Expanded mechanism and/or structural vitalism: further thoughts on the animal economy

Charles T. Wolfe

ERC EarlyModernCosmology (GA 725883) and

Ca' Foscari University, Venice, Italy

ctwolfe1@gmail.com

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Abstract

The opposition between mechanism and vitalism is an old and venerable one. It seems to be particularly active in the hands of historians of biology, particularly late nineteenth and early twentieth-century biology (Hein 1972, Allen 2005). Broadly speaking, histories of biology and medicine endlessly and ceaselessly oppose mechanism and vitalism, usually focusing on the most dogmatic pronouncements of both such perspectives (iatromechanistic rhetoric and immaterial vital forces). Thereby they neglect the fertility and diversity of types of early modern mechanism (a diversity noted in Des Chene 2001; see also Hutchins 2015, Wolfe 2014), including as attempts to do justice to the ontological status of Life itself, and conversely, the mechanism-friendly dimensions of core moments of vitalist theorization, notably in the notions of 'organisation' and 'animal economy' in Montpellier vitalism (Wolfe and Terada 2008, Wolfe 2017a, 2019a). Furthermore, the opposition between mechanism and vitalism effectively obscures the singularity and the importance of specifically *structural* concepts, which are neither restrictively mechanistic (bottom-up reductionism) nor wholly organismic (top-down holism). What kind of history of vitalism results from this new emphasis on the interrelation between mechanism and vitalism? I suggest that vitalism, at least when it is not caricaturally positing immaterial vital forces, is concerned with vital *materiality* overall, and particularly with 'the living machine', to borrow a phrase from Claude Bernard (Bernard 1865).

1. Mechanism and vitalism: the situation

Mechanism and vitalism are very general terms but they convey equally vivid intuitions, that recur in different historical, theoretical and scientific contexts. Broadly speaking, mechanism conveys the idea of a *reductive strategy*, i.e. a *decomposition strategy*[1], while vitalism is widely

[1] Bechtel and Richardson 1993. Already in 1972, William Wimsatt wrote that "[a]t least in biology, most scientists see their work as explaining types of phenomena by discovering mechanisms" (Wimsatt 1972, p. 67). Bechtel and

held to be an appeal to immaterial vital forces, or in any case, to something precisely *irreducible* (whether this is to taken to be a type of force, a principle, the soul, vital seeds, etc.). It is thus unsurprising that the opposition between mechanism and vitalism is an old and venerable one, particularly active in the hands of historians of biology, especially late nineteenth and early twentieth-century biology (Hein 1972, Allen 2005) and earlier histories of medicine (Toellner 1977; Rey 2000, p. 137; compare Riskin 2016).

Seizing on the most dogmatic pronouncements of both such perspectives – iatromechanist rhetoric (I say 'rhetoric' because iatromechanist proclamations in their simplicity, such as Archibald Pitcairne's statement in his 1717 *Elementa Medicinae* that "All Diseases of the Fluids consist either in a Change of their Qualities, or a Change of the Velocities of their Motions," so that "The cure of every Disease, whether in the Vessels or Fluids, or both, is to be effected only by mechanical Laws,"[2] are often not equivalent to the complexity of iatromechanist practice or even overall theoretical commitments: Bertoloni Meli 2011) and immaterial vital forces –, these histories maintain us in a state of complacency. They neglect, inter alia, the fertility and diversity of types of mechanism (for the case of the complexity and richness of early modern mechanism, see Des Chene 2001, Hutchins 2015, Wolfe 2014), including as attempts to do justice to the ontological status of Life itself, and conversely, the mechanism-friendly dimensions of core moments of vitalist theorization like the discussions on the 'animal economy' in eighteenth-century Montpellier vitalism (Ménuret 1765c; Wolfe and Terada 2008, Wolfe 2017a, 2019a), that is, the school associated with the Faculty of Medicine at Montpellier.

Concepts of what a machine and an organism are, and by extension, what mechanistic and vitalistic doctrines are, obviously vary considerably from Giovanni Alfonso Borelli to the steampump, and from vital force or fiammula to mereological concepts. Yet nevertheless this opposition remains. In what follows I wish to challenge some of the pertinence of the opposition by, as it were, weakening the boundaries or lessening the distance between these two theoretical constellations. In his provocative essay "Aspects du vitalisme" (in Canguilhem 1965), Georges Canguilhem had, in his own way, insisted on an interrelation of mechanism and vitalism. But he emphasized more their functioning as 'positions', as 'standpoints' (with a partly Kantian flavour) whereas I focus more on the actual empirical modelling commitments that are implicit (and explicit) in each case.

Richardson distinguish different kinds of decomposition arguments (notably, structural decomposition into parts versus functional decomposition into operations: Bechtel and Richardson 1993, p. xxx); here I primarily mean decomposition into parts.

[2] Pitcairne, *Elementa Medicinae* (1717), translated as *The Philosophical and Mathematical Elements of Physick* (1718), §§ LXXVII and LXXXVIII, in Pitcairne 1718, pp. 353, 354.

What does the opposition between mechanism and vitalism neglect, or obscure? Not just their general interrelation, richness or pluralism. More specifically, the opposition effectively obscures the singularity and the importance of specifically *structural* concepts, which are neither restrictively mechanistic (bottom-up reductionism) nor wholly organismic (top-down holism). Two such concepts in Montpellier vitalism are 'organisation' and 'animal economy', which, to radicalize a claim made in my earlier work, run directly counter to the opposition between mechanism and vitalism. Indeed, they show the *interrelation* of mechanist and vitalist intuitions (they are not always arguments) in the efforts to grasp, model and explain complex organisms, functions such as health, or organ systems such as the glands or (in admittedly rudimentary form) the nervous system. This interrelation can be studied from the standpoint of a history of mechanism, in which case it yields a concept of 'expanded mechanism' (e.g. Duchesneau 1998, Wolfe 2019a, ch. 2). Expanded mechanism is not just the ontological reduction to size, shape and motion but a chemically overdetermined ontology, and/or one which includes Newtonian forces. But what happens if we study this interrelation as a chapter in the history of vitalism? Perhaps vitalism, at least when it is not caricaturally positing immaterial vital forces, is concerned with vital *materiality* overall, and particularly with the "living machine," to borrow a phrase from Claude Bernard (Bernard 1865, II, i, pp. 108, 131, 162), himself a physiologist and theorist absorbed almost to the point of obsession with mechanistic and vitalistic explanations of life, sometimes opposing them, sometimes brilliantly highlighting their dialectical relation.

2. All mechanism is complex

It is well-known that early modern mechanist approaches to 'life' (living complex bodies rather than microorganisms) are not univocal. As Des Chene and others have shown, mechanism could borrow from a diverse panoply of strategies, analogies and intuitions, sometimes moving seamlessly from the invocation of a foundational ontology of size, shape and motion and its various arrangements[3] to analogies with *actual* machines and/or with automata. Furthermore, mechanistic explanations often turn out to be *functional* explanations rather than

[3] E.g. this classic statement by Descartes: "I think that all these bodies [sc. salt, sulphur, mercury and the four elements of the philosophers] are made of the same matter, and the only thing which makes a difference between them is that the *tiny parts* of this matter which constitute some of them do not have the *same shape or arrangement* as the parts which constitute others" (Letter to Newcastle, 23 November 1646, AT IV, 568). Or Charleton, who speaks of how the various "offices and uses" of the parts of the "Machine of the Heart" are all "plainly *Mechanic*" (emphasis his), because they are "necessarily consequent from the structure, conformation, situation, disposition and motions of the parts, by which they are respectively performed" (Charleton 1683, p. 69). I am not seeking to provide an exhaustive or rigorous history of early modern mechanism here; one issue would be to what extent an important figure like Descartes combines a more 'atomistic' trend, with which he became acquainted via Isaac Beeckman, with a more 'machine'-focused trend, in which he was more influenced by Galileo (Bertoloni Meli 2006, p. 135f.)

rigorously 'decomposing' explanations: to state that 'the heart pumps blood' (or, 'the heart is like a pump') turns out to be as legitimately mechanistic as a reductive analysis of the matter of which the heart (or the blood) is composed, even if Descartes gently rebuked Harvey for just such a slippage from purportedly rigorous mechanism to excessively analogical mechanism[4]). And, as I shall describe briefly below, it is also the case that most forms of purportedly 'pure' mechanism turn out to be 'impure', or at least 'enriched', 'enhanced', 'expanded', 'broadened', 'teleomechanistic', etc.[5]

But let us start with classic formulations of mechanism faced with life ('iatromechanism', thus 'medical mechanism', is a narrower term which is not without its own problematic baggage[6]). In both Descartes and the anatomist William Croone, the mechanical analogy is used to say 'there is nothing more to see here, keep moving'.

