Justin E. H. Smith, *Divine Machines: Leibniz and the Sciences of Life*. Princeton: Princeton University Press, 2011. pp. 380

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Justin Smith's book *Divine Machines. Leibniz and the Sciences of Life* is two things at once: a treasure trove and a trailblazer. It is a treasure trove, on the one hand, because it draws upon or even uncovers a large collection of writings by Leibniz, which reflect his interest in what we would call life sciences today, encompassing various fields such as medicine, paleontology, or microscopy. Smith's book is a trailblazer, on the other hand, since it goes far beyond the currently growing tendency among Leibniz scholars to read Leibniz not only as a philosopher of mathematics, logic, language, or physics but also as a philosopher of biology. Smith surely presents one of the most comprehensive and in-depth analyses of Leibniz's writings in order to defend such a reading. Thus, *Divine Machines* is not only indispensable for any scholar interested in Leibniz's metaphysics, but rather, any scholar interested in the origins of modern philosophy of biology would greatly benefit from it.

However, in his book Smith does not merely want to show, that among the many subjects Leibniz had been interested in there was yet another, namely biology. Smith's aim is much more ambitious and, for that very reason, much more interesting. According to Smith, biology played such a crucial role for Leibniz, that far from merely constituting another one of Leibniz's fields of interest, biology should be seen "as central to and constitutive of (his philosophical) projects" (8). Hence, in order to be properly understood, Leibniz's philosophy has to be read through his biology. The same is true for his physics. It has to be read through his biology as well. Biology, so the book's main argument, is *the* basic science for Leibniz to which other sciences such as physics are reducible. And since the objects of biological inquiries are animals, Leibniz held "that all of nature is to be conceived after the model of animals" (5), "all motion is to be explained in the (…) way of birds and fish" (16).

Given, that up to now Leibniz's theories have typically been read from his perspective on either theology, or physics and mathematics, or logic and language, an approach that argues for the central role of biology in Leibniz's thinking is highly innovative because it offers a very new picture of Leibniz. This Leibniz is much more empiricist than it is usually assumed.

One of the many challenges such an approach must face is surely the mature Leibniz who famously claimed that bodies result from monads. Many, if not most, Leibniz scholars have argued that this claim needs to be understood as a change of perspective from realism to phenomenalism or idealism that the mature Leibniz underwent. Now, if, ultimately, there are no such things as bodies, this should be all the worse for biology, one might think, for this science, then, seems to be deprived of its objects. However, Smith offers an elegant way out of this seeming dilemma. He argues, that the shift we can observe in the late Leibniz should be seen not so much as one from realism to idealism, but rather as a shift in Leibniz's understanding of the nature of body from "being decomposable along 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" (7). It is this the second central claim of *Divine Machines* and it is taken by Smith to support his first, main claim of the centrality of biology in Leibniz's system. Thus, biology or life sciences must have been basic for Leibniz throughout his life, according to Smith. What did change, by contrast, was Leibniz's conception of reduction, and which basic entities could be involved in it.

Divine Machines has four parts that will be presented in the following while questions and reservations will be raised along the way. The first part is divided into two chapters. The first chapter is a detailed account of Leibniz's intense occupation with medicine. Smith cites Leibniz who wrote in a letter to Bouvet in 1697: "Medicine is the most necessary of the natural sciences" because it contributes to the maintenance and even to the improvement of the human body so that, in the end, "medicine gives (men) the means to work for the glory of God" (26). It is hence not surprising that Leibniz shows an avid interest in medical, which is to say, experimental methods and experiments, as well as in the institutional aspects of the medical profession. Although it was the latter Leibniz himself was most engaged in, Smith shows in great detail that Leibniz's interests range from what we today would call pharmacy, chemistry, vivisection, and microscopy to physiology. All of these areas belong to medicine in Leibniz's sense, since knowledge in theses areas can contribute to the well-being of the human body.

Leibniz's occupation with both chemistry and physiology is especially noteworthy, because theses disciplines consider the animal body under two different aspects: as masses on the one hand, and as structures on the other. In fact, Leibniz "saw the two domains of inquiry as deeply interwoven, even inseparable" (30).

