PART ONE

THE NATURE OF LIVING BEINGS

1

Infinity and Life

The Role of Infinity in Leibniz's Theory of Living Beings

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1. Introduction: What Does Infinity Have to Do with Life?

What does infinity have to do with life and the nature of living beings? At first glance, the answer seems to be "not very much." Infinity seems to belong primarily to mathematics and, since human observational capacities are finite and limited, infinity (or any infinite thing, for that matter) cannot be observed in nature. Thus it would seem that infinity would have no place in an adequate description of nature, in general, and in its living part, in particular.

And yet infinity does play a major role in some important views of the natural world. One need only recall that one of the most crucial transformations from the old to the new science was described as a turn from a closed world to an infinite universe.[1] The story of the role this transformation played in the scientific revolution (in the 16th and 17th centuries), as well as its impact on human psychology and imagination, is quite well known (if perhaps somewhat

[1] A. Koyré, *From the Closed World to the Infinite Universe* (Baltimore, MD: Johns Hopkins University Press, 1957). Abbreviations are as follows: A: G. W. Leibniz, *Sämtliche Schriften und Briefe*, Darmstadt/Leipzig/Berlin: Edition of the German Academy of Sciences, 1923–, cited by series, volume, and page. If not otherwise indicated, the reference is to series 6, vol. 3. AG: G. W. Leibniz, *Philosophical Essays*, D. Garber and R. Ariew (eds. and trans.) Indianapolis,IN: Hackett, 1989. GP: *Die Philosophischen Schriften von G. W. Leibniz*, C. I. Gerhardt (ed.), 7 vols. Berlin: Weidmann, 1875–90; reprinted Hildesheim, DE: Olms, 1978. GM: *Die mathematischen Schriften von G. W. Leibniz*, C. I. Gerhardt (ed.), Berlin: Winter, 1860–75; LLC: G. W. Leibniz, *The Labyrinth of the Continuum. Writings on the Continuum Problem, 1672–1686*, translated by R. Arthur, New Haven, CT, and London, Yale University Press, 2001. *Theodicy*: G. W. Leibniz, *Essays on the Goodness of God the Freedom of Man and the Origin Evil*, translated by E. M. Huggard (La Salle, IL: Open Court, 1993), first published (London: Routledge & Kegan Paul, 1951).

underappreciated). At the same time, it is much less known and much less appreciated that the turn from a finite and closed world to an infinite one has taken place not only in cosmology and astronomy but also in the life sciences. In other words, the change from the finite to the infinite has taken shape not only at the macroscopic level, regarding the non-limited nature of space, but also at the microscopic level where worlds within worlds of minute animals (*animalcula*) have been discovered or postulated.

One might say that what the invention of the telescope has given the scientific imagination at the macroscopic level, the invention of the microscope has given the scientific imagination at the microscopic level—that is, some empirical insight into new phenomena and a lot to stimulate the scientific imagination.[2]

In fact, during this time period scholars were preoccupied not only with the infinitely large but also with the infinitely small. Thus, infinitesimals were used not only in pure mathematics but also in describing and understanding motion (as exemplified in Hobbes's notion of conatus); forces (as exemplified both in Leibniz's and Newton's work); the division of matter; and, what is the main concern of this project, the nature of living beings.[3] The work of early microscope observers, such as Malpighi and Leeuwenhoek, is most pertinent here. Pascal's example of a mite stands out as an illustration of this preoccupation. Pascal's eloquent remarks regarding the infinitely large and the infinitely small may serve here as a reminder of the role infinity plays in both domains. Pascal writes:

> What is a man in the infinite? Who can comprehend it? But to show him another prodigy equally astonishing, let him examine the most delicate things he knows. Let a mite be given him, with its minute body and parts incomparably more minute, limbs with their joints, veins in the limbs, blood in the veins, humours in the blood, drops in the humours, vapours in the drops. Dividing these last things again, let him exhaust his powers and his conceptions, and let the last object at which he can arrive be now that of our discourse. Perhaps he will think that here is the smallest point in nature. I will let him see therein a new abyss. I will paint for him not only the visible universe, but also everything he is capable of conceiving of nature's immensity in the womb of this

[2] It is an open question how important a role these devices play in these transitions, but there is no doubt that both play a considerable role in the development of astronomy, as well as the life sciences. Leibniz himself noted that one could have anticipated the existence of microscopic animals prior to their empirical discovery just "as Democritus foresaw the imperceptible stars in the Milky Way before the discovery of the telescope." See footnote 23 for the reference and some discussion of this point.

[3] It is also worth recalling Giordano Bruno's lines in this context: "The minimum of nature or reality is amazingly smaller than the smallest perceptible minimum. There is no art to define it." De triplici minimo et mensura, LIB.i cap. 9.

> imperceptible atom. Let him see therein an infinity of worlds, each of which has its firmament, its planets, its earth, in the same proportion as in the visible world; in this earth of animals, and ultimately of mites, in which he will find again all that the first had, finding still in these others the same thing without end and without cessation. Let him lose himself in wonders as amazing in their littleness as the others in their vastness.[4]

While the mathematical, astronomical, and physical facets of the scientific revolution have been studied in great detail, the history of the life sciences and its development during the 16th and 17th centuries deserve more attention. Specifically, the role infinity plays in the early stages of the life sciences and the way it figures in various conceptualizations of living beings certainly deserve more attention.

Part of the reason for this lack of attention may be due to the way infinity was considered by some major figures in the making of the scientific revolution. Both Descartes and Pascal, who were among the most important mathematicians of the time, were skeptical about using infinity in a scientific description of nature. They argued that, due to the finite nature of our mind, the infinite is incomprehensible to us and must remain beyond our grasp. In stressing the contrast between the finite and the infinite, Pascal and Descartes delineated an irreconcilable gap between the infinite creator and its finite creatures, suggesting

[4] The passages continues thus: "For who will not be astounded at the fact that our body, which a little while ago was imperceptible in the universe, itself imperceptible in the bosom of the whole, is now a colossus, a world, or rather a whole, in respect of the final smallness which we cannot reach? He who regards himself in this light will be afraid of himself, and observing himself suspended in the mass given him by nature between those two abysses of the Infinite and Nothing, of which he is equally removed, will tremble at the sight of these marvels; and I think that, as his curiosity changes into admiration, he will be more disposed to contemplate them in silence than to examine them with presumption." Blaise Pascal, *Pensées de M. Pascal sur la religion et sur quelques autres sujets* (Paris, 1670), XXII, 169–175; the English translation is from Lloyd Strickland's website (http://www.leibniz-translations.com/pascal.htm#note2).

