# Biology and Ideology from Descartes to Dawkins

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CHAPTER TWO

# Biology, atheism, and politics in eighteenth-century France

*Shirley A. Roe*

In eighteenth-century Europe, many intellectuals (often called *philosophes*) worried about the specter of atheism. Referring to the question raised by the skeptic Pierre Bayle, "Could a society of atheists be a moral one?," major figures such as François-Marie Arouet de Voltaire (1694–1778) refuted atheism at every turn. One arena for these debates was that of living organisms, where questions about generation (reproduction) occupied center stage. Just as in the nineteenth century, when the evolution of living things became an explosive issue, or the twentieth century, with its controversies over when individual human life begins, how the process of generation could be explained in the eighteenth century led not only to biological but also to religious and political questions. How the natural world operates and how we understand it have been repeatedly at the center of major controversies that have spilled over into the realms of religion and politics.

One answer to the question of generation that was popular in the eighteenth century was preformation, the belief that "germs," pre-organized matter from which all organisms would ever be developed, had existed since the Creation, when they were directly created by the hand of the Divinity. Encased within one another (the theory of *emboîtement*), all germs existed in the first member of each species. By involving God's creative power in every future instance of reproduction, preformation came to be seen by many as a bulwark against the immorality to which

atheism would inevitably lead. By contrast, the theory of epigenesis, which explained each instance of reproduction as the formation of an organism out of unorganized matter, was thought by many to open the door to materialism and atheism. Major naturalists at mid-century, such as Charles Bonnet (1720–93) and Albrecht von Haller (1708–77), combined scientific evidence in favor of the preexistence of germs with arguments concerning the existence of God. Even one of the century's major opponents of preformation, John Turberville Needham (1713–81), explained to Bonnet late in his life that he had undertaken to produce a new theory of generation not based on preexistence precisely because that theory, which he thought would collapse under the weight of new evidence, had provided one of the best defenses against atheism. Needham wanted to forestall the triumph of materialism and atheism by providing a new nonpreformationist foundation for religion and morality.[1]

In the eighteenth century, moral behavior was generally believed to rest on a belief in God and in a future day of judgment. Revealed religion, that is religious belief based on God's having revealed himself to mankind through revelation and miracles, was still very widespread. Natural religion, belief in God based on understanding and admiring the created world, was certainly increasing as a complement to revealed religion, as was deism, which based religious belief solely on the order and harmony present in nature. Deism was much more threatening to some because of its proximity to atheism. Yet whether as deists or as believers in revealed religion, naturalists and natural philosophers viewed nature as evidencing God's design and as providing a foundation for religious belief. Were nature to be separated from God as creator and explained solely in terms of natural or material categories, this source of religious belief would be seriously threatened. And thus the foundations of morality and social order could be undermined.

Furthermore, a self-creative nature, one based on active matter, would exhibit no preordained order, only an order born out of material interactions. Human beings, as part of nature, would now have to be understood as part of this material, continuously active nature, rather than as part of a divinely ordered system. Thus a new naturalistic basis for moral behavior, one resting on human nature rather than on divine rules, would have to be developed to replace religion. Those who supported materialism, the self-creative activity of matter, such as Denis Diderot (1713–84) and Paul-Henri Thiry d'Holbach (1723–89), welcomed the new biological evidence and set out to develop a natural basis for morality and society.

But why in the mid-eighteenth century did generation become the central arena in which these contradictory views clashed? Why did naturalists and *philosophes* such as Voltaire point to preformation in particular as a counteracting force to atheism? The answer is twofold. First, the rise of belief in the preexistence of germs in the late seventeenth century was directly tied to concerns over the limitations of the new mechanical philosophy. Whether matter and motion could be sufficient to produce new organisms at reproduction was doubted by many (although not by René Descartes). The complexities and regularities of living organisms seemed to be beyond the capabilities of mechanical interactions. Furthermore, mechanism, especially in its Cartesian form, skirted close to the edges of atheism. If God could have created the universe by simply creating all of the matter and adding the initial motion to start things off, was there not a danger that such a philosophy could easily lead to a denial of the necessity for God at all? Preformation by preexistence provided a solution to both of these problems.

The second way in which generation theory brought the atheism question to the fore was that new evidence was discovered for active matter and a self-creative nature. Observations of very small and microscopic creatures by Abraham Trembley (1710–84), Georges-Louis Leclerc, Comte de Buffon (1707–88), and Needham indicated that preexistence might not be the norm in the microscopic world. This new evidence directly challenged the hold preformation had maintained over generation theory for more than a half-century. The result was a resurgence of preformationist research and thinking, especially in the work of Bonnet, Haller, and Lazzaro Spallanzani (1729–99), as well as the rise of a truly materialist view of living phenomena, in the hands of Diderot. This placed generation theory at the heart of the debates over biological materialism that dominated the 1750s, 1760s, and 1770s. The implications for atheism and consequently for morality of a self-creative nature without preexistent germs was obvious to both sides—worrisome to the preformationist, provocative to the materialists.

But it was not only naturalists and *philosophes* who worried about the implications of material activity and generation. These concerns entered the political sphere as well, especially in France in the 1750s and 1760s, when controversies between King Louis XV and the Paris Parlement over political power, an attempted assassination of Louis himself, and increased censorship of radical or atheistic publications brought the problem of the generation of living organisms into the realm of political controversy. Not

only was active matter seen as providing a foundation for atheism and immorality but for challenges to the political hierarchy as well. If all living organisms (including human beings) had been created as part of an ordained political order, preformationism provided good evidence for maintaining the status quo of a stable society with an unchangeable religious and political hierarchy. But if material activity produced all that we know in nature, without divine guidance, then the traditional view of a monarchical society could be undermined. Concerns over the implications of these new views of nature entered the political realm of debate in the storm of protest over the *Encyclopédie* and other scandalous works that erupted in the late 1750s.

In this chapter I look first at the rise of preformationist thinking in the late seventeenth century. I then turn to the biological evidence that challenged preexistence in the mid-eighteenth century and to the reaction this provoked among the preformationists. I also focus on the work of Voltaire and Diderot to illustrate the connections between the generation debates and the materialism question more widely. Finally, I demonstrate how these controversies about nature entered the wider political debate in France.