> Descartes: "And indeed one may very well compare the nerves of the machine which I am describing with the tubes of the machines of those fountains, the muscles and tendons of the machine with the other various engines and springs which serve to move these machines, and the animal spirits, the source of which is the heart and of which the ventricles of the brain are the reservoirs, with the water which puts them in motion. Moreover breathing and other like acts which are natural and usual to the machine and which depend on the flow of the spirits are like the movements of a clock or of a mill which the ordinary flow of water can keep going continually" (*L'Homme*, AT XI, 131).

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[4] Descartes devotes a significant part of section 5 of the *Discourse on Method* to Harvey, who he refers to as 'an English physician'. He praises him for the discovery of circulation but disagrees as to the functioning of the heart, viewing it as a more passive organ, receiving a good deal of its 'activity' from the heat of the blood, etc (AT VI, 50). Scholars have debated who is the more consistent mechanist in this respect. In the *Description du corps humain*, Descartes argues that if we suppose "that the heart moves in the way that Harvey describes, not only must we imagine some faculty which causes the movement, the nature of which is much more difficult to conceive than what it is invoked to explain: we must also suppose the existence of yet other faculties that alter the qualities of the blood while it is in the heart" (AT IV, 243-244). Descartes also famously wrote to Mersenne, "I am prepared to admit that if what I have written on this topic [the cardiac cycle] [...] turns out to be false, then the rest of my philosophy is entirely worthless" (1639 letter, AT II 501). A classic study is Grene 1993.

[5] Jacques Roger spoke of "neo-mechanism" (Roger 1963/1993, pp. 628, 771); François Duchesneau of a "special mechanist hypothesis"; Maria Teresa Monti, of "micro-mechanism" (Duchesneau 1982, pp. 126-170, 201-234, here, 156; Monti 1997, p. 43). Duchesneau also describes Haller's complexification of mechanism as a "mécanisme rénové" (Duchesneau 1982, p. 229). I discuss the notion of 'expanded mechanism' further in Wolfe 2019a, pp. 37, 78f., 88, 94-96, 229. As far as 'complexifying mechanism' historically, one can also speak, with Vera Keller, of "the ways quantitative mechanical philosophy intervened in an already robust, machine-based, but non-mechanical natural philosophy" (Keller 2010, p. 42, discussing the 17th-century Dutch inventor Cornelis Drebbel). Cases of what I would call 'hybridization' of mechanism also include the various syncretistic blends of Aristotelianism and 'new' mechanism.

[6] R. Andrault notes that the term 'iatromechanist' is mistakenly thought of as an 'actors' category' when it is in fact the result of a later translation: an 1851 French translation of Baglivi speaks of "iatromécaniciens" while the original has "mechanici philosophantes." She also emphasizes the influence of Daremberg's quotation and discussion of this passage (Daremberg 1870, vol. II, pp. 786-787), including on Canguilhem's essay "Machine et organisme" (Andrault 2018, pp. 176-179).

> W. Croone: "we shall consider the living body to be nothing else but a kind of machine or automaton and the Mind, which is in us, we may move meanwhile by its own thought, or at least we may arrange to sit in the brain merely as a spectator of this play which is acted out in the scene of the body" (Croone 1664, § 26, p. 15; Wilson 1961, p. 161)

Iatromechanism is generally taken to be a kind of 'Galileanism of life': an attempt to quantitatively inscribe anatomical and physiological phenomena within a Galilean mechanistic scheme (notably, animal motions); but in fact, the various, apparently pure statements of iatromechanism mask a more complex reality, in which functional dimensions are never wholly absent from physiological explanations. Even Descartes will speak of the "office" of the liver (e.g. to Elisabeth, May 1646, AT IV, 407) and use functional language, as discussed below. Thus it makes sense that even Descartes himself is increasingly seen as having a more complex physiology than what we would expect from the classic (well, classic since Kant) opposition between 'mechanism' and 'teleology'. If one conceives mechanism as strictly an ontology of size, shape and motion, with different more or less atomistic, more or less reductionist variants, and one conceives of teleological notions as directly opposed to all of this, it will indeed be difficult to make sense of the presence of all these functional ideas.

The neat conceptual clarity of this opposition does not match up with the historical and experimental context well at all. As Stephen Gaukroger has observed, Cartesian mechanistic physiology, far from denying the existence of goal-directed processes, is in fact replete with functional language, e.g. when discussing the circulation of blood and the motion of heart; the Cartesian point is not that bodies actually are machines (an eliminativist view, as Gaukroger puts it) but rather that the structure and behaviour of bodies are to be explained in the same way that we explain the structure and behaviour of machines (a reductionist view). Or, following a distinction proposed by Gary Hatfield, Descartes rejects 'extrinsic finality', but operates with an implicit notion of 'intrinsic finality'.[7]

Major figures of early modern iatromechanism do speak of the mathematically specifiable mechanical properties of the bodies they study as laws of nature, since these ensure that the appeal, e.g. to the functioning of a pump or a sieve to explain a heart or a liver, is backed up by further guarantees.[8] But what is their overall mechanistic commitment? This

[7] Gaukroger 1995, p. 279; see Hatfield 2008 (also discussed in Brown 2012, which proposes an interesting analysis of Cartesian functionalism); on the interplay of mathematical mechanics and teleological explanations of the functioning of parts in an animal (particularly on Fabricius), see Distelzweig 2014.

[8] Thus Cornelis van Hogelande: "... we hold that all bodies acting in any way whatsoever, must be considered as machines, and their actions and effects must be explained or made explicable as if mechanical and corporeal, and consequently only mechanically, that is, according to mechanical laws" (Van Hogelande 1646, p. 276 cit. in Ragland 2015, p. 186). Or Boerhaave: "The solid parts of the human body are either membranous Pipes, or Vessels including the Fluids, or else *Instruments* made up of these, and more solid Fibres, so formed and connected, that each of them is capable of performing a particular Action by the Structure, whenever they shall be put into Motion; some of them resemble Pillars, Props, …, some like Axes, Wedges, Leavers and Pullies, others like Cords, Presses or

ranges from the idea of the world as a machine (clockwork, design) to a mechanistic ontology of the particles or components that compose the physical world, to – more interestingly for present purposes – an interest in the heuristic potential of mechanism, e.g. automata (from Descartes' fountains to 'living machines'). This heuristic potential is of particular interest because it is both adapted to and challenged by the specific reality of living bodies (their organization, their embodiment) – the challenge of mechanical models faced with the living body.[9]

Even pure forms of mechanism, if they exist, have a *functional* dimension, visible in the increasing focus on (a) the structure (or 'fabric', as when physicians speak of the "fabric and position of the heart"[10]) and purpose of the body, (b) its description in purposive terms, and (c) properly teleomechanist[11] descriptions of "the human machine" as an integrated system of mechanisms and higher purposes, the "animal economy."

The notion of animal (o)economy itself is complex, in its history, different meanings and different theoretical and scientific contexts (for a fuller analysis of the term see Balan 1975; Wolfe and Terada 2008). "Économie animale," "oeconomia animalis," was by no means a new word in the mid-eighteenth century. It had a Hippocratic pedigree dating at least back to the sixteenth century, when it was used by Hippocratic physicians such as Louis Duret in Paris (who speaks of an "oeconomia naturalis, vitalis et animalis"[12]), and earlier by followers of Paracelsus, who added onto the older theological sense of an *oeconomia* as an order, an alchemical sense

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Bellows ; and others again like Sieves, Straines, Pipes …; and the Faculty of performing various Motions by these Instruments, is called their *Functions*, which are all performed by *mechanical Laws* (*lege mechanica*), and by them only are intelligible" (Boerhaave 1708, "Physiologiae," § 40, in Boerhaave 1713, p. 12; translation, Boerhaave 1715, p. 9).