Leibniz's response to Pascal's remarks (in a note he later deleted) is extremely interesting: The full English translation reads: "What he has just said on the subject of the double infinity is only an entrance into my system. What would he not have said with that power of eloquence he possessed if he had gone further, if he had known that all matter is organic, and that the least portion contains, through the actual infinity of its parts in an infinity of ways, a living mirror expressing the whole infinite universe, so that one could read in it (if one had sufficiently keen sight and mind) not only the present stretched out to infinity, but also the past, and the whole infinitely infinite future, since it is infinite in every moment, and there is an infinity of moments in each part of time, and more infinity than one could express in the whole of future eternity." *G. W. Leibniz: Textes inédits d'après les manuscrits de la Bibliothèque provinciale de Hanovre,* G. Grua (ed.), Paris, 1948, 553; F. de Buzon 554. The English translation is from Lloyd Strickland's website (http://www.leibniz-translations.com/pascal.htm#note2).

that it would be not only cognitively impossible but also morally and theologically misguided for us to investigate the infinite.[5]

This surely contributed to a hostile attitude for the use of infinity beyond its theological context (as an essential attribute of God). Galileo, for his part, exposed the paradoxical nature of the infinite, arguing that even the most basic relations of the quantitative sciences, such as 'larger than', 'smaller than', or 'equal to', cannot be applied when we are dealing with the infinite.[6] If one accepts Galileo's reasoning, it would follow that infinity cannot be used in a scientific description of nature for, according to the norms of the new philosophers, such a description must surely involve quantification.

2. Infinity in Leibniz

At the same time, when we turn our attention to Leibniz, we see that infinity figures in almost every aspect of his philosophy. Infinity plays a crucial role not only in his views of God, space, number, and possible worlds, but also in his views of the natural world, as can be seen in his response to Pascal.[7] Leibniz is not wary of using infinity. Rather, he believes that infinity should be admired and investigated precisely because created things, which he identifies with living beings, bear the mark of their author, that is, a mark of perfection and infinity imprinted in their very nature.

In his early work on the infinitesimal calculus (initiated in Paris under the guidance of Huygens), Leibniz discovered a rational method to treat infinity in mathematics. By translating infinitesimal quantities into finite ones, arguing that they can be regarded as variables, smaller or larger than any assignable quantity, he showed that infinitesimals could in fact be used in calculations.[8] Leibniz's sophisticated approach (evident in his early work in mathematics) certainly contributed to his applying infinity in other domains of his philosophy as well.

[5] Descartes's *Principles of Philosophy*, Part I, articles 26–27. See Pascal's *Pensées* fragments 194–427, 104–105 in Galimard–Flamarion edition (1976). As Pascal notes, we perceive the infinite but do not understand its nature (fragments 233–418, Galimard–Flamarion edition (1976), 113).

[6] In his *Discourses and Mathematical Demonstrations Concerning the Two New Sciences*, Galileo writes: "For I believe that these attributes of greatness, smallness, and equality do not befit infinities, about which it cannot be said that one is greater than, smaller than, or equal to one another" (Edition Nazionale 77–78; cited from Richard Arthur's translation in LLC 355).

[7] It is also worth mentioning the role infinity plays in the resolution of the two "labyrinths" the human mind gets entangled in: "the labyrinth of the continuum" and "the labyrinth of human freedom" (AG 95).

[8] See Arthur's introduction to LLC and his "Actual Infinitesimals in Leibniz's Early Thought" in *The Philosophy of the Young Leibniz*, Studia Leibnitiana Sonderheft, edited by M. Kulstad, M. Laerke, and D. Snyder (Stuttgart, DE: Franz Steiner Verlag, 2009), 11–28.

For, given this approach, one could feel free using infinity without falling into paradox.[9]

And Leibniz indeed felt free to use infinity in his philosophy. Thus, for example, he held that the actual world is one of infinitely many possible worlds and that possible worlds, in turn, are conceived by God's infinite intellect[10] (which is the region of all possibilities). God himself is seen as an *infinite* and most perfect being. The actual world, too, consists of infinitely many individual substances, each of which involves relations to infinitely many others and "exhibits an infinite series of operations" (Comments on Fardella, AG 102). Likewise, for Leibniz, "[e]ach portion of matter may be conceived as a garden full of plants and as a pond full of fishes. But each branch of every plant, each member of every animal, each drop of its liquids is also some such garden or pond" (*Monadology* §67; AG 222).

Leibniz clearly applies infinity both to the large and to the small. Far from avoiding the infinite in his metaphysics, as Descartes and Pascal recommend, Leibniz is celebrating infinity. He obviously finds it essential for an adequate description of the world.[11] As he writes to Foucher:

> I am so much in favor of actual infinity that, instead of admitting that nature rejects it, as it is vulgarly said, I hold that it affects it everywhere, *for better marking the perfections of its author*. Thus I believe that there is no part of matter which is not, I do not say divisible but actually divided and, by consequent, the least particle would be considered as a world full of an infinity of diverse creatures. (Letter to Foucher, GP I 416)[12]

[9] Leibniz's approach is far more complicated. He certainly rejects infinite number (and infinite quantities) as paradoxical but shows that the syncategorematic sense of infinity avoids these paradoxes. In addition, he distinguishes between different kinds and different degrees of infinity.

[10] *Monadology* §53; *Theodicy* §225.

[11] «Mes méditations fondamentales roulent sur deux choses, savoir sur l'unité et sur l'infini. Les âmes sont des unités et les corps sont des multiplicités, mais infinies tellement que le moindre grain de poussière contient un monde d'un infinités des créatures » (Letter to Sophie, November 4, 1696).