## Mechanism and the preexistence of germs

The theory of the preexistence of germs, or preformationism, arose in large part as a reaction to Cartesian mechanism. René Descartes (1596–1650), whose goal was to explain all natural phenomena on the basis of matter and motion alone, extended his work on physical nature to human physiology, writing his treatise *L'Homme* in the 1630s (Figure 2.1).[2] Yet the key to generation eluded him for another decade, and it was not until shortly before his death in 1650 that he finally worked out his explanation for the mechanical formation of animal embryos from the mixing of semen from both parents, through a fermentation of particles. His resulting treatise, *De la formation du foetus*, appeared posthumously with his earlier physiological work in 1664. (Descartes, a Catholic, had feared reprisals from the Catholic church after the condemnation of Galileo and did not publish these works himself.) Descartes' mechanistic explanation of generation based solely on matter in motion was for him the capstone of his mechanistic view of life. The organism that was to result from reproduction was, he believed, determined by the matter out of which the two semens were


FIGURE 2.1 Mechanical coordination among eyes, brain, muscles, and nerves as the finger points to different spots on the arrow. (From René Descartes, *L'Homme*, 1664. Courtesy of Yale University, Harvey Cushing/John Hay Whitney Medical Library.)

made and the mechanical process that ensued upon their mixing. As he put it, "If one knew what all the parts of the semen of a certain species of animal were, for example, particularly of man, one could deduce from this alone, by reasons entirely mathematical and certain, the whole figure and conformation of each of its members."[3]

Descartes' theory, however, was seen by others as both insufficient and disturbing. Nicolas Malebranche (1638–1715), who first formulated a theory of the preexistence of germs in 1674, was responding directly to Descartes when he wrote, "The rough sketch given by this philosopher may help us to understand how the laws of motion are sufficient to bring about the gradual growth of the parts of an animal. But that these laws should form them and link them together is something no one will ever prove. Apparently M. Descartes recognized this himself, for he did not press his

ingenious conjectures very far." As a Cartesian in physics, Malebranche believed that God's role in the physical universe was limited to his having imparted the initial motion that then would be communicated from body to body for as long as the world existed. The question regarding generation was: "Could this communication of motion from one particle of matter to another be sufficient to create a new organism?" Malebranche thought not and found evidence in the tulip bulb, in which he saw, using a magnifying glass, the folded up parts of the future tulip plant. Others believed they had seen the same thing in chicken and frog eggs. These observations made sense to Malebranche because "it is easy to see that the general laws of communication of motion are too simple for the construction of organized bodies." Rather, motion was the means by which God's initial creative act was to be carried out through all future time: "At the time of the Creation he constructed animals and plants for all future generations; he established the laws of motion that were necessary to make them grow. Now he rests, for he does nothing other than follow these laws."[4] As to the question of how all future organisms of each species could possibly be contained in their first representative created by God, Malebranche argued that because matter is infinitely divisible (another Cartesian position), this is at least conceivable. But what is not conceivable, he maintained, is that the laws of the communication of motion themselves could create new organisms at each generation. Thus preexistence combined mechanistic physics with the Cartesian view of God's initial involvement in our world. After creating the matter out of which it would form and imparting to it the initial necessary motion, God ceased to be directly involved in natural phenomena.

Malebranche was well aware of microscopic research being done by his contemporaries, and he referred to Marcello Malpighi's observations on chick eggs (Figure 2.2) and Jan Swammerdam's on frog eggs to support his ideas on preexistence. Swammerdam had proposed the preexistence of germs in a Dutch work of 1669, which became more widely available in Latin in 1672. Malpighi's observations on chick development, published in 1673, gave clear evidence that the rudiments of the embryo could be seen in a fertilized egg that had not yet been incubated (but not in an unfertilized egg). Even so, Malpighi's observations, along with Swammerdam's, were often cited as evidence for the preexistence of the tiny preformed organism in the chick egg or the frog egg, or in the plant seed.[5]

Yet the fact that these observations were immediately taken up by those making preformationist claims indicates that the concept of

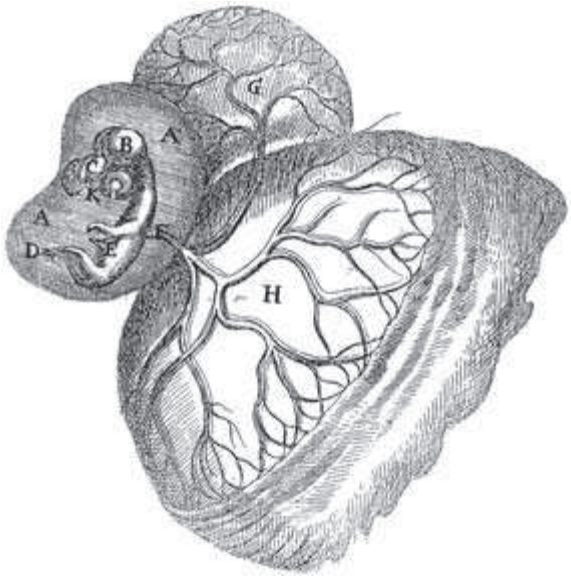


FIGURE 2.2 Chick embryo at six days. (From Marcello Malpighi, *Opera omnia*, 1686.)

preexistence was not one that grew out of observational evidence alone. It is clear, as several scholars have pointed out, that preformation through preexistence was a theory that responded more to philosophical than to observational needs. Jacques Roger was the first to explore the ties between preexistence of germs and mechanism, and to point out that, because the mechanistic view of the universe rested on passive matter and a non-interventionist God, preexistence made very good sense: "nature as a whole . . . , by becoming a complex of mechanisms, had lost all spontaneity and become pure passivity in the hands of God, the God who had created it and was now content with simply maintaining its existence and motion. In the last analysis, nothing appeared in nature that did not come from the original creation of all things."[6]

Furthermore, as in the case of Malebranche, one of the principal motivations behind preformationist theories was the need to combat the implications that trying to explain generation mechanistically without preexistence would entail. Although it was widely believed in the late seventeenth century that the universe must operate through mechanical laws, it was also felt that these laws were not sufficient to account for its origins and especially for the construction of living organisms. Claude

Perrault, another early proponent of development through preexistent germs, made explicit such a concern over the limits of mechanical laws. As he remarked in 1680, "I do not know if one can comprehend how a work of this quality would be the effect of the ordinary forces of nature . . . for I find finally that it is scarcely more inconceivable . . . that the world has been able to form itself from matter out of chaos, than an ant can form itself from the homogeneous substance of the semen from which it is believed to be engendered."[7]

The preformation–mechanism synthesis was very successful. Although there was some early opposition among a few mechanists, preexistence became the dominant theory by 1705 and remained so until mid-century. Among its supporters one can cite a number of figures who did not agree in many other aspects of their philosophies, including, for example, Hermann Boerhaave, Gottfried Wilhelm Leibniz, Bernard de Fontenelle, and René Antoine Ferchault de Réaumur. (Some believed in preexistence in the male spermatozoa, but most were ovists.) The notion that God must be fundamentally involved in each instance of reproduction, but only from his initial creative act and the mechanical laws that he had established, had widespread appeal.

As mentioned earlier, atheism was seen by many as implicit in the Cartesian universe. Descartes had shown how God could have created the world out of matter mechanistically had he so chosen. But if matter could form the universe by itself, who is to say that it had not? Likewise, if the material interactions resulting from the mixing of male and female semen could produce a living organism, how were any of us tied to God's creative act? The problem of origins, of the world and of living things was, for many, the weak point in Descartes' vision, and requiring simply that God give the universe the first motion was seen as insufficient by most to provide a bulwark against atheism. Preformation by preexistence of germs created a much more satisfying bulwark by ensuring that God was part of each and every generation of a living organism. Thus one had good mechanistic science without the specter of a godless universe.