[9] 'Mechanism' exists in many forms – whether Cartesian, Boylean, iatromechanistic or Boerhaavian – and within physiology itself it is possible to speak of an 'expanded' mechanism in which vital properties are accounted for in terms of the interrelation between anatomical structure (the cause) and physiological function (the effect). The model of the machine has significant heuristic value because it is primarily an *explanatory* model. A related point has been made by scholars including Peter Dear, Dennis Des Chene and Jessica Riskin (and myself), namely that early modern automata should also be understood as "models of intelligibility" (including in Descartes) (Dear 1998, p. 59; Des Chene 2007; Riskin 2016; Wolfe 2019a, chapt. 2): that is, that they are 'boosters' of argument just like thought experiments. In other words, they have heuristic value.

[10] Richard Lower writes, "I must preface my account of (the movement of the blood) by some remarks on the Position and Structure of the heart. When these have been duly considered and collated, it will be easier to grasp how carefully both its Fabric and Position are adapted for movement, and how fittingly everything is arranged for the distribution of the blood to the organs of the body as a whole" (Lower 1669/1932, p. 2). The language of 'fabrica' and 'usus' is also very present in early modern medicine, including in Harvey.

[11] In a sense my account of mechanism here as always expanded or in the process of expansion and hybridization runs counter to the idea of 'teleomechanism' (Lenoir 1981 and 1982), as the latter implies a synthesis (originally post-Kantian) between the mechanical and the teleological, i.e., an explanation of systems (whether these be machines, automata or living bodies) which blend teleological features such as an appeal to purpose and function, and mechanistic features such as an account of their material properties and the interaction of their components.

[12] Duret, *Hippocratis magni Coacae Praenotiones* [1588], Paris, 1621, pp. 29, 146, 440, quoted in Balan 1975, p. 301.

of the body as a distillation vat (Balan 1975, p. 289). But it is used loosely, *not as a technical term*. In the seventeenth century, it was extremely common, in Newtonian medicine and in Walter Charleton's 'Epicurean' medicine; Charleton published several works with *oeconomia animalis* in the title (e.g. Charleton 1659). Where the story takes a different turn, in the eighteenth century, 'animal economy' was explicitly turned into a new, polemical and programmatic term by vitalists such as Ménuret de Chambaud, in his crucial contributions to the *Encyclopédie*, including "Œconomie Animale," "Inflammation," "Mort" and "Observation" and many others. Ménuret also speaks self-consciously about his recognition of the animal economy as an over-arching concept (or "function"): "The priority of this function has escaped the attention of almost all observers; they have only examined one function after another, ending up in a vicious circle in which . . . causes become effects, and effects causes" (Ménuret 1765c, p. 362b).[13]

A curious feature of this notion, beyond its specifically vitalist context, is the way in which it oscillates between being the name for a science or at least a part of a science, and the name of an object of scientific study. Thus In the nineteenth-century Littré medical dictionary, the animal economy is described as comprising "the laws governing the organization of animals and plants"; but the authors note that by the mid-eighteenth century the term took on the meaning, not of the laws or theoretical system, but of the actual "set of the parts of organized beings" ("Économie," in Littré and Robin 1863, p. 486). It is as if there was one word that could mean both 'organism' and 'organismic biology'. Another feature which makes the notion of 'animal economy' all the more central in the present analysis, given my stress on the interplay and overlap between forms of mechanism and forms of vitalism, is that it allows of more mechanist and more vitalist instantiations, with plenty of variation in between. Thus early studies of the animal economy like Cornelis van Hogelande's 1646 *Historia Oeconomiae Corporis Animalis … Mechanice explicatur* or William Cockburn's 1695 *Oeconomia Corporis Animalis*, study it "mechanically," while Edward Eizat (quoted below in section 4) treats it mechanistically *while emphasizing that it is more complex than a 'simple machine'*; others are neutral in this regard, or emphasize chimiatric and humoral properties rather than mechanism, but without focusing on specifically vital, systemic features (Quesnay 1736), or stress that the 'fluid dynamics' or 'staticks' involved therein are what supports life (Hales 1727); lastly, vitalist treatments, like Ménuret's tour de force "Oeconomie Animale" (1765) are, if not anti-mechanistic, as I discuss below in section 4, at least 'meta-mechanistic'.

[13] Ménuret initially signed his entries by name, then 'm' or 'M' after vol. IX. As Roselyne Rey showed (Rey 2000), Ménuret authored 86 articles in the *Encyclopédie*; not an enormous number, but if one takes into consideration the length of some of the articles, such as "Pouls" (over 70 columns), his contribution amounts to more than 1 % of the 17 volumes of the *Encyclopédie*. Moreover, he uses the term "œconomie animale" at least sixty times, which amounts to almost 15 % of its specifically conceptual occurrences in the *Encyclopédie* (60 out of 410).

Let me say it more bluntly. Classic mechanism – let's say 'pure' mechanism – depending on one's methodological presuppositions (i.e. discussions of mechanism in the history of science are not identical with those in the history of philosophy, where conceptual hybridity is frowned upon, and so on) either

- gradually becomes something of a *hybrid* (which implies that initially there was a pure form), or
- was never pure, if we look closely at particular forms of mechanism

First, hybridization. One can distinguish two broad lines of development here. One is what I would call 'ontological expansion', notably by *integrating chemical properties* into a framework that continues to present itself as (and to defend the colors of) mechanism. Examples include Robert Boyle's corpuscularianism, Stephen Hale's 'staticks', Herman Boerhaave's Newtonian mechanism of 'fibres', but this sort of expansion can be seen vividly in a usefully synthetic statement by Bernard de Fontenelle, in his report on the proceedings of the Académie des Sciences from 1707. Commenting on the functioning of the pituitary gland, Fontenelle actually provides a short 'genetic' account of the evolution and complexification of mechanism itself:

> The human body considered in relation to an infinite number of voluntary movements it can perform, is a prodigious assemblage of Levers pulled by Ropes. If one considers it in relation to the motion of the liquors it contains, it is another [sort of] assemblage of an infinite number of Tubes and Hydraulic Machines. Finally, if one examines it in relation to the production of these liquors, it is an infinite assemblage of Chymical Instruments or Vessels, Filters, Distillation Vats, Receptacles, Serpentines, etc. . . . The greatest Chemistry apparatus of all in the human Body, the most wonderful Laboratory is the in the Brain, from whence this Extract of the blood is drawn known as Spirits, the sole material motors of the entire Machine of the Body (Fontenelle 1730, p. 16)[14]

Another strategy is also a kind of expansion but rather than seeking to literally integrate additional (typically chemical) properties in an 'ontological expansion', figures such as Nicolas Steno argue for an expansion of the 'scope' of mechanism, as Boerhaave does in his celebrated

[14] Fontenelle in 1707, then Boerhaave and Stephen Hales (in his *Vegetable Staticks*) in the first decades of the eighteenth century, bear witness eloquently to this complexification of mechanism. The Newtonian dimension is important in facilitating the integration of new (typically chemical) properties and forces into a mechanistic framework, or at least a framework presenting itself as such. One can see this as a growing 'eclecticism' in mechanism (Duchesneau 1997, p. 301) but it is also possible to see mechanism as *always* engaged in this process of hybridization. Doubtless Descartes would have been unhappy with Haller's *vis insita*, or with Hieronymus Gaub (a pupil of Boerhaave)'s idea of the "chemical skeleton of the body," its "principle of cohesion, stability and inertness" (Gaub 1758, cit. in Verwaal 2014). But all of these ideas were presented deliberately and happily as contributing to the 'broad church' of mechanism. A case apart, which is neither heuristic mechanism nor a standard instance of expanded mechanism, is Digby's Aristotelian-infused version of mechanism, in which parts are potential rather than actual (as discussed in Georgescu 2019, who speaks of Digby's "relational mechanism").

lecture on mechanical methods in medicine, *De usu ratiocinii mechanici in medicina* (1703), and Haller does in the mid-eighteenth century. They all support the view that mechanism is the right way to go but that one needn't be strictly Cartesian in one's mechanism.