[12] «Je suis tellement pour l'infini actuel, qu'au lieu d'admettre que la nature l'abhorre, comme l'on dit vulgairement, je tiens qu'elle l'affecte partout, pour mieux marquer les perfections de son auteur. Ainsi je crois qu'il n'y a aucune partie de la matière qui ne soit, je ne dit pas divisible, mais actuellement divisée, et par conséquent, la moindre particelle doit être considérée comme un monde plein d'une infinité des créatures différentes» (Letter to Foucher, GP I 416). See also Monadology §65: "Every portion of matter is not only divisible to infinity, as the ancients realized, but is actually subdivided without end, every part into smaller parts, each part divided into parts having some motion of their own" (AG 221). Compare this to Aristotle's view expressed in his *Generation of Animals*: "Nature avoids what is infinite, because the infinity lacks completion and finality, whereas this is what nature always seeks" (1.1.715b15). As I argue below, there is a sense of infinity in Leibniz that means precisely absolute perfection and completion. But, of course, this is not completion in Aristotle's teleological sense.

While this passage makes clear that Leibniz is keen on using infinity in his description of the natural world, I would like to stress that Leibniz employs different notions of infinity in different contexts. He is particularly careful to distinguish between using infinity in mathematical contexts, which usually pertain to abstract and ideal entities, and in metaphysical contexts, which usually pertain to concrete and real beings. This approach is exemplified by Leibniz's position regarding the labyrinth of the continuum. According to Leibniz, the labyrinth of the continuum is produced when we confuse the mathematical and the ideal realms, which admits of potential infinity, and the metaphysical or the real, which admits of actual infinity. Likewise, the way out of the labyrinth would be to disentangle the confusion by carefully distinguishing between the two realms and the corresponding types of infinity.[13]

I shall return to this point in attempting to discern the exact sense in which Leibniz ascribes infinity to living beings. But before we come to focus on the different ways Leibniz employs infinity, I would like to substantiate and enrich the claim that Leibniz is using infinity in describing (and in defining) living beings by reviewing some relevant texts set in a chronological order.

2.1 Infinity and Life in Leibniz

As early as his Theory of Concrete Motion (1670–71) Leibniz articulates the doctrine that there are worlds within worlds to infinity. In this context the doctrine appears as a consequence of the infinite divisibility of the continuum. As he writes, "any atom will be of infinite species, like a sort of world, and there will be worlds within worlds to infinity" (A 6.2 N40; LLC 338–339). A similar view appears in Leibniz's notes from Paris (1676), where he writes that every part of the world, regardless of how small, "contains an infinity of creatures" which is itself a kind of "world" (A 6.3 474).[14]

In a letter to Malebranche, from 1679, Leibniz writes:

> There is even room to fear that there are no elements at all, everything being effectively divided to infinity in organic bodies. For if these microscopic animals are in turn composed of animals or plants or other

[13] "As long as we seek actual parts in the order of possibles and indeterminate parts in aggregates of actual things, we confuse the ideal things with real substances and entangle ourselves in the labyrinth of the continuum and inexplicable contradictions" (Leibniz letter to De Volder, January 19, 1706, translated in AG 185). See also Pauline Phemister, *Leibniz and the Natural World Activity, Passivity and Corporeal Substances in Leibniz's Philosophy* (Dordrecht, DE: Springer, 2005) and Richard Arthur's introduction to LLC.

[14] G. W. Leibniz, *De Summa Rerum: Metaphysical Papers 1675–76*, edited and translated by G. H. R. Parkinson (New Haven and London: Yale University Press, 1992) 25.

> heterogeneous bodies, and so on to infinity, it is apparent, that there would not be any elements. (A Iii 719, translation in Smith 2010, 235)

In *Primary Truths* (1689–90), Leibniz again notes that "every particle of the universe contains a world of an infinity of creatures" (A 6.4 1647–48).[15]

In the course of his correspondence with Arnauld, it begins to become clear that what Leibniz has in mind by these creatures (that are to be found everywhere) is living things:

> [A]nd since matter is infinitely divisible, no portion can be designated so small that it does not contain animated bodies, or at least bodies endowed with a primitive Entelechy or (if you permit me to use the concept of life so generally), with a vital principle; in short, corporeal substances, of all of which one can say in general that they are living. (G II 118)

Furthermore, in a letter (to Arnauld) from November 28, 1686, Leibniz suggests that living (or being animate) is the mark of a true corporeal substance:

> I cannot say precisely whether there are true corporeal substances other than those that are animated, but souls at least serve to give us some knowledge of others by analogy. (AG 79)

In the same letter, Leibniz clarifies that being animate is the only limit to the infinite divisibility of matter:

> For the continuum is not merely divided to infinity, but every part of matter is actually divided into other parts as different among themselves as the aforementioned diamonds. And since we can always go on in this way, we could never reach anything about which we could say, here is truly a being, unless we found *animated machines* whose soul or substantial form produced a substantial unity independent of the external union arising from contact. (My italics, AG 80)

As we can see in these passages, in the correspondence with Arnauld, Leibniz begins to use the notion of life as a criterion for being, and he is clearly ascribing

[15] In a note on a letter of Michelangelo Fardella from 1690, we find again Leibniz's commitment to the worlds within worlds ad infinitum. He writes: "…there are substances everywhere in matter, just as points are everywhere in a line…[J]ust as there is no portion of a line in which there is not an infinite number of points, there is no portion of matter which does not contain an infinite number of substances" (AG 105).

infinity to living beings, so that they are to be found everywhere (or in the least part of matter).[16]

From 1695, beginning with the *New System of Nature*, Leibniz is no longer using infinity merely in a general way (of describing nature as worlds within worlds to infinity). From now on, he is clearly using infinity as one of the defining features of living beings. In arguing (in the *New System*) against Descartes's claim that living things are nothing but subtle machines, akin to artificial machines, though more subtle and complex, Leibniz argues that natural machines are essentially different than artificial machines in that they are machines to the least of their parts, so that they are machines within machines ad infinitum.