## Challenges to preexistence

The impact of Newtonian mechanism on generation theories was not felt until mid-century, when, at the hands of Newtonians such as Pierre-Louis Moreau de Maupertuis (1698–1759) and Buffon, new ideas on epigenetic

development by attractive forces were proposed. The preformation–mechanism synthesis was thus challenged by the broadening of mechanism to include forces in addition to matter and motion. Might one be able to conceive of a theory of generation not based on preexistent germs but rather on matter and forces? This is what both Maupertuis and Buffon attempted to do; not wholly independently of one another, for the two apparently discussed issues relating to generation frequently in the mid-1740s. Maupertuis' anonymous work, *Vénus physique* (1745), presented an explanation of generation based on the notion that particles resembling all parts of the body are collected in the reproduction organs, there to form, via attractive forces, the new organism when seminal fluids from both parents are mixed together. Attractive forces had long been used in astronomy and chemistry: "Why," Maupertuis asked, "should not a cohesive force, if it exists in Nature, have a role in the formation of animal bodies?"[8] As one of the first proponents of Newtonianism in France, Maupertuis felt that attributing generation to attractive forces was far preferable to the absurdities of preexistence.

But it was not just Newtonian notions of attraction that led to these new challenges to preexistence theories. During the 1740s a series of biological discoveries seemed to indicate that matter is not totally passive in the generation process, at least among very small organisms. The first of these was Abraham Trembley's discovery in late 1740 that a little aquatic creature, the freshwater polyp, possessed remarkable regenerative capabilities. Unlike other creatures that could regenerate an injured limb, the polyp, when cut up into several pieces, regenerated into as many completely new organisms as there were cut-up pieces. Trembley's observations caused an immediate stir when they were announced to the Paris Academy of Sciences and to the Royal Society, for, as Aram Vartanian has remarked, "Trembley's contemporaries had the startling spectacle of Nature caught, as it were, *in flagrante* with the creation of life out of its own substance without prior design."[9]

Two other sets of observations from the 1740s were to prove equally controversial, those of Needham on revivification of eels in blighted wheat and those of Needham and Buffon on the generation of microorganisms in infusions. In the early 1740s Needham had observed that when he added water to whitish fibers found in grains of blighted wheat these fibers appeared to come to life as tiny worms, or "eels," that moved in a twisting motion for several hours. When he tried the experiment two years later on some of the grains he had saved from the original lot, the same

phenomenon occurred. Similar, but somewhat more ambiguous observations were made by Needham and a colleague on "eels" found in mixtures of flour and water.[10] Although Needham made few speculations in these early years about the manner in which these organisms appeared to generate, his observations later became quite controversial in the hands of Voltaire (who ridiculed them) and d'Holbach (who used them as evidence for materialism).

The event that was to have the most impact was the publication in 1749 of the first volumes of Buffon's *Histoire naturelle*. The theory of generation and view of life that was presented in volume 2 was immediately controversial. Here Buffon argued that all animals and plants were composed of a type of matter that was both particulate and active. His *molécules organiques* [organic molecules] cycled through living systems in an unending process of generation, growth, and decay. Buffon countered preexistence of germs with the reorganization of organic particles into new creatures at each instance of reproduction. And he unequivocally promoted active matter as the basis of this process, proclaiming, "Living and animation, instead of being a metaphysical degree of being, is a physical property of matter."[11]

Buffon conceived of his new theory in the mid-1740s and began writing an account of it. Then in 1748 Buffon joined forces with Needham to perform a series of microscopic observations on seminal fluids and on infusions (Figure 2.3). These observations provided new evidence, both believed, for the operation of active matter at the microscopic level. Buffon concluded that freed organic particles could unite together spontaneously to produce microscopic organisms. Needham built his own theory of generation on the evidence these observations seemed to provide for the existence of a universal vegetative force.[12]

The publication of Buffon's and Needham's new views on generation, based on concepts of active matter and on evidence from the microscopic world, had a profound effect on biological thinking. The immediate effect was to change, or to begin to change, the theorizing of several figures who were soon to play key roles in the materialism debates. Diderot, for example, read the first volumes of the *Histoire naturelle* in 1749 while imprisoned at Vincennes for publishing the *Lettre sur les aveugles*.[13] The effect on him was to turn his attention toward biology as a fertile source of evidence for materialism. Haller, to take another example, reacted to the *Histoire naturelle* by beginning a shift in thinking that eventually brought him back from epigenesis to preformationism. Haller's encounter with Buffon's

FIGURE 2.3 Needham and Buffon (seated) performing observations with a microscope. (From Georges-Louis Leclerc, Comte de Buffon, *Histoire naturelle*, vol. 2, 1749.)

theory of generation brought him up against the materialist implications of epigenesis, only a few short years after he himself had adopted epigenesis largely in reaction to the discovery of the polyp's regenerative abilities.[14]

Bonnet, to cite a third example, was in the midst of composing his own treatise in support of preformation when he read the first volumes of the *Histoire naturelle*. The effect on him was to cause him to abandon his project altogether for over a decade. Only after Haller completed his own transition back to preformationism and published a series of important observations on chick development did Bonnet resuscitate his book, adding significant new material to it for its publication in 1762.[15] He later explained in his autobiography the reasons why he felt compelled to present his own preformationist theory: "to combat the different systems based on epigenesis, particularly those of MM. de Buffon and Needham; . . . [and] to oppose to these strange opinions a hypothesis that conforms more to the facts and to the principles of sane philosophy."[16]

Thus one of the effects of the new theories of generation proposed by Maupertuis, Buffon, and Needham was the production of the most clearly articulated theories of preformation in the work of Haller and Bonnet. Another effect was to promote materialism and to provide biological evidence for the existence of active and self-creative matter. This is most clearly seen in the works of Diderot and d'Holbach, and in the rising concern over materialism expressed by Voltaire. Both Haller and Bonnet

found two principal areas of concern in the new biological theories. First, they did not see how forces could, on their own, be responsible for the generation of complex, seemingly designed, living organisms. Second, they were worried about the implications of active matter—not just in biology, where the old issue of spontaneous generation was given new life, but even more for religion, morality, and social stability.

With regard to the role forces were required to play in generating new organisms, the objections were quite similar among the preformationists. Réaumur was the first to make these worries clear, in his reaction to Maupertuis' *Vénus physique*:

> how will attractions be able to give to such and such a mass the form and structure of a heart, to another that of a stomach, to another that of an eye, and to another that of an ear? How will they fashion other masses into vessels, valves, etc. . . . . It is too evident that in order to succeed in forming such a complicated edifice, it is not enough to multiply and vary the laws of attraction at pleasure, and that it is necessary to give to this attraction the greatest amount of knowledge.[17]

Haller echoed these sentiments two years later when, in critiquing Buffon's new theory, he argued,

> I do not find in all of nature the force that would be sufficiently wise to join together the single parts of the millions and millions of vessels, nerves, fibers, and bones of a body according to an eternal plan. . . . M. Buffon has here the necessity of a force that seeks, that chooses, that has a purpose, that against all of the laws of blind combination always and infallibly casts the same throw.[18]

Buffon had argued that a "penetrating force" acted as part of the process whereby the *moule intérieur* [internal mold] organized the organic molecules in the mixed semen into the new offspring. But such a force, Haller believed, would violate the laws of Newtonian mechanism, where forces were considered to be invariable and automatic, and without any capacity to "choose" or to have a "purpose."

But it was not just the addition of forces to the generation process that caused problems for Haller, Bonnet, and other supporters of preformation. Buffon and Needham had based their theories on conceptions of matter that went beyond the traditional mechanist reliance on passive matter. The new generation theories—supported by the new biological

evidence provided by the polyp and by microorganisms—proclaimed a nature in which matter was fundamentally active, not one that relied entirely on God-given automatic forces for any activity. And it was this new view of nature that was so provocative for individuals like Diderot and so disturbing to preformationists like Bonnet and Voltaire. Nature seen as active and self-creative directly challenged the conception of a divinely ordered, unchanging, and hierarchically arranged nature so fundamental to the preformationists. This clash of views of nature and the reactions to the possibility of defining a nature in which God was no longer necessary can best be seen by examining more closely the works of Voltaire and Diderot.

## Voltaire and preformation

Having been born before the turn of the eighteenth century, Voltaire was one of the oldest of the *philosophes*; he was also the longest lived. One of the formative influences on his life was the years of exile he spent in England from 1726 to 1729; he returned to France a confirmed Newtonian. Along with Maupertuis, Voltaire was to greatly influence the introduction of Newton's ideas on the continent, in part through his *Éléments de la philosophie de Newton* (1738).[19] Voltaire adopted as well a deistic vision of nature, believing that the order and harmony of the universe testified to the existence of an intelligent cause, and he subscribed to the mechanist view of passive matter.

Although Voltaire indicated his belief in preexistence as early as 1740, in his *Métaphysique de Neuton* his preoccupation with biological topics, which is prominent in many of his later writings, did not begin until the 1760s.[20] He had learned of the new epigenetic ideas from reading Maupertuis' *Oeuvres* in 1752. He reacted quite critically to Maupertuis' theory, but it was what he learned about Needham's observations about finding live "eels" in formerly dried blighted wheat grains that piqued his satirical wit. In a series of pamphlets he wrote satirizing Maupertuis' work, Voltaire described a "séance mémorable," a parody of the Berlin Academy of Sciences, of which Maupertuis was president for ten years. Voltaire humorously portrayed the "galant" president serving the ladies present "a superb dish composed of pâté of eels all one within the other and born suddenly from a mixture of diluted flour" as well as "great platters of fish that were formed immediately from grains of germinated wheat."[21]

But it was not until the mid 1760s that Voltaire became alarmed at the implications of Needham's and Buffon's work for materialism. What seems to have prompted this concern was a visit Voltaire had from one of Diderot's friends, Étienne-Noël Damilaville (1723–68). Damilaville visited Voltaire in the summer of 1765, and he apparently presented pro-atheism and pro-materialism arguments to Voltaire, under the exhortation of Diderot (who was writing to him at Voltaire's house).[22] It was very likely from these conversations with Damilaville that Voltaire began to realize the connection between the new biological theories and materialism. By 1765 Diderot had completed his own transition from deism to atheism, and his growing interest in biological evidence for materialism had played a major role in this transition.

By coincidence, Voltaire had become embroiled, that same summer, with Needham in a pamphlet war over the subject of miracles. He did not discover Needham's authorship until August, and thereafter he included lampoons on Needham's biological work along with his arguments on miracles. "You have made a small reputation for yourself among atheists by having made eels from flour, and from that you have concluded that if flour produces eels, all animals, starting with man, could have been born in approximately the same manner." This was not in fact what Needham had been arguing, but Voltaire never bothered to learn much more about Needham's actual views. In a collection of his and Needham's pamphlets he published that same year, Voltaire added a preface to one of his pamphlets, which made his concern over the implications of Needham's work even more explicit. Falsely characterizing Needham as an Irish Jesuit disguised in secular clothing and roaming the countryside spreading papist dogma, Voltaire explained that he had also "meddled with experiments on insects" and believed he had seen the flour of blighted wheat change into small animals. Needham had been wrong, Voltaire claimed, as had recently been shown by experiments made by Spallanzani. Furthermore, Voltaire continued, Needham's claim was false for another even more superior reason, namely, that the fact is impossible.

> If animals are born without germs, there would no longer be a cause of generation: a man could be born from a lump of earth just as well as an eel from a piece of paste. This ridiculous system would moreover obviously lead to atheism. Indeed it happened that several philosophers, believing in the experiment of Needham without having seen it, claimed that matter could organize itself; and the microscope of Needham came to be seen as the laboratory of atheists.[23]

Among these duped philosophers Voltaire was to include Maupertuis, Buffon, whose *Histoire naturelle* Voltaire seems to have first read in 1767, and an anonymous translator of a new French edition of Lucretius' *On the Nature of Things*, which appeared in 1768 and which contained a positive report of Needham's work in a note. This translation had actually been produced by the tutor of d'Holbach's children (an individual named Lagrange) under the direction of Diderot and d'Holbach, and it is quite likely that the note came from Diderot. When d'Holbach's anonymous *Système de la nature* appeared in 1770 he too was added to the list. During 1767 and 1768 Voltaire unleashed a series of attacks on Needham and the philosophers misled by him. In *Des singularités de la nature* (1768), for example, he described Needham's experiments, then remarking, "Immediately several philosophers did their best to cry marvel, and to say: There is no germ; everything is formed, everything is regenerated by a living force of nature. It is attraction, said one [Maupertuis]; it is organized matter, said another [Buffon]; these are living organic molecules that have found their molds. Good physicists were deceived by a Jesuit."[24]

In 1770 Voltaire's fears about the foundation that Needham's work could provide for materialism were realized in d'Holbach's *Système de la nature*. Using Needham's observations, along with examples of chemical combustion, d'Holbach argued that matter is fundamentally active. Needham's work had shown "that inanimate matter can pass into life, which is itself only an assemblage of movements." Moreover, d'Holbach continued in a footnote, "would the production of a man independently from the ordinary means be more marvelous than that of an insect from flour and water?"[25] Voltaire was incensed by d'Holbach's book as well as its reliance on Needham's views. His reaction culminated in a pamphlet, *Dieu: Réponse de Mr. de Voltaire au Système de la nature* (1770), which formed parts of his entry "Dieu, Dieux" [God, gods] in his *Questions sur l'encyclopédie.*[26] Voltaire attacked Needham's work and d'Holbach's having been duped by it, and in response simply reaffirmed his belief in the incapacity of matter to produce life and intelligence. Thinking, sensing beings could only have been created by a power superior to mankind.

In many respects Voltaire was not the typical preformationist. He was not a naturalist himself, relying on what he had read or heard about the new biological discoveries. He was also atypical in being a deist, for Bonnet, Haller, and other preformationists were believers not only in the

order and harmony of nature but also in revealed religion. (Both Bonnet and Haller, for example, wrote books on religious apologetics during the same years they were publishing on preformation and combating the work of Buffon and Needham.) Voltaire was always critical of organized religion and wrote much against the excesses of Christian fanaticism. Yet Voltaire's underlying concerns that led him to defend preformation were surprisingly similar to those of Bonnet and Haller, even though they never recognized him as an ally. For Voltaire, the rise of atheism would mean the demise of a moral society. As he explained in a letter written in 1768, atheists had never been able to answer the argument "that a watch proves a watchmaker." Mentioning to his correspondent the work of Needham, who had "recently furnished arms to atheistic philosophy in pretending that animals can form themselves all alone," and "another fool Maupertuis," Voltaire proclaimed, "May God preserve us from such atheists." Finally Voltaire concluded simply, "My dear Marquis, there is nothing good in atheism. This system is very bad in physics and in morals. An honest man can protest strongly against superstition and fanaticism; he can detest persecution, he renders a service to the human race if he spreads human principles of toleration; but what service can he render if he spreads atheism?"[27]

This concern was echoed two years later in another letter written in response to d'Holbach's *Système*. Pointing once again to Needham's "false experiment" as the foundation of d'Holbach's views, Voltaire continued, "Moreover, I think that it is always very good to support the doctrine of the existence of a rewarding and vengeful God; society needs this opinion. I do not know if you recognize this verse, 'If god did not exist, it would be necessary to invent him.'"[28] This verse was in fact Voltaire's own, written a year earlier in a poem intended as a reply to the infamous anonymous tract, *Traité des trois imposteurs* (1765).[29] Whatever Voltaire's own personal views were with regard to God, he felt that belief in God's existence was essential to preserving the social order, in addition to being demonstrated by the natural order. For Voltaire the proper society required a government based on an enlightened monarch and a moral code founded on justice, toleration, and a belief in God. Preformation, by involving God necessarily in the formation of each living organism and by laying out a lawful process whereby development could proceed, provided just the biological foundation Voltaire sought to ward off the onslaught of atheism and social disorder.

## Diderot and materialism

Born nineteen years later than Voltaire, Diderot was one of the next generation of *philosophes* and was most active from the mid 1740s through the 1770s. His early work as a translator led to the *Encyclopédie* editorship, which began in 1747 and lasted until the final volumes of plates were published in 1772.[30] He was imprisoned for just over three months in 1749 for the publication of his *Lettre sur les aveugles* (1749); previously, his *Pensées philosophiques* (1746) had been condemned and burned by the Paris Parlement.[31] These experiences caused Diderot to leave many of his more radical writings unpublished during his lifetime.

Sometime between 1749 and 1751 Diderot made the acquaintance of the Baron d'Holbach; from then on he was a constant participant in the famous dinners at d'Holbach's house, and a friend and intellectual confidant of d'Holbach himself. D'Holbach contributed a number of articles to the *Encyclopédie* (many on mineralogy and geology, but also on more controversial topics), and Diderot very likely made at least an editorial contribution to d'Holbach's *Système de la nature*. He was actively involved in the series of anti-clerical works that issued from d'Holbach's pen in the 1760s, prompting Diderot to remark in a letter in 1768, "It is raining bombs in the house of the Lord."[32]

Diderot's introduction to the new biological theories occurred in 1749 with his reading of the first volumes of Buffon's *Histoire naturelle* while he was imprisoned. Previous to this he does not seem to have been particularly interested in biology, and in his *Pensées philosophique* (1746) he presented the classic deist argument for the existence of God: "It is not from the hand of the metaphysician that atheism has received its heaviest blows. The sublime meditations of Malebranche and of Descartes were of less use in shaking materialism than a single observation of Malpighi's." Diderot rejected spontaneous generation as well, claiming "The discovery of germs alone has destroyed one of the most powerful arguments for atheism."[33] Although a deist in the *Pensées*, by 1749 Diderot had moved much closer to atheism.

In 1751 Diderot published an article "Animal" in the first volume of the *Encyclopédie*, in which he reprinted sections from Buffon's *Histoire naturelle* with interspersed comments that indicate a willingness to go beyond Buffon's views (for example, by suggesting that animals possess the faculty of thinking). In his *Pensées sur l'interpretation de la nature* (1754),

Diderot began questioning Buffon's distinction between organic and inanimate matter, asking if there were really any differences between living and dead matter other than organization and self-movement.[34] In his letters in the late 1750s he continued to wonder how matter could pass from a dead state to a living one. In one of these he remarked that, by eating dead food, organisms grow, so that, as he put it "something dead put alongside something living began to live." Yet, he continued, "You might as well say that if I put a dead man in your arms he would come back to life."[35] By 1765 Diderot seems to have rejected Buffon's distinction and to have settled on the idea that there is no essential difference between dead and living matter; rather something he called *sensibilité* is a property of all matter—inert in inanimate matter but rendered active in living organisms and even producing thought in higher organisms. It was in this same year that, after hearing of Diderot's views from Damilaville, Voltaire became alarmed at the implications of active matter in biology and began his extended critique of Needham and Buffon.

The culmination of Diderot's materialist thinking in biology was his witty and provocative dialogue, written in the late summer of 1769, the *Rêve de d'Alembert*. While in the midst of its composition, he wrote to his friend Sophie Volland,

> It is the height of extravagance and at the same time the most profound philosophy. It is quite shrewd to have put my ideas in the mouth of a man who is dreaming. It is often necessary to give wisdom the appearance of folly to gain admittance for it. I like it better when it is said: But this isn't so mad as you might think, than to say: listen, here are some very wise things.[36]

In the second part of the *Rêve*, Diderot portrayed his fictional character d'Alembert in the midst of a dream. At one point d'Alembert dreamt he was looking through a microscope at an infusion. As one of the other characters described it, "The flask in which he perceived so many momentary generations he compared to the universe; he saw in a drop of water the history of the world. . . . He said 'In Needham's drop of water everything happens and passes away in the twinkling of an eye. In the world the same phenomenon takes a little longer; but what is our duration in comparison with the eternity of time?'" Depicting a universe of ceaseless activity and change, Diderot proclaimed, "You have two great phenomena, the passage from the state of inertia to the state of sensibility, and spontaneous

generation; let them suffice for you: draw from them the correct conclusions."[37] For Diderot, Needham's microscopic observations provided the model for a world based on ceaseless activity and change, rather than preordained stability.

During the same years as he was developing his ideas on biological materialism, Diderot was actively involved in the anti-clerical and atheistic publication ventures of d'Holbach's coterie. Their program was not entirely negative. For one of their goals was to replace the traditional concept of morality based on future reward and punishment with a new naturalistic morality, one that would be founded on the laws of human nature and human society. Diderot developed a purely empirical moral theory, one that based moral ideas and the development of a moral sense on the individual's experiences of pleasure and pain. Yet Diderot did not make these views public; after the publication of the *Système de la nature*, it was d'Holbach who went on to publish a series of books in the 1770s expounding a materialist view of morality.[38]

## The political stakes

A naturalistic morality not based on religious tenets also challenged the underpinnings of absolute monarchy. The threat that a ceaselessly active material world presented to a hierarchical, preordained political world was not lost on the French government. This is evident in the clash between the *philosophes* and the monarchy over the *Encyclopédie*, which began with the very first volume. Once again, we find Diderot at the center of the controversy.

Diderot's political views were most clearly presented in two of his *Encyclopédie* articles, "Autorité politique" [Political authority] and "Droit naturel" [Natural rights]. Diderot extolled the virtues of a monarchy limited by law, in which sovereignty would lie with the will of the people. A firm believer in natural rights, Diderot argued like others of his contemporaries that humans are by nature reasonable and sociable. He opposed both the divine sanction of monarchy and the concept of enlightened despotism. His views were thus by no means radical but they were clearly in opposition to the existing governing institutions in France.[39]

It was through his editorship of the *Encyclopédie* that Diderot found himself in direct conflict with the monarchy and the Paris Parlement. The first volume appeared in 1751, and by the time the second one ap-

peared, Diderot and d'Alembert found themselves in trouble with the authorities. On 7 February 1752, the King's Council issued a decree suppressing the first two volumes of the *Encyclopédie*. In part, the decree read: "His Majesty has recognized that several maxims inserted in these two volumes aim to destroy royal authority, to establish a spirit of independence and revolt, and, under obscure and ambiguous terms, to promote the foundations of error, of moral corruption, of irreligion, and of unbelief."[40]

The article that provoked much of the controversy was Diderot's "Autorité politique." Coupled with growing tensions between the king and Parlement over who had the final authority to approve laws, Diderot's political views found ready critics. The crisis died down, however, and the *Encyclopédie* resumed publication. Yet the 1750s continued to be tumultuous years, with France entering the Seven Years' War (1756–63), the king exiling Parlement, and the shocking assassination attempt in 1757, in which Louis XV was fortunate to escape serious injury. Surveillance of authors and their publications by the police increased, and following the assassination attempt, a draconian law was passed about subversive literature. "Anyone who is convicted," the new law read, "of having composed and printed writings tending to attack religion, to stir up spirits, to endanger our [the king's] authority, and to disturb the order and tranquility of our state, will be punished with death."[41] Although this law was apparently never enforced, its passage indicates that the king's ministers had become extremely hostile to the *philosophes*.

After five more volumes had appeared, the *Encyclopédie* was completely shut down. The most controversial article appearing in the seventh volume was d'Alembert's "Genève" [Geneva] in which he praised the Genevan clergy for their supposed deism, which incensed not only the Calvinist pastors but the French authorities as well, for the not-so-subtle implied criticism of the French Catholic church by comparison could not be tolerated. Consequently in January 1759, the Attorney General Joly de Fleury rose before the Paris Parlement to condemn the *Encyclopédie*, Claude Adrien Helvétius' *De l'esprit* [Concerning the spirit] and six other books deemed to be too radical. Joly de Fleury's speech opened with the following dire pronouncement: "Society, the State, and Religion present themselves today at the tribunal of justice . . . their rights have been violated, their laws disregarded. Impiety walks with head held high. . . . Humanity shudders, the citizenry is alarmed." What was the source of this fear and disquiet? A conspiracy, claimed Joly de Fleury, one that existed for

the purpose of destroying society: "there is a project conceived, a Society formed, to uphold materialism, to destroy Religion, to inspire a spirit of independence, and to nourish the corruption of morals." Remarking that it was sad to think what posterity would think of their century, Joly de Fleury claimed that it had fostered "a sect of so-called Philosophers who . . . imagined a project . . . to destroy the basic truths engraved in our hearts by the hand of the Creator, to abolish his worship and his ministers, and to establish instead Deism and Materialism."[42]

Joly de Fleury was particularly critical of the *Encyclopédie* and the way the editors used cross-referencing among articles to subtly bring out radical points hidden in articles seemingly on an innocuous topic. One of his prime examples pointed again to biology. In Diderot's article on "Éthiopiens" [Ethiopians], which does not actually say much about Ethiopians, we find an interesting passage about how animals develop from the earth through fermentation caused by the heat of the sun (which was quoted by Joly de Fleury). At one point, Diderot claimed,

> The Ethiopians take themselves to be more ancient than the Egyptians, because their country has been more strongly struck by the rays of the sun, which give life to all beings. Whence one sees that these people are not far from regarding animals as the development of earth put into fermentation by the heat of the sun, and to conjecture in consequence that species have undergone an infinity of diverse transformations, before becoming the form that we see them in.[43]

At the conclusion of the article, Diderot cross-referenced the article "Dieu" [God]. Although this article is not especially controversial, in one section, drawn from the work of Fontenelle, we find a discussion about whether the first animals of each species were formed by chance interactions of matter or by the will of God. Fontenelle concluded that it was the latter, but principally by arguing that if animals had been formed by chance, why was it not still happening? A paragraph claiming that generation from corruption, or spontaneous generation, had been shown to be false by modern experiments ended in a cross-reference to "Corruption." This leads us to another d'Alembert article where Buffon's theory of organic molecules was favorably discussed. D'Alembert highlighted not only Buffon's claim that microscopic organisms can be formed by the fortuitous combination of organic molecules but also that tiny "eels" (larvae) form in flour paste in the same manner. Although d'Alembert admitted that most cases that appear to be spontaneous generation are actually regular

generation from eggs, he queried, "but is it demonstrated in all cases that corruption can never engender an animated body?"[44]

These articles in the middle volumes of the *Encyclopédie* thus presented a very strong argument for the material basis of life and called into question the need for God's involvement even in life's creation. That Joly de Fleury used them as his prime example of the dangers contained within the pages of the *Encyclopédie*, which were reinforced by its pernicious system of cross-referencing to even more radical arguments, is clear evidence that debates in the biological realm had become central to those in the political realm as well.

As a result of Joly de Fleury's denunciation, Parlement suspended publication of the *Encyclopédie* pending further examination. Then, in March 1759, a royal decree was issued that condemned the *Encyclopédie* and suppressed its further publication by revoking its royal "privilege." The decree declared: "The advantage to be derived from a work of this sort, in respect to progress in the arts and sciences, can never compensate for the irreparable damage that ensues from it for morality and religion."[45] Diderot feared arrest, but he vowed to continue the project, even hiding some of his manuscripts in the home of the monarchy's director of the book trade and censorship, Chrétien-Guillaume de Lamoignon de Malesherbes.[46]

A second example demonstrating the central role radical views about life and matter played in the political discourse of this period can be found in a satirical pamphlet on the *philosophes*, the *Nouveau mémoire pour server à l'histoire des Cacouacs*, written by Jacob Nicolas Moreau (1717–89). Moreau, who had been employed by the Ministry of Foreign Affairs to write pro-France propaganda during the Seven Years' War (1756–63), was regarded by the *philosophes* as being aligned with the court. The "Cacouacs," a fictional tribe of savages, were the creation of the abbé Odet Joseph de Vaux de Giry de Saint-Cyr (1699–1761), advisor to the Dauphin (the heir to the French throne), who noted the similarity of their name to the Greek word "cacos," meaning "malicious."[47] The Cacouac episode began just when the seventh volume of the *Encyclopédie* was published and was part of the anti-*philosophe* publications that followed.

In Moreau's *Nouveau mémoire* we again find the connection between materialist biology and the dangerous threat the *philosophes* represented to society. The memoir opened with the capture of the young hero of the piece, who was eventually able to tell his story after he escaped and returned to Paris. The Cacouacs, he reported, lived in tents to signify their freedom, had no government, regarded ethics as a matter of convention,

and did not believe in the existence of God. Although I do not want to describe the young man's adventures in detail, the key episode for my purposes here was when he was interrogated by a group of Cacouacs in preparation for his induction into their society. His first question, from a venerable old man, was "If dead matter could combine with living matter? How does this combination come about? What is the result?" A woman continued, asking, "If molds are the principal forms? What is a mold? Is it a real and preexisting being, or is it only the intelligible limits of a living molecule united to dead or living matter . . . ?" Under the influence of incense, the young man began "to understand everything perfectly," and he was told he could now regard the Cacouacs as his brothers. Eventually our young hero was rescued; he returned home only to find "dangerous and ridiculous" Cacouacs there as well. "I found," he reported, "that they had been given the name *Philosophes*, and that their works were being printed."[48]

Giry de Saint-Cyr wrote a follow-up work, the *Catéchisme et decisions de cas de conscience, à l'usage des Cacouacs*. The catechism was supposedly to be used by Cacouacs for the proper inculcation of the young into their philosophy, which of course allowed Giry de Saint-Cyr to expose the most radical and dangerous doctrines of the *philosophes* through the ruse of instruction. The catechism is in the traditional question-response format, beginning with the question "What is God?" and proceeding through topics such as the creation of the world, the soul, the relationship between humans and animals, humans in their primitive state compared with humans in civil society, freedom of thought, the nature of morality, happiness, and free will. What is most revealing about the catechism is that the instructor's responses to the questions posed are compiled from direct quotations from works by the *philosophes*. One can imagine the abbé, with works by Diderot, Jean Jacques Rousseau, Voltaire, and Helvétius scattered about on his desk, earnestly searching for yet another scandalous quote to add to the catechism. The result is a somewhat disconnected pastiche, but effective nevertheless.

Giry de Saint-Cyr again used the question of living or dead matter as a key part of his critique. In the second section, on the creation of the world and the formation of beings, quotations from Diderot are used to claim that the universe had formed by the chance combination of atoms and that living organisms formed as well from particles that already possessed "desire, aversion, memory, and intelligence" (a reference to Maupertuis). In an even more revealing quotation, again from Diderot's *Pensées*, the Cacouac teacher explained, "the embryo, formed out of these elements,

has passed through an infinity of organizations and developments; that it has had in succession movement, sensations, ideas, thought, reflection, conscience, feelings, passions, signs, gestures, sounds, articulate sounds, language, sciences and the arts."[49]

Although there are many more topics of ridicule in both Moreau's and Giry de Saint-Cyr's depictions of the Cacouacs, my purpose is to point out that here again we see biological ideas connecting life and matter, drawn from the work of Buffon, Maupertuis, and Diderot, being attributed as foundational to the *philosophes*' whole enterprise. It was only by understanding these issues that one could become a true Cacouac/*philosophe*, at least in the eyes of those who found them so dangerous. Of course, the use of these questions also heightened the satirical quality of the narrative, since they sound even more absurd out of context. Yet I do not believe that Moreau or Giry de Saint-Cyr used these simply because they would sound hilarious. Rather they were definitional and seen as providing a foundation for the *philosophes*' dangerous undermining of religion and society. Both authors were closely connected with the French court, and we can see, in this episode and in the attorney general's condemnation of the *Encyclopédie*, just how high up in the political realm worries over the implications of such radical ideas reached.

Although Diderot never wrote any political treatises, it is clear from his other writings that he favored a limited monarchy and feared the rise of a despotic one. His concern over the state of the monarchy is evident in his reaction to unfolding political events. As France's financial difficulties skyrocketed in the late 1760s, following the country's defeat in the Seven Years' War, the struggles between Louis XV and the Paris Parlement intensified. The Parlements were opposed to new taxes, and much of their bid for power coalesced around the taxation issue. When the new chief minister René Nicolas de Maupeou proposed in 1770 a new tax, the vingtième, the Paris Parlement refused to accept it; in a bold stroke Maupeou simply dissolved Parlement, exiling its members to the provinces. Diderot was shaken by this action. Although he was highly critical of the Parlement, it was really the only body in the French government that could serve as a limiting force against the monarch. Imperfect as it was, dissolving it was a step toward despotism. As he wrote in a letter: "This event has caused great emotion among all the orders of the State. . . . Heads are warming up and the heat is slowly spreading. The principles of liberty and independence, formerly hidden in the hearts of a few people who think, now take hold and are openly expressed." Diderot went on in this letter to claim what was

perhaps the real basis for the fear of atheism expressed by Bonnet and Haller. As he explained, "Once men have dared in some way to attack the barrier of religion, the most formidable and most respected barrier that there is, it is impossible to stop. When they have cast a hostile glance over the majesty of heaven, they will not hesitate the next moment to cast one over earthly sovereignty."[50] In other words, anti-clericalism and the promotion of atheism went hand in hand, in Diderot's mind, with political reform.

Diderot's answer, then, to Bayle's question, "Could a society of atheists be moral?," was unhesitatingly "Yes." In fact he believed such a society could be far more moral insofar as it incorporated principles of toleration and justice, and was founded on a naturalistic concept of human behavior. What Diderot opposed was the rigidly hierarchical, unchangeable social order of French society, and, like others, he recognized the underlying ties between such a concept of society and a natural world built on preordained order. Diderot's discovery of biology as a source of materialist arguments developed into an unbridled enthusiasm for any evidence that demonstrated material activity. Thus nature and society were both to be understood on the basis of natural laws.

Did Diderot, then, promote what Voltaire and the other preformationists feared? In one sense he did. Diderot's and d'Holbach's search for a definition of morality based on human nature grew out of a total rejection of religion as a foundation for moral behavior. Even though Voltaire was a deist he still claimed that society needed a notion of God's future judgment, at least for the masses. The other preformationists like Bonnet and Haller went even further in promoting organized religion based on God's revealed word. Yet in another sense Diderot was never as radical as atheists were feared to be. However, the potential for the breakdown of social order was there, according to the preformationists, in the loss of the natural order being necessarily tied to God. And this had to be prevented. As Needham wrote to Bonnet in 1768, "In spite of all that . . . we have done to bring our unbelievers to reason, I have always hoped that somehow we will stop the contagion by warding it off from those it has not yet touched."[51] Needham was not a preformationist; but, as was mentioned earlier, he was just as worried about the impact on morality and society that the collapse of preformation would entail. It was the "contagion" of atheism that had to be stopped, because if the generation of living organisms could happen without God then so could the generation of human societies.

94. *Encyclopaedia Britannica* (1788–97), 3rd ed., s.v. "Philosophy."

95. John Gascoigne, "The Eighteenth-Century Scientific Community: A Prospographical Study," *Social Studies of Science* (1995) **25**: 575–81 (577f).

96. Quoted in John Gascoigne, "The Study of Nature," in *The Cambridge History of Eighteenth Century Philosophy*, ed. K. Haakonssen (Cambridge: Cambridge University Press, 2006), 860. Gascoigne provides an excellent account of the relations between natural history and natural philosophy.

97. J. Llana, "Natural History and the *Encyclopédie*," *Journal of the History of Biology* (2000) **33**: 1–25.

**Chapter Two**

1. Renato G. Mazzolini and Shirley A. Roe, eds., *Science Against the Unbelievers: The Correspondence of Bonnet and Needham, 1760–1780*, Studies on Voltaire and the Eighteenth Century, no. 243 (Oxford: Voltaire Foundation, 1986), 309; Letter from Needham to Bonnet, 28 October (September) 1779. See also Shirley A. Roe, "John Turberville Needham and the Generation of Living Organisms," *Isis* (1983) **74**: 159–84.

2. René Descartes, *Treatise of Man*, French text with translation and commentary by Thomas Steele Hall (Cambridge: Harvard University Press, 1972).

3. René Descartes, *L'homme et un traitté de la formation du foetus* [Man and a treatise on the formation of the fetus] (Paris: Charles Angot, 1664), 146. Unless otherwise noted, all translations are my own.

4. Nicolas Malebranche, *Oeuvres complètes* [Complete works], ed. André Robinet, 20 vols. (Paris: Librairie Philosophique J. Vrin, 1958–67), vol. 12, 264, 252, 253.

5. Marcello Malpighi, *Dissertatio epistolica de formation pulli in ovo* [A dissertation on the formation of the chicken in the egg] (London: J. Martyn, 1673); Jan Swammerdam, *Miraculum naturae, sive uteri muliebris fabrica* [A wonder of nature, or the fabric of the female uterus] (Leiden: S. Matthaei, 1672); Jacques Roger, *The Life Sciences in Eighteenth-Century French Thought*, ed. Keith R. Benson, transl. Robert Ellrich (Stanford: Stanford University Press, 1997); Peter J. Bowler, "Preformation and Pre-existence in the Seventeenth Century: A Brief Analysis," *Journal of the History of Biology* (1971) **4**: 221–44; Shirley A. Roe, *Matter, Life, and Generation: Eighteenth-Century Embryology and the Haller-Wolff Debate* (Cambridge: Cambridge University Press, 1981), 2–9; Edward Reustow, *The Microscope in the Dutch Republic* (Cambridge: Cambridge University Press, 1996; and Carla Pinto-Correia, *The Ovary of Eve: Egg and Sperm and Preformation* (Chicago: University of Chicago Press, 1997).

6. Roger, *Life Sciences*, **262**. See also Elizabeth Gasking, *Investigations into Generation, 1651–1828* (Baltimore: Johns Hopkins University Press, 1967).

7. Claude Perrault, "La mechanique des animaux" (1680), in *Oeuvres diverses de physique et de mechanique* [Diverse works on physics and mechanics] (Leiden: Pierre Vander Aa, 1721), 481.

8. Pierre-Louis Moreau de Maupertuis, *Vénus physique* (n.p., 1745); quotation from *The Earthly Venus*, transl. Simone Brangier Boas, Sources of Science, no. 29 (New York: Johnson Reprint Corporation, 1966), 55–6. See also Mary Terrall, "Salon, Academy, and Boudoir: Generation and Desire in Maupertuis' Science of Life," *Isis* (1996) **87**: 217–29; Mary Terrall, *The Man Who Flattened the Earth: Maupertuis and the Sciences in the Enlightenment* (Chicago: University of Chicago Press, 2002); David Beeson, *Maupertuis: An Intellectual Biography*, Studies on Voltaire and the Eighteenth Century, no. 299 (Oxford: Voltaire Foundation, 1992).

9. Aram Vartanian, "Review of *Abraham Trembley of Geneva: Scientist and Philosopher* by John R. Baker," *Isis* (1953) **44**: 388. See also Virginia P. Dawson, *Nature's Enigma: The Problem of the Polyp in the Letters of Bonnet, Trembley and Réaumur* (Philadelphia: American Philosophical Society, 1987).

10. See Roe, *Isis* (1983) **74**: 159–84; Mazzolini and Roe, *Science Against the Unbelievers*, 12–5.

11. Georges-Louis Leclerc, Comte de Buffon, *Histoire naturelle, générale et particulière, avec la description du cabinet du roy* [Natural history, general and particular, with a description of the king's cabinet] (Paris: De l'Imprimerie Royale, 1749–89), vol. 2, 17. See also Jacques Roger, *Buffon: A Life in Natural History*, transl. Sarah Lucille Bonnefoi, ed. L. Pearce Williams (Ithaca, NY: Cornell University Press, 1997).

12. See Shirley A. Roe, "Buffon and Needham: Diverging Views on Life and Matter," in *Buffon 88: Actes du Colloque international* [Buffon 88: Proceedings from an international colloquium], ed. Jean Gayon (Paris: Librairie philosophique J. Vrin, 1992), 439–50. Needham's theory was presented in his "A Summary of some late Observations upon the Generation, Composition, and Decomposition of Animal and Vegetable Substances; Communicated in a Letter to Martin Folkes Esq; President of the Royal Society," *Philosophical Transactions* (1748) **45**: 615–66.

13. Denis Diderot, *Lettre sur les aveugles à l'usage de ceux qui voyent* [Letter on blindness for the use of those who have their sight] (London, 1749).

14. See Shirley A. Roe, "The Development of Albrecht von Haller's Views on Embryology," *Journal of the History of Biology* (1975) **8**: 167–90; and Roe, *Matter, Life, and Generation*, 21–44.

15. Charles Bonnet, *Considérations sur les corps organisés* [Considerations on organized bodies] (Amsterdam: Marc-Michel Rey, 1762).

16. Raymond Savioz, ed., *Mémoires autobiographiques de Charles Bonnet* [Autobiographical memoires of Charles Bonnet] (Paris: Librairie philosophique J. Vrin, 1948), 210.

17. René Antoine Ferchault de Réaumur, *Art de faire éclorre et d'élever en toute saison des oiseaux domestique de toutes espèces* [The art of hatching and bringing

up domestic fowls by means of heat], 2 vols. (Paris: L'Imprimerie Royale, 1749), vol. 2, 362–3.

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## Chapter Three

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