In his *Discours sur l'anatomie du cerveau* (a lecture on the structure of the brain given in 1665 at the Academy of the diplomat Melchisedech Thévenot in Paris), Steno challenges Descartes' detailed views on the brain, including his excessively figural mechanistic commitments (strings, ropes, pulleys, funnels, sieves, etc.), stressing that Descartes' mechanical construction of the body is anything but empirical. Yet Steno also praises Descartes for the explanatory sufficiency of his ontological mechanism: "no one but he explained all human actions, especially those of the brain, mechanically" (Steno 1669, p. 13). The problem then lies in people taking Descartes at face value: "because some take [Descartes] to be providing a faithful account of what lies most hidden in the springs of the human body" (p. 14) contrary to the empirical, counter-Cartesian evidence provided by Sylvius, Steno finds it necessary to insist on the "difference between the machine as Mr Descartes imagined it and that which we see when we engage in the anatomy of human bodies" (pp. 14-15). That is, Cartesian mechanism, according to Steno, was too perfect and not experimental enough – one might say too ontologically foundationalist.

Contrasting with these various expansions and hybridizations of mechanism, it is also possible to view mechanism as *never having existed in a pure form*. That is, from the beginning it deals with '*function*' ("office"), *usus*, self-maintenance, appetite, desire[15], in other words, different modes of rudimentary teleology. Descartes speaks of "the function of respiration," Harvey of "the office of the hen's uterus"; followers of Harvey such as Richard Lower speak explicitly of "fabric" and "structure" as "fittingly arranged" (i.e., functionally arranged).[16] The language of 'position', 'structure', 'fabric' is quite striking here. These are not notions one can derive from basic atomic properties! In various figures of early modern mechanism, especially when the focus is on the phenomena of life, we can see versions of 'intrinsic finality' at work, i.e., a weak version of teleology, including when mechanism functions on a more analogical level, as in the case of automata like Vaucanson's digesting duck.

[15] It may seem odd to attribute notions such as desire or appetite to the mechanistic programmes. Descartes after all (like Hobbes and Spinoza notably) sought to cast ridicule on the vision of Nature as appetitive, goal-oriented or otherwise anthropomorphic. But he does not seek to conceal or downplay the dimension of self-preservation in the functioning of our senses; something similar could be said about the conatus in Spinoza. A different case that I cannot discuss here (it is done so brilliantly in various studies by Guido Giglioni) is that of Bacon (and Francis Glisson), for whom matter is full of desire and appetite.

[16] "the true function of respiration is to bring enough fresh air into the lungs to cause the blood entering there from the right-hand cavity of the heart, where it has been rarefied and almost changed into vapors, to thicken into blood again before returning to the left-hand cavity" (Descartes, *Discourse on Method* V, AT VI, 53; CSM 138); Harvey writes that he has provided an account of "the uterus of the hen and its office" (Harvey 1651/1981, Ex. 13, p. 83).

Of course, the more the emphasis is on a kind of interconnection (called sympathy, consensus, cohesion, etc., with often chemical specifications such as the notions of action and reaction) rather than the nature of the components, the further away we are from a componential, mechanistic ontology. This can also be explicated in terms of mechanism operating as a "systemic" theory, as Barnaby Hutchins does, using notions from some of the recent literature on mechanisms: "instead of reduction to corpuscular mechanics, Descartes explains the operation of the body through whole systems whose components exist at different levels (for at least some, central cases)."[17] Mechanism here is understood as allowing of decomposition and reduction, *but* "the objects that are parts of mechanisms may themselves be complex structures" (Glennan 2002, p. 352); a systemic explanation involves "the entire composition that explains the effect (rather than the behaviour of individual corpuscles), where each component is taken from the level that is explanatorily relevant for that component" (Hutchins 2015, p. 687).

Furthermore, as will become manifest in the case of automata as discussed below, early modern mechanism also expands, evolves and indeed mutates in a heuristic direction. This was partly Steno's suggestion I just mentioned, that mechanism (and Descartes) are legitimate bases for scientific practice, but are to be treated as methodological and analogical 'boosters', not as literally sets of true claims. But the more the focus is on systemic properties of living systems (i.e. of the animal economy), the less we see praise for the restrictive models of the machine.

3. Mechanism and life

Early modern mechanists do not necessarily deny or neglect the specific features of life. Either because, like Borelli, they reflect on the "shadowy similarity" between automata and living bodies (this is his own term in *De motu animalium*: "automata have a certain shadowy sameness (*umbratilem similitudinem*) to animals in that both are organic self-moving bodies"; Borelli 1685, II, prop. CXVI, p. 164; Borelli 1989, p. 319). Or because they seek to grasp the distinctively functional properties of bodies. From automata and man-machines to structural models of organism like the animal economy, there is a fascination with the 'challenge of Life'. Witness this description of Vaucanson's digesting duck by the Oxford literary scholar Joseph Spence, in 1741:

[17] Hutchins 2015, p. 671. He adds that "Descartes cannot give an account of the heartbeat without also referring to and relying on everything involved in respiration and circulation. Each plays a necessary role in explaining how the heartbeat works: in the absence of circulation or respiration, there would be no heartbeat. And each plays its role within a specific organisation: if respiration did not precede the entry of blood into the left ventricle, the blood would be 'too rare and too fine' for the process to continue; if circulation did not follow the active phase of the heartbeat, there would be no blood to re-enter the heart" (p. 676); this describes a system.

> If it were only an artificial duck that could walk and swim, that would not be so extraordinary: but this duck eats, drinks, digests and sh-ts. Its motions are extremely natural; you see it eager when they are going to give him his meat, he devours it with a good deal of appetite, drinks moderately after it, rejoices when he has done, then sets his plumes in order, is quiet for a little time, and then does what makes him quite easy.[18]

This is quite different from a picture we may have, of 'dead mechanism', which perpetuates the old idea of how mechanists saw the world and more importantly the body as a clock, or a piece of clockwork, hence they could only 'deny' the existence of life, as at best epiphenomenal. Hermann von Helmholtz made a version of this classic point, appealing to thermodynamics:

> To the builders of automata of the last century, men and animals appeared as clockwork which was never wound up, and created the force which they exerted out of nothing. They did not know how to establish a connexion between the nutriment consumed and the work generated. Since, however, we have learned to discern in the steam engine this origin of mechanical force, we must inquire whether something similar does not hold good with regard to men.[19]

There is a mistaken view of mechanism here as a model which was incapable of grasping various types of complexity or systemic features (early versions of this claim referred to chemistry, which fails if one considers figures such as Boyle or Fontenelle, or to selfhood, or here to thermodynamics).

Borelli, like Descartes before him and Vaucanson after him, emphasizes that part of the significance of artificially created mechanical objects (including but not restricted to automata: it can also be a clock or a pump) is that they enable a further theoretical but more generally cognitive engagement with the properties of natural objects. The machine here is functioning as a kind of go-between, enabling the interface between ontology and heuristics, within which actual machines can serve as 'matière à penser', so to speak. In Georges Canguilhem's elegant phrase: "Essentially, a machine is a mediation or as mechanics say, a relay (*relais*)."[20]

This increasing expansion of mechanism also ends up 'trespassing' into a more distinctively organismic arena. Consider the complex (and deliberate) semantic game La Mettrie plays with the ideas of body and machine. If, as I noted above, the expansion of mechanism can

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[18] Spence 1741/1975, pp. 413-414, cit. Kang 2011, p. 104. I have emphasized elsewhere (Wolfe 2017b, Wolfe 2019a, chapt. 3) how the 'vital' dimension of such expanded mechanist projects, or at least the presence of vitality as an *explanatory challenge* for mechanism, should lead us to reject certain older constructs such as 'mechanistic materialism', as applied to authors like La Mettrie, whose 'man-machine' is, despite its name, irreducibly organismic, a creature of flesh and blood and appetites.

[19] Helmholtz 1854/1995, p. 36, cit. in Kang 2011, pp. 230-231.

[20] "Aspects du vitalisme," in Canguilhem 1965, p. 87.

take different forms, notably (a) an ontological expansion (à la Boyle, Fontenelle, Boerhaave), in which the machine model turns out to be very *inclusive*, and (b) a more heuristic reconfiguration of mechanism (à la Steno, some Descartes, and Vaucanson), La Mettrie seems to be playing on both of these when, in a work which bears perhaps the most famously (but misleadingly) mechanistic title ever – namely, *L'Homme-Machine* – he declares that "The body is but a watch, whose watchmaker is the new chyle." La Mettrie is playing on the most classic mechanistic analogy of all (the watch or clock), while infusing the clockwork with living chemistry (chyle is the vital substance in organic chemical processes).[21]

For La Mettrie, our machine is very much an *organic* machine, a flesh and blood system. It is a 'machine' in the sense that our drives, our urges, our instincts, our hormones, the 'blood that flows in our veins', in La Mettrie's language (La Mettrie, 1987, II, p. 262), don't allow us to function in a kind of absolute freedom. This machine is not one that boils down to a foundationalist ontology of the sort we today might call physicalism:

> Man is so complex (*composée*) a machine that it is impossible to get a clear idea of the machine beforehand, and hence impossible to define it. For this reason, all the investigations which the greatest philosophers have conducted a priori, using their intellects, have been vain (La Mettrie 1987, I, pp. 66-67).

The machine here becomes an entity with an internal principle of organization, which empirically is a 'mechanico-chemical' hybrid, and conceptually is more laden with function but also appetitive features than the classic, restrictive picture of mechanism[22] (and as we saw, even in Descartes the reality is less restrictive than the reputation).

Similarly, notice how far a machine as 'relay' or analogy (that is, as a construct designed to tie together qualitatively different realms like hydraulics, blood circulation and digestion) is, from the stark opposition between 'a watch made of copper and a watch made of flesh', in Diderot's evocative image, when he insists in the *Éléments de physiologie* on "what a difference there is between a copper or silver watch, and a sensing, living watch" (Diderot 1975-, XVII, p. 335). Diderot's point is that an instrument made of wood or iron cannot feel, while an

[21] To quote the full passage: "The body is but a watch, whose watchmaker is the new chyle. Nature's first care, when the chyle enters the blood, is to excite in it a kind of fever which the chemists, who dream only of retorts, must have taken for fermentation. This fever produces a greater filtration of spirits, which mechanically animate the muscles and the heart, as if they had been sent there by order of the will" (La Mettrie, *L'Homme-Machine*, in La Mettrie 1987, I, p. 105). But even in the period of more literal appeals to clock and watch metaphors, these allowed of more or less mechanistic interpretations (as discussed in Neumann 2010, Andrault 2016 and Riskin 2016), and also, of more abstract and more concrete interpretations (Roux 2012, particularly the discussion of Borelli). In La Mettrie's case, one might say the watch metaphor implodes.

[22] It is likely this this more restrictive image of mechanism stems from the contrast with earlier ontologies, e.g. Aristotelian, Scholastic and those of the Renaissance novatores, a type of hostile positioning found typically in authors like Galileo, Descartes and Hobbes.

instrument made of flesh can feel, as he reiterates with a different image later in the same text: "Difference between the clamp of a wooden or iron set of pliers, and that of pliers made of flesh or two fingers. The wooden clamp does not feel, the flesh clamp feels; the wooden clamp does not suffer, the flesh clamp suffers" (*ibid*., p. 499).

The more analogical the machine or mechanical model is (that is, the more it functions analogically, rather than literally), the more it can serve as a heuristic: after all, automata have a certain shadowy sameness to animals… Similarly, automata could be fascinating *both* because they were a form of mechanism, *and* because they called attention to the specifically 'vital' (teleological, purposive, intentional, homeostatic …) properties of living beings. As Riskin put it, discussing Vaucanson's *canard digérateur*,

> The defecating Duck and its companions commanded such attention, at such a moment, because they dramatized two contradictory claims at once: that living creatures were essentially machines and that living creatures were the antithesis of machines (Riskin 2003, p. 612).

Another question would be, do these differences between a copper watch and a living watch (in Diderot's image), or between an ordinary machine and a self-organizing machine powered by chyle (in La Mettrie's), amount to an *ontological difference*? In fact, early modern mechanists do not seem to insist on such an ontological difference (and nor do eighteenth-century vitalists in their focus on the organism, contrary to an equally common misconception).

To take again an example from the most 'paradigmatic' mechanist, Descartes, in a 1640 letter to Mersenne we find something supporting my point here. Descartes toys with the opposition between machine and organism, or mechanical matter and living flesh, as precisely playing out at different levels: empirically (as in Helmholtz's comment on automata and bodies) and ontologically (as in Diderot's comment on flesh watches and wooden clamps, with its faint Aristotelian resonance).[23] In Descartes' terminology, the different levels are called physical (or moral) and metaphysical – and notice that he rejects any "metaphysical" difference:

[23] That is, if we ask what this difference is, between a copper and a living watch, or a metal clamp and flesh-and-blood hand, it is not based on some kind of innate Aristotelian teleology in the flesh which is lacking in the iron or the wood. Recall Aristotle's influential argument for why a hand separated from the body is no longer a hand: the material structure of a part *per se* matters less than 'where' it is: "Blood will not be blood, nor flesh flesh, in any and every state." A hand can only be understood as a hand inasmuch as it belongs to an ensouled body, i.e., matter animated by a form. Thus the material part, the hand, is derivative of the formal part, the soul. It is precisely this mere homonymy between a 'dead' hand and a 'live' hand which materialists miss, in Aristotle's view. If each animal and part would be defined by shape and colour, "Democritus would be right"; but "the dead man has the same conformation of shape [as a man], but nevertheless is not a man" (respectively, *Generation of Animals* I 18, 722b34; *Metaphysics* Z 11, 1036b32; *Parts of Animals* I 1, 640b29, b35).

> Metaphysically speaking, one might well build a machine that supports itself in the air like a bird, because birds, at least according to me, *are* such machines. But not speaking physically or morally [*non pas physice ou moraliter loquendo*], because it would take springs so subtle and overall so strong, that they could not be made by men (to Mersenne, 30 August 1640; AT III, 163).

As I shall discuss in the next section, vitalist concepts of organization, organic unity, and the interdependence of parts similarly do not appeal to some basic ontological divide between machines and organisms, e.g. some mysterious vital forces. They appeal to structure. Indeed, when Ménuret does so it is one of the rare moments where he provides a direct, frontal critique of mechanism – saying, what the mechanists could not account for or do justice to, regarding the nature of the animal economy, was "organic structure":

> They [*sc*. the mechanists]believed that movement merely obeyed the ordinary laws that apply to all *inorganic* machines, treated the human body geometrically, and rigorously calculated all the various degrees of force required for particular actions, or how much was lost, etc. – but all these calculations, which obviously varied tremendously, shed no light on the *animal economy*. They did not even pay attention to the *organic* structure of the human body which is the source of its main properties (Ménuret 1765c, p. 364b).

Challenging both the authority of pure or paramount mechanism, and the supernaturalism of a Stahlian soul powering the body, the vitalists insist that what we should "pay attention to" is "the organic structure of the human body which is the source of its main properties." In the following section I seek to reconstruct what they meant by this.

4. Structural vitalism: the notion of animal economy

The word 'vitalism' may have been first used to describe the doctrines of the Montpellier medical faculty in the eighteenth century, and it is definitely used as a self-description of the school by the later eighteenth century.[24] I do not use it here in a broader sense to refer to any doctrine of the irreducibility of life, the ontological reality of organisms or the presence of some 'spark', 'force' or 'impulse' in matter, but just to refer to the ideas propounded by members of this school (not that there is a pure, monolithic 'system' or 'credo', but definitely recurring positions, examples, critiques, attempts at modelization…).

Various authors in the mid-century, including prominent vitalists such as Bordeu, model the structural, systemic and 'network' quality of the living organism (often, the human or animal body), using the language of 'animal economy'. Interestingly, this modeling often employed the

[24] Rey 2000, Williams 2003, Wolfe and Terada 2008, Wolfe 2017a and 2019a, and Toepfer 2011.

metaphor of a bee-swarm (i.e., one organ is to the whole organism as an individual bee is to the bee-swarm).[25] This metaphor conveys a strong sense of organismic interdependence – thus for Bordeu, "the body's organs are linked with one another; each has its *district* and action; the relations between these actions, and the resulting harmony [between them], constitutes *health*" (Bordeu 1751, § CXXV, in Bordeu 1818, vol. I, p. 187). But beyond simply this interdependence, it is important that the parts – the organs – themselves are conceived of as alive, each with its own weakly purposive behavior. This is neither the body strictly as a machine, nor the body as mass of inanimate matter controlled by (indeed, animated by) the soul.

The Montpellier vitalists overtly try and position their 'doctrine' as a 'neither-nor' in between the two strongly opposite positions of mechanism and animism. Bordeu, Ménuret, Fouquet, Barthez in different ways and with different emphases, criticize mechanism – whether Italian iatromechanism, Descartes, Boerhaave or even Haller (who is of course already something of a hybrid figure in terms of 'strict mechanism') – for its lack of attention, or explanatory weakness faced with the 'fact' of living, embodied agents, which require specific types of explanations. Thus, Sauvages on Borelli:

> The Mechanists or those Moderns who claim to explain all movements of our body without any mover (*moteur*), do not seek very far to find in man the motive forces required for these effects: they imagine that the smallest pressure, like that of a pinch of tobacco affecting the nerves, can be multiplied thanks to the properties of machines, and produce a movement that is thousands of times greater than its cause – these are the principles of mechanics on which they reason (see Descartes' *L'Homme*). These Mechanists show quite clearly that they do not understand mechanics; Borelli, who knew the mechanics of the human body, clearly showed that muscles, far from multiplying forces, require immense forces to lift small weights (Sauvages 1770, p. 32, referring to Borelli, *De motu animalium*, I, chap. III, prop. 8 / Borelli 1989, p. 15).

But symmetrically, they criticize the animism of G.E. Stahl for its lack of explanatory power, since it is a form of 'supernaturalism', in which "the life of the soul consists . . . particularly in action exercised and carried out in a body, by means of a body, on and affecting bodily activities" ("De vera diversitate corporis mixti et vivi" [1707] in Stahl 1708, p. 113). Notably, they criticize the recourse to appeals to the soul and/or divinity to explain the phenomena of life which can sufficiently be explained in terms of the "coordination of an undefined number of living parts" (Grimaud 1776, p. 15).

[25] Ménuret 1765b, pp. 318b-319a and Ménuret 1765c; Diderot, *Rêve de D'Alembert*, in Diderot 1975-, XVII, pp. 121-123; Wolfe and Terada 2008; Sheehan and Wahrman 2015, chapt. 4, Wolfe and Kleiman-Lafon (forthcoming).

Jean-Charles Grimaud, discussing the ideas of some of his vitalist peers (including Bordeu, Ménuret and Barthez), asks if muscles "are part of a *system of lives*?" (Grimaud 1776, p. 26, emphasis mine); by 'system of lives' one should understand 'system of organic interrelations'. And he answers in the affirmative: the particular life of the muscles is "coordinated" with that of "the other living organs composing the animal"; hence, "it is necessary that [muscular activity] is variously modified in accordance with this coordination" (*ibid*.). But the types of interaction at work in the coordination of the different living parts (or 'little lives') in the animal economy are not reducible to contiguity and efficient causality. The "physical disposition of the machine" (here, the term 'machine' refers to the body as it often did in the period) is "a certain order amongst the organs composing it," and the effects of this "order" are "determined by *relations* or *sympathies*, which throughout the animal's existence, continuously and reciprocally connect all the parts subserving its mixtion" (*ibid*., p. 43).

In other work I have tried to investigate the extent to which vitalism can be seen as a naturalization of the animist model of 'soul-body control'; here I am more concerned with the surprising extent to which vitalist models, notably of the 'animal economy', are not *anti*-mechanistic. Even a vitalist so committed to talk of a vital principle as Paul-Joseph Barthez writes that "mechanics" is useful for determining exactly what "the advantages of the living body's organs are, in the mechanism of its intended functions" (Barthez 1858, p. 37). While Bordeu does emphasize the 'evident fact' that animal bodies are not like watches because they are self-winding, he insists that this should not be taken to mean, as the Stahlians did, that the higher-level features of vitality (fighting off illness and maintaining stability in the body, whether its temperature, digestive system, etc.) are dependent on the soul (Bordeu 1751, § CXXXI, in Bordeu 1818, vol. 1, p. 204). Louis de La Caze describes his aim as the explanation of "the mechanism which subserves the functions of the animal economy," a mechanistic level "chiefly founded on anatomical observations" (La Caze 1755, p. 2). In his important article for the *Encyclopédie* on the pulse, Ménuret speaks in rather hybrid terms of "l'organisation animée de notre machine"[26] ('the term 'organisation' in these texts is roughly synonymous with 'animal economy': Wolfe and Terada 2008). 'Organisation' means complexity, of a sort we might see as 'meta-mechanical'.

[26] Ménuret 1765d, p. 239. I am not seeking to provide here a detailed history of the shifts of the term 'machine' as applied to the body, but it has been noted in a number of studies that 'machine' at one time could be a term for the body. By the nineteenth century the situation is different, with the *Encyclopédie méthodique* explaining (in 1808) that one should no longer use the expression "machine humaine" … but that "animal economy" or "organism" are suitable substitutes: "It is preferable to use the synonymous expressions 'living economy', 'vital economy', 'animal economy', 'organism', 'organic mass', 'the entire economy of the human body'. The term 'machine' seems to refer to a system of causes and effects which belongs wholly to the mechanistic theory" ("Machine," in Anon., ed., 1808, p. 310).

A major case, including because it has an experimental dimension, of this interplay of the mechanistic and the 'meta'-mechanistic in the vitalist conceptualization of the animal economy, is Bordeu's study of the workings of the glands.

Bordeu is often described as having selected the glands as his theoretical object because they are the exemplar of what is non-mechanistic about the animal economy, since all mechanistic physiologies stumble, not on the humours the glands extract from the blood, but on the workings of the secretory organs themselves: for instance, how does a gland differentiate between one fluid and another, given that they are clearly 'intended' to deal with specific fluids and not others?[27] Humours, Bordeu says, cannot be explained according to "the actions of solids and the disposition of the organs" (Bordeu 1751, Preface, in Bordeu 1818, vol. 1, p. 48). But at the same time Bordeu is not content with a strictly chemical account of glands and their secretions. His original idea is that each gland possesses its 'sensitivity' (which works like a force). Now, to achieve this level of analysis the glands have to be studied according to "position and interconnections, in order to know their action" (*ibid*., p. 46). Position and interconnection taken together, are precisely the mechanistic and the 'meta'-mechanistic levels (the latter indeed functioning in terms of sympathetic relations, themselves accessible to chemical analysis).

Bordeu is less 'anti-mechanistic' than he is an 'expanded mechanist', performing experiments by compressing a piece of sponge in the jaws to study how a gland reacts to compression by muscular tissue:

> Take a piece of sponge of the size and shape of the part of the gland contained in the parotid gland in the jaw; soak it with water; put it in the place of the gland you have removed; push it into the hollow and move the jaw: the sponge should release all of its water if it is compressed, or at least yield some drops; but in the experiment, the sponge retains the water, however much one moves the lower jaw, following the natural direction of the movement of this part, in good faith; the sponge retains the water, hence it is not compressed; why should the gland be?[28]

Fouquet, in his article "Sécrétion," provides a useful summary of this work of Bordeu's:

> M. de Bordeu demonstrates, by means of fascinating experiments and dissections, that most of the glands are located such as to prevent their being compressed in any case by the surrounding parts; indeed, one can sense that various misfortunes would result from this compression, among which the hardening and shrinking of the glands would be the least. The parotid gland, which people claim to be the

[27] An interpretive essay on the development and conceptual variety of 'post-mechanistic' gland theories remains to be written, despite the important work of Grmek, Belloni, and Duchesneau. Cf. for a first real contribution, Williams 2012.

[28] Bordeu 1751, § IX, Première expérience en notre faveur, in Bordeu 1818, vol. 1, p. 57.

> example, the most telling proof of this compression, is actually inaccessible to all the agents which, it is claimed, this gland is exposed to. A short anatomical inspection of the parts says more than any reasoning; we will only note that the space between the angle of the jaw and the mastoid eminence in which a major part of the gland is located, increases with the lowering of the jaw, . . . you can do this on yourself. [29]

Elizabeth Williams explains the importance of this combination of 'experiment' and 'speculative' concept quite well:

> Mechanists had long attributed glandular action to the compression of glandular bodies by surrounding muscle and bone, but by 1750 it was widely recognized that this approach did nothing to explain why particular glands secreted particular fluids. Indeed it was in regard to this problem that vitalists first made inroads against mechanists, denying the explanatory power of such a model for glandular action and substituting for it a view based on the 'internal sensations' alluded to earlier, specifically the 'taste' or 'desire' of the gland that determined which components of blood it drew to itself and acted upon in furtherance of its specific function (Williams 2012, p. 398).

Bordeu's analysis is positional and focuses on interconnections; in that sense we could term it *structural*. But it also includes, as Williams notes, the active, functionally specific behaviour of each gland (its "taste," in Bordeu's terms).

It is worth noting that Bordeu presents his work as "indeed part of *Anatomy*" (Bordeu 1751, Preface, in Bordeu 1818, vol. 1, p. 46, emphasis in original). Simply, the scope of "anatomical inquiry" must be widened, he argues, to include "the use of the parts, their interplay, connections and relations." This is what he means by "animating the skeleton of anatomy."[30] Bordeu speaks positively of the project of an "anatomie médicinale" (*ibid*., p. 48) which he feels has not yet properly been carried out. Overall, we should thus note that Bordeu makes positive use of a term (anatomy) which officially belonged to the opposing, mechanistic camp (think of all the oppositions between 'dead' anatomy and 'living' physiology with its

[29] Fouquet 1765, p. 874a; also summarized in Williams 2003, p. 155 (and in Wolfe 2013). In case the reader felt this boiled down to earlier iatromechanist anatomy, Fouquet adds that experiments on corpses may not be sufficient evidence of the above points. But it is not an ontological rejection of the pertinence of cadaverous anatomy – see Wolfe 2013. As to Ménuret, he defines a specifically physiological explanation as one based on "the structure of the human body and its properties," taking account of "the changes occurring in the organization of the body and the mechanism of the functions, as age increases" (Ménuret 1765a, p. 721). Notice the recurring parallel between 'organisation' and 'mechanism', here made more complicated by the idea that the *organisation* is the structure and the mechanism … the function). These changes in bodily structure and function are defined mechanistically as a tightening and hardening of the fibres, which become "less sensitive, less irritable" (*ibid*.).

[30] Bordeu 1751, Preface, in Bordeu 1818, vol. 1, p. 46 – a formulation curiously recalling Haller's description of physiology as "animated anatomy" ("Physiologia est animata anatome", Haller 1747, p. 5).

irreducible functional or perhaps even teleological dimension). Careful focus on the vitalist concept of animal economy reveals it to be, with some caveats and flurries (Sauvages, Barthez occasionally) a form of *expanded mechanism*.

Bordeu (and Fouquet's description of his experiments) uses what I would term expanded mechanist language. Similarly, when Bordeu discusses the functioning of the seminal vesicles, he explains function in terms of the spatial disposition of the parts: "All the parts have been arranged so as to favour this convulsion; they are extremely sensitive and nervous, and are disposed so that, by communicating their movements to each other, they sustain and reinforce one another" (Bordeu, §§ C, LXXI, in Bordeu 1818, vol. 1, pp. 157, 125-126). In this passage, the language of organic sympathies and communication via sensitivity is seamlessly combined with that of spatial contiguity and communication of impulses through strictly efficient causality. So even in as apparently anti-mechanistic an area of physiological inquiry as glands and glandular secretions, Bordeu reasons in terms of parts, locations, pressure, and quantities of fluids – but, once again, with a pronounced functional dimension.

The image of the living body as a dynamic system of interrelations between organs understood metaphorically as 'little lives', that is, each being possessed of a life (or, as Bordeu says about the glands, a sense of taste) of its own, is explicitly functional (in a weakly teleological sense). As Grimaud writes, each organ "performs different functions but supports the life of the whole (*la vie générale*) in and through its particular life" (Grimaud 1776, p. 10). If there is teleology here, it is at the immanent level of "position . . . interconnections . . . use of the parts . . . their interplay, connections and relations" (Bordeu 1751, Preface, in Bordeu 1818, vol. 1, p. 46). Anti-mechanists in more contemporary forms of theoretical biology tend to oppose 'circular causality' to the merely 'efficient causality' of mechanism, and to locate teleology squarely in the former. In fact, as we saw in the first sections of this paper, mechanism is shot through with functional and thus weakly teleological language and concepts, sometimes quite deliberately; conversely, some of the vitalist appeals to circular causality (in early modern language, the "circle of action"[31]) explicitly present it as refuting the possibility of strong, top-

[31] Viitalism, *montpelliérain* and other, famously insists on the irreducible complexity of the "cercle d'action" (La Caze 1755, pp. 68-69; Wolfe 2019b): "at any time, effects therein become causes, and causes in turn become effects" (La Caze, *op. cit*.). For Ménuret, "life and health" are dependent on a "continuous antagonism of actions" which can be expressed in the formula, "*nulle action sans réaction*" (Ménuret 1765e, p. 435b; emphasis in original). Diderot speaks of the ceaseless "action and reaction" in the animal economy (Diderot 1975-, XVII, p. 119), and overall, of "the human body [as] a system of actions and reactions" (*ibid*., p. 337). These were key expressions in the chemical vocabulary: thus Hales, concluding his massive *Vegetable Staticks*, explains that it is "by the infinite combinations, action, and reaction of these principles" (i.e., sulphur, volatile salt, water and earth) that "all the operations in animal and vegetable bodies are effected" (Hales 1727, pp. 318-319). Bernard, in his later reflections on organic chemistry, is more skeptical as to the utility of circular causality in explaining organic function: "in complex organisms, the organism of life indeed forms a closed circle, but a circle with a head and a tail, in the sense that all vital phenomena do not have equal importance, even if they follow one another in the fulfillment of the vital *circulus*" (Bernard 1865, II, ch. II, i, p. 152). But Bernard's homeostatic conception is itself a form of circular

down teleology: “it is absurd to search for final causes in an order of things in which everything is connected, without beginning or end, cause or effect …” (Grimaud 1776, p. 38).

Furthermore, beyond the ‘circle of action’ (the theme of a circular chain of causes and effects in the organism that make it impossible to discern, as the mechanist would hope to, causes from effects), we find plenty of vitalist appeals to efficient causality, to direct, spatial transmission from one material part to another, contiguous part. Speaking of the living body, Bordeu writes that “the machine is arranged in such a way that one function is the cause of the next, such that there is a chain of successive actions, which are the causes of the others” (Bordeu 1751, §§ LXXI, LXXXVIII, in Bordeu 1818, vol. 1, pp. 125, 145). Ménuret extends this linear, structural emphasis on efficient causality a bit further, in discussing excretory mechanisms:

> In a word, isn’t it more natural to think that these movements, which are entirely beyond the control (*empire*) of the soul, are *the necessary consequence of the organic disposition of these parts*? That there are *primitively existing laws of the organization of the machine*, according to which the various movements occur, without one needing to assume an intelligent being who is constantly busy producing and directing them? This is why some illnesses are advantageous, and others not; such combinations of good and evil always presuppose a *blind mechanism* (*aveugle machinisme*) (Ménuret 1765f, p. 137a, emphasis mine).

In “Œconomie Animale,” he also reasons in terms of efficient causality and bluntly says that with the body, as with any other machine, we need to find its ‘springs’ to understand how it works:

> everything leads us to believe that the human body is like the other machines which art can assemble and disassemble, displaying their tiniest springs; it is a fact known to any artist (*i.e. artisan, CW*), that in even the most complex machines, the entire movement rests and bears on one particular piece from which the movement began, and from which it spreads to the rest of the machine, producing various particular effects in each particular spring. It is only by discovering such a spring in man that we can come to properly know and determine the way of acting of the general causes of life, health, sickness and death. To arrive at a right understanding of the *animal economy*, one must necessarily move back to a basic (*primitive*) function preceding and determining all the others (Ménuret 1765c, p. 362b).

But all of this is expanded mechanism or meta-mechanism: all the talk of ‘springs’, motion, and efficient causality is in the service of systemic notions (of which health is perhaps the ultimate case), wherein the basic features include interconnection, sympathies, cohesion,

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causality.

consensus … The more the emphasis is on interconnection, the further away we are from a componential, classic-mechanistic ontology, and the more the properties of the 'animal economy' seem like *relational properties.*[32] Not necessarily because what we are seeing in the appeal to "commixture," "mutual influence," "action and reaction" is a *rival ontology* (i.e. organismic ontology as opposed to mechanistic ontology). But because it is *not an ontology*. As Barthez writes in a lengthy (and wordy) self-criticism regarding his earlier commitment to the independent existence of the "vital principle": "I am as indifferent as could be regarding Ontology considered as the science of entities" (Barthez 1858, p. 129, n. 3). And when Bordeu, Ménuret, Grimaud elaborate on the model of the life of the organism (or animal economy) as composed of 'little lives', they never insist on an irreducible ontological uniqueness of each of these lives. In that sense, the vitalist concept builds on the functional and systemic dimensions present in mechanism (whether the latter is taken in its pure or complex forms).

A fascinating feature of the vitalist version of the animal economy concept is its simultaneous investment in the mechanist core concept, and expansion thereof. Whenever the mechanical model is presented as limited or insufficient, sophisticated mechanistic language is used! (From 'springs' to the more chemical language of 'action and reaction', or the appeal to circular causality.) I have termed this 'expanded' or 'meta'-mechanism, but it also reflects, to use a term Ménuret called attention to explicitly, a notion of structure. Now, structure of course allows of mechanist conceptual reconstruction; but conversely, it captures some of the systemic quality of what 'pure mechanism' seems not to grasp (the interrelations in service of a more distributed structural integrity).[33] The animal economy, like all other concepts, of course exists in different forms, but consistently, including when it is appealed to outside of the vitalist context, it retains this interplay of the mechanical, the chemical and the meta-mechanical (or systemic). In a perfectly iatromechanical (here, Scottish medical-Newtonian) context, Edward Eizat speaks of the body as a machine but insists on its complexity and indeed on the irreducibly systemic features of this machine due to the variety of the interactions between its parts:

> Who doubts but the body of man, in some sense, may be called a *machine*? Yet it is of such a wonderful structure and curious contrivance (for we are wonderfully made) has so many small Parts and Springs, such variety of Motions, &c. that none either knows, or can know, but the great artificer that first made it, and set it a

[32] One might compare this portrayal of mechanism as applied to the body, as increasingly structural and relational, to Eric Schliesser's account of gravity as a relational property (Schliesser 2011). One difference is that in the latter case, gravity *is* relational, it *is* an ontology, whereas here there is a gradual move *away* from ontology in favor of description of systems.

[33] Some of the mechanism-friendly themes presented in Ménuret (but also, Bordeu, Grimaud, and later Bernard) are attributed to mechanism itself by Lisa Shapiro in a provocative paper. Objecting to the idea that a mechanistic analysis cannot include the notion of health, since the latter is teleological, Shapiro argues that "mechanist ascriptions of health can rest on a notion of intrinsic stable structure (I will call this form), and that this structure (or form) need not be conceived of teleologically" (Shapiro 2003, p. 426).

> going. All we can do is diligently to observe its natural motions, and take notice what disturbs their regularity, and endeavour to find out by experience, assisted with reason, what may put it right again. And this I think may be done without the mathematicks (Eizat 1695, p. 15).

Equally outside the vitalist context, in his 1683 anatomy lectures, Walter Charleton reflects on Harvey's discovery of the circulation of the blood and makes, not for the first time, an analogy between the heart and something political – except whereas this is usually the monarch, Charleton says blood is like money, or rather money like blood, and proceeds to invoke the systemic nature of the animal economy: "the blood of all states, as well monarchies as republicks, for the support of the government: so the office and work of the heart is to stamp the character of vitality upon the mass of the blood, for the maintenance of life in the whole animal economy."[34] A century later, Lavoisier describes the animal economy as an equilibrium of forces (thus as dynamic, not purely mechanistic):

> How admirable is the result of continually diverse forces in equilibrium, that we can observe at every moment in the animal economy, and which enable the individual to adapt to each circumstance in which chance places him! . . . Is he inactive and at rest? Then his circulation and respiration are slower, he consumes less air . . .[35]

But the vitalist version of the animal economy concept, however much it may borrow from the mechanistic playbook or toolbox, does so with an additional 'systemic' emphasis. An important instance, because it smoothly moves in one paragraph from the language of 'springs' and motion to the 'higher-level' property of health, is this statement from Ménuret:

> What is man? Or to avoid any misunderstanding . . . *what is the human machine?* It appears at first sight to be a harmonious *composite of various springs*, each of which is *impelled by its own motion* but (which) all concur in the *general motion*; a general property especially restricted to organic composites, known as irritability and sensibility spreads through all springs, animates them, vivifies them and excites their motions. But, modified in each organ, it infinitely varies their actions and motions: it leads the various springs to tighten against one another, to resist, to press, act and mutually influence one another. This reciprocal commixture sustains motions, no action without reaction. From this continuous antagonism of actions, life and health result (Ménuret 1765e, emphasis mine).[36]

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[34] Charleton 1683, p. 72. See also, on Hobbes' discussion of these motifs, Garau 2016.

[35] Lavoisier & Seguin 1862 (1789), p. 699. The term 'animal economy' is still being used in physiology by Bichat in the early 1800s, in his *Anatomie générale*, by Chaptal in his 1817 memoirs (Chaptal 1893, pp. 19-20) and even by Bernard (Bernard 1848 and Bernard 1865, pp. 233, 275).

[36] Blumenbach, perhaps influenced by Montpellier vitalist texts (he refers to Bordeu a number of times), has very similar language in his *Institutiones physiologicæ* of 1787, on how the "agreement" between solids, fluids and vital

The idea that the complexity of chemical processes at work in maintaining the vital 'internal environment', as Claude Bernard was to term it in the mid-nineteenth century was not reducible to the basic laws of mechanistically specifiable matter, is increasingly emphasized in the generations *after* the Montpellier vitalists I have discussed. While in the above-cited passage, Ménuret builds upwards from springs and basic motions to higher-level properties such as health, *via* intermediate functions such as irritability and sensibility, by the nineteenth century a prominent chemist like Chaptal insisted that "vital laws could not be grasped by mechanics, hydraulics, or chemistry," as the "motions of living bodies were dependent on some basic laws that we needed to study, and the effects of which should be compared without searching for their causes" (Chaptal 1893, p. 19: these are memoirs from 1817 published posthumously at the end of the century). Granted, Chaptal added, "the laws of mechanics, hydraulics and chemical affinities govern all of matter"; but "*in the animal economy, the laws of vitality govern them to such an extent that their effect* [of the former laws, CW*] is almost nil*" (*ibid*., p. 20, emphasis mine).

5. Expanded mechanism and structural vitalism

Opposing mechanism to vitalism is a commonplace in the historiography, as I remarked at the outset. But it is also alive and well in the 'primary' texts themselves (e.g. Sauvages on Borelli, or conversely, texts in which vitalists are presented as overly holistic, insufficiently experimental and in that sense far removed from a robust mechanistic approach to scientific practice). For instance, the animal economy at first sight appears to be defined explicitly against mechanistic models of explanation. And we are often told that mechanistic models are limited in their emphasis on the 'non-living' features of organisms, notably physical laws, whereas 'organismic' models emphasize the 'organizational features' of organisms; on this view, a mechanistic model deliberately *excludes* relevant features of living organisms in order for the model to 'work', in contrast to the emphasis on 'holistic' features of living systems. However, I have sought to challenge the apparently undeniable force of this opposition.

But it is worth dwelling a bit more in closing, on more subtle versions of the opposition between mechanism and its 'other'. Some stress that vitalism itself necessarily excludes certain areas of analysis in order to promote others, i.e., claiming a regional ontological uniqueness for organisms, in which they have teleological features which differentiate them from mechanical nature overall. As Jessica Riskin puts it, "'Vitalists' were those who set living beings apart from

forces (the latter being of special interest to him, as he distinguishes between various kinds of forces), but also the "sympathy between the parts" and the union of body and soul, are what comprises "life and health" (Blumenbach 1787, Chapt. V, De Sanitate et Natura Humana, § 56, p. 41).

the rest of the natural world, as requiring a distinct set of explanatory principles" (Riskin 2016, p. 252). Addressing an aspect that I touched on earlier under the heading of 'ontology', Silvia Berryman suggests that mechanist and materialist approaches present the world in "restrictive" terms (i.e. as only possessing certain features), while in contrast, "a vitalist or teleological approach need not claim that every feature of the world is vital or susceptible to teