Chapter 5
Leibniz on Artificial and Natural Machines: Or What It Means to Remain a Machine to the Least of Its Parts

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1 Some Background and Motivation

The topic of the present paper is Leibniz's distinction between nature and art, which he spells out in terms of his distinction between natural and artificial machines. Leibniz holds that a natural machine, unlike an artificial one, remains a machine in the least of its parts, and my main objective here is to attempt to cast some light on what Leibniz means by this phrase.

Before attending to Leibniz's curious distinction, I would like to present a broader perspective on this question. In the first and second sections, I will do so by looking at the way in which some other thinkers, both before Leibniz (mainly Descartes) and also after Leibniz, have distinguished between nature and art (or as became customary, between organism and clockwork). This will help us understand Leibniz's motivation for drawing the distinction and also hint at some of its possible repercussions in present day discussions of this question. As an aside then, this broad perspective will also show that the question is in fact still very pertinent today. In the third section I will present Leibniz's distinction between natural and artificial machines. In the fourth section I will question the coherence of Leibniz's distinction. In the fifth section I will offer a structural reading of Leibniz's notion of a natural machine and in the sixth section I will offer a functional reading of this notion. In conclusion, I will suggest that both readings (structural and functional) are compatible and that both illuminate Leibniz's definition of a natural machine as a machine that remains a machine in the least of its parts.

1.1 Erwin Schrödinger's What Is Life

The final section of Erwin Schrödinger's remarkable and influential study, *What is Life*, entitled "The Relation between Clockwork and Organism" reads:

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> Clockworks are capable of functioning 'dynamically', because they are built of solids, which are kept in shape by London-Heitler forces, strong enough to elude the disorderly tendency of heat motion at ordinary temperature.
>
> Now, I think, few words more are needed to disclose the point of resemblance between a clockwork and an organism. It is simply and solely that the latter also hinges upon a solid – the aperiodic crystal forming the hereditary substance, largely withdrawn from the disorder of heat motion. [Schrödinger is contrasting here the inner structure of the chromosome with physical systems.] But please do not accuse me of calling the chromosome fibers just the 'cogs of the organic machine' – at least not without reference to the profound theories on which the simile is based.
>
> For, indeed, it needs still less rhetoric to recall the fundamental difference between the two and to justify the epithets novel and unprecedented in the biological case.
>
> The most striking features are: first, the curious distribution of the cogs in a many celled organism, for which I may refer to the somewhat poetical description on page 79; and secondly, the fact that the single cog is not of coarse human make, but is the finest masterpiece ever achieved along the lines of the Lord's quantum mechanics.[1]

As we shall see below, these two features are strongly reminiscent of Leibniz's approach to the distinction between natural and artificial machines.

In his "poetic" description (on page 79), Schrödinger suggests that the chromosomes may "resemble stations of local governments dispersed through the body, communicating with each other with great ease, thanks to the code that is common to all of them". However, Schrödinger remarks,

> . . . it needs no poetic imagination but only clear and sober scientific reflection to recognize that we are here obviously faced with events whose regular and lawful unfolding is guided by a 'mechanism' entirely different from the 'probability mechanism' of physics. For it is simply a fact of observation that the guiding principle in every cell is embodied in a single atomic association existing only in one copy (or sometimes two) – and a fact observation that it results in producing events which are a paragon of orderliness. Whether we find it astonishing or whether we find it quite plausible that a small but highly organized group of atoms be capable of acting in this manner, the situation is unprecedented, it is unknown anywhere else except in living matter.[2]

Schrödinger is keen to point out that we need not appeal to any mysterious vital forces in order to account for the difference in the order and regulation observed in clocks and the order observed in organisms. In his terms, the difference is clear-cut: in the one, entropy (or degree of order) is statistical and hence decreases; in the other, entropy is dynamical and hence order is maintained and preserved. In spite of this difference of category, there is nothing inexplicable in scientific terms about this difference.

Let us recall that Schrodinger's insightful observations precede the discovery of the structure of genetic material (DNA) in 1953 by almost a decade – his book was first published in 1944. The discovery of how information is coded in the chromosomes through the sequential order of base pairs would give much support to Schrödinger's characterization of living organisms as possessing a unique way of

[1] Schrödinger [1944] 2007: 85.

[2] Ibid., 79.

preserving order in each of their cells. Notice that order is preserved in two distinct contexts: in regulating the development of an organism and in passing its characteristics to future generations, thus preserving a dynamical (biological) order in local systems (namely, living beings) within a physical universe whose ultimate order is decreasing (in a statistical sense).

Indeed, since the rise of molecular genetics in the 1950s, it has become common to use the very presence of DNA in cells as the mark of living things. The chemical nature of the genetic information and program of development has inspired some (notably, François Jacob in the early 1970s) to claim a resolution of the old tensions between teleological and mechanical considerations in living things.[3]

Likewise, the image of an a-periodic crystal suggested by Schrödinger as characterizing the living material hidden in the chromosomes has inspired the development of many computer programs and fractal-like structures as models of living systems. Some of these projects do not only pretend to represent life artificially but also, according to some (e.g., Langton[4]), actually to constitute living systems as self generating "creatures" in an attempt to respond to Fontenelle's old (but still pertinent) challenge:

> Do you say the Beasts are Machines just as Watches are? Put a Male Dog Machine and a Bitch Machine side by side, and eventually a third little Machine will be the result, whereas two Watches will lie side by side all their lives without ever producing a third Watch?[5]

This challenge was taken up by Van-Neumann and his colleagues in the 1950s. Since then many self-producing computer simulations have been produced, some of which have the remarkable fractal structure that, as we shall see, plays an important role in Leibniz's distinction between nature and art.

Before we turn to Leibniz, however, let us consider another immensely influential formulation of the distinction between nature and art (or as it came to be phrased, the distinction between an organism and a watch).

1.2 Kant's Third Critique

In his *Critique of the Power of Judgment* (*CPJ*), Kant articulates the distinction between an organism and a watch as follows:

> In a watch one part is the instrument for the motion of another, but one wheel is not the efficient cause for the production of the other: one part is certainly present for the sake of the other but not because of it. Hence the producing cause of the watch and its form is not contained in the nature (of this matter), but outside of it, in a being that can act in accordance with an idea of a whole that is possible through its causality. Thus one wheel in the watch does not produce the other, and even less does one watch produce another, using for that purpose other matter (organizing it); hence it also cannot by itself replace parts that have been taken from it, or make good defects in its original construction by the addition of the other parts, or somehow repair itself when it has fallen into disorder: all of which,

[3] See Jacob 1970.

