in the Late Leibniz," *Eighteenth-Century Thought* 4 (2009).

14. We will intentionally be eliding "idealism" and "phenomenalism," two positions some commentators have sought to distinguish in their interpretations of Leibniz. For our purposes, phenomenalism, whether Leibniz held it or not, may be seen as a variety of idealism.

15. One notable exception to this is Rutherford's recent article, "Leibniz as Idealist," to be discussed shortly.

16. Marie-Noëlle Dumas, *La pensée de la vie chez Leibniz* (Paris: Vrin, 1976), 121.

17. Leroy Loemker, ed., *Gottfried Wilhelm Leibniz: Philosophical Papers and Letters* (Dordrecht: Reidel, 1969 [1976]), 528.

18. Donald Rutherford, "Metaphysics: The Late Period," in *The Cambridge Companion to Leibniz*, ed. Nicholas Jolley (Cambridge: Cambridge University Press, 1995), 124–75, at 154.

19. Letter to Damaris Masham, May 1704. G II 253.

20. Robert Merrihew Adams, *Leibniz: Determinist, Theist, Idealist* (New York: Oxford University Press, 1994), 306.

21. Glenn Hartz, "Why Corporeal Substances Keep Popping Up in Leibniz's Later Philosophy," *British Journal for the History of Philosophy* 32, no. 6 (1998): 193–207, at 201. In fact, as we'll see shortly, Hartz does understand the distinction between organic body and corporeal substance, and the list he gives here should not be taken as a list of synonyms.

22. This is a point that has already been made by Michel Fichant, most notably in his influential 2003 article "Les machines de la nature." At the same time, however, 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.

23. Donald Rutherford, "Leibniz as Idealist," in *Oxford Studies in Early Modern Philosophy*, vol. 4, ed. Daniel Garber and Steven Nadler (New York: Oxford University Press, 2008), 141–90, esp. 141.

24. Ibid., 142.

25. Ibid., 143.

26. See Anne-Lise Rey, "Action, Perception, Organisation," in *Machines of Nature and Corporeal Substances in Leibniz*, ed. Justin E. H. Smith and Ohad Nachtomy (Springer, 2011).

27. G II 253.

28. See Daniel Garber, *Leibniz: Body, Substance, Monad* (New York: Oxford University Press, 2008).

29. This singular occurrence reads: "Je definis l'Organisme, ou la Machine naturelle, que c'est une machine dont chaque partie est machine, et par consequent que la subtilité va à l'infini" (G III 356). This again seems to be a one-off occurrence of the term in a sense compatible with its general understanding today. See also Leibniz's letters of June 30, 1704 (G III 356), and September 1704 (G III 362). Masham uses the term "organism" in her letter of June 1704 (G III 350) and it appears again in her letter to Leibniz of August 8, 1704 (G III 358). For an extensive analysis of the concept of organism from the seventeenth to the nineteenth centuries that takes its shift from an abstract noun to a count noun into account, see Tobias Cheung, "From the Organism of a Body to the Body of an Organism: Occurrence and Meaning of the Word 'Organism' from the Seventeenth to the Nineteenth Century," *British Journal for the History of Science* 39 (2006): 319–39.

30. G III 340. "Organisme c'est à dire l'ordre et l'artifice, est quelque chose d'essentiel à la matière produite et arrangée par la sagesse souveraine."

31. A VI iv1615. As Duchesneau rightly notes, it is impossible that this passage dates from the period in which the Academy editors have placed it, for precisely the reason that Leibniz did not yet have the concept of organism employed in it (*Les modèles du vivant de Descartes à Leibniz*, 341). The academy editors rightly note that the reference to "organism" might point to a later date, but also mistakenly understand the phrase "pleine d'organisme" as referring to *organisms* in the plural: "Die These, in jedem Teil der Materie seien Organismen enthalten, könnte aber auch auf eine spätere Entstehungszeit verweisen" (A VI iv 1614).

32. Nehemiah Grew, *Cosmologia Sacra: Or a Discourse of the Universe as It Is the Creature and Kingdom of God* (London: W. Rogers, S. Smith, and B. Walford, 1701), 20; see also Tobias Cheung, *Res vivens. Agentenmodelle organischer Ordnung 1600–1800* (Freiburg: Rombach Verlag, 2008), chap. 2, § 5.

33. G VII 344; AG 319.

34. G VII 415–18.

35. Anne Conway, *Principles of the Most Ancient and Modern Philosophy*, ed. Alison P. Coudert (Cambridge: Cambridge University Press, 1996), 64.

36. Johannes Micraelius, *Lexicon Philosophicum terminorum philosophis usitatorum* (1662; repr. Düsseldorf: Stern-Verlag Janssen, 1966).

37. G VI 599.

38. *Physics* II i 193a.

39. L. A. Kosman, "Animals and Other Beings in Aristotle," in *Philosophical Issues in Aristotle's Biology*, ed. Allan Gotthelf and James G. Lennox (Cambridge: Cambridge University Press, 1987), 360–91, at 379.

40. Ibid., 377. Kosman bases this distinction on *Parts of Animals*, II i 646b.

41. *De anima* 412b 10–24.

42. Brandon Look has compellingly argued that Leibniz is unable to give an adequate account of monadic domination without making essential reference to the relation between the dominant monad and its body. At the same time, Look maintains that these bodies are in the end intentional objects. See Look, "On Monadic Domination in Leibniz's Metaphysics," *British Journal for the History of Philosophy* 10, no. 3 (2002): 379–99.

43. G IV 395–96.

44. Italics added. Cited in Sarah Carvallo, *Stahl-Leibniz: Controverse sur la vie, l'organisme et le mixte* (Paris: Vrin, 2004), 82. This sentence is suppressed in the 1720 and 1768 editions, but is included parenthetically in the original manuscript.

45. G V 297.

46. Letter to Sophie, November 4, 1696; G VII 542.

47. G III 260. See also GM III 536–37.

48. G III 260.

49. G VI 598.

50. G II 296.

51. Donald Baxter, "Corporeal Substances and True Unities," *Studia Leibnitiana* 27, no. 2 (1995): 64.

52. G II 96f. "Ce qui fait l'essence d'une armée n'est qu'une maniere d'estre des hommes qui la composent."

53. Grua 323, "nullum enim reale in ipso est, quod non resultet ex partium unde aggregatur realitate."

54. G II 100.

55. R. C. Sleigh, *Leibniz and Arnauld: A Commentary on Their Correspondence* (New Haven, CT: Yale University Press, 1990), 126.

56. Steven Nadler, Introduction, *Causation in Early Modern Philosophy: Cartesianism, Occasionalism, and Preestablished Harmony*, ed. Steven Nadler (University Park: Pennsylvania State University Press, 1993), 5.

57. G III 262.

58. G III 657.

59. G IV 572.

60. G III 457.

61. Michel Fichant, "Les machines de la nature," *Studia Leibnitiana* 35, no. 1 (2003): 19.

62. Sleigh, *Leibniz and Arnauld*, 126.

63. G IV 482.

64. For a rich account of the context of Leibniz's reintroduction of a form-matter philosophy, see Michel Fichant, "Mécanisme et métaphysique: Le rétablissement des formes substantielles," in *Science et métaphysique dans Descartes et Leibniz* (Paris: Presses Universitaires de France, 1998), 163–204.

65. G II 270.

66. Adams, *Leibniz: Determinist, Theist, Idealist*, 306.

67. Garber, "Leibniz and the Foundations of Physics," 63.

68. Nicholas Rescher, *Leibniz's Metaphysics of Nature* (Dordrecht; Boston: Reidel, 1981), 46.

69. Donald Rutherford, *Leibniz and the Rational Order of Nature* (Cambridge: Cambridge University Press, 1995), 154f.

70. See Etienne Gilson, *Index Scholastico-Cartésien* (Paris, 1979), 126; cited in Garber, "Leibniz and the Foundations of Physics: The Middle Years," 29.

71. Garber, "Leibniz and the Foundations of Physics," 39.

72. Ibid.

73. G VI 618.

74. Ibid., 607.

75. More recently Garber has offered a highly plausible account of the difference between the middle and late periods, according to which Leibniz remains committed to corporeal substance throughout his life, while what changes from the middle to the late periods is that, in the late period, corporeal substance is underlain by rock-bottom entities, the monads, whereas in the middle period corporeal substances really are just "bugs-within-bugs" ad infinitum. See Garber, *Leibniz: Body, Substance, Monad*.

76. Michel Fichant, "La constitution du concept de monade," in *La monadologie de Leibniz: Genèse et contexte*, ed. Enrico Pasini (Paris: Mimesis, 2005), 31–54, esp. 33.

77. G VI 599.

78. Ibid.

79. Ibid., 617–18.

80. G II 171.

81. See William R. Newman, *Atoms and Alchemy* (Chicago: University of Chicago Press, 2006), chap. 1.

82. Paul of Taranto, *Theorica et practica*; cited in Newman, *Atoms and Alchemy*, 41. "Quoniam autem redeunt haec eadem sicut prius, manifestum est ea ad quedam sua componentia tantum resoluta fuisse et non ad elementa vel ad primam materiam ut mentuntur prefati."

83. Newman, *Atoms and Alchemy*, 42.

84. The latest extant work on a subject relating to the nature of "inorganic" mixtures and compositions, prior to the development of the organic model of bodies, is "Meditatio de Separatione Salis et aquae dulcis, novoque Separationum Chymicarum genere," published in the *Acta Eruditorum* in December 1682 (386–88; Dutens II 2 108–10).

85. In order to drive home the distinction between animals and organic bodies, it is interesting to consider the early text, *Principium mechanicae universae novum* of 1680–86, in which Leibniz says that the world is a single and unique machine. This machine is assuredly natural, but we should certainly not infer from this that Leibniz believed that the world is a single and unique *animal*. Such a view—requiring as it does that the world itself have a soul—was widely deemed heretical, and was avoided even by the Cambridge Platonists, notwithstanding their admiration for Plato's *Timaeus*.

86. This term was coined by Donald Rutherford in his *Leibniz and the Rational Order of Nature*. See especially chapter 8.

87. Fichant, "Les machines de la nature," 19.

88. G II 268.

89. Martial Guéroult, *Dynamique et métaphysique leibniziennes* (Paris: Les Belles Lettres, 1934), 187.

90. Michel Fichant makes a similar point when he notes of Leibniz's ontology: "Ce n'est pas … un idéalisme quasi-berkeleyen, qui réduirait la réalité des corps au seul contenu objectif des représentations perceptives. Ce qu'il y a toujours eu en Leibniz de fidélité aristotélicienne le préservait de la *Scwhärmerei* où Kant verra la marque de cette sorte là d'idéalisme" (Fichant, "Les machines de la nature," 28).

91. G VI 545.

92. As Rutherford writes: "For every monad representing itself as an embodied creature … there is a ground in reality for that appearance: monads whose perceptions represent them as the organic components of those bodies. In this account, there is clearly no inconsistency between Leibniz's monadic and panorganic models. They represent complementary ways of understanding the universe: one from the point of view of reality as it is in itself, a system of harmoniously related monads; the other from the point of view of the order determined by those monads' expression of themselves as embodied creatures naturally subordinated to one another. There is thus no problem with Leibniz's asserting … that reality consists solely of monads and their harmonious perceptions" (Rutherford, *Leibniz and the Rational Order of Nature*, 230).

93. See *De principiis* 2.8.3, in Origen, *An Exhortation to Martyrdom, Prayer, and Selected Works*, trans. and ed. Rowan A. Greer (Mahwah: Paulist Press, 1979).

94. Ibid., 2.2.2.

95. Henry More, *Democritus Platonissans, or, An Essay upon the Infinity of Worlds* (Cambridge: Roger Daniel, 1646), stanza 12.

96. Conway, *Principles of the Most Ancient and Modern Philosophy*, 30–32.

97. G VI 507.

98. G VI 548.

99. Origen, *An Exhortation to Martyrdom, Prayer, and Selected Works*, 214.

100. Ibid.

101. Brandon Look pointed this problem out (in personal correspondence).

102. In *Being and Time*, Martin Heidegger makes a similar point about the different ways in which the label "idealist" has been applied to figures in the history of philosophy: "If what the term 'idealism' says, amounts to the understanding that Being can never be explained by entities but is already that which is 'transcendental' for every entity, then idealism affords the only correct possibility for a philosophical problematic. If so, Aristotle was no less an idealist than Kant. But if 'idealism' signifies tracing back every entity to a subject or consciousness whose sole distinguishing features are that it remains *indefinite* in its Being and is best characterized negatively as 'un-Thing-like,' then this idealism is no less naive in its method than the most grossly militant realism" (*Being and Time*, ed. and trans. John Macquarrie and Edward Robinson [Oxford: Blackwell, 2000], 251–52).

103. As discussed in chapter 2, this notion is Paracelsian in origin, and initially served primarily as an explanation of the alchemical force that guides digestion, conceived as the transformation of food into a new bodily substance.

104. Dutens II 2, 225.

105. Cudworth, *True Intellectual System*, I.3.37, art. 5, 150.

106. Ibid., I.3.37, art. 3, 148.

107. Ibid., I.3.37, art. 4, 150. On the connection of Cudworth's pananimism to Plotinus, see Alain Petit, "Ralph Cudworth: Un platonisme paradoxal. La nature dans la *Digression concerning the Plastick Life of Nature*," in *The Cambridge Platonists in Philosophical Context*, ed. G.A.J. Rogers, J. M. Vienne, and Y.-C. Zarka (Dordrecht; Boston: Kluwer, 1997), 101–10.

108. Cudworth, *True Intellectual System*, I.3.37, art. 21, 165.

109. Duchesneau, *Les modèles du vivant de Descartes à Leibniz*, 181.

110. Cudworth, *True Intellectual System*, 1.3.37, art. 15, 158–59.

111. For a detailed account of Cudworth's theory of natural growth and change, see François Jacob, *La logique du vivant* (Paris: Gallimard, 1970), 110–14.

112. Philo of Alexandria, *The Contemplative Life, The Giants, and Selections*, trans. and ed. David Winston (Garden City: Doubleday, 1997), 97.

113. Ibid., 114.

114. Cudworth, *True Intellectual System*, I.2.10, 72.

115. Interestingly, in the *Metaphysical Foundations of Natural Science*, Kant refers to hylozoism as "the death of all natural philosophy" (AA 4:544). According to Brandon Look (in personal correspondence), it is Leibniz that Kant has in mind here.

116. Cudworth, *True Intellectual System*, I.3, note 37, 178.

117. Cited in Petit, "Ralph Cudworth: Un platonisme paradoxal. La nature dans la *Digression concerning the Plastick Life of Nature,*" 103.

118. NO 177.

119. GM 241.

120. G IV 391.

121. G V 126.

122. G III 368.

123. G VI 544.

124. G III 371.

125. G III 371.

126. G III 374.

127. G IV 391.

128. On the connection between material plastic natures and derivative force, see Pauline Phemister and Justin E. H. Smith, "Leibniz and the Cambridge Platonists and the Debate over Plastic Natures," in *Leibniz and the English-Speaking World*, ed. Pauline Phemister and Stuart Brown (Dordrecht: Springer, 2007).

129. G VII 417–18.

Chapter 4
Organic Bodies, Part II: Context and Legacy

1. This term first occurs in Ohad Nachtomy, Ayelet Shavit, and Justin Smith, "Leibnizian Organisms, Nested Individuals, and Units of Selection," *Theory in Biosciences* 12, no. 2 (2002): 205–30. The notion of nested individuality is extensively developed in Ohad Nachtomy, *Possibility, Agency, and Individuality in Leibniz's Metaphysics* (Dordrecht: Springer, 2007). It is above all Nachtomy's work that has brought to our attention the importance of the notion of nestedness

for understanding Leibniz's notions of individuality and substance. Parts of this section overlap with the coauthored article.

2. G II 250.

3. Leibniz writes that "no entelechy ever lacks an organic body" (G II 251).

4. G II 251.

5. "A substance—that which is called a substance most strictly, primarily, and most of all—is that which is neither said of a subject nor in a subject, e.g., the individual man or the individual horse" (*Categories* 5 2a 11–13).

6. As much work in the contemporary philosophy of biology shows, moreover, biological organisms (or organism colonies) that do not easily fit with the commonsense view of individuality—that is, the view passed down from Aristotle—continue to pose conceptual difficulties. Philosophers admit that asexual protozoan or siphonophore colonies can be comprehended only with difficulty in terms of our commonsense intuitions about what a biological individual is, and the fact that these cases continue to be written about as threatening to our ordinary views about the biological world so long after phenomena such as parthenogenesis were first noticed by science shows just how entrenched the commonsense view of the biological world really is. See, in this connection, Jack Wilson, *Biological Individuality* (Cambridge: Cambridge University Press, 1999); John Dupré, *The Disorder of Things* (Cambridge, MA: Harvard University Press, 1993); Michael T. Ghiselin, "Natural Kinds and Supraorganismal Individuals," in *Folkbiology*, ed. Douglas L. Medin and Scott Atran (Cambridge, MA: MIT Press, 1999), 447–60.

7. Ludwig Feuerbach, *Darstellung, Entwicklung und Kritik der Leibnitz'schen Philosophie* (Ansbach: C. Brügel, 1837), 86.

8. David L. Hull, "Individuality and Selection," *Annual Review of Ecology and Systematics* 11 (1980): 314.

9. Peter van Inwagen, *Material Beings* (Ithaca, NY: Cornell University Press, 1995), 89.

10. Hull recognizes the ultimately arbitrary nature of our effort to get at the "true" individuals in nature. He writes: "Individuals are spatiotemporally localized entities that have reasonably sharp beginnings and endings in time … [i]t is only an accident of our relative size, longevity and perceptual acuity that we can see the distances between the organisms that comprise a species but not the even greater relative distances that separate the atoms that make up an organic body" (Hull, "Individuality and Selection," 313).

11. Eva Jablonka, "Inheritance Systems and the Evolution of New Levels of Individuality," *Journal of Theoretical Biology* 170 (1994): 301–9, at 301.

12. See Richard C. Lewontin, "The Units of Selection," *Annual Review of Ecology and Systematics* 1 (1970): 1–18; Robert N. Brandon, "The Units of Selection Revisited: The Modules of Selection," *Biology and Philosophy* 14, no. 2 (1999): 167–80.

13. G VI 599.

14. Robert Merrihew Adams, *Leibniz: Determinist, Theist, Idealist* (Oxford: Oxford University Press, 1994), 228.

15. Catherine Wilson, "Leibniz and the Animalcula," in *Studies in Seventeenth-Century European Philosophy*, ed. M. A. Stewart (Oxford: Clarendon Press, 1997), 174.

16. Jacques Roger, "Leibniz et les sciences de la vie," *Studia Leibnitiana Supplementa* 2, no. 2 (Wiesbaden: Steiner, 1969): 209.

17. It is radically new, at least, as a theoretical model of body. It is likely, however, that for a full account of the background to Leibniz's model of nested individuals, one would have to delve into the literary sources that constituted part of the broader cultural background of Leibniz's work. Worlds within worlds appear to be an important theme of baroque literature, but one that lies well beyond the scope of the present investigation. For an interesting account of the possible influence on Leibniz of one expression of this theme in seventeenth-century fiction, namely, Cyrano de Bergerac's *Les empires de la lune*, see Antonio Nunziante, "Continuity or Discontinuity? Some Remarks on Leibniz's Concepts of 'substantia vivens' and 'Organism,'" in *Machines of Nature and Corporeal Substances in Leibniz*, ed. Justin E. H. Smith and Ohad Nachtomy (Springer, 2011).

18. *Historia animalium* 611b.

19. *Historia animalium* 602b.

20. *Historia animalium* 548b.

21. See *Alexander von Tralles: Ein Beitrag zur Geschichte der Medicin*, vol. 2, ed. Theodor Puschmann (Vienna: Wilhelm Braumüller, 1878), 586–99.

22. Jack Wilson, *Biological Individuality*, chap. 1.

23. AG 105; see S 322–25; FdeC 317–23.

24. Couturat 522. "Nullum est corpus tam exiguum, quin sit actu subdivisum."

25. For a thorough and revealing treatment of Leibniz's complicated relationship to atomism, see Richard T. W. Arthur, "The Enigma of Leibniz's Atomism," *Oxford Studies in Early Modern Philosophy* 1 (2003): 183–227.

26. A VI ii, 280.

27. G II 111–29.

28. G II 118.

29. G II 184.

30. GM III/2 565.

31. G II 475.

32. G II 451.

33. GM III 565.

34. Catherine Wilson, *The Invisible World: Early Modern Philosophy and the Invention of the Microscope* (Princeton, NJ: Princeton University Press, 1995), 160.

35. Hartsoeker to Andry, February 26, 1699; in Nicolas Andry, *De la génération des vers dans le corps de l'homme* (Amsterdam, 1700), 232f.

36. Friedrich Christian Lesser, *Théologie des insectes, ou demonstration des perfections de Dieu*, 212–13. Originally published in German (Frankfurt, Leipzig: Blochberger, 1738; French edition, La Haye, 1742).

37. Ibid., 232–33.

38. Charles Bonnet, *Considérations sur les corps organisés* (Amsterdam, 1762), vol. 1, 131.

39. Balthasar de Monconys, *Journal des voyages de Monsieur de Monconys* (Lyons: Boissat and Remeus, 1665–66), vol. 1, 177; cited in Wilson, *The Invisible World*, 173.

40. G VI 586.

41. Wilson, *The Invisible World*, 76.

42. Christia Mercer, *Leibniz's Metaphysics: Its Origins and Development* (Cambridge: Cambridge University Press, 2001), 69.

43. G IV 64.

44. Robert Hooke, *Micrographia; or, Some Physiological Descriptions of Minute Bodies Made by Magnifying Glasses with Observations and Inquiries Thereupon* (London: Jo. Martyn and J. A. Allestry, 1665), preface, unpaginated.

45. Wilson, *The Invisible World,* 88–119.

46. G I 19.

47. WBG V/2, 302.

48. LH III 5, 111–12.

49. G VI 327.

50. A VI iv 953.

51. GM 641.

52. Hans Poser, "Leibniz' Parisaufenthalt in seiner Bedeutung für die Monadenlehre," *Studia Leibnitiana*, Supplement 18 (Wiesbaden: Steiner 1978): 131–44, at 141.

53. Ibid., 142.

54. Monconys, *Journal des voyages*, vol. 1, 177; cited in Wilson, *The Invisible World*, 173.

55. That is, the infection of the eyelids with pubic lice.

56. LH XXXVII, 2, 123v.

57. G II 92. As we will see in chapter 6, it is from the observation of grafting in plants that Leibniz and fellow Lutheran defenders of the doctrine of traducianism derive their account of the "splitting" of souls and the consequent transmission of original sin.

58. G V 296.

59. Antoni van Leeuwenhoek, *Alle de brieven van Antoni van Leeuwenhoek*, vol. 14 (Amsterdam: Swets and Zeitlinger B.V., 1996), 169. Interestingly, the eighteenth-century Danish naturalist Otto Friedrich Müller traces the history of experiments in parthenogenesis back to Aristotle and Augustine, though this may be more a convention characteristic of the prefaces to eighteenth-century scientific treatises than the expression of a genuine belief that premodern philosophy contributed anything of significance to the field of inquiry. Müller writes that "Aristotle, great in many ways, had already made remarks concerning the continuation of life in the divided insect, even concerning the centipedes." As for Augustine's contribution, Müller claims to know even the precise species of creature on which he experimented: "The Church Father Augustine had made similar experiments in Liguria with a long, many-footed earthworm, whereupon his students put him in something of a predicament. It is clear that Augustine's worm was a spiny worm, and quite likely even the same as ours; his description is much too clear for us to require any proof: it was no Polyp" (see Otto Friedrich Müller, *Vermium terrestrium et fluviatilium, seu animalium infusoriorum, helminthicorum et testaceorum, non marinorum, succincta historia* [Copenhagen and Leipzig: Heineck and Faber, 1773], 137 n. 9).

60. This argument may be traced in particular to Aram Vartanian, "Trembley's Polyp, La Mettrie, and Eighteenth-Century French Materialism," *Journal of the History of Ideas* 11 (1950): 159–86.

61. It is perhaps worth noting that Trembley began his career as a mathematician, obtaining his *Promotion* with a thesis on the infinitesimal calculus. See his *Theses mathematici de infinito et calculo infinitesimali* (Geneva: Marci-Michaelis Bousquet, 1730).

62. For an exhaustive account of Trembley's experiments and their scientific context, see Virginia P. Dawson, *Nature's Enigma: The Problem of the Polyp in the Letters of Bonnet, Trembley and Réaumur* (Philadelphia: American Philosophical Society, 1987).

63. Charles Bonnet, *Considérations sur les corps organisés* (Amsterdam: Marc-Michel Rey, 1762), vol. 1, 218. Bonnet himself offers this very interesting response to the metaphysical anxiety parthenogenesis had induced in his contemporaries: "I consider the existence of the souls of beasts as only probable, since it is only based on analogy: people who are led by sentiment go further; they decide upon the reality of its existence, and even the philosopher has trouble not following them. But in according a soul to the polyp, my reader apparently fears that I am preparing tortures for myself. Almost all men have in their mind certain metaphysical ideas on the basis of which they reason: almost all of them know, more or less, that the soul is a *simple* being, from which they easily conclude that it cannot be divided. How, then, can one bring about, with a single cut of the scalpel, many animals from a single worm or polyp? What surprises me the most is that the philosophers, like the common men, have to a certain extent limited themselves to sensing the difficulty, without making a proper effort to resolve it. It seems to me that they have in general regarded it as irresolvable. … They have contented themselves with admiring, and with declaiming upon the uncertainty of our knowledge in metaphysics. They would have done better to use their time thinking, rather than wasting it on discourses" (*Considérations sur les corps organisés*, vol. 1, 76–77).

64. Bonnet, *Considérations sur les corps organisés*, vol. 2, 71. Italics added.

65. Pierre-Louis Moreau de Maupertuis, *Système de la Nature*, in *Oeuvres* (Lyon, 1756; repr. Hildesheim: Olms, 1965–74), 137–84.

66. Müller, *Vermium terrestrium et fluviatilium*, 1–22.

67. C. G. Ehrenberg, *Die Infusionsthierchen als vollkommende Organismen. Ein Blick in das tiefere organische Leben der Natur* (Leipzig, 1838).

68. Ibid.

69. Müller, *Vermium terrestrium et fluviatilium*, "Genus Infusoria," no page numbers.

70. Roger, "Leibniz et les sciences de la vie," 218.

71. Julien Offray de La Mettrie, *L'homme machine*, in *Oeuvres philosophiques* (Hildesheim: Georg Olms, 1970), 286.

72. Denis Diderot, *Eléments de physiologie,* ed. Jean Mayer (Paris: Société des textes français modernes, 1964), 56.

73. Ibid., 56.

74. Ibid., 192.

75. Ibid., 189–91.

76. Wilson, "Leibniz and the Animalcula," 153.

77. Wilson attributes this view to Daniel Garber, "Leibniz and the Foundations of Physics: The Middle Years," in *The Natural Philosophy of Leibniz*, ed.

K. Okruhlik and J. R. Brown (Dordrecht: Reidel, 1985), 29ff.; and to C. D. Broad, *Leibniz: An Introduction* (Cambridge: Cambridge University Press, 1975), 83.

78. Wilson, "Leibniz and the Animalcula," 174.

79. Ibid., 175.

80. In the *Micrographia* of 1665, Robert Hooke describes the "cells" of cork, by which he means, as the term suggests, only small, roomlike cavities within it. In the eighteenth century, a number of authors (e.g., Haller, Lecat) described globules or bubbles in muscle tissue. As Ernst Mayr notes, though, "it took a century and a half after Hooke's first description before any real progress was made in the study of cells" (Mayr, *The Growth of Biological Thought* [Cambridge, MA: Harvard University Press, 1982], 653).

81. Georges Canguilhem, "Note sur les rapports de la théorie cellulaire et de la philosophie de Leibniz," in *La connaissance de la vie* (Paris: Vrin, 1998), 187.

82. Wilson, "Leibniz and the Animalcula," 153.

83. A II i 719.

Chapter 5
The Divine Preformation of Organic Bodies

1. G VI 544.

2. Letter to Schelhammer, December 6, 1680; Dutens II 2, 166.

3. Dutens II 2, 165.

4. See G VI 601.

5. Many of the significant points of this chapter were already developed in Justin E. H. Smith, "Leibniz on Spermatozoa and Immortality," *Archiv für Geschichte der Philosophie* 89, no. 3 (2007): 264–82.

6. For a late example of such popular work, see the treatise attributed to Albertus Magnus, *Die Heimligkeit des Weiblichen geschlechts* (Frankfurt: Sigmund Feyrabendt, 1581).

7. François Mauriceau, *Des maladies des femmes grosses et accouchées* (Paris, 1668), 69.

8. William Harvey, *Exercitationes de generatione animalium. Quibus accedunt quaedam de partu; de membranis ac humoribus uteri; & de conceptione* (London: Typis Du-Gardianis; Impensis O. Pulleyn, 1651).

9. For a thorough treatment of this aspect of Harvey's generation theory, see Guido Giglioni, "'Conceptus uteri/conceptus cerebri': Note sull'analogia del concepimento nella teoria della generazione di William Harvey," *Rivista di storia della filosofia* 48 (1993). See also James G. Lennox, "The Comparative Study of Animal Development: William Harvey's Aristotelianism," in *The Problem of Animal Generation in Early Modern Philosophy*, ed. Justin E. H. Smith (Cambridge: Cambridge University Press, 2006), 21–46.

10. G VI 544. Leibniz writes similarly to Arnauld in a letter of April 30, 1687: "We can probably say of [animals] … that they were already alive from the creation of the world, and that they will live to its end, and that since generation is apparently only a change consisting in growth, so death will only be a change consisting in diminution, which causes this animal to reenter the recesses of a world of minute creatures where perceptions are more limited."

11. G VI 543f.
12. G VI 543.
13. G VI 544.
14. See Jacques Roger, *Les sciences de la vie dans la pensée française du XVIIIe siècle* (Paris: Armand Colin, 1963); Peter Bowler, "Preformation and Preexistence in the Seventeenth Century: A Brief Analysis," *Journal of the History of Biology* 4 (1971): 221–22.
15. See Andrew Pyle, "Animal Generation and the Mechanical Philosophy: Some Light on the Role of Biology in the Scientific Revolution," *History and Philosophy of the Life Sciences* 9 (1987): 225–54.
16. For a good account of the eighteenth-century developments in the preformation-epigenesis debate, see Walter Bernardi, *Le metafisiche dell'embrione: Scienze della vita e filosofia da Malpighi a Spallanzani (1672–1793)* (Florence: Olschki, 1985); see also Shirley Roe, *Matter, Life, and Generation: Eighteenth-Century Embryology and the Haller-Wolff Debate* (Cambridge: Cambridge University Press, 1981).
17. AT VI, 45; cited in Dennis Des Chene, *Spirits and Clocks: Machine and Organism in Descartes* (Ithaca, NY: Cornell University Press, 2001), 32.
18. John Ray, *The Wisdom of God Manifested in the Works of His Creation* (London, 1691), 67f.
19. Georges Canguilhem perceptively notes that "historians of biology have very often connected the epigenetic conception of development to mechanistic biology, forgetting the close and almost necessary relationship that connects the theory of preformation to that same biology. Since a machine does not build itself, since there are no machines, in an absolute sense, to build machines, it was necessary that the living machine should have a connection to some machinist. . . . Insofar as [this machinist] was not perceivable in the present, he was presumed to have been there at the beginning and through the theory of the *emboîtement* of germs was able to meet the exigencies of intelligibility that sustained the theory of preformation" (Canguilhem, *Etudes d'histoire et de philosophie des sciences* [Paris: J. Vrin, 1983], 325f.). On Canguilhem's account, for second-wave mechanists such as Leibniz, preformation was the only way out of the evident failure of the Cartesian embryological program to account for conception and fetal development. Other scholars have argued that this account, on which preformationism or preexistence theory presented itself as an escape route from the dead-end into which mechanism had led embryology, is rather too simplistic. See in particular Karen Detlefsen's careful and helpful article, "Supernaturalism, Occasionalism, and Preformation in Malebranche," *Perspectives on Science* 11, no. 4 (2003): 443–83. While in general we agree with the account presented here, in the particular case of Leibniz, as we will see shortly, there can be no question but that for Leibniz one of preformation's strongest attractions is its ability to circumvent the evident inability of mechanism to account for generation.
20. J. F. Bertram, *Eine bescheidene Prüfung der Meinung von der Præexistentz oder dem Vorherseyn menschlicher Seelen in organischen Leibern* (Bremen: Saurmann, 1741), preface, no page numbers given. Bertram was an ardent anti-Wolffian (and, by extension, anti-Leibnizian) polemicist. In 1739, he published another work denouncing the theory of preestablished harmony, *Beleuchtung der*

Neu-getünchten Meynung von der Harmonia Praestabilita durch Veranlassung der jüngst-edirten Reinbeckischen Erörterung (Illumination of the Newfangled Opinion of the Preestablished Harmony in View of Reinbeck's Recently Published Discussion). Johann Gustav Reinbeck was a defender of physical influx theory who had been appointed by Friedrich the Great to lead a commission inquiring into the merits, or lack thereof, of the Wolffian philosophy. See Eric Watkins, "From Pre-Established Harmony to Physical Influx: Leibniz's Reception in Eighteenth Century Germany," *Perspectives on Science* 6, nos. 1 and 2 (1998): 136–203. Although Bertram had been opposed to both theories, it is interesting to note that he appears to understand the connection between preestablished harmony and preformation: in order for all substances to have always existed in a harmonious order of individually causally self-sufficient substances, these substances must have always preexisted in an organically embodied form.

21. Bertram, *Bescheidene Prüfung*, preface, no page numbers given.

22. Ibid.

23. Ibid.

24. Ibid., chaps. 10, 32.

25. Garden, "A Discourse concerning the Modern Theory of Generation," *Philosophial Transactions* (January 1691): 474.

26. G II 251.

27. G VI 620.

28. OH 179.

29. *De Trinitate*, Book III, chap. 9; in St. Augustine, *The Trinity*, trans. Stephen McKenna (Washington, DC: Catholic University of America Press, 1963), 112.

30. G VI 534.

31. A VI iv 427.

32. G VII 539.

33. See Jan Swammerdam, *Ephemeri vita, of, Afbeeldingh van 's menschen leven* (Amsterdam: Abraham Wolfgang, 1675).

34. Interestingly, the very term "spermatozoon" reveals an important conceptual confusion at the root of animalcular preformationism. In fact, spermatozoa are cells of the male body, just like any other, with the one difference that they are equipped with flagella that make self-motion possible. They are not, however, spermatic "animals," as their name suggests, no matter how strong the temptation to associate the capacity for self-motion with substantial individuality.

35. Ian Hacking, "Do We See through a Microscope?" *Pacific Philosophical Quarterly* 62 (1981): 305–22; repr. P. M. Churchland and C. A. Hooker, eds., *Images of Science* (Chicago: University of Chicago Press, 1985), 132–52.

36. See Elizabeth Gasking, *Investigations into Generation, 1651–1828* (London: Hutchinson, 1967), chap. 3.

37. K. E. von Baer, *De ovi mammalium et hominis genesi* (Leipzig, 1827). Translated by C. D. O'Malley in *Isis* 48, no. 148 (1956).

38. See Appendix 5.

39. In this connection, Leibniz's preformation theory has at least one feature in common with earlier, nonempirical theories of generation, such as that of Aristotle, that take the father to be the source of the future individual. As Françoise Heritier has argued from an anthropological point of view, the attribution of

primary, active responsibility for generation to the father is a widely recurring view in folk cultures, and indeed has had such a strong hold on the Western imagination as to find itself smuggled into recent scientific accounts of generation with alarming explicitness. She cites, for example, the article on "Fécondation" from the *Encyclopaedia universalis* of 1984: "The distinctive feature of female gametes is a particular metabolic regime. Once they are differentiated, these cells display an extraordinary inability to develop on their own. They enter into a state of physiological inertia, so that they are bound to die unless they are activated. It is in this way that the necessity of fecundation arises: *the male gamete fulfills the natural activating function*" (Heritier, *Masculin/Féminin I: La pensée de la différence* [Paris: Odile Jacob, 1996], 204).

40. Catherine Wilson, "Leibniz and the Animalcula," in *Studies in Seventeenth-Century European Philosophy*, ed. M. A. Stewart (Oxford: Clarendon Press, 1997), 158.

41. Catherine Wilson also notes a number of other important influences on Leibniz's thought about microscopy from around this period. Among these are the following: In 1676 Leibniz mentions Borel's experiments on cherry seeds in his discussion of Boyle's ideas about resurrection in *De sede animae* (A VI iii 478).

42. *Alle de brieven van Antoni van Leeuwenhoek*, vol. II, 335.

43. *Philosophical Transactions* 22, no. 268 (1700): 739–46, at 741. The letter he refers to is in *Philosophical Transactions* 12, no. 142 (1677): 1040–46.

44. This discovery certainly did not settle the matter. In a 1669 report to Oldenburg from Leiden, Samuel Colepresse worries that "it may be Hollanders have other Testicles than English men." In any case, Colepresse will not be the one to settle the matter. Commenting on De Graaf's search for an answer to this question through the collection of samples of human semen, he declares in evident exasperation: "Truelie should De Graaf desire ye experiment on me I should looke but soure on't" (*The Correspondence of Henry OIdenburg*, ed. and trans. A. Rupert Hall and Marie Boas Hall [Madison: University of Wisconsin Press, 1965–86], vol. 6, 193).

45. *Alle de brieven van Antoni van Leeuwenhoek*, vol. III, 19–21.

46. Ibid., vol. VII, 35.

47. Ibid., vol. XII, 317.

48. Ibid., vol. XXI, 270.

49. Ibid., vol. VII. 380f.

50. Ibid., vol. V, 209. Leeuwenhoek himself attributes this view to the physician Cornelis Bontekoe, a Cartesian iatrochemist.

51. Ibid, vol. V, 209.

52. Nicolas Andry de Bois-Regard, *De la génération des vers dans le corps de l'homme* (Amsterdam, 1700), 203.

53. François Duchesneau, *Les modèles du vivant de Descartes à Leibniz* (Paris: Vrin, 1998), 319.

54. G II 122.

55. G IV 478f.

56. G VI 601.

57. Duchesneau, *Les modèles du vivant de Descartes à Leibniz*, 251.

58. G III 564.
59. Ibid., 564f.
60. For example, G VI 601; G VI 619f.
61. Klopp 159.
62. G V 295.
63. Contrary to Bowler, who identifies metamorphosis as the spontaneous production of all parts after conception (Bowler, "Preformation and Preexistence in the Seventeenth Century: A Brief Analysis," 222), this term is used here to refer specifically to the development of new organs out of a preexisting organism, either at conception or at another significantly transformative moment, such as the emergence of an insect from a cocoon or, for Leibniz, death.
64. G VI 621.
65. Cotgrave's 1611 *Dictionarie of the French and English Tongues* translates "revestement" as "a reinuesting, reattiring, new clothing."
66. G VI 601.
67. G V 215–16. Italics added. Heliogabalus was a third-century Roman emperor, notorious for his gluttony and decadent behavior.
68. For example, *Difficultates circa naturam et originem animarum* (A VI iv 1494f., Summer 1683–Winter 1684/85); *De animarum creatione atque mentium origine* (A VI iv 1496f., Summer 1683–Winter 1684/85).
69. G IV 480.
70. Ibid.
71. Ibid., 481.
72. G VI 601.
73. Ibid.
74. See Daniel C. Fouke, "Spontaneity and the Generation of Rational Beings in Leibniz's Theory of Biological Reproduction," *Journal of the History of Philosophy* 29, no. 1 (1991): 33–45.
75. G VI 601.
76. A VI iv 1491.
77. Ibid.
78. I 136. "*μετενσωματοσις* id est, transcorporatio, qua est anima de corpore humano in corpus felinum migratio."
79. G II 99.
80. G VI 533.
81. Ibid.
82. Klopp-SC, 184f.
83. WBG 4, 17.
84. G III 349.
85. OCM I, chap. XI, 13.
86. Following Robert Sleigh, "mind-body concomitance" may be seen as a subdoctrine of the doctrine of preestablished harmony. The latter holds that the perceptions of all minds or mindlike monads are coordinated from the beginning to express the same order of coexistence without any real interaction between them. Since, however, this perception is always a perception of the world qua totality of bodies—created monads never perceive other monads directly—pre-

established harmony is always also an agreement between minds or mindlike substance and the world of bodies from which the minds are causally cut off.

87. For the most complete account of the similarities and differences between the philosophies of Malebranche and Leibniz, see André Robinet, *Malebranche et Leibniz: Relations personelles* (Paris: Vrin, 1955).

88. *Alle de brieven van Antoni van Leeuwenhoek*, vol. XXI, 270f.

89. G VI 541.

90. G IV 498.

91. *Alle de brieven van Antoni van Leeuwenhoek*, vol. V, 151.

92. *Alle de brieven van Antoni van Leeuwenhoek*, vol. VII, 35.

93. *Alle de brieven van Antoni van Leeuwenhoek*, vol. VII, 35.

94. *Alle de brieven van Antoni van Leeuwenhoek*, vol. VII, 35.

Chapter 6
Games of Nature, the Emergence of Organic Form, and the Problem of Spontaneity

1. Jonathan Swift, *Gulliver's Travels* (London: Penguin Books, 1994), 106–7.

2. Marsilio Ficino, *Three Books on Life*, ed. and trans. Carol V. Kaske and John R. Clark (Binghamton, NY: Medieval and Renaissance Texts and Studies, 1989), 323–25. For a thorough treatment of Ficino on imagination and embryogenesis and his relation to other thinkers on this topic, see Concetta Pennuto, *Simpatia, fantasia e contagio: Il pensiero medico e il pensiero filosofico di Girolamo Fracastoro* (Rome: Edizioni di Storia e Letteratura, 2008).

3. Antoine Goudin, *Philosophie suivant les principes de Saint Thomas*, trans. T. Bourard (Paris, 1864 [original ed. Paris, 1668]), 301: *Des corps mixtes inanimés, dit fossiles*. Thanks to Roger Ariew for bringing this work to my attention.

4. For a subtle discussion of the metaphysical grounds of Leibniz's theory of spontaneity, see Donald Rutherford, "Leibniz on Spontaneity," in Donald Rutherford and J. A. Cover, *Leibniz: Nature and Freedom* (Oxford University Press, 2005), 156-180.

5. *Directiones* 37.

6. G V 295.

7. See, for example, Andrew Pyle, who asks of Malebranche's acceptance of the theory: "Why does Malebranche endorse the old wives' tale? The empirical evidence in its favour is only anecdotal (of a kind that in other contexts he would dismiss with scorn); there is no remotely plausible mechanism to convey the supposed influence; the theory of pre-existence seems to render such an influence redundant. Everything, it seems, should militate against endorsing the old wives' tale" (Pyle, *Malebranche* [London: Routledge, 2003], 180).

8. See, e.g., Georges Canguilhem, *Le normal et le pathologique* (Paris: Presses Universitaires de France, 2003).

9. Pietro Pomponazzi, *Les causes des merveilles de la nature ou les enchantements*, ed. and trans. Henri Busson (Paris, 1930).

10. Lynn Thorndike, *History of Magic and Experimental Science*, vol. 7 (New York: Columbia University Press, 1947–64), 449.

11. Paracelsus, *De natura rerum* (1537), book 9, *Sämtliche Werke*, 4 vols. (Leipzig: Zentralantiquariat der Deutschen Demokratischen Republik, 1975).

12. *Directiones* 22.

13. See Aristotle, *Metaphysics*, book VI, chap. 2. Here Aristotle defines the "accidental" as that which fails to happen "always or for the most part."

14. Coimbricenses, *In phys*. Cited in Dennis Des Chene, *Physiologia: Natural Philosophy in Late Aristotelian and Cartesian Thought* (Ithaca, NY: Cornell University Press, 1996), 206f.

15. AT VI, 45.

16. AT II 254. Des Chene describes this entire process in wonderful detail in *Spirits and Clocks*. I am only interested in communicating a basic sketch of Descartes' concerns and limitations in his account of fetal development before moving on to what interests us here: the imagination theory and its use in mechanist embryology.

17. There were a number of two-seed theorists among the late Aristotelians for whom sexual reproduction would involve both a material and formal contribution from each of the two parents. Yet one may certainly ask how much these thinkers remain, at least in this regard, Aristotelians.

18. AT II, 525–26.

19. This distinction between the legitimacy of some aspects of physiognomy on the one hand and the fraudulence of chiromancy, astrology, and other such disciplines on the other seems widespread throughout the seventeenth century. Thorndike mentions a 1683 miscellaneous volume by Wilhelm ten Ryne that "upheld physiognomy but decried astrology and chiromancy and their association with physiognomy" (Thorndike, *History of Magic and Experimental Science*, vol. 7, 472). He also mentions François Bayle's *Dissertationes physicae*, in which the author "approaches the subject of physiognomy through the foetus. … By certain reactions certain parts of the body are nourished and strengthened more than others. The foetus is easily affected by the nervous juice. Other juices, too, excite reactions in the foetus, to which the mores and mode of life of the mother greatly contribute" (471). On this understanding, the mother is capable of transmitting moral as well as physiological traits to the fetus, and even this capacity is distinguished by its defenders from occult connections, such as that between the lines of the hand and a person's future.

20. AT III, 21.

21. Ibid., 49.

22. AT VI, 129.

23. AT XI, 177.

24. OCM I 243.

25. Ibid., 241f.

26. Ibid., 234.

27. Ibid., 242.

28. Pyle, *Malebranche*, 181.

29. OCM I, 243.

30. NO 7.

31. G IV, 433.

32. OCM I, 247.

33. Ibid., 246.

34. For a thorough account of Leibniz's engagement with this doctrine, see Richard T. W. Arthur, "Animal Generation and Substance in Sennert and Leibniz," in *The Problem of Animal Generation in Early Modern Philosophy*, ed. Justin E. H. Smith (Cambridge: Cambridge University Press, 2006), 304–59.

35. A II i 97–98.

36. Daniel Sennert, *Hypomnemata physica* (Venice, 1651), 54.

37. As an example of this way of thinking, in a letter to Mersenne of February 14, 1631, Jean-Baptiste van Helmont claims that sin leaves its mark on the bodies of sinners and their offspring, and that this marking is the foundation of physiognomy. For van Helmont, these marks might also come from the inclination of the stars, or directly from God. François Bayle, to cite a contemporary of Malebranche and Leibniz who has similar ideas about the acquisition of moral and physical traits, describes physiognomy effectively as a branch of embryology in his *Dissertationes physicae* of 1677. For him, the study of physical and moral traits is one that reads back from the adult to events in utero. In his view, as Thorndyke explains, "the foetus is easily affected by the nervous juice. Other juices, too, excite reactions in the foetus, to which the mores and mode of life of the mother greatly contribute" (see Thorndike, *History of Magic and Experimental Science*, vol. 7, 471). Later in the seventeenth century, there were, not surprisingly, many efforts to render the art of correlating physical traits with moral ones comprehensible in mechanistic terms. For example, in a remarkable article in the *Philosophical Transactions* of 1694 Owen Gwither acknowledges of this art that "most Men reject it as a Folly. … But upon strict Enquiry," he goes on, "I find reason to conclude that a sober Naturalist may find much truth in that Art, which may be useful, and well solve all its Phaenomena intelligibly, which has not been done by any one that I know. … But, lest it be mere folly, it needs to be accounted for in terms of the motion of animal spirits in the body: "The manner I conceive to be thus, the Animal Spirits moved in the Sensory by an Object, continue their motion to the Brain, whence the motion is propagated to this or that particular part of the Body as is most suitable to the design of its Creation, having first made an alteration in the Face by its Nerves, especially the Pathetick, and *Oculorum motorii*, actuating its many Muscles, as the Dial-plate to that stupendious piece of Clock-work, which shews what is to be expected next from the striking part" (*Philosophical Transactions* 18, no. 210 [1694]: 119).

38. Stuart Brown, "Malebranche's Occasionalism and Leibniz's Preestablished Harmony: An 'Essay Crossing' or an Unbridgeable Gap?" in *Nicholas Malebranche: His Philosophical Critics and Successors*, ed. Stuart Brown (Assen, The Netherlands: Van Gorcum, 1991), 116.

39. Catherine Wilson, "Leibniz and the Animalcula," in *Studies in Seventeenth-Century European Philosophy*, ed. M. A. Stewart (Oxford: Clarendon Press, 1997), 169.

40. NO 8.

41. As in, e.g., *Discourse on Metaphysics* § 16 (G IV, 441–42).

42. Henry More, *The Immortality of the Soul*, ed. A. Jacob (Dordrecht: Nijhoff, 1987), 70.

43. Ibid., 257.

44. Giuliano Gliozzi, *Adamo e il Nuovo Mundo: La nascità dell'antropologia come ideologia coloniale; dale genealogie bibliche alle teorie raziale (1500–1700)* (Florence: La Nuova Italia, 1977), 427.

45. Ibid., 432.

46. Plato espouses his myth of the earthborn men in the *Statesman*: "At the beginning of the cycle before our own … there was no such thing as the procreation of animals from one another, but they were born of the earth, and of this our ancestors, who came into being immediately after the end of the last cycle and at the beginning of this, have preserved the recollection" (*Statesman* 279d–271b). If the mythical character of this report makes it difficult to attribute a belief in the spontaneous generation of human beings to Plato, at least it serves as confirmation of La Mothe Le Vayer's claim that in antiquity such a view was widespread.

47. Gliozzi, *Adamo e il Nuovo Mundo*, 432.

48. Ibid.

49. GA II 3 736b29.

50. See C.S.F. Burnett, "The Planets and the Development of the Embryo," in *The Human Embryo: Aristotle and the Arabic and European Traditions*, ed. G. R. Dunstan (Exeter: University of Exeter Press, 1990), 113–22.

51. See Bruno Nardi, "La teoria dell'anima e la generazione delle forme secondo Pietro d'Abano," in *Saggi sull'Aristotelismo Padovano dal secolo xiv al xvi* (Florence: Sansoni, 1958), 1–17.

52. Of course, in the end Leibniz will also deny that corruption happens just as surely as he denies generation. Generation and corruption both will thus amount to varieties of alteration.

53. For another very interesting account of heterogenesis as an origin of plague, and indeed one that takes this topic as directly relevant to the metaphysical problem of the inherence of subordinate forms in bodies, see Daniel Sennert, *Quaestionum medicarum controversarum liber, cui accessit tractatus de pestilentia* (Wittenberg, 1609).

54. Athanasius Kircher, *Scrutinium physico-medicum* (Leipzig: Schüreri and Götzii, 1659), sec. I, chap. 7; cited in Harry Beal Torrey, "Athanasius Kircher and the Progress of Medicine," *Osiris* 4 (1938): 246–75, at 258.

55. Athanasius Kircher, *Scrutinium medico-physicum*; cited in Charles Singer, "Notes on the Early History of Microscopy," *Proceedings of the Royal Society of Medicine* 7 (1914): 247–79, at 278.

56. Nathaniel Highmore writes in his *History of Generation* of 1651: "From our own flesh, from other Animals, from Wood, nay, from every thing putrified, these imprisoned, seminal principles are muster'd forth, and oftentimes having obtained their freedom, by a kinde of revenge feed on their prison; and devour that which preserv'd them from being scatter'd" (Highmore, *The History of Generation* [London: John Martin, 1651], 27). Margaret Cavendish, in her *Observations upon Experimental Philosophy*, of 1666, would similarly explain that the "generation" of certain organisms may be accounted for entirely as an alteration in their source material: "I have mentioned in my *Philosophical Letters* that no animal creature can be produced by the way of metamorphosing, which is a change of motions in the same parts of matter; but (as I do also express in the same place) I mean such animals which are produced one from another, and

where the production of one is not caused by the destruction of the other; such creatures, I say, it is impossible should be produced by a bare metamorphosis, without transmigration or translation of parts from the generator: but such insects, as maggots, and several other sorts of worms and flies, and the like, which have no generator of their own kind, but are bred out of cheese, earth and dung, etc. their production is only by the way of metamorphosing, and not translation of parts" (Cavendish, *Observations upon Experimental Philosophy* [London: A. Maxwell, 1666], 37–38.).

57. Michel Fichant, "Mécanisme et métaphysique: Le rétablissement des formes substantielles (1679)," in *Science et métaphysique dans Descartes et Leibniz* (Paris: Presses Universitaires de France, 1998), 163–204, at 171.

58. G I, 19.

59. A VI ii, 241.

60. See G VI, 601.

61. G I, 20.

62. William R. Newman, *Atoms and Alchemy: Chymistry and the Experimental Origins of the Scientific Revolution* (Chicago: University of Chicago Press, 2006), 49.

63. Ibid.

64. G. W. Leibniz, "Protogaea G.G.L.," *Acta eruditorum Lips.* (January 1693): 40–42; repr. Barrande 198–201.

65. Bodemann, 231.

66. One of Conring's greatest preoccupations in this work is with the giants supposed to have previously occupied the region of Germany he is describing. Conring adduces paleontological evidence of their presence there, which, we may presume, in fact consisted in nothing other than dinosaur fossils. Leibniz as well is interested in the hominoid giants that once ruled the earth, and he treats them as a subject for paleontology, as in the *Protogaea*, and also as part of his project of what might be called "ethnohistory," tracing the origins of the current inhabitants of Europe. On the latter, see his *Epistola ad amicum, de titanis et gigantibus ex Scythia oriundis* (Letter to a Friend, on the Titans and Giants Originating from Scythia) (Dutens IV, 2, 209–10). One interesting question, far beyond our present scope, concerns the extent to which the widespread legends of giants, which would subsequently be incorporated into the historiography of Leibniz, Conring, Vico, and others, were themselves initially inspired by the observation of fossil remains.

67. See, in particular, his *De solido intra solidum naturaliter contento dissertationis prodromus* (Sketch of a Dissertation on the Solid That Is Naturally Contained within a Solid) (Florence, 1669). The "solid within a solid" to which Steno refers is the fossil embedded in rock. In December 1677, Leibniz meets Steno and is disappointed that as a result of his conversion to Catholicism and his newfound devoutness the Danish physician and geologist has abandoned his natural-scientific inquiries entirely. Leibniz writes to Conring on January 13, 1677: "He is a modest and, I believe, good man, very well-versed in anatomy and in natural philosophy in general, as you know. But now unfortunately he has abandoned this sort of studies" (II 1, 385; MK 50).

68. *Protogaea* V; Barrande 23.

69. See Leibniz's letter to Jean Gallois of October 1682; A II i, 834–35.

70. A I iii, 149–66. Certainly the most extensive account of the practical, technological, and economical aspect of Leibniz's mining endeavor is Jon Elster's *Leibniz et la formation de l'esprit capitaliste*, chapter 3, "Les mines de Harz." See also Jürgen Gottschalk, "Technische Verbesserungsvorschläge im Oberharzer Bergbau," in *Gottfried Wilhelm Leibniz: Das Wirken des großen Universalgelehrten als Philosoph, Mathematiker, Physiker, Techniker*, ed. K. Popp and E. Stein (Hanover, 2000), 109–32.

71. According to Elster, Leibniz's work on the Harz project was an expression of his rationalism, in view of its "constant concern for planning and implementation, so very different from the tentative empiricism of the epoch." Yet Elster maintains that Leibniz's work was nonetheless "condemned to failure by its very negligence of this empiricism, its disregard for detail, its tendency to confuse intention and realization" (Elster, *Leibniz et la formation de l'esprit capitaliste*, 78). Elster's historiographical orientation (Marxist) is one that rates ideas in history in view of their realizability at the practical level. Here, in contrast, we are mostly interested in the speculative aspect of Leibniz's engagement with geology, which could not in any case have been "tested" in real-world applications.

72. For a sustained treatment of the emergence of the science of geology out of natural-philosophical speculation about the distant origins of the earth and the cosmos, see Rhoda Rappaport, *When Geologists Were Historians* (Ithaca, NY: Cornell University Press, 1997).

73. *Protogaea* VI; Barrande 26.

74. §§ 2–3, Dutens II ii 201–2.

75. George MacDonald Ross, "Leibniz and the Origin of Things," in *Leibniz and Adam*, ed. Marcelo Dascal and Elhanan Yakira (Tel Aviv: University Publishing Projects, 1993), 241–57.

76. LH XXXVII, 4, 16r; cited in Claudine Cohen and Andre Wakefield, eds., *Protogaea* (Chicago: University of Chicago Press, 2008), xxvi–xxvii. For a thorough study of this important manuscript, see Claudine Cohen, "An Unpublished Manuscript by Leibniz (1646–1716) on the Nature of 'Fossil Objects,'" *Bulletin de la Société Géologique de France* 169, no. 1 (1998): 137–42.

77. G VI, 263.

78. *Protogaea* XXIX; Barrande 96. Leibniz is most likely referring here to Joachim Becher's *Physica subterranea* of 1669.

79. Couturat, *Op.* 445.

80. *Protogaea* XVIII; Barrande 69.

81. *Protogaea* XXIX.

82. *Protogaea* XXX.

83. *Protogaea* XVIII; Barrande 97. In their new English edition of the *Protogaea*, Cohen and Wakefield misleadingly translate the phrase "seminales, nescio quas ideas" as "some ideas about generation." But it is not a matter of what *observers* might have thought about the generation of fossils; rather, it is a matter of the formative principles in nature that were supposed by Leibniz's opponents to produce zoomorphic forms in what we would call "inorganic" matter.

84. Presumably, given Leibniz's commitment to postformation, he would be compelled to believe that wherever a fossilized fish is found, there must remain

somewhere in the vicinity some microscopic living body of a fish or former fish. The organic body, of which the fossil is a vestige, was never, strictly speaking, created, and can never be destroyed.

85. *Protogaea* XVIII; Barrande 95–97. The Latin reads: "Et sane plerumque video, quantoquisque in observando diligentior, et cum natura familiarior fuit, eo proniorem in nostram sententium visum, ut peritissimi viri merito animalium exuvias, aut aliarum rerum reliquias putent obrutas, nec facile persuaderi sibi patiantur, organica corpora sine exemplo, sine usu, sine seminiis praeter, naturae consuetudinem in limo saxove, ineptis matricibus, nescio qua plastica facultate natas."

86. *Protogaea* XVIII; Barrande 95–97.

87. *Protogaea* IX; Barrande 45.

88. *Protogaea* X.

89. In fact, both senses attached to the Greek term *automatos* as well, though the sense of "acting of one's own will" was far more common.

90. Friedrich Schiller, *On the Aesthetic Education of Man: In a Series of Letters*, ed. and trans. Elizabeth M. Wilkinson and L. A. Willoughby (Oxford: Clarendon Press, 1967), 11.

Chapter 7
The Nature and Boundaries of Biological Species

1. The classic and most forceful case for Leibniz's nominalism is Benson Mates's *The Philosophy of Leibniz: Metaphysics and Language* (New York: Oxford University Press, 1989). Here, Mates is principally concerned with the nonexistence for Leibniz of abstract entities such as numbers, geometrical figures, and other mathematical objects, and in this connection it is not surprising that Mates does not dwell on the fact that different considerations come into play for Leibniz when it is a question of the existence of biological kinds.

2. John Ray, *Historia plantarum*, vol. 2 (London, 1688); cited in John C. Green, *The Death of Adam: Evolution and Its Impact on Western Thought* (Ames: Iowa State University Press, 1959), 129. Leibniz frequently praises the work of Ray, writing, for example, in the *Protogaea* of the "diligent English investigator of the works of nature, John Ray [*diligens naturae operum investigator Joh. Raius Anglus*]" (*Protogaea* XXVI; Barrande 90).

3. For an account of the emergence of species fixism in the early modern period, along with an extensive bibliography for further reading, see Justin E. H. Smith, "'The Unity of the Generative Power': Modern Taxonomy and the Problem of Generation," *Perspectives on Science* 17, no. 1 (2008): 78–104.

4. For more thorough treatment of the Adamic language in the seventeenth century, see David S. Katz, "The Language of Adam in Seventeenth-Century England," in *History and Imagination: Essays in Honour of H. R. Trevor-Roper*, ed. Hugh-Lloyd Jones, Valerie Pearl, and Blair Worden (London, 1981), 132–45; Hans Aarsleff, *From Locke to Saussure: Essays on the Study of Language and Intellectual History* (Minneapolis: University of Minnesota Press, 1982).

5. Hieronymus Bock, *Neu Kreutterbuch* (Strasburg, 1577), preface, no page numbers.

6. John Ray, *Synopsis methodica stirpium Brittanicarum* (London: Smith and Walford, 1696), 30f.

7. John Ray, *De variis plantarum methodus dissertatio brevis* (London: Smith and Walford, 1696), chap. 6; cited in Scott Atran, *Cognitive Foundations of Natural History: Towards an Anthropology of Science* (Cambridge: Cambridge University Press, 1991), 164.

8. While here we are distinguishing between Leibniz's "classificatory realism" on the one hand and Locke's thoroughgoing nominalism on the other, the contrast may not be so great. Peter Anstey and Stephen Harris have argued that Locke as well has "realist" concerns in his very sophisticated interest in botanical systematics. See Anstey and Harris, "Locke and Botany," *Studies in History and Philosophy of Biological and Biomedical Sciences* 37 (2006): 151–71.

9. See John Dupré, *The Disorder of Things: Metaphysical Foundations of the Disunity of Science* (Cambridge, MA: Harvard University Press, 1993).

10. See, for example, Robert A. Wilson, "Realism, Essence, and Kind: Resuscitating Species Essentialism?"; Richard Boyd, "Homeostasis, Species, and Higher Taxa," both in *Species: New Interdisciplinary Essays*, ed. Robert A. Wilson (Cambridge, MA: MIT Press, 1999). Both authors argue, in different ways, that some kind of modified realism can be made to fit with an evolutionary account of species. For a classical statement of the view that evolutionary theory renders essentialism about species untenable, see David Hull, "The Effect of Essentialism on Taxonomy—2000 Years of Stasis (I & II)," *British Journal for the Philosophy of Science* 15, no. 69; 16, no. 60 (1965): 314–26; 1–18.

11. It is remarkable that from Locke through Kripke and beyond biological species are regularly adduced as examples in the discussion of the problem of natural kinds, alongside naturally occurring elements, as though these two different examples presented all and only the same problems. (See, for example, S. A. Kripke, "Identity and Necessity," in *Identity and Individuation*, ed. M. K. Munitz [New York: New York University Press, 1971], 135–64.) Of course, as Elliott Sober points out, atom smashers can now transform one element into another, but this is not in itself proof that elements are not, after all, natural kinds. Arguably, the immense difference between the relative ephemerality of, say, a species of finch on the one hand, and the relative fixity of, say, gold on the other, does at least problematize their interchangeability as stock examples for the discussion of natural kinds (see Elliott Sober, *Philosophy of Biology* [Boulder, CO: Westview Press, 2000], chap. 6).

12. Locke, *Essay concerning Human Understanding*, ed. Peter H. Nidditch (Oxford: Clarendon Press, 1975), 451–52.

13. OCM I, 243.

14. Nathaniel Highmore, *The History of Generation* (London: R. N., 1651), 15.

15. Ibid., 22.

16. Michael Ayers, *Locke, Volume II: Ontology* (London: Routledge, 1991). See Part I, chap. 6, "Species and Their Names in the Corpuscularian World."

17. G V, 284.

18. Anne Conway, *Principles of the Most Ancient and Modern Philosophy*, trans. and ed. Taylor Corse and Alison P. Coudert (1692; Cambridge: Cambridge University Press, 1996), 28.

19. Dutens VI 1, 213.

20. Conway, *Principles of the Most Ancient and Modern Philosophy*, 34.

21. The classic study of this idea and its long history is Arthur O. Lovejoy's *The Great Chain of Being* (Cambridge, MA: Harvard University Press, 1936).

22. Dutens II 2, 169.

23. G V, 271.

24. Dutens II 2, 171.

25. Ibid.

26. OH 414.

27. G V, 289–90.

28. Immanuel Kant, *Von den verschiedenen Rassen der Menschen*, in *Werke*. Band 9. (1775 [Darmstadt, 1964]); cited in Ernst Cassirer, *Die Philosophie der symbolischen Formen*. Band II: *Das mythische Denken* (Berlin, 1925), 180.

29. Ibid., 294.

30. Ibid., 281.

31. Ibid., 287.

32. Ibid., 288.

33. Ibid.

34. Dutens II 2, 171.

35. Ibid.

36. A VI iv, 1625.

37. Dutens II 2, 171.

38. G IV, 445.

39. LH III 1, 2, § 3.

40. NO 4.

41. NO Ad I, 135–36.

42. On Leibniz's take on the question of unicorns, see Roger Ariew, "Leibniz on the Unicorn and Various Other Curiosities," *Early Science and Medicine* 3, no. 4 (1998): 267–88.

43. "Extrait d'une lettre de Mr. de Leibniz, A l'Auteur, du Journal des Savans, écrite d'Hanovre le 18. Juin 1677. Contenant la Rélation, et la figure d'un Chevreuil coëffé d'une manière fort extraordinaire," *Journal des Sçavans*, July 5, 1677, 166–68; repr. Dutens II 2, 175–76.

44. E.g., G V, 290–91.

45. See, in particular, Lorraine Daston and Katharine Park, *Wonders and the Order of Nature, 1150–1750* (New York: Zone Books, 1998).

46. G V, 295.

47. Ibid., 289–99.

48. Ibid., 299.

49. Charles Darwin, *The Descent of Man*, in *Darwin: A Norton Critical Edition*, ed. Philip Appleman (New York: W. W. Norton, 1979), 202f.

50. Letter to Burnett de Kemney, 1696, in Barrande, 201. Leibniz was evidently very impressed by the mammoth bones uncovered in 1696. There are at least two

other letters from the same year in which he brings them up quite independently. In a letter to Grimaldi he writes: “Recently in Gotha, in Thuringia, the bones of a very large animal from the elephant genus were dug up. Curious men marvel that they are found in these parts. But indeed similar ones have been found by ploughing in Braunschweig, Brabant, and elsewhere. I likewise do not doubt that things are sometimes dug up in China that nowadays in those parts are not seen [walking] the earth, notice of which would be advantageous to Europeans in setting up comparisons” (OH 24). And in a letter to Bussingius of December 24, 1696: “I do not know whether you have seen what Tenzelius wrote about the skeleton of the elephantiform animal dug up in Thuringia. I agree entirely that it is from the animal, not the mineral, kingdom, but I do not know whether it is credibly said to be an animal transported here from distant lands by the waters of Noah’s flood. … And it is plausible that some were formerly marine or amphibious animals that today are at home on land” (OH 31).

51. August 22, 1696. C. L. Grotefend, *Leibniz-Album aus den Handschriften der Königlichen Bibliothek zu Hannover* (Hanover, 1846).

52. See Horst Bredekamp, *Gottfried Wilhelm Leibniz’ Theater der Natur und Kunst* (Berlin: Akademie Verlag, 2004), 125.

53. The so-called *A* version was the basis of Wolf von Engelhardt’s 1949 German translation of the *Protogaea*, as well as of the excellent new bilingual Latin-English 2008 edition by Claudine Cohen and Andre Wakefield. The *B* version, in turn, has been the basis of at least three editions (Scheidt 1749; Bertrand de Saint-Germain 1859; Barrande 1993). Cohen and Wakefield note that much of the *B* version shows signs of substantial editorial interpolation on the part of Eckhart (Leibniz’s executor) and Scheidt. In the case of the citation under discussion, however, it is unlikely that it comes from anyone but Leibniz himself. Bredekamp here cites the 1949 German edition, which reads as follows: “Einstmals, als der Ozean alles bedeckte, die Tiere, die heute das Land bewohnen, Wassertiere gewesen [seien], dann seien sie mit dem Fortgang dieses Elementes allmählich Amphibien geworden und haetten sich schliesslich in ihrer Nachkommenschaft ihrer urspruenglichen Heimat entwoehnt. … Doch solches widersprucht den heiligen Schriftstellern, von denen abzuweichen sündhaft ist” (*Protogaea*, ed. and trans. W. von Engelhardt [Stuttgart, 1949], 25).

54. *Protogaea* VI; Barrande 26.

55. *Protogaea* XXXIV; Barrande 126.

56. The American paleontologist George Gaylord Simpson wrote in 1951: “Discontinuities are more frequent and of more varied sorts in paleontology than in neontology. This has certain disadvantages for paleontological theory and interpretation, but it also has some practical advantages. Discontinuities of observation, only, due to inadequate sampling of local populations or inadequate distribution of sampling stations, occur in both fields but are generally harder to fill in when paleontological. Discontinuities of record, that is, in the organisms actually present and available for sampling in the field, are a particular paleontological problem and may concern both time and space. When samples have been obtained from different localities or horizons, rocks and fossils intermediate between them may not exist. Such discontinuities are, as of now, facts in nature. Their use to delimit taxonomic groups is non-arbitrary, by definition. Yet they

do not necessarily coincide with any particular sort of discontinuity that existed when the organisms were alive. Hence their relationship to the sorts of units defined in neontology may be and remain ambiguous." George Gaylord Simpson, "The Species Concept," *Evolution* 4 (1951): 285–98, at 291.

57. G V, 296.

58. Ibid., 305.

59. Marin Cureau de la Chambre, *A Discourse of the Knowledge of Beasts, Wherein All That Hath Been Said for, and against Their Ratiocination Is Examined* (London: Thomas Newcomb, 1657), 3.

60. Ibid., preface, no page numbers given.

61. John Bulwer, *Anthropometamorphosis: A vievv of the people of the vvhole vvorld* (London: Thomas Gibbs, 1658), 445. Remarkably little has been written about Bulwer's anthropology. He is widely and rightly cited as a significant contributor to the development of the field of sociolinguistics and to the study of gesture, having published five books on the semiotics of the human body. On this aspect of his work, see Jeffrey Wollock, "John Bulwer (1606–1656) and the Significance of Gesture in 17th-Century Theories of Language and Cognition," *Gesture* 2, no. 2 (2002): 227–58.

62. Thomas Willis, *De anima brutorum* (1672) in *Opera omnia*, 76. For Willis's most extended treatment of the brain and its functions, see his *Cerebri anatome* (London, 1664). For a general overview of Willis's work, see T. J. Hughes, *Thomas Willis: His Life and Work* (London: Royal Society of Medicine Services, 1991). For an interesting discussion of Willis's easy passage between anatomy and psychology, see William F. Bynum, "The Anatomical Method, Natural Theology, and the Functions of the Brain," *Isis* 64, no. 4 (December, 1973): 444–68. For a fairly extensive treatment of Willis's place in the history of neurology, see William Feindel, "The Beginnings of Neurology: Thomas Willis and His Circle of Friends," in *The History of Neurology: The British Contribution, 1660–1910*, ed. F. C. Rose (Oxford: Butterworth-Heinemann, 1999), 1–18.

63. "Exposé d'une lettre de M. Leibnitz à l'abbé de Saint-Pierre sur un chien qui parle," *Histoire de l'académie des sciences* 1706; Dutens II 2, 180.

64. Richard Serjeantson, "The Passions and Animal Language," *Journal of the History of Ideas* 62, no. 3 (2001): 425–44, at 428.

65. AT V, 344–45.

66. A VI iv 1474.

67. Locke, *Essay concerning Human Understanding*, 450–51.

68. *The City of God against the Pagans*, ed. R. W. Dyson. (Cambridge: Cambridge University Press, 1998), Book XVI, chap. 8.

69. G V, 217.

70. Edward Tyson, *Orang-Outang, sive, Homo sylvestris, Or, the Anatomy of a Pygmie, compared with that of a Monkey, an Ape, and a Man* (London, 1699), 28.

71. Ibid., Epistle Dedicatory, no page numbers.

72. For a thorough account of Tyson's study of the porpoise, see L. Kruger, "Edward Tyson's 1680 Account of the 'Porpess' Brain and Its Place in the History of Comparative Neurology," *Journal of the History of the Neurosciences* 12, no. 4 (2003): 339–49.

73. Edward Tyson, *Phocaena; or, The Anatomy of a Porpess, dissected at Greshame Colledge; with a Praeliminary Discourse concerning Anatomy, and a Natural History of Animals* (London: Benjamin Tooke, 1680), 16–17.

74. Tyson, *Orang-Outang*, 7.

75. Ibid., 55.

76. Ibid., preface, no page numbers.

77. Ibid., 51f.

78. Ibid., 52.

79. Ibid., 54–55.

80. Ibid., 14.

81. G V 254.

82. James Burnet, Lord Monboddo, *Of the Origin and Progress of Language* (Edinburgh, 1773), vol. 1, book 2, chap. 4, 347.

83. G V, 293.

84. Tyson, *Orang-Outang*, preface, no page numbers.

85. A IV i, 208.

86. "Definitiones notionum ex Wilkinsio" (1677–86[?]), A VI iv 30–34. "*Catena* est series rerum talis, ut initium posterioris sit ante finem prioris. *Race*, genus, Geschlecht. Series generationum. *Genealogia* seriei hujus Explicatio," 34.

87. Peter Fenves, "Imagining an Inundation of Australians; or, Leibniz on the Principles of Grace and Race," in *Race and Racism in Modern Philosophy*, ed. Andrew Valls (Ithaca, NY: Cornell University Press, 2005), 73–89, at 73f.

88. OH, 36–38.

89. OH, 158. The paraphrase reads, in part: "Nova terrae divisio per diversas hominum species vel generationes, quas magnus peregrinator misit Domino Abbati della Chambre, Parisino, extat in Diario Eruditorum Parisino A. 1684. d. 24. April. Res huc redit. Geographi terram per regiones (gubernationes potius) dividunt. Ego quinque species vel generationes observo. Prima continet homines Europae, parte Moscoviae excepta; His addo littus Africae a Nilo ad columnas Herculis, Imperium Turcicum, Persicum, Mogolis, Golcondam, Visapur, Maldivas, partem regionum Arakan, Pegu, Siam, Sumatrae, Bantam, Borneo. Equidem non parum differre Indos a nostris negari non potest, non satis tamen ut speciem faciat differentem. Secunda species est Africanorum: Grandia labra, naso scaffo o simo, paucissimis labia mediocria, nasusque aquilinus. Nigredo non a Sole, sed natura, nam & transplantati retinent nisi coniugia misceantur. Cutis levis, polita, mollis & velut oleosa, exceptis locis ubi Sole velut torrentur. Barbae vix tres quatuorve pili, capilli lanae similes, ut canum, quos barbettos dicimus. Dentes ebore candidiores, lingua corallii rubedine. Tertia species implet partem regnorum Arakam, Siam, Sumatrae, Borneo, tum Philippinas vel Manillas, Japoniam, Pegu, Tunkinum, Cocincinam, Chinam, Tulariam intra Chinam, Gangem, Moscovi sitam, Usbek, Turkestan, Zagetai partem Moscici Imperii; Tartaros Europaeos & Turcomannos versus Euphratem & Aleppum habitants. His omnibus color albus, sed humeri largi, facies plana (viso piatto,) nasus exiguus (picciolo & schiacciato) oculi exigui & porcini, (lungi & incavati) & pauci in barba pili."

90. For an impressively detailed account of this voyage, see André Robinet, *G. W. Leibniz: Iter italicum (mars 1689–mars 1690). La dynamique de la république des lettres* (Florence: Olschki, 1988).

91. Ibid.

92. Richard H. Popkin, "Leibniz and Vico on the Pre-Adamite Theory," in *Leibniz and Adam*, ed. Marcelo Dascal and Elhanan Yakira (Tel Aviv: University Publishing Projects, 1993), 377–86, at 381.

93. Cited in Anthony Pagden, *The Fall of Natural Man* (Cambridge: Cambridge University Press, 1982), 138.

Appendix 1
Directions Pertaining to the Institution of Medicine (1671)

1. Jan Marek Marci (1595–1677), a Bohemian physician and astronomer, and the author of *De proportione motus seu regula sphygmica* (1637).

2. Santorio Santorio (1561–1636), a Paduan physician and author of *De statica medicina* (Venice, 1614). The concept described in the title would best be translated as "medical measurement."

3. Francesco Eschinardi (1623–1700[?]), an Italian Jesuit mathematician and astronomer. Leibniz is referring here to his "Difetti di termometri," in *Giornale de Letterati* (February 22, 1670), 22f.

4. Lodewijk De Bils (Ludovicus Bilsius) (1624–1671) was a self-taught Dutch anatomist, widely known for his proposals for the preservation of corpses.

5. This is a reference to Philipp von May, *Chiromantia medica: Mitt einem anhang von den zeichen auff den Näglen der Finger. Nebens einem Tractätlein Von der Physiognomia Medica* (Den Haag, 1667).

6. Moyse Charas was a Parisian pharmacist and the author of the *Pharmacopée royale galénique et chimique* of 1676.

7. This is evidently a play on words alluding to the tarantella, an Italian folk dance that, like the spider, derives its name from the southern Italian town of Taranto. The dance itself may have originated in ritualized contortions intended to alleviate the effects of spider bites. These would not in fact be the bites of tarantulas, however, since in that region tarantulas are not venomous. In any case, to be "bitten by the tarantula," in Leibniz's usage here, is to be overtaken by an urge to dance upon hearing a seductive melody.

8. See *Republic* IV 424c.

9. This is a reference to the tropical hardwood *Pterocarpus indicus*, a naturally fluorescent substance whose properties had been studied by, among others, Kircher and Boyle.

10. "Antimonium crudum" is an addition in the manuscript. Leibniz probably intended to write "Antimoniale" instead of "Antimonachale." Either way, what he has in mind is sulfide of antimony.

11. Laurenz Scholz, a German physician and author of, among other works, the *Consiliarum medicinalium* (Frankfurt, 1598).

12. Marcus Meibom (ca. 1630–1710), a Danish scholar. Leibniz is here referring to Meibom's *Epistolae de longaevis ad serenissimum celsissimumque principem ac dominum Dn. Augustum ducem Brunsvicensem ac Lunaeburgensem octogesimum sextum annum agentem* (Helmstedt, 1664).

13. Daniel Ludwig (1625–1680), a German pharmacist and the author of the *Pharmacopoeia ludoviciana*, which went through a number of editions. The earliest edition we have succeeded in locating is the *Pharmacopoeia ludoviciana, seu medicamentorum sylloge quae in prompta asservanda velit Clariss. D. Ludovicus* (London: G. Sawbridge, 1712).

14. That is, Francis Bacon. See his *Historia vitae & mortis. Sive, Titulus secundus in historia naturali & experimentali ad condendam philosophiam: quae est instaurationis magnae pars tertia* (London: Haviland, 1623).

15. That is, raw.

16. This is a reference to the Venetian traveler Lazaro Soranzo's *L'Ottomanno* (Ferrara, 1599).

17. See note 7.

Appendix 3
The Human Body, Like That of Any Animal, Is a Sort of Machine (1680–83)

1. In the *Specimen Inventorum* of 1688(?) Leibniz describes the *Elastrum* as "causam impulsus corporis a corpore esse ipsum corporis Elastrum, quo ab alio resilit" (VI iv, 1620). The Greek terms *ἐλατήρ* and *ἐλαστιχός*, for which no equivalent had existed in Latin, were introduced by Jean Pecquet in 1654 in connection with his research on the atmosphere. They were then taken up by Boyle who in 1660 writes of the "*ἐλατήρ*, or elastical power of the air" (Boyle, *New Experiments Physico-Mechanicall, Touching the Spring of the Air, and Its Effects* (London, 1660), I, *Exp.* 1. See Pasini, *Corpo e funzioni cognitive in Leibniz*, 1996, 123.

2. See "Extrait d'une lettre de M. Leibniz à l'auteur du Journal touchant le principe de justesse des horloges portatives de son invention," *Journal des Sçavans* (1675); repr. Dutens III 135–37.

3. It is a well-known theme from Aristotle's biology that sexual reproduction amounts to a sort of approximation of eternity in kind, if not in number. See Aristotle, *De Generatione animalium*, II 1 731b 33–36.

4. See Girolamo Cardano, *De subtilitate*, in *Opera omnia* (Lyon, 1663), III, 359–60.

5. The registers of furnaces are holes or notches in the wall of the furnace that enable one to place whatever is to be heated at various distances from the fire.

6. In June 1682, Leibniz composes a short work on the "Compositio des Feuers oder pyropi" for Tschirnhaus (GM IV, 497–98).

7. In animals, the parenchyma (pl.: parenchymata) is the tissue characteristic of a functioning organ, as contrasted with any connective or supporting tissue; that is, parenchymata are any elements of an organ essential to its functioning, in contrast with the stroma or framework of supporting tissue.

8. Bartholin in contrast cites Galen's authority to affirm that the heart is not a muscle: "Galenus recte negavit cor esse musculum, 1. Quia omnis generis fibras habet. 2. Quia musculus est motus voluntarii instrumentum" (*Anatomia Reformata*, II vi, 238–39).

9. See Descartes, AT VI 46, 7–8.

10. With Pasini, *Corpo e funzioni cognitive in Leibniz*, 1996, we note that in the *Hypothesis physica nova* of 1671 (A VI ii 240–41), Leibniz makes no mention of the ebullition of nonhomogeneous fluids. This topic is first treated in the *Propositiones quaedam physicae* of 1672 (A VI iii 48–49).

11. This last sentence is one of the hardest in the manuscript to decipher, and likely for that reason Mahrenholtz, "Leibniz' Literaturquellen zu einigen frühen Texten medizinischen Inhalts," 1990, misreads it as claiming that for Leibniz an animal *is* a hydraulico-pneumatic machine (353).

12. That is, if it does not find a ready food source, it will at least know how to prepare its food.

13. Reference is to the third edition of the *Anatomia reformata* of the Danish anatomist Thomas Bartholin (1616–1680), published in several editions beginning in 1651. See *Anatome, ex Caspari Bartolini parentis Institutionibus … quartum renovata* (Louvain, 1673).

14. Here Bartholin devotes a section of the chapter, "De corde in genere," to the question, "an facultas pulsifica admittenda?" In his lengthy answer, he notes that "facultas pulsifica cordi insita ad motum ejusdem cum sanguine necessario est conjugenda, sive ut sanguinis in fluxum & exitum juvet dirigatque, inordinate alioquin procedentem, sicut ego explico: sive ut per se producat motum, ex sententia antiquoru, qui conservari non potest, si sanguinis perpetuus fluxus inhibeatur" (*Anatomia Reformata*, II vi, 255). Leibniz disagrees with Bartholin to the extent that he seems to see the pulse as explicable entirely in the same terms as other instances of elasticity.

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