> I believe that this conception (in which the difference between natural machines and ours is merely one of degree) does not give us sufficiently just and worthy idea of nature, and that my system alone allows us to understand the true and immense distance between the least production and mechanisms of divine wisdom and the greatest masterpieces that derive from the craft of a limited mind; this difference is not simply a difference of degree, but a difference in kind. We must then know that the machines of nature have a truly infinite number of organs, and are so well supplied and so resistant to ~~het~~ all accidents that it is not possible to destroy them. A natural machine sill remains a machine in its least parts, and moreover, it always remains the same machine that it has been, being merely transformed through different enfolding it undergoes, sometimes extended, sometimes compressed and concentrated as it were, where it is thought to have perished. (*New System of Nature*, AG 142)
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> Moreover, a natural machine has the great advantage over an artificial machine, that, displaying the mark of an infinite creator, it is made up of an infinity of entangled organs. And thus, a natural machine can never be absolutely destroyed just it can never absolutely begin, but it only decreases or increases, enfolds or unfolds, always preserving in itself some degree of life [*vitalitas*] or, if you prefer, some degree of primitive activity [*actuositas*]. (*On Body and Force, Against the Cartesians*, May 1702, AG 253)[17]

[16] G II 111–129.

[17] It is very interesting to observe that (in addition to the connection between infinity and life) the notion of a degree of life is clearly related here to degree of primitive activity.

Leibniz's last point that some degree of life is always preserved in a natural machine, and that it corresponds to some degree of primitive activity will be developed in the last section. For now I would like to observe that, according to Leibniz, a living being is infinite both in being ever active and in its internal structure.[18] It is significant, too, that the infinity of living beings is intrinsically related to their being creations of an infinite creator, or, in other words, to their being what Leibniz calls "divine machines."

This point is made explicitly in the *Monadology* §64:

> Thus each organized body of a living being is a kind of divine machine or natural automaton, which infinitely surpasses all artificial automata. For a machine constructed by man's art is not a machine in each of its parts. For example, the tooth of a brass wheel has parts or fragments which, for us, are no longer artificial things, and no longer have any marks to indicate the machine for whose use the wheel was intended. But natural machines, that is, living bodies, are still machines in their least parts, to infinity. That is the difference between nature and art, that is, between the divine art and our art. (AG 221)[19]

To wrap up this quick survey of texts, let us note that, in the *Principles of Nature and Grace, Based on Reason* (1714) §4, Leibniz writes: "Each monad, together with a particular body, makes up a living substance. Thus, there is not only life everywhere, joined to limbs or organs, but there are also infinite degrees of life in the monads, some dominating more or less over others" (AG 208).[20]

[18] In a letter to Lady Masham from 1704 Leibniz writes: "I define an organism or a natural machine, as a machine each of whose parts is a machine, and consequently the subtlety of its artifice extends to infinity, nothing being so small as to be neglected, whereas the parts of our artificial machines are not machines. This is the essential difference between nature and art, which our moderns have not considered sufficiently" (GP III 356).

[19] «[U]ne Machine faite par l'art de l'homme n'est pas Machine dans chacune de ses parties. Par exemple: la dent d'une roue de laiton a des parties ou fragments qui ne nous sont plus quelque chose d'artificiel, et n'ont plus rien qui marque de la Machine par rapport à l'usage où la roue était destinée. Mais les Machines de la Nature, c'est-à-dire les corps vivants, sont encore des Machines dans leurs moindres parties, jusqu'à l'infini. C'est ce qui fait la différence entre la Nature et l'Art, c'est-à-dire entre l'art Divin et le nôtre.» See also Leibniz's Fifth Letter to Clarke (arts. 115, 116, in AG 344–345).

[20] See also: "But in this way I restrict composite or corporeal substance to living things alone, that is to organic machines of nature. The rest are for me mere aggregates of substances, which I call substantiated things; but an aggregate constitutes only an accidental unity" (Letter to Des Bosses, May 29, 1716, in G. W. Leibniz, *The Leibniz-Des Bosses Correspondence*, eds. and trans. B. Look and D. Rutherford (New Haven, CT: Yale University Press, 2007), 377.

3. Empirical, Mathematical, and Metaphysical Sources for Leibniz's View

This brief survey, drawn from Leibniz's early writings to his very late ones, shows that infinity figures (though in importantly different ways) in Leibniz's description of living beings throughout his career. In fact, it shows more than that. These texts also demonstrate that, at least since the *New System of Nature* (1695), Leibniz is employing infinity not only to *describe* living beings but also as one of their *defining* features, that is, as a mark of living beings.

One must wonder, though, what were Leibniz's reasons for using infinity as the distinctive mark of living beings? It turns out that Leibniz's reasons for connecting infinity and life in this strong way reveal something not only about Leibniz but also about the philosophical and scientific background in the early modern era.

As François Duchesneau has argued, in the background of Leibniz's view, there is a new approach to the study of living things, viz., that of *iatro*-mechanism. This tradition draws on two main sources: a commitment to a mechanistic description of natural things advocated by Descartes and the new discoveries made through the invention of the microscope by Malpighi in Italy, Leeuwenhoek in Holland, and Hook in England. These observations have revealed a world of minute animals (*animalcula*) within animals, which were previously invisible.[21]

In his recent book *Divine Machines*, Justin Smith argues that Leibniz's theory of organic body indeed develops out of the *anatomia subtilis* of his predecessors, but that Leibniz renders it distinctly Leibnizian, by the introduction of infinity as a way of accounting for the fundamental difference between natural machines and artificial ones. Smith writes:

> …however much the microstructural strain of iatro-mechanism provides a starting point for Leibniz's mature conception of organic body, the German philosopher's conception nonetheless amounts to a radical departure from the earlier subtle-anatomical conception of bodies as consisting in numerous little machines. The crucial difference lies in Leibniz's introduction of *infinity* into his account of the assemblage of machines that make up the body: for him, an organic body is contrasted with a mere machine to the extent that there is literally no lower limit to its mechanical composition. Leibniz's theory of organic body indeed develops out of the *anatomia subtilis* of his predecessors, but Leibniz takes his predecessors' work and renders it, so to speak, distinctly Leibnizian, by means of the introduction of infinity as a way of

[21] See Catherine Wilson, *The Invisible World* (Princeton, NJ: Princeton University Press, 1995).

> accounting for what he takes to be not just a difference of degree of complexity between natural and artificial machines, but rather a fundamental difference in kind. (155)

While I certainly agree with Smith on the "introduction of infinity" as the distinctive feature of Leibniz's view, I think that he slightly overstates the role microscopical and anatomical research plays in Leibniz's reasoning.[22] It should be noted that there is a serious discrepancy between the microscopists' successful project of discovering smaller and smaller *animalcula* and Leibniz's claim that one of the defining features of living beings is that they have a nested a structure that develops ad infinitum. Such a claim simply cannot be supported by observation, no matter how subtle a microscope one would use. One might suppose, as some *iatro-mechanists* have, that, as our means of observation improve, smaller and smaller animals shall be further discovered. By extrapolation, one might argue that this could go on indefinitely. But the claim that the structure of a living creature is infinite cannot be based on observation, for observation itself is necessarily finite.[23] Probably no one in the early modern era knows this better than Leibniz.[24]

[22] At the end of chapter 4 of his book, Smith raises very interesting questions: "Why the infinite nestedness? We may agree with Roger that Leibniz's theory of organic body is motivated by a desire to take account of the real. But we still must ask, why does 'the real' come out looking precisely like that? The answer seems to have much to do with the state of microscopical and anatomical research in the scientific context out of which Leibniz's philosophy emerged" (235).

[23] For a similar critique, see Jeffrey McDonough's review of Justin Smith's book in the *Notre Dame Philosophical Review* (NDPR), April 14, 2012 (http://ndpr.nd.edu/news/30317-divine-machines-leibniz-and-the-sciences-of-life-2/,2012).

[24] There is some textual evidence that Leibniz himself was well aware of the fallacy of arriving at the infinite on the basis of experience. For example, in a letter to Rémond (November 4, 1715), Leibniz writes: "The author [the reference is to Du Tertter's *Réfutation* of Malbranche's system published in Paris in 1715] adds (vol. 1, 307) that in the so-called knowledge of infinity, the mind only sees that lengths can be placed end to end and be repeated as much as one would like. Very well, but this author might consider that knowing that this repetition can always be made already amounts to knowing infinity" (G III, 658–689; English translation is from http://www.leibniz-translations.com/remond1715.htm). Leibniz's point here is that the idea that the infinite is based on thinking that one could go on indefinitely, presupposes (rather than yields) the notion of infinity. While this is written in a different context, it is clear that the same argument would apply to observation of smaller and smaller animals, and it supports the point that Leibniz should not base his claim that the structure of living beings is infinite on the microscopic observations alone. More direct evidence can be found in this passage:

"Although the conservation of the animal is favored by the microscopes, nonetheless we were aware of small bodies before their discovery, and thus we were already very well able to foresee the small animals, as Democritus foresaw the imperceptible stars in the Milky Way before the discovery of the telescope." *Gottfried Wilhelm Leibniz: Philosophische Schriften*, ed. and trans. Hans Heinz Holz, 5 vols. (Darmstadt, DE: Wissenschaftliche Buchgesellschaft, 1985), V/2, 302, translation in Smith (2011), 222.

Thus it seems to me that, however exciting, the discoveries made through the invention of the microscope are not sufficient for connecting infinity and life in the strong way that Leibniz does, that is, as a mark (or a defining feature) of living beings.

There is another (and even more important) point regarding the role infinity plays in Leibniz's view that could not have been motivated by empirical considerations. The introduction of infinity to Leibniz's account of natural machines (and thus of living beings) does not regard the mere infinity of their organs. Rather, Leibniz's use of infinity in this context reveals something deeper about the nature of living beings. For Leibniz, natural machines are not aggregates or composites of infinitely many parts. Rather, natural machines are active organic units that have an infinite *structure*. Such a structure implies that the activity of living beings is informed and regulated by a law that makes their infinite structure intelligible. I will get back to this point in my conclusion, but here I would like to point out that Leibniz's use of infinity in characterizing living beings cannot be fully comprehended in light of the observations made with the newly invented microscope.

It is also important to stress that the theories of the microscope observers (especially those Leibniz refers to) are grounded in theological commitments. This concerns in particular the issue of preformation, that is, the supposition that animals' inner structure is preformed in minute form in their creation, which would account for the apparent generation and could be seen as development of their preformed nature.[25] Thus it is very telling that, in the *New System of Nature*, Leibniz notes that the "*transformations* of Swammerdam, Malpighi, and Leeuwenhoek, the best observers of our time, have come to my aid, and made it easier for me to admit that animals and all other organized substances have no beginning, although we think they do, and that their apparent generation is only a development, a kind of augmentation" (AG 140).

As Smith observes, it is also significant that Leibniz's doctrine regarding the nested structure of living beings to infinity is much more present in his philosophical writings than in his medical ones. In light of the above-mentioned points, I suggest that, in addition to the empirical (observational) source, Leibniz's view of living beings also draws on (1) a mathematical source, related to developments in mathematics, in general, and to his development of the infinitesimal calculus, in particular; (2) a theological source, concerning the commitment to the preformation of creatures; and (3) a metaphysical source, which I pursue in the rest of this chapter.

The metaphysical source for Leibniz's use of infinity in his account of living beings is grounded in the traditional connection between infinity and being.

[25] Regarding preformation, see Karen Detlefsen's chapter in this volume.

This connection is most clearly expressed in the absolute infinity and being of God. Unlike most thinkers of the period, Leibniz, as we have seen, does ascribe infinity to created beings as one of their essential features. Unlike Pascal and Descartes, Leibniz rejects the dichotomy between an infinite Creator and finite creatures, as well as the epistemological imperative (explicit in both Pascal and Descartes) that, as finite minds, we cannot (and thus should not attempt) comprehend the infinite. In contrast, Leibniz thought that the infinite need not be dreaded; rather, it should be investigated, so that the glory of God and its expression in the created world would become more apparent and comprehensible. Thus, created substances are seen as imitations of their Creator *in this respect* (infinity) as well. This point is articulated in Leibniz's response to Pascal's note on the double infinity, where Leibniz writes:

> …all these wonders are surpassed by the envelopment of what is infinitely above all greatnesses in what is infinitely below all smallnesses. That is, our pre-established harmony, which has only recently appeared on the scene, and which yields even more than absolutely universal infinity, concentrated in the more than infinitely small and absolutely singular, by placing, virtually, the whole series of the universe in each real point which makes a Monad or substantial unity, of which I am one. That is, in each substance truly one, unique, primitive subject of life and action, always endowed with perception and with appetition, always containing in what it is the tendency to what it will be, to represent everything else which will be.[26]

Leibniz goes on to say that this substantial unity, which is a primitive subject of life, a living mirror, is like a "diminutive God"; like God in that it is a living, active being that will never cease to act and perceive; but unlike God in that some of its perceptions are indistinct and confused.

Leibniz's response to Pascal nicely brings out the way he conceives of the relation between infinity and life. Leibniz does not dispute Pascal's description of living beings as infinite; rather, he argues that Pascal did not go far enough in ascribing infinity to living beings. Had Pascal comprehended the true nature of the organic world, he would see that infinity cuts even deeper into the very nature of things. As Frederic de Buzon noted,

> That the parts of living beings are also living beings, and this to infinity, is exactly Leibniz's conception of natural machines, whose difference

[26] Grua, 553–555; F. de Buzon, *Les Études philosophiques*, n° 4/2010, 549–556. English translation is by Lloyd Strickland; see http://www.leibniz-translations.com/pascal.htm.

> from artificial machines is only that they are 'machines to the least of their parts.' (My translation)[27]

My only slight correction to this point is that, for Leibniz, it is not the *parts* of living beings that are themselves living beings but rather that each living being consists of infinitely many other living beings, not as parts (which can presumably be taken away or put together) but as essential constituents, and that their nested structure goes to infinity. This subtle difference implies that, for Leibniz, natural machines are divinely created machines, endowed with an infinite capacity to act and perceive and thus to maintain their unity as long as they act. Since activity is their very essence, once created, they would act and live forever, unless annihilated by God. In this regard, too, creatures are clearly seen as infinite.

However, it is also clear that the kind of infinity Leibniz ascribes to created beings is not the same as the absolute infinity he ascribes to God. It is also not the (quantitative) infinity he employs in mathematics. In considering Leibniz's ascription of infinity to living beings in this metaphysical context, I will try to clarify the kind of infinity he is employing in defining living beings as natural machines, machines whose nested structure develops to infinity. My suggestion is that the infinity of creatures is best understood as a middle degree between the absolute infinity of God and the quantitative infinity applicable in mathematics. In what follows I develop this point by focusing on the relation between infinity, perfection, and being (and to some extent the activity of living beings). I will show that, according to Leibniz, these notions are interestingly correlated in that they admit of similar grades and hierarchical order.

4. Perfection, Being, Infinity, and Life

Let me begin by examining Leibniz's notion of perfection. I then consider how Leibniz's notion of perfection is related to his notion of infinity. One of Leibniz's early definitions of perfection appears in an interesting piece composed during his stay in Paris:

> Perfection is an absolute affirmative attribute; and it always contains everything of its own kind, since there is nothing which limits it."

[27] "Que les parties des êtres vivants soient aussi des êtres vivants, et ce à l'infini, est exactement la conception des machines de la nature, dont la différence avec les machines de l'art est que les premières sont machines jusques dans leurs moindres parties" (*Que lire dans les* deux infinis? *Remarques sur une lecture leibnizienne*, in *Les Études philosophiques*, n° 4/2010, 547). See also *Considérations sur les principes de vie et sur les natures plastiques*, GP VI, 543. See also my "Leibniz on Artificial and Natural Machines" in *Machines of Nature and Corporeal Substances in Leibniz*, eds. Justin E. H. Smith and Ohad Nachtomy (Dordrecht, DE: Springer, The New Synthese Historical Library, 2010).

> (March 18, 1676, *Excerpts from Notes on Science and Metaphysics*; A 6.3 391, LLC 53–55)

It is interesting to observe that this definition of perfection is reminiscent of Spinoza's definition of an attribute as being infinite in kind, and distinct from the absolute infinity God (which entails all attributes or perfections). In addition, this definition of perfection suggests that there are various kinds of perfections—one corresponding to each quality or a kind of thing, where perfection is seen as a maximum (or the highest degree) of that thing or quality, such as wisdom and power. And indeed, ten years later (1686), in the first paragraph of the *Discourse on Metaphysics*, Leibniz takes up this point and makes it explicit:

> there are several entirely different ways of being perfect, [. . .] God possess them all together, and [. . .] each of them belongs to him in the highest degree. (AG 35).

As this passage shows, according to Leibniz, perfections (seen as attributes of God) admit of both variety and degrees. In the same paragraph of the *Discourse on Metaphysics*, Leibniz articulates a very interesting test for identifying a perfection:

> We must also know what a perfection is. A fairly sure test for being a perfection is that forms or natures that are not capable of a highest degree are not perfections, as for example, the nature of number or figure. For the greatest of all numbers (or even the number of all numbers), as well as the greatest of all figures, imply a contradiction, but the greatest knowledge and omnipotence do not involve any impossibility. (AG 35)[28]

Knowledge and power are notions that can be regarded as perfections since their having a highest degree is possible (maximal knowledge or power does not involve a contradiction). By implication, a notion that can have a highest degree (a maximum) can be regarded as a perfection. The fact that Leibniz regards the notions of greatest knowledge and maximal power to be consistent, unlike the notions of the greatest number and the greatest figure, suggests that he considers their maximum not as a quantity, that is, in a non-quantitative sense. If wisdom

[28] "For I believe it to be the nature of certain notions that they are incomparable of perfection and completion, and also of having the greatest of their kind (*suo genere summi*)" (A 6.3 552; LLC 179).

and power would be quantifiable as number and shape, they would involve similar contradictions. This suggests that the sense in which Leibniz is using perfection and infinity to qualify maximal knowledge and power is not quantitative. This point can be clearly seen in considering God's perfection (as well as that of his attributes, which Leibniz also calls perfections). God is the most perfect being, but he cannot be most perfect in a quantitative sense for otherwise its notion would be contradictory.[29] In this context, it seems rather clear that perfection is used in an absolute and non-quantitative sense. In this absolute sense, perfection signifies completeness that cannot be measured by (or compared with) size, length, speed, or any other magnitude.

But this is not the only way in which Leibniz is using the notion of perfection. In some well-known texts, such as "On the Radical Origination of Things," Leibniz defines perfection as a *degree of essence.* Here the notion of degree is explicit in the very definition of perfection. It is remarkable that, in this context, perfection also serves Leibniz as the principle of existence, in the sense that God would choose to realize the most perfect (possible) world (G VII 304). According to Leibniz, "The most perfect exists for perfection is nothing other than the quantity of reality."[30] For this reason, God would choose the most perfect world or the world whose degree of reality is the highest.

This notion of perfection is articulated in a number of Leibniz's texts. Here are some examples:

> Perfection is a degree of reality or essence (*perfectionem esse gradum seu quantitatem realitatis seu essentiae*). (Letter to Eckhard, A No. 148, 453)[31] Perfection is nothing but the degree or measure of positive reality (*la perfection n'étant autre chose que la grandeur de la réalité positive*). (GP VI, 613) Perfection is nothing but quantity of essence (*est enim perfectio nihil aliud quam essentiae quantitas*). (GP VII, 303)[32]

Leibniz uses this notion of perfection mainly in the context of justifying God's choice of the best among all possible worlds. According to Leibniz, the reason

[29] For details regarding this comparison, see my "Leibniz on the Greatest Number and the Greatest Being," in *The Leibniz Review* 15 (2005): 49–66.

[30] «Existe donc le plus parfait, puisque la perfection n'est autre chose que la quantité de réalité» (in J. B. Rauzy, ed. and trans.), *Recherches générales sur l'analyse des notions et des vérités, 24 thèses métaphysiques et autres textes logiques et métaphysiques* (Paris: Presses Universitaires de France, 1995), 469.

[31] See G. W. Leibniz, *Philosophical Papers and Letters*, edited and translated by L. E. Loemker, 2nd edition (Dordrecht, DE: Kluwer, 1969), 178.

[32] "The Perfection about which you ask is the degree of positive reality, or what comes to the same things, the degree of affirmative intelligibility, so that something more perfect is something in which more things worth of observation are found" (Letter to Wolff, AG 230).

to realize a possible world concerns its degree of perfection.[33] But let us take note that, if possible things have various degrees of perfection, it is clear that this degree would also be expressed in their actual counterparts in the created world. After all, this is precisely the reason they are created (or why they are chosen for actualization). Leibniz also makes it clear that "the reality of creatures is not the same absolute reality that is in God, but a limited reality, for that is the essence of a creature" (*De abstracto et concreto* [1688], A 6. 4. 990).

As we have seen, perfection serves Leibniz as a measure of reality. It is thus clear that creatures would have a lower degree of perfection than God. As Leibniz writes to de Volder,

> …the supreme substance has poured forth his perfection as much as was permitted into the many substances that depend on him, which ought to be conceived of as individual concentrations of the universe and (some more than others) as imitations of the divinity. (Letter to de Volder, January 1705, in Paul Lodge's translation, PDF version 477)

Unlike Descartes and most other thinkers in the early modern period, Leibniz is not merely distinguishing between the absolute reality and perfection of God and the limited and imperfect nature of creatures. This distinction certainly holds for Leibniz, as creatures for him are imperfect with respect to the absolute perfection of God. But, at the same time, and as we have seen in the second section, in Leibniz's metaphysical system, creatures also admit of some degree of perfection.

When we connect this point with the distinction between various kinds and various degrees of perfections, it becomes clear that, for Leibniz, the distinction between God and creatures is not merely between a perfect Creator and imperfect creatures; rather, it is a distinction between the absolute perfection of God and a lesser degree of perfection ascribed to creatures (which, in turn, admit of various degrees of perfection as well).

Now, how does Leibniz relate this (graded) notion of perfection to his notion of infinity? In his *Meditations on First Philosophy*, Descartes assumes a very strong connection between infinity and perfection. He contrasts the infinity and perfection of God with human finitude and imperfection. Indeed, the connection between infinity and perfection seems to be so strong in this context that it almost appears as an identity (insofar as Descartes uses these terms interchangeably). Leibniz's analogy between perfection and infinity (imperfection

[33] "And this reason [for existence] can only be found in fitness, or in the degree of perfection that these worlds contain, each possible world having the right to existence in proportion to the perfection it contains" (*Monadology* §54 ; see *Theodicy* §§74, 167, 350, 201, 130, 352, 345, 354).

and finitude or limitation), however, is restricted to one sense of infinity, namely to the absolute sense of infinity, which pertains to the *Ens Perfectissimum* alone. Unlike Descartes, Leibniz distinguishes between different senses and different degrees of infinity. Whereas the infinity of God is absolute and includes all perfections, creatures are infinite in kind, that is, creatures are infinite, too, but to a lesser extent (or in a lower degree of infinity).

Quite early in his career (1676) Leibniz draws a very interesting distinction (or more precisely a threefold distinction) between three degrees of infinity. An early formulation of this distinction appears in Leibniz's responses to Spinoza—both in his summary of a conversation he had with Tschirnhaus about Spinoza's philosophy and in his annotations on Spinoza's letter (Ep. 12) to Ludwig Meyer—the so-called letter on the infinite. As we know well from the *Ethics* and from Spinoza's letter, Spinoza draws a distinction between the absolute infinity of God and the infinity in kind (suis generis) of its attributes.

In his summary of Tschirnhaus's account of Spinoza's philosophy, Leibniz writes:

> He [Spinoza] thinks that there are infinitely many other affirmative attributes other than thought and extension, but that there is thought in all of them, as there is here in extension; but that we cannot conceive what they are like, each one being infinite in its own kind, as, here, is space.

Immediately following this remark, Leibniz makes this note:

> I usually say that there are three degrees of infinity. The lowest is, for the sake of example, like that of the asymptote of the hyperbola; and this I usually call the mere infinite (*tantum infinitum*). It is greater than any assignable, as can also be said of the other degrees. The second is that which is greatest in its own kind (*maximum in suo scilicet genere*), as for example the greatest of all extended things is the whole of space, the greatest of all successives is eternity. The third degree of infinity, and this is the highest degree, is *everything* (*omnia*), and this kind of infinite is in God, since he is all one; for in him are contained the requisites of existing of all others." (February 1676, A 6.3 386; LLC 43)[34]

[34] «Ego Soleo dicere: tres infiniti gradus, infimum v.g. ut exempli causa asymptoti hyperbolae; et hoc ego soleo tantum vocare infinitum. Id est majus quolibet assignabili; quod et de caeteris omnibus dici potest; alterum est maximum in suo scilicet genere, ut maximum omnium extensorum est tosum spatium, maximum omnium successivorum est aeternitas. Tertius infiniti, isque summus gradus est ipsum, *omnia*, quale infinitum est in Deo, is enim est unus omnia; in eo enim caeterorum omnium ad existendum requisita continentur. Haec obiter annoto» (A 385; LLC 42).

In his annotations to Spinoza's letter, Leibniz makes these distinctions even more explicit:

> I set in order of degree: *Omnia*; *Maximum*; *Infinitum*. Whatever contains *everything* is maximum in entity; just as a space unbounded in every direction is maximum in extension. Likewise, that which contains everything is most infinite, as I am accustomed to call it, or the absolutely infinite. The *maximum* is *everything* of its kind (*omnia suis generis*), i.e., that to which nothing can be added, for instance, a line unbounded on both sides, which is also obviously infinite for it contains every length. [Finally those things are *infinite in the lowest degree* whose magnitude is greater than we can expound by an assignable ratio to sensible things, even though there exists something greater than these things. (A 6.3 282, LLC 115)[35]

If the analogy between perfection and infinity may be developed along these lines, then I would suggest that creatures are also partly perfect, that is, perfect in a particular way—the very way that defines their unique essence and nature (i.e., their unique set of predicates or their complete concept). Unlike God, creatures have some perfections but also many imperfections and limitations.[36]

This complex and interesting status of creatures, set between the absolute infinity of God and the mere infinity of mathematical beings, requires much more attention than I have space for here. My discussion is therefore limited to drawing attention to this complex and interesting status that constitutes,

[35] «Ego semper distinxi Immensum ab Interminato, seu terminum non habente, Et id cui nihil addi potest, ab eo quod numerum assignabilem superat. Breviter gradus constituo: Omnia, Maximum, Infinitum. Quicquid *omnia* continent, est maximum in entitate; quemadmodum spatium in omnes dimensiones interminatum est maximum in extensione. Item quod omnia continet, infinitissimum, ut vocare soleo, sive absolute infinitum est. *Maximum*m est *omnia* sui generis, seu cui nil apponi potest, ut linea recta utrinque interminata, quam et infinitam esse patet; nam omnem continet longitudinem. *Infinita* denique *infini gradus* sunt quorum magnitude major est, quam ut a nobis ratione assignabili ad sensibilia, possit explicari. Quanquam aliquid detur ipsis majus. Quemadmodum spatium infinitum inter asymptoton et Hyperbolam Apollonii comprehensum quod ex moderatissimis infinitis unum est, cui respondet quodammodo in numeris summa huius spatii; 1/1 ½ 1/3 ¼ etc. quae est 1/0. Modo scilicet intelligamus ipsum 0, seu Nullitatem, aut potius hoc loco quantitatem infinite seu inassignabiliter parvam, majorem esse minoremve, prout ultimum seriei huius fractionum, infinitae, Nominatorem, qui infinitus et ipse est minorem majoremve assumserimus. Maximum enim in numeros non cadit.»

[36] "The imperfections, on the other hand, and the defects in operations spring from the original limitation that the creature could not but receive with the first beginning of its being, through the ideal reasons which restrict it. For God could not give the creature all without making of it a God; *therefore there must needs be different degrees in the perfection of things and limitations also of every kind*" (*Theodicy* §31, my italics).

I suggest, the mark of living beings for Leibniz, namely that each (created) living being is both perfect and infinite in a certain way and that this implies that it is also limited in many other ways (for it realizes one way of being, unlike God who is all things). It is like a diminutive God in being infinite and perfect in its own kind—that is, in one limited and determined way, which also defines it as a unique expression of God.

5. Conclusion

I have argued that Leibniz connects the notion of infinity and life so that, after the *New System of Nature*, infinity figures as a mark of living beings. I examined Leibniz's sources for this view, arguing that it is best seen as a synthesis of mathematical, empirical, theological, and metaphysical sources. I then focused on the metaphysical source, examining the connection between infinity, perfection, and being in some more detail. My conclusion is that Leibniz defines living beings as infinite in a qualified (graded) sense, so that they are infinite in kind, that is, infinite in some ways but limited in others, and that their infinity is distinct from the absolute infinity (and perfection) of God, on the one hand, and the mere infinity of mathematical things, on the other.

Let me now return very briefly to my original questions. Why does Leibniz introduce infinity into the definition of living beings? And what does infinity contribute to his notion of a living being? In thinking about these questions, it is important to note that, for Leibniz, a living being is divinely created, that is, a divine or a natural machine, distinct from an artificial machine, and, at the same time, an indestructible (but ever-changing, self-regulating) being. Such a (created) being is not composed of parts but has an intrinsic unity, which is derived from its inner activity and regulated by its law of generation. Such an infinite law constitutes the unique nature or essence of a living being. The activation and realization of such a law can only be initiated by an infinite creator with the result that each creature is seen as a limited (and particular) expression of God's infinite nature. Creatures, for Leibniz, are seen as diminutive gods to the extent that their nature manifests to a certain degree the absolutely infinite and active nature of the Creator.