[4] See for example, Langton 1984.

[5] Cited from Fox-Keller 2002.

> by contrast, we can expect from organized nature. – An organized being is thus not a mere machine, for that has only **motive** power, while the organized being possesses it itself a **formative** power, and indeed one that it communicates to the matter, which does not have it (it organizes the latter); thus it has a self-propagating formative power, which cannot be explained through the capacity for movement alone (that is, mechanism). (*CPJ*, A 5: 374; Kant 2001, 246)

In the paragraph just preceding this one Kant writes:

> In such a product of nature each part is conceived as if it exists only **through** all the others, thus as if existing **for the sake of the others** and **on account** of the whole, i.e., as an instrument (organ), which is, however, not sufficient (for it could also be an instrument of art, and thus represented as possible at all only as an end); rather, it must be thought of as an organ that **produces** the other parts (consequently, each produces the others reciprocally), which cannot be the case in any instrument of art, but only of nature, which provides all the matter for instruments (even those of art): only then and on that account can such a product, as an **organized** and **self-organized** being, be called a **natural end**. (*CPJ*, A 5: 373–74; Ibid., 245)

This leads to Kant's definition of an organized product of nature in the following section: "An organized product of nature is that in which everything is an end and reciprocally a means as well. Nothing in it is in vain, purposeless, or to be ascribed to a blind mechanism of nature" (*CPJ*, A 5: 376; Ibid., 247–248).

It is well known that Kant's notion of the organism played a decisive role in the formation of biology as a distinct domain of scientific knowledge. However, it wasn't Kant who invented the notion of the organism. If anyone is to be credited with its invention, Leibniz is probably more worthy.[6] At the turn of the eighteenth century, Leibniz appropriated the terms "organism" and more frequently *organique* and/or *organicum* to characterize living beings.[7] In this respect, Leibniz's view of living beings is important not only for our understanding of the debate concerning the conceptualization of living beings in the seventeenth and eighteenth centuries but also for understanding one of the most influential concepts in the yet-to-be-born biological sciences.

Two central features of Leibniz's characterization of living things, which we today designate as organisms, stand out: the first is the conjunction of both mechanistic and teleological (or functional) aspects in their scientific description and conceptualization, which is evident and explicit in Kant's definition of an organism. The second, and most conspicuous in Schrödinger's description of an organism, is the dispersion of the inner structure in each organic cell, which obeys an order different from that of the inanimate world. In what follows, I will substantiate this

[6] See Duchesneau 1998.

[7] As Justin Smith and Enrico Pasini have stressed, one has to be careful not to conflate Leibniz's usage with the contemporary usage of organism, as designating an individual. While the term "mechanism" was used to qualify the mechanic, or machine-like, the term "organism" would be used to qualify the organic(um). On the other hand, Leibniz's notion of a natural machine, on which I focus here, does designate an individual living being. In this sense, the notion of a "natural machine" might even be more important for the later notion of an organism in the sense of a living unit.

claim by showing how these two characterizations play a central role in Leibniz's notion of a natural machine.

While the notion of an "organism" has come to dominate biological discourse, the earlier (and more distinct) concept Leibniz was using to designate living beings in his late writings is that of a natural machine. In his later writings, Leibniz describes living beings as machines nested one within the other *ad infinitum*. As we shall see, according to him, the nested structure *ad infinitum* is the main difference between a natural machine, which is God's creation, and an artificial machine, which is made by humans.

2 Descartes and the Analogy Between Natural and Artificial Machines

While the distinction between artificial and natural machines has considerable consequences for Leibniz's metaphysics, it turns, as we shall see, on a very subtle nuance. The first (rather obvious) point to notice is that Leibniz describes both natural and artificial things as machines, that is, in mechanistic terms. This is very significant considering the Cartesian program to describe the natural world in purely mechanistic terms. Particularly relevant is Descartes' program to describe animals (as well as the human body) as subtle and complex machines that lack internal power, let alone spontaneity and vitality.[8] By contrast, Leibniz's agenda may be seen as an attempt to revive the Aristotelian distinction between animate and inanimate things in "an intelligible way" and resist the Cartesian reduction of natural machines to artificial ones.[9] It is with this aim in mind that Leibniz draws the distinction between artificial and natural machines in the *New System of Nature* of 1695 – a work in which he suggests reconciling the ancient and the modern philosophies of nature (basically by accepting mechanical description at the level of physics and Aristotelian description at the level of metaphysics). Thus, while Leibniz accepts a mechanical description of bodies, he strongly resists the Cartesian attempt to describe natural machines in terms of artificial ones. As he writes,

[8] In fact, in his *Principles of Philosophy* part 4, article 203, Descartes seems to assimilate the artificial and the natural. For him, artificial machines serve as models to explain the natural ones. Natural machines are like artificial ones, except much more complicated. He wants to establish that they are of the same kind. He uses the notion of divinely created machines to show that the subtle parts of machines are extremely complex and invisible to us. While both Descartes and Leibniz argue that machines are extremely subtle, Descartes uses this point to argue for his view that, in the final analysis, animals are nothing but subtle machines. By contrast, Leibniz uses this point to argue that there is a categorical difference between them. See also *Les passions de l'ame,* first part, articles 5 and 6 where he writes e.g., that the body has in it "the corporeal source of movement" (art. 6).

[9] See for example, Leibniz's controversy with Stahl (Carvallo 2004). where Leibniz criticizes the Moderns for pretending that "*nihil aliud sit natura corporum quam Mechanismus*" (there is nothing in the nature of bodies but mechanism).

> I am the most readily disposed person to do justice to the moderns, yet I find that they have carried reform too far, among other things, by confusing natural things with artificial things, because they have lacked sufficiently grand ideas of the majesty of nature. (AG 141–42)

To better understand what Leibniz is resisting here, let us briefly review the reform suggested by Descartes. This will help us see why Leibniz thinks that it was carried too far.

Descartes' agenda in his projection of a new science was clear and ambitious. He sought no less than a full mechanization of the natural world. More precisely, he sought a mechanization of our view of the natural world described in terms of extended matter in motion. In effect, Descartes sought to replace any reference to incorporeal agencies, such as powers, faculties, or forms in the explanation of nature with the quantitative and measurable features of extended matter in motion. In this way, the natural world – or at least the part belonging to *res extensa* – would be described in purely geometrical/quantitative terms.

One of the most difficult tasks facing this project was to provide an account of the phenomenon of life and especially of some features of living things such as nutrition, growth, and generation, which were traditionally explained by reference to a vegetative and sensitive soul. Descartes supposed that nature always acts in accordance with the laws of mechanics. Thus he attempted to show that vital force is reducible to heat in the heart, understood as matter in motion. Likewise, he argued that any movement in the bodies of animals can be explained by attending to the mere disposition of their organs.

As Descartes writes in the preface to his *Description of the Human Body*:

> Il lest vrais qu'on peut avoir de la difficulté à croire que la seule disposition des organes soit suffisante pour produire en nous tous les mouvements qui ne se déterminent point par notre pensée; c'est pourquoi je tacherai ici de le prouver, et d'expliquer tellement toute la machine de notre corps, que nous n'aurons pas plus sujet de penser que c'est notre âme qui excite en lui les mouvements que nous n'expérimentons point être conduits par notre volonté, que nous en avons de juger qu'il y a une âme dans une horloge, qui fait qu'elle montre les heures.[10] (AT XI, 226)

As Gary Hatfield notes, "Descartes' aim was to mechanize virtually all of the functions that had traditionally been assigned to the vegetative and sensitive souls," and, "[t]o a large extent, Descartes physiology may be seen as a straightforward translation of selected portions of previous physiology into the mechanistic idiom".[11]

[10] "It is true that we may find it hard to believe that the mere disposition of the bodily organs is sufficient to produce in us all the movements which are in no way determined by our thought. So I will now try to prove the point, and to give such a full account of the entire bodily machine that we will have no more reason to think that it is our soul which produces in it the movements which we know by experience are not controlled by our will than we have reason to think that there is a soul in a clock which makes it tell the time." (CSM I, 315)

[11] Hatfield 1992: 341–343.

Descartes' attempt to mechanize all of the functions that had traditionally been assigned to the vegetative and sensitive souls comes out clearly in the conclusion to his *Treatise on Man*:

> ces fonctions suivent toutes naturellement, en cette Machine, de la seule disposition de ses organes, ne plus ne moins que font les mouvements d'un horloge, ou autre automate, de celle de ses contrepoids et de ses roues; en sort qu'il ne faut point à leur occasion concevoir en elle aucune autre âme végétative, ni sensitive, ni aucun autre principe de mouvement et de vie, que son sang et ses esprits, agités par la chaleur du feu qui brûle continuellement dans son cœur, et qui n'est point d'autre que tous le feux qui sont dans les corps inanimés. (See also AT XI 202; AT VI, 45–46)[12]

While Descartes aim was very clear and even somewhat simplistic – namely, to show that all living phenomena can be explained mechanistically – his argumentative strategy was rather subtle and sophisticated. Descartes' strategy – and one might say, his powerful rhetorical device – was first to conceive of all natural animals (as well as the human body) as *machines*. Once the body of an animal has been referred to as a machine, Descartes traded on the comparison between a machine manufactured by humans and a machine created by God. Roughly stated then, Descartes' strategy was to model natural machines on artificial ones. More precisely, he argued that the differences between the workings of a complex artificial machine, such as a clock or a fountain, and those of animal bodies are only apparent and turn on their degree of subtlety alone. Descartes attempted to show that in essence complex machines and animal bodies are of the same kind, and that the only differences between them reduce to degrees of complexity and the subtlety of their parts. Thus, just as we don't need to invoke an occult agency in a clock that shows the hour, so there is no need to invoke such agency in our body other than the dispositions of its organs and parts. This is all the more true in animals that have sensitive functions alone. Both functionality and the movement of animals can be ascribed to their internal workings, just as are the workings of complex machines.

As Descartes clearly states in the *Principles of Philosophy*, part 4, article 203:

> [Je] ne reconnais aucune différence entre les machines que font les artisans et les divers corps que la nature seule compose, sinon que les effets des machines ne dépendent que de l'agencement de certains tuyaux, ou ressorts, ou autres instruments, qui, devant avoir quelque proportion avec les mains de ceux qui les font, sont toujours si grands que leurs figures et mouvements se peuvent voir, au lieu que les tuyaux ou ressorts qui causent les effets des corps naturels sont ordinairement trop petits pour être aperçus de nos sens. Et il est certain que toutes les règles des Mécaniques appartiennent à la physique, en sorte que toutes les choses qui sont artificielles, sont avec cela naturelles. Car, par exemple, lors

[12] "...these functions follow from the mere arrangement of the machine's organs every bit as naturally as the movements of a clock or other automaton follow from the arrangement of its counter-weights and wheels. In order to explain these functions, then, it is not necessary to conceive of this machine as having any vegetative or sensitive soul or other principle of movement and life, apart from its blood and its spirits, which are agitated by the heat of the fire burning continuously in its heart – a fire which has the same nature as all the fires that occur in inanimate bodies." (CSM I, 108)

> qu'une montre marque les heures par le moyen des roues dont elle est faite, cela ne lui est pas moins naturel qu'il est à un arbre de produire des fruits. (AT IX, 321–322)[13]

It is mainly to this powerful and influential attempt to reduce natural machines to artificial ones that Leibniz responds. It is worth stressing that Leibniz does not object to Descartes seeing both artificial and natural machines as subtle machines. Rather, he attempts to draw a distinction between them as two distinct *types* of machines.

3 Leibniz's Distinction Between Natural and Artificial Machines

In the *System Nouveau* Leibniz insists that natural machines have something substantial – *Soul or Form* – that makes them one and the same thing in the *least of their parts*. Leibniz's formulation of the distinction is that, while both are said to be machines, a natural machine, unlike an artificial one, "remains machine to the least of its parts, and what is more, it always remains the same machine" (GP IV, 482). Note that this characterization constitutes the main difference between two *types* of machines. Furthermore, this characterization applies both to the internal structure of a natural machine, so that all its parts are machines, and to its development, so that it remains the same machine through its various states.

Leibniz's view concerning the unity and identity of a natural machine, in contrast to an artificial one, is confirmed in the sequel to the passage cited above:

> In addition, by means of the soul or form there is a true unity corresponding to what is called *the self* in us. Such a unity could not occur in the machines made by a craftsman or in a simple mass of matter, however organized it may be; such a mass can only be considered as an army or a herd, or a pond full of fish, or like a watch composed of springs and wheels. (AG 142)[14]

Leibniz draws here a sharp distinction: an artificial machine is understood on the model of things that lack true unity, namely aggregates. By contrast, a natural machine is understood on the model of things that have true unity, namely substances. Even if it involves infinitely many states and infinitely many machines, a

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[13] "I do not recognize any difference between artefacts and natural bodies, except that the operations of the artefacts are for the most part performed by mechanisms which are large enough to be easily perceivable by the senses – as indeed must be the case if they are to be capable of being manufactured by human beings. The effects produced in nature, by contrast, almost always depend on structures which are so minute that they completely elude our senses. Moreover, mechanics is a division or special case of physics, and all the explanations belonging the former also belong to the latter so it is no less natural for a clock constructed with this or that set of wheels to tell the time than it is for a tree which grew from this or that seed to produce the appropriate fruit." (CSM I, 288)

[14] "De plus, par le moyen de l'âme ou forme, il y a une véritable unité qui répond à ce qu'on appelle moi en nous; ce qui ne saurait avoir lieu ni dans les machines de l'art, ni dans la simple masse de la matière, quelque organisée qu'elle puisse être, qu'on ne peut considérer que comme une armée ou un troupeau, ou comme un étang plein de poissons, ou comme une montre composée de ressorts et de roues." (GP IV, 482)

natural machine has (or is) a true unity. By 1695 Leibniz is well equipped with this fundamental distinction between substances and aggregates, which he develops and defends in the second part of his correspondence with Arnauld (1686–1687).[15] While a substance has a true unity, an aggregate, which is a collection of substances, does not. The unity of an aggregate is not a natural one in the sense that it requires a mental act, i.e., the very aggregation of its constituents into a single group (such as sheep into a herd, stones into a pile, soldiers into an army, birds into a flock). Such a union is the result of a mental act of unification, namely that of perceiving a plurality of things together (sheep, fish, stones, soldiers) or as one group.[16] I have to stress that these are just analogies and examples to illustrate something that cannot be visualized, namely the difference between a true and natural unity and an artificial one.

In any event, Leibniz is very clear that artificial machines fall on the aggregate side of the divide while natural machines fall on the substance side of the divide. Yet it is not at all clear how Leibniz can account for and justify this division, given that the sole difference between them is that a natural machine remains a machine to the least of its parts. This is the main question I take up here.

Before addressing this question more directly, let me briefly return to Leibniz's motivation for drawing the distinction and to some of the roles it plays in his metaphysics. On this score it is impossible to do better than to appeal to Michel Fichant's admirable article, "Leibniz et les machines de la nature" (to which this article owes a great deal). As Fichant has stressed:

> Le concept [machine de la nature] est [. . .] introduit [en 1695 dans le *Système Nouveau*] comme un moyen de limiter les prétentions d'un mécanisme intégral, qui 'en confondant les choses naturelles avec les artificielles', a réduit les phénomènes de la nature à des effets de machines analogues, au seul degré près, aux machines de l'artifice humain. . .(Fichant, 2003:1–2).[17]

According to Leibniz, the difference between "the least productions and mechanisms of divine wisdom and the greatest works of human art" is not one of degree but one of kind. Likewise, to limit the claims of the all-encompassing Cartesian mechanistic program in this context means not only to draw a line between divine and human production but also between living and non-living things. As it turns

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[15] "La substance demande une véritable unité [. . .] Tout être par agrégation suppose des êtres doués d'une véritable unité, parce qu'il ne tient sa réalité que de celle de ceux dont il est composé, de sorte qu'il n'en aura point du tout, si chaque être dont il est composé est encor un être par agrégation [. . .] S'il y a des agrégés de substances, il faut bien qu'il y ait aussi des véritables substances dont tous les agrégés soient faits. [. . .] Il n'y a point de multitude sans des véritables unités. Pour trancher court, je tiens pour un axiome cette proposition identique qui n'est diversifiée que par l'accent, *que ce qui n'est pas véritablement* un *être, n'est pas non plus véritablement un* être." (*Lettres de Leibniz à Arnauld d'aprés un manuscrit inédit*, ed. Geneviève Lewis (Paris, Presses Universitaires de France: 1952), 68–69; see also GP II, 164–165)

[16] For Leibniz's notion of aggregate and its peculiar sense of unity see Nachtomy 2007. Chapter 9.

[17] Fichant 2003. Leibniz et les machines de la nature. *Studia leibnitiana* 35: 1–28. See also *Monadology* § 74: "a kind of divine machine which infinitely surpasses all artificial automats."

out, for Leibniz, this also means drawing a line between active and non-active things and, likewise, between truly existing things (which he typically identifies with substances) and well founded phenomena (which he typically identifies with aggregates). At the same time, Leibniz's characterization of both divine creation and human production in terms of machines is meant to meet his conviction that things can be described both mechanically, by appealing to efficient causes, and teleologically, by appealing to final causes.

Unlike what we might tend to associate with the word today, according to Leibniz and some of his contemporaries, a machine is understood not only in terms of efficient causes but also in terms of final ones.[18] For Leibniz, a machine is also understood as an instrument, that is, in terms of the function and the end it serves – a point to which I will return.

In addition, as Fichant has argued, "in the *Système Nouveau,* Leibniz is concerned. . . with a structural and ontological characterization of natural machines in an attempt to give bodies the reality of a substance".[19] According to Fichant, this strategy is the basis for a realistic interpretation of substance that extends well into the *Monadological* period, which is regarded by many as idealistic.

We can now better appreciate the significance of the distinction for Leibniz. Clearly, a lot hangs on this distinction. Not only does it serve to distinguish between divine creation and human production but also between animate and inanimate things, as well as to reconstruct a (new/old) non-Cartesian model of the living world in which the Aristotelian notions of entelechy, form, and *telos* play a central role.

4 Does Leibniz's Distinction Make Sense?

However, the question arises whether we can make sense of Leibniz's distinction. Let us turn to examine whether Leibniz has the resources to maintain the high expectations he has for it. In other words, we need to examine whether the distinction can indeed differentiate between divine creations and human artifacts; true unities and aggregates; living beings and inanimate things; and we need to examine whether the resulting concept of a natural machine is a coherent one. The most striking difficulty concerning the notion of a natural machine is this. As Fichant observes, the central characteristics of a natural machine are (1) that its composition extends to infinity

[18] "In each machine, one has to take into consideration at once its functions or its end and the mode of operation or the means by which the author of the machine sought its end." "In omni Machina spectandae sunt tum functiones ejus, sive finis, tum modus operandi, sive quibus mediis autor machinae suum finem sit consecutus " (Pasini 1996: 212). The best way to define a machine is by its final cause, in a way that each of its parts would appear [in the explication of its parts] to be coordinated by its designated [destinatum] usage. "Machina autem omnis a finali causa optime definitur, ut in explicatione partium deinde appareat, quomodo ad usum destinatum singulae coordinentur " (Ibid., 217–218; English translations are my own but see the forthcoming translation of these texts by Justin Smith).

[19] Fichant 2003: 7.

and (2) that it is a true unity.[20] Yet it is precisely the conjunction of these two traits that is difficult to grasp. In other words, it is difficult to grasp how Leibniz considers infinitely many machines within machines as one substantial thing?

It is clear that, according to Leibniz, a natural machine is supposed to have a substantial unity that an artificial machine lacks. In the herd analogy, a natural machine is like a sheep; an artificial machine is like a herd. We know that, for Leibniz, the single sheep exemplifies a natural and substantial unity, which the herd, the army, the clock lacks. But the picture is more complicated, and in two respects. On the one hand, an artificial machine, too, has substance-like, sheep-like constituents or composants. It is, in brief, an aggregate of *substances*. On the other hand, each sheep or a natural unity itself consists of other sheep-like, substance-like, creatures.[21]

The challenge then, is to distinguish between an artificial machine and a natural machine, both seemingly consisting of infinitely many natural machines. Clearly, Leibniz's distinction must be very nuanced in order to perform this task.

In a number of texts, Leibniz offers the following mark in order to distinguish between these two kinds of machines: while a natural machine is infinite, an artificial machine is finite. In the *Système Nouveau* Leibniz states clearly that "the machines of nature have a truly infinite number of organs, and are so well supplied and so resistant to all accidents that it is impossible to destroy them" (GP IV, 482; AG 142). And in the following passage Leibniz is saying that a natural machine "is made up of an infinity of entangled organs": "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."[22]

These passages suggest that, according to Leibniz, the distinctive feature of a natural machine is that it has infinitely many organs. Yet this cannot be all there is to his distinction. In fact, praising the subtlety of natural machines is not far from what Descartes says (with the important qualification that Leibniz is committed to *infinite* subtlety whereas Descartes would qualify it as *indefinite*). Taken at face value though, Leibniz's point that a natural machine "is made up of an infinity of entangled organs" cannot account for the difference between artificial and natural machines. The reason is that, as we have observed, an artificial machine would involve infinitely many organs as well. If an artificial machine consists of infinitely

[20] "Cette différence se marque à deux traits: l'infinité de composition, garante d'indestructibilité, et l'unité véritable, fondement de substantialité." (Fichant 2003: 2)

[21] "Dans les corps je distingue la substance corporelle de la matiere, et je distingue la matiere premiere de la seconde. La matiere seconde est un aggregé ou composé de plusieurs substances corporelles, comme un trouppeau est composé de plusieurs animaux. Mais chaque animal et chaque plante aussi est une substance corporelle, ayant en soy le principe de l'unité, qui fait que c'est veritablement une substance et non pas un aggregé. Et ce principe d'unité est ce qu'on appelle Ame ou bien quelque chose, qui a de l'analogie avec l'ame. Mais outre le principe de l'unité la substance corporelle a sa masse ou sa matiere seconde, qui est encor un aggregé d'autres substances corporelles plus petites, et cela va à l'infini." (Draft letter to Thomas Burnett, 1699: AG 289, GP III 260) See also the Replies to Stahl (Carvallo, 2004: 102–103).

[22] *On Body and Force*, *Against the Cartesians*, AG 253.

many natural machines, it would also have infinitely many organs and in this sense would be indistinguishable from a natural one.

At the same time, it is clear in these passages that Leibniz sees the composition to infinity as what guarantees the unity and indestructibility of a natural machine. Yet the mere infinity of organs cannot account for this alleged unity and indestructibility. There are two reasons for this: First, a mere infinity of organs does not provide unity but, if anything, multiplicity and infinite divisibility. As Leibniz writes, "an infinity of things is not one whole" (A 6.3 503). Second, as far as we know, Leibniz cannot accept without qualification an infinity of organs as making up one whole because he rejects the notion of an infinite number as a contradictory notion.[23] Thus, if Leibniz's distinction is supposed to turn on the infinite versus finite *number* of organs, it does not seem to be a happy solution for him. Instead, it would seem to render his notion of a natural machine not only as one that lacks unity, but as altogether contradictory.

It might prove more promising to attend carefully to Leibniz's repeated claim regarding the infinite number of organs in a natural machine. Thus, I will try to clarify what Leibniz means by "organ" in this context. My conjecture – to be developed below – is that this might be a different way of expressing the view that a natural machine remains a machine to the least of its parts in the sense that each organ serves a certain function. Likewise, I will attend to the point that Leibniz actually talks about "entangled organs" and suggest that what extends to infinity is not so much the *number* of organs or parts but rather the *structure* of the whole machine, as including more machines within machines to infinity. I will also examine what Leibniz means by "infinite" in this context. Thus I will now propose two ways to read Leibniz's point that a machine remains a machine in the least of its parts – one structural and one functional – in order to clarify the sense in which he employs the notion of infinity in this context.

5 A Structural Reading of "What It Means to Remain a Machine to the Least of Its Parts"

Let me begin with the structural suggestion. This idea comes out clearly in passages such as the following:

> . . . the machines of nature being machines to the least of their parts are indestructible, due to the envelopment of a small machine in a larger one, to infinity. (GP VI 543)[24]

In the following passage, from a 1704 letter to Lady Masham, Leibniz says that, in a natural machine, the composition goes to infinity, or, more precisely, that the subtlety of its artifice extends to infinity:

[23] For more details on this issue, see Brown 2000; Arthur 2001; and Nachtomy 2005.

[24] "[Le] corps est organique quand il forme une manière d'automate ou de machine de la nature, qui est machine non seulement dans le tout, mais encore dans les plus petites parties qui se peuvent faire remarquer." (PNG §3 GF 224) See also *Monadology* § 67–70.

> 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. . . (GP III 356)

According to the reading I suggest, what extends to infinity is not the *number* of organs or machines but rather the very *structure* of a natural machine which involves machines within machines. Elsewhere I called this the nested structure of natural machines.[25] My suggestion is that the structure of a natural machine develops *ad infinitum*, while that of an artificial machine does not. It is in this sense, I suggest, that an artificial machine does not remain a machine to the least of its parts. While the number of machines within this structure is clearly not finite, we cannot also say that it involves an infinite number of machines (which would be a contradiction), but that the machine's structure extends to infinity. Before exemplifying this point, let me first consider an objection.

One might object that this only means that we need to count structures instead of organs and, if so, the contradiction would arise only with an infinite number of structures. Let me clarify that, while the structure of a natural machine might include many sub-structures, the point is that there is one structure corresponding to the whole machine – and that structure might involve many nested machines as its constitutive elements.

Leibniz's picture of nestedness to infinity is not a simple containment or inclusion of one thing inside another. This can be seen in a passage in the *Nouveaux Essais* where Leibniz evokes the image of the Harlequin – an image that might be misleading indeed. Notice, however, that Leibniz is *denying* that it provides a good model for the richness of natural subtlety.

> c'est. . .comme Arlequin qu'on voulait dépouiller sur le théâtre, mais on n'en put venir à bout, parce qu'il avait je ne sais combien d'habits les uns sur les autres: quoique ces réplications des corps organiques à l'infini, qui sont dans un animal, ne soient pas si semblables ni si appliqués les unes aux autres, comme des habits, l'artifice de la nature étant d'une tout autre subtilité. (NE II, ch. VII, §42; G V, 309)[26]

Leibniz does not clarify here what he has in mind when he says that "[the artifice] of nature is of an entirely different subtlety" from that of human production. I have suggested above that the difference between human-made machines and natural/divine ones is related to a difference in the kind of infinity involved in the two cases. While an artificial machine might also have an infinity of parts, a natural machine has an internal structure that extends to infinity. More importantly still (and I will try to illustrate this below) a natural machine, while infinite in structure, is essentially one, and therefore, must have a notion of infinity that would be compatible with true unity.

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[25] See Nachtomy 2007: Chapter 10.

[26] "it is as if someone tried to strip Harlequin on the stage but could never finish the task because he had on so many costumes, one on top of the other; though the infinity of replications of its organic body which an animal contains are not as alike as suits of clothes, and nor are they arranged one on top of another, since nature's artifice is of an entirely different order of subtlety." (Bennett and Remnant 1996).

Let me now try to illustrate this difference. Let us think of a natural machine as having a fractal-like structure, that is, a structure defined by a simple rule of generation, whose continuous application produces an infinite structure, such that each of its parts has a similar structure to the whole. While the analogy with a fractal structure sounds anachronistic, let us attend to what Leibniz writes to Des Boss in 1706:

> When I say that there is no part of matter that does not contain monads, I illustrate this with the example of the human body or that of some other animal, any of whose solid and fluid parts contain in themselves in turn other animals and plants. And this, I think, must be said again of any part of these living things, and so on to infinity. . .

To a possible objection that this view seems to imply an infinitesimally small being, Leibniz responds[27]:

> I shall use an analogy. Imagine a circle; in it draw three other circles which are the same size and as large as possible, and in any new circle and in the space between circles again draw the three largest circles of the same size which are possible. Imagine proceeding to infinity in this way: it does not follow that there is an infinitely small circle, or that there is a center having its own circle, in which (contrary to the hypothesis) no other is inscribed.[28]

It is easy enough to illustrate the geometrical analogy Leibniz draws here. As it turns out, Leibniz's example corresponds to the contemporary definition of a fractal. It is produced by a simple generation rule and each of its parts is homomorphic to the whole. Notice that, in such a fractal structure, the situation is just as Leibniz is fond of saying, namely "C'est tout comme ici, partout et toujours". In these words, Leibniz states somewhat poetically one of the central principles of his philosophy (see especially the letter to Sophie Charlotte of May 8th, 1704, G III 343–348).[29]

A qualification is in order here. Leibniz clearly overstates his case when he says that "C'est tout comme ici, partout et toujours". While each of the internal structures in a fractal is the same as the whole with respect to the structure, it is also different. If we take Leibniz's principle of considering the whole method of production of a given thing we see that there are differences between these structures, such as their place within the whole structure.

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[27] I should note that the commentators I have seen using and developing this analogy are not attending to the fact that the geometrical analogy, which they call the schema of emboitment, does not come right after the passage cited. In between there is a complex discussion not only about matter but about machines, entelechies and their complex relations. In fact, it is not obvious which passage Leibniz does attempt to exemplify with the analogy. What he says immediately before "I shall use an analogy" is this: "Yet you see that it should not be concluded from this that an infinitely small portion of matter (such as does not exist) must be assigned to any entelechy, although we routinely jump to such conclusions."

[28] To Des Bosses 11–17 March, 1706; G 305–306; Look 2007.

[29] For more details on the way in which Leibniz uses this principle, see Phemister 2004.

Let me now try to use Leibniz's analogy for my current purpose. In this analogy, an artificial machine would be a collection of fractals. A natural machine would be a single fractal that includes infinitely many sub-fractals as its intrinsic constituents.[30] Note that, in this illustration, a natural machine would remain a machine to the least of its constituents, while, at the same time, the whole machine would remain one single machine. An artificial machine, however, does not preserve this structure to infinity; nor is it, for this very reason, truly one being – not at any given moment and not over time, even if it is composed of such machines. On this model, it seems, we can maintain Leibniz's point that the distinction between artificial machines and natural ones coincides with the distinction between a true unit – that is, a substance – and, a collection of them – that is, an aggregate.

In addition, we know that Leibniz defines an individual substance in terms of its individual law of generation – "the law of the series", as he often calls it. Drawing on the fractal analogy as exemplifying how such a law of generation can produce a structure that develops to infinity, we can suggest that a natural machine can be defined as including an infinity of machines and as having a nested structure to infinity, in the sense that its law of production can be seen as including sub-programs as essential constituents (but not parts) of it.

An artificial machine, however, is not constituted in this way. Rather, it is seen as a collection of such individuals, not as a single one that makes up one whole. If this is correct, the distinction between artificial and natural machines turns, strictly speaking, on the question of unity, or, more precisely, it turns on the appropriate conjunction of infinity and unity. In fact, the very composition to infinity of a natural machine suggests that it is individuated by a single law or a single program of action. On this reading, a natural machine turns out to be one *thing* while an artificial machine, being an aggregate, turns out to be a compositional product, or a collection of many things. Thus we can see why Leibniz regards natural machines as substances and artificial machines as aggregates.

Let us now examine how this reading fits with the distinction between divine creation and human production. We certainly know that, according to Leibniz, God creates complete individual substances alone – the rest supervenes on their existence. Furthermore, we know that such substances are individuated by their complete concepts, which are conceived in God's mind before their creation. In a recent book,[31] I suggested that such a concept should be defined not as a set of predicates but through the law that generates a unique structure of predicates in God's mind. The main reason for defining the concept of an individual in this way is that such a genetic definition (via a generative rule) can capture the infinite character of

[30] The idea of using a fractal analogy to exemplify the distinction between a composed substance and an aggregate has been proposed (though in a very loose and imprecise way) in an article by Chazerans 1991.

[31] Nachtomy 2007.

a Leibnizian individual in a consistent way. Otherwise, if we define it simply as a set or a collection of infinite predicates, it would fall into contradiction and would not be seen as a whole, as an infinite number does. The definition of a complete concept in terms of its law of production aims at capturing Leibniz's characterization of an individual substance as having an infinite structure and as informing its development upon creation.

If these observations are adequate, it would clarify Leibniz's identification of a natural machine (but not an artificial one) with the divinely created individual substances. Such an infinite structure, which expresses the infinite nature of the Creator, cannot be produced by humans. Rather, it can only be brought about by an act of creation, that is, a super natural event constituting the natural world by realizing a variety of natural machines. As natural machines cannot be produced, they cannot be destroyed. Thus we see that the indestructibility of a natural machine goes hand in hand with (and in fact is just the other side of) the fact that they cannot be produced but can only be (supernaturally) created or annihilated by God.[32] Leibniz makes it very clear that the indestructibility of natural machines derives from their composition to infinity. As he explains to Des Boss:

> whoever reflects on the doctrine of the conservation of animals, must also consider, as I have shown, that there are infinite organs in the body of an animal, some enfolded in others; and from this it follows that an animated machine, and in general a machine of nature, is absolutely not destructible. (To Des Bosses, 11 March 1706 (Look and Rutherford 2007: 37))

Considering the context in which this passage appears[33] shows that Leibniz connects here the lawfulness of natural machines (created by God), their nested structure, and their natural indestructibility. Leibniz is just as clear about this point in his "Consideration on the Principles of Life":

> Ce qui nous découvre encore des merveilles de l'artifice divin, ou l'on n'avait jamais pensé: c'est que les machines de la nature étant machines jusque dans leurs moindres parties, sont

[32] "Quand aux Mouvemens des corps celestes, et plus encore quant à la formation des plantes et des animaux, il n'y a rien qui tienne du miracle, excepté le commencement des ces choses. L'organisme des animaux est un mechanisme qui suppose une préformation divine: ce qui en suit, est purement naturel, et tout à fait mechanique." (GP VII. 417–418)

[33] "As to my claim that the soul and the animal do not perish, I shall again explain it with an analogy. Imagine an animal as a drop of oil and the soul as some point in the drop. If the drop is now divided into parts, the point will exist in one of the new drops, since any part in turn is transformed into a spherical drop. In the same way, the animal will survive in that part in which the soul remains and which best agrees with the soul itself. And just as the nature of the liquid in any fluid aims at sphericity, so the nature of the matter constructed by the wisest author always aims at order or organization. From this it follows that neither souls nor animals can be destroyed, although they can be diminished and concealed, so that their life does not appear to us. And there is no doubt that in generation, as also in corruption, nature obeys certain laws, for nothing of divine workmanship is lacking in order. Moreover, whoever reflects on the doctrine of the conservation of animals, must also consider, as I have shown, that there are infinite organs in the body of an animal, some enfolded in others; and from this it follows that an animated machine, and in general a machine of nature, is [not] absolutely destructible." (Look and Rutherford 2007: 35–7)

> indestructibles, a cause de l'enveloppement d'une petite machine dans une plus grande à l'infini. (G VI 539–546)[34]

My suggestion is that natural machines are indivisible units in the sense that they are defined and informed by a single rule of generation, compatible with their having an infinitely complex structure such as an infinite series or a fractal-like structure.

I argued above that the infinite structure of a natural machine provides evidence for its being a divine, and law governed creation. These strands come together in the following passage from the PNG:

> Et ce corps (de la Monade Centrale) est organique, quand il forme une manière d'Automate ou de Machine de la Nature, qui est Machine non seulement dans le tout, mais encore dans le plus petites parties qui se peuvent faire remarquer. . . Et les perceptions dans la Monade naissent les unes des autres par les lois des Appétits, ou des *causes finales du bien et du mal*, qui consistent dans les perceptions remarquable, réglées ou déréglées. (PNG 3, GF 224; see also 110)

This passage is remarkable in clarifying under what conditions a body is considered organic and for tying together the nested structure of such a natural machine with its internal law of action (perceptions). Even more important, this passage points to the connection between the internal law of action and the final causality involved in the internal perceptions of a natural machine, to which I now turn.

6 A Functional Reading of "What It Means to Remain a Machine to the Least of Its Parts"

Let us now examine another sense in which the subtle distinction between natural and artificial machines may be understood, namely by emphasizing a functional reading of the notion of machine (and of machines within machines). This sense of machine is related to the traditional notion of organ as an instrument. Leibniz is very explicit about the functional role of machines in texts from the 1680s. As he writes: "In each machine, one has to take into consideration at once its functions or its end and the mode of operation or the means by which the author of the machine sought its end."[35] Leibniz is even more explicit in the following passage: "The best way to define a machine is by its final cause, in a way that each of its parts would appear [in the explication of its parts] to be coordinated with the other by its designated [*destinatum*] usage."[36]

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[34] See also this passage: ". . . la matière arrangée par une sagesse divine doit être essentiellement organisée partout, et qu'ainsi il y a machine dans les parties de la machine naturelle a l'infini, et tant d'enveloppe et des corps organiques enveloppés les uns dans les autres, qu'on ne saurait jamais produire un corps organique tout a fait nouveau" (GF 99; G VI 539–46).

[35] "In omni Machina spectandae sunt tum functiones ejus, sive finis, tum modus operandi, sive quibus mediis autor machinae suum finem sit consecutus." (Pasini 1996).

[36] "Machina autem omnis a finali causa optime definitur, ut in explicatione partium deinde appareat, quomodo ad usum destinatum singulae coordinentur." (Ibid., 217–18)

It is worth reflecting on the similarity between Leibniz's formation here and Kant's formulation cited above. Leibniz's functional reading of his notion of a natural machine comes out quite clearly in the following passage from the *Monadologie* §64 where he writes:

> [. . .] une Machine, faite par l'art de l'homme, n'est pas Machine dans chacune de ses parties, par exemple le dent d'une roue de leton a des parties ou fragmens, 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 étoit destinée. Mais les Machines de la Nature, c'est à dire les corps vivans, sont encor 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 Notre. (G IV, 618)[37]

Here it seems that, "to remain a machine to the least of its parts" means that a machine involves serving a certain end or function. An artificial machine is invested with the human purposes and the usage humans make of it. Yet, at a certain level of its internal structure these purposes come to an end. The machine as a whole has a purpose but not each of its constituents, or, more precisely, not each of its constituents to infinity. The cogwheel, for example, has a function within the machine, and in this sense it, too, is a machine; the dents on the wheel have a function as well, but this functional structure does not continue to the fragments of the dents, which cannot therefore be seen as machines. At this point, the functional chain terminates, which is why this is seen as an artificial machine rather than as a natural one.

By contrast, a natural machine expresses God's purposes and designs and, in this respect, it is of a different category: in a natural machine the functional and machine-like structure go to infinity while in the artificial machine they come to an end.

Evidently, according to Leibniz, there is nothing created by God that does not fulfill a certain function. More precisely, everything is created *thanks to* its function or end in the world, which is a very familiar Leibnizian theme. Note that, in this functional sense of nestedness to infinity, the functional chain, or the chain of final causes need not at all be seen as a physical or even structural emboîtement of machines within machines. What is crucial is only that, at every level, each part or constituent serves a function with respect to the other constituents and with respect to the main (dominating) *telos* of the whole. Such a model of functional relations may well be illustrated by circular rather than linear infinity. And once again one is reminded here of Kant's formulation that in a natural product each organ is both means and end.

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[37] "Thus every organic body of a living being is a kind of divine machine or natural automaton, which infinitely surpasses any artificial automaton, because a man-made machine is not a machine in every one of its parts. For example, the tooth of a brass cog-wheel has parts or fragments which to us are no longer anything artificial, and which no longer have anything which relates them to the use for which the cog was intended, and thereby marks them out as parts of a machine. But nature's machines – living bodies, that is – are machines even in their smallest parts, right down to infinity. That is what makes the difference between nature and art, that is, between the divine art and our own." Franks and Woolhouse 1998: 277.

As we have seen, this system of functional relations does not apply to human production in the same way. Even if the cog is made up of other things, and ultimately these things are going to be living things, they are not functionally related as organs are related to the whole organism. In a living animal the constituents are seen as inseparable and as inseparably individuated from the whole structure and *telos* of the animal (which is defined or given by their law of production). In this respect, my liver is not like a cogwheel in my bike, whether or not the technology for their replacement exists. According to this reading of Leibniz, what distinguishes between the natural and the artificial is precisely that the functional chain or, if you will, the teleological chain is never ending – any natural thing, however small or insignificant, serves a certain function in a well defined and well ordered system of ends. Not so in an artificial machine, whose series of functions comes to an end.

In this vein, Leibniz draws a distinction between the ends of machines, which are proper and interior to them, and the ends of aggregates, which are the result of the relations between different machines. This distinction is made very explicitly in the controversy with Stahl between particular final causes that Leibniz ascribes to natural machines and general final causes that he ascribes to the concurrence between them:

> Interim concedimus magnum esse discrimen inter machinas et aggregata massasque, quod machinae fines et effectus habent vi suae structurae, at aggregatorum fines et effectus oriuntur ex serie rerum concurrentium atque adeo ex diversarum machinarum occursu, qui etsi etiam sequatur divinam destinationem, plus tamen minusque manifestae coordinationis habet.[38]

7 Conclusion

I have presented two ways to read Leibniz's characterization of a natural machine as remaining a machine to the least of its parts – one structural, suggested by the fractal analogy, and one functional, suggested by examples such as *Monadologie* §64. In conclusion, let me briefly touch on the question of their relations.

In particular, the question arises whether the functional and structural readings are compatible or whether they exclude one another. Are these readings complementary, so that the one is contributing to the other or are they independent from one another?

Let me briefly state my suggestion: the internal law of the structure of a natural machine expresses the unique *telos* of this machine, as well as the machines nested in it. Thus, through the generative law, the structural and functional aspects of a

[38] "We have recognized a great difference between machines and aggregates or masses, because machines have their effects and ends by the force of their proper structure, while the effects and ends of aggregates originate from a series of concurrent things and diverse machines. . ."(Carvallo 2004: 102–103; my translation)

natural machine are compatible. Hence both structural and functional considerations are essential to Leibniz's notion of natural machine.

And let me close with a question for further research: Given the way I have suggested to read Leibniz's distinction, the following question arises: Does the same kind of infinity apply to both natural and artificial machines? And, if not, what kind of infinity applies to natural machine and what kind to artificial machines?

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