But that changed. The remainder of the book is dedicated to showing that Leibniz gradually shifted his interests and that this shift parallels a shift in the way Leibniz modeled the animal body. While the Leibniz of the 1670s and early 1680s focused on the vivisection of macroscopic animal bodies, the Leibniz of the 1690s and later was interested in the microscopic study of the animal bodies' small parts as well as of microorganism. Leibniz's conception of the animal body changed accordingly from the "hydraulico-pneumatico-pyrotechnical machine" to the "machines within machines to infinity" (58).

The question that arises in this context is, of course, how this parallelism of shifts is to be interpreted. Smith's terminology in this first chapter suggests two different readings. Thus, when he writes that Leibniz's "models of the animal body will contribute directly to his metaphysical model of corporeal substance" we can conceive of these contributions as empirical confirmations of independently developed metaphysical claims (48). However, there are other formulations to be found, such as that "medical questions are for him (Leibniz) 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" and that "Leibniz's eventual conception of the harmony between body and soul is ultimately rooted in (a) perceived parallelism between medicine and theology" (26). These formulations are much stronger, suggesting that the order of rational support goes from empirical facts to metaphysical claims. It is evident that the question of how to interpret the parallelism of shifts in empirical interests in animal bodies and in models of these very bodies is of some importance and I will come to it again.

The second chapter is devoted to Leibniz's interest in animal economy, that is, "the study of the relation between organs and functions" (62). Animal economy includes several disciplines such as anatomy, physiology, and ethology, while there is one discipline that is explicitly excluded by Leibniz, namely pneumatics. The soul for Leibniz, as Smith develops in great detail, must not play an explanatory role in "an autonomous scientific discipline that gains nothing from its mention" (62). This holds for both of the periods Smith examines, namely the period from 1677 to roughly 1683, and the period from 1709 to 1710, in which the controversy between Leibniz and Stahl took place.

As Smith explains, for Leibniz the animal can be conceived along Cartesian, that is, mechanistic lines. Yet, there are decisive differences between Leibniz and Descartes to be found in their characterization of an animal. Smith mentions two (63). Firstly, contrary to Descartes, Leibniz allowed animal bodies and their parts to have real ends or functions, which he thought could be described in entirely mechanistic terms. Secondly, each animal belongs to a certain species with a certain activity specific to it. Bees, for instance, produce honey. Animal bodies, thus, are machines. More precisely, they are machines that are capable of self-nutrition and self-motion, the latter of which Leibniz thought to be explicable as results of internal thermodynamical processes (73). And they are machines that are capable of passing on their own likeness to other machines (72). In these respects an animal machine is superior to an artificial machine, while it is, of course, inferior to an ideal, that is, perpetual-motion machine in that it requires constant refueling. Finally, animals are machines with a certain species. To put it succinctly, in the study of animal economy, an animal for Leibniz is "a *hydraulico-pneumatico-pyrotechnical machine of quasi-perpetual motion with a trademark activity specific to it*" (64).

Although Leibniz continuously claimed we could conceive of animal bodies along mechanistic lines, a change of what exactly the explanandum was took place. While Leibniz thought until roughly 1683 that it is the animal body itself that should be envisaged as living he did not think so anymore by the time of his controversy with Stahl. For, as Smith clearly demonstrates, there was a shift of the notion of life in Leibniz, from an understanding of life as a combination of perception and motion (82) to one that conceived life as mere perception and perception not as a bodily phenomenon but rather as a process driven by the soul (83). Thus, by the time of his controversy with Stahl, it was the animal body together with the soul that counted as living for Leibniz. That is to say, animal economy stopped being an inquiry into the nature of life (88). However, there are two reasons why Leibniz did not consider this as problematic. He mentions them in his controversy with Stahl, who thought that without the soul the preservation of the body would be jeopardized. First of all, life, Leibniz argues, cannot be identified with the preservation of the body, since, then, flames would have to count as living, too. Secondly, if the soul were needed in the preservation of the body, then, Leibniz mocking Stahl, the function of the soul would be similar to that of salt used in preserving ham (89).

The second part of *Divine Machines*, chapters three and four, is the central part of the book. Here, Smith turns to the transition in Leibniz's interest from animal economy to subtle anatomy mentioned earlier and shows how this transition parallels a shift in Leibniz's model of animal bodies. More precisely, Smith turns to "one of the most important special features of the machine of the animal body (…), namely, his (Leibniz's) notion of the *organism* of the body" (93).

The third chapter introduces the mature Leibniz as a philosopher with a metaphysics, which "was thoroughly *micro*biological" (97). Leibniz as well as other thinkers of his time was deeply impressed by the study of organic microstructure that became possible with the invention of the microscope. According to his organics, the animal body is composed of infinitely many organic bodies; in fact, the animal body is composed of infinitely many animals. That is, the animal body is an infinite complex. This, however, does not mean, that Leibniz renounced mechanism. On the contrary, as Smith argues, the animal body still is a machine for Leibniz, if only a "more exquisite", "more divine" machine with machines in its least parts (100). It is, in sum, a machine of nature. Thus, contrary to what other commentators believed, "organic" should not be seen as the antonym of "mechanical" (108). Instead, as Smith explains, organism "is to natural machines what mechanism is to artificial machines; and this organism is not contrasted with mechanism, but rather conceived as a variety of it" (106).

Hence, animals are still conceivable along mechanistic lines here. The difference between Leibniz's treatments of the animal in both periods is the following: in his animal economy, the distinction from artificial machines was functionally drawn; while, by the time of his organics, the distinction was drawn on the microstructural level (100). However, we have to be careful here, as Smith points out. Strictly speaking, it is not the animal that is understood along mechanistic, that is, along microstructural lines, but rather the animal's body. By the time of Leibniz's controversy with Stahl and his preoccupation with organics, he conceives of the whole animal as a corporeal substance, that is, a unity that belongs to the metaphysical realm, because it is constituted by a vital principle, its dominant monad or soul. This soul, however, cannot play an explanatory role when it comes to physical questions concerning the animal's body. Thus, Smith recommends to distinguish, if only conceptually, the animal, that is, the corporeal substance from its body, that is, the natural machine (108). We therefore have two realms of inquiry here: the physical and the metaphysical. On the physical level, the organic body is on a par with a pile of sawdust. It is nothing more than an aggregate, albeit a special one, since it cannot be created or taken out of existence by decomposition due to its infinite complexity (111). The animal as a living thing, in contrast, belongs to the metaphysical level. However, or so Smith explicitly points out, each level "suffices for the determination of the identity of the thing in question" (109). But, or so I would like to ask, is this really the case? How does a biologist individuate his objects of inquiry? Or, for that matter, how can he be sure that he investigates the body of a real dog, instead of some artificial dog-machine? The answer should be, of course, that, contrary to the artificial dog-machine, the body of the real dog is infinitely complex. It is a machine in its least parts. But, one might ask further, how does the biologist know that this is the case? Surely, organic bodies, that is, natural machines display infinite complexity. The question is, how could infinite complexity be discovered or even seen? Strictly speaking, it cannot be seen, for infinity cannot be *seen*. However, it could be inferred, namely by the fact that natural machines display a unity, as well. And unity can be seen (sic!). The question is: Why can it be seen? One answer might be that it can be seen, because the bodily functions fulfill needs, which obviously serve the wellbeing of the body as a whole. Yet, if we accept this answer we have already left the physical realm (at least in Leibniz's system), for then an overall principle is assumed which is teleological in its nature. It makes sure that the internal structure of the thing in question is sustained and that the operations of the parts serve its preservation. And for Leibniz this principle is, of course, the dominant monad. Hence, even if one tries to distinguish the animal body from the animal as a whole, this body seems to be identifiable only derivatively – via its owner (if you like).

However, given that Leibniz repeatedly indicates that a distinction between the physical and the metaphysical levels of explanation is not only desirable but also required, the problem just mentioned seems to be his. Leibniz's aim, as Smith makes it very clear, is to explain nature mechanistically. Now that he considers the basic objects in the world to be "worms rather than atoms," the conclusion follows naturally that we should see biology as the basic science for Leibniz (125).

In the fourth chapter Smith continues to engage with Leibniz's model of organic bodies. He discusses Leibniz's theory of nested individuality, according to which a corporeal substance is a hierarchical structure of infinitely many corporeal substances, and he takes a look at the scientific background of the 17th century and shows how this theory fits in there.

According to Smith, Leibniz's theory of nested individuality, extraordinary as it might be, has decisive shortcomings. It does not only differ from the Aristotelian metaphysical and grammatical characterization, but it also stands in conflict with our current notion of biological individuality. According to the latter, "biological individuals are identified with multicellular organisms – organisms in our sense, not 'organism' in Leibniz's sense – and for this reason groups or parts of organisms are excluded from the ranks of the complete individuals" (139). However, by the time Leibniz developed his theory, the empirical life sciences had just discovered "the ubiquity of subvisible living creatures" and were becoming more and more aware "of the deep interdependence of all living entities" (137). Smith argues persuasively against the view that throughout the history of philosophy of science, multicellular organisms such as horses have served as the paradigm cases of biological individuals. In fact, there was a "sharp shift" of focus in the seventeenth century "from macro- to microorganisms" (144). The idea of a "plurality of worlds both too large and too small to be detected through unaided perception" became popular, and simultaneously, another idea began to spread for the first time, namely "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" (144). Hence, worms as they were found for example in the pineal gland were not considered as parasites and causes of alarm anymore, but rather as constituents contributing to the well-being of the animals in which they were found.

Smith shows in great detail that Leibniz was equally fascinated by these ideas. And he exposes convincingly that, contrary to some suggestions, Leibniz must have known about the existence of microorganisms before 1672. Therefore, it is indeed very plausible to suppose that Leibniz's theory of harmoniously nested individuality was inspired by microscopy. As Smith points out, "microscopic discovery played an important role in the development of Leibniz's metaphysics of corporeal substance" (153). However, Smith's wording could be more careful in this point. One might easily be misled to take such sentences to suggest that Leibniz might have thought that microscopic discoveries are in fact some kind of rational support or proof for his theory of infinite nestedness. But a suggestion such as this is not very plausible, for at least two reasons. Firstly, Leibniz himself offers well-known metaphysical reasons for this theory, reasons that are commonly regarded as sufficient on their own. Secondly and more importantly, it is not very likely that someone like Leibniz could have thought a metaphysical claim about infinity to be justifiable empirically. No microscope, no matter how sophisticated in its construction, can prove infinity. No one could have known this better than Leibniz.[1] His model of nested individuality, thus, might apply to empirical objects, but this does not make the theory itself empirical.

The third part of *Divine Machines*, chapters five and six, examines the origin of organic forms. In the fifth chapter, Smith explores the following tension in Leibniz's theory of animal bodies. On the one hand, these bodies (taken separately) are mechanistically explainable, according to Leibniz. However, on the other hand, they are machines that are infinitely structured. This means they must be divine in their origin, which is to say, that there can be no mechanistic explanation of the coming-into-being of organic bodies. The doctrine, Leibniz opts for in order to solve this problem, is well known. Living creatures as well as their bodies are not generated at all, rather they must have been brought into being by God and now continue to exist since creation. That is, each living being is preformed by God. It is not born, strictly speaking, and it does not die either, strictly speaking. The only things that happen to a living being are augmenting and diminishing. These processes, however, should be explicable in fully mechanistic terms. Insofar it is not surprising that Leibniz took special interest in spermatozoa and metamorphosis in insects, two of the discoveries of the microbiologists Swammerdam and Leeuwenhoek. Both men had a strong influence on Leibniz's theory of preformation, as Smith demonstrates in length.

The sixth chapter focuses on three problems: "(i) the influence of the maternal imagination on fetal development, (ii) spontaneous generation, and (iii) the origins of paleontological forms" (200). Given his theory of preformation, it is not surprising that Leibniz stands in great opposition to the idea of spontaneity. "Nature does not play" (223). However, in the early modern period the question of how to explain the existence of apparently spontaneously generated organisms played an important role. In fact, theories of spontaneous generation underwent important changes, as Smith shows; they developed from the idea that spontaneous generation could be explained by cosmic influences to the idea that, strictly speaking, there is no such thing as spontaneous generation. According to the latter theory, apparently spontaneously generated animals, such as flies and worms on a dead body, had to be explained as effects of one or another natural cause, even if those effects were only by-products of decay.

Given his opposition to the idea of spontaneous generation, Leibniz's explanation of the origin of fossils is an obvious consequence of it. Although there was a time when Leibniz held the view that fossils are games of nature, this conviction did not hold for long. In the early 1690s at the latest, by the time of the *Protogaea*, Leibniz held the opinion that nature does not play. That is, although they lack infinitely complex structure, Leibniz considers fossils as animals, if only as once-living animals, to which all the characteristics apply (or applied) which are true of living animals: they came to existence through preformation, and their bodies were infinitely complex. Hence, although as natural machines they could be mechanically explained, such an explanation could never be exhaustive, for, natural machines cannot be made. This last point is important: as Smith demonstrates, Leibniz concludes from it that the formation of fossils, contrary to that of crystals, cannot be fully understood in terms of the geometrical relations of their parts (227). It follows that crystals can be produced artificially, while animals, and for that matter, fossils cannot.

Concerning the question of the role of the imagination in the development of the fetus, Leibniz held the view "that soul activity can have no role in the formation or the maintenance of the body" (207). Smith cites two reasons in order to support this claim: firstly, because of his preformation-theory, Leibniz thought that every mark of the fetus had already been present in the preformed individual, that is, in the spermatozoon, "from the beginning of the time" (210). No "searing in at some point in the course of development" is necessary (209). Secondly, due to his theory of preestablished harmony, Leibniz cannot accept any view that lets souls cause bodily changes. Although there is, of course, agreement between the mother's soul and her womb, the relation between them can maximally be described as "as if" or quasi-causal (210).

Now even if it is convincing to say that Leibniz himself allowed only quasi-causal relations between the mother and her fetus, one could ask, why there should be a difference between this fetus and the worm in the mother's pineal gland, or the worm in her finger, for that matter. They all are individuals, that is, corporeal substances. But the mother can move her finger on purpose, that is, she can cause one of her sub-substances to move. Of course, given the parallelism of soul and body, this causation is only quasi-causation. The question remains what the difference between these two kinds of causation could consist in. What is the difference between this latter kind of quasi-causation and the quasi-causation in the case, when the passions of the mother's soul quasi-cause changes in the formation of the fetus? One possible difference could be that at some point, the fetus will be a self-contained living-being. However, this could also be true for the worm in the mother's finger.

The seventh chapter of *Divine Machines* is the last and fourth part of the book. Here, Smith discusses Leibniz's notion of biological species. Instead of confronting Leibniz's view on the matter with that of John Locke only, Smith proceeds in this chapter in the way he did it in the preceding chapters: he relates Leibniz's views to those of his contemporaries, thereby helpfully contextualizing Leibniz's own position. Leibniz is a species realist (235). Species are a real kind. And what is more, species are fixed for Leibniz. They themselves do not change, even though changes within one species are possible and sometimes even actual (266). By taking this position, Leibniz can deny both the possibility of evolution and the possibility of spontaneous production of organic forms.

There are two factors that naturally determine what species a specific animal belongs to: the line of descent on the one hand (236) and a trademark activity that is specific to it on the other. "It is of the essence of a squirrel to dance or jump, so a squirrel is, essentially, a dancing or jumping machine" (248).

That species are regarded as fixed, and thus real from the time of their creation, is consistent with Leibniz's theory of preformationism. And it is consistent with Leibniz's theory of gradationism, the view that there is a continuous chain of being (242), as well. However, if, in addition to common descent, species are defined by certain characteristics specific to it, Leibniz cannot deny the possibility of abrupt breaks. For, as Smith argues, some species-defining characteristics "are all-or-nothing affairs" (243). Smith's example is reason. "Either you possess reason or you do not", he writes (243). If reason were a matter of degree, human beings would lose their special position in nature. Now, granted that the possession of reason is an all-or-nothing affair for Leibniz, the question is, whether this would have constituted a sufficient reason for him to break with his commitment to the principle of plenitude, and consequently to allow the scale of being to be dense instead of continuous. Smith thinks that this is the case. However, it might be worth looking into this matter more deeply. In fact, one might want to consider many issues further after one has read this comprehensive, thoroughly investigated, and impressive book. It sheds light on Leibniz from a new angle and will surely become one of the standard references for those engaging in the philosophy of life sciences in the early modern period.

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Notes

[1] Jeffrey K. McDonough had similar reservations in his review of *Divine Machines*. http://ndpr.nd.edu/news/30317-divine-machines-leibniz-and-the-sciences-of-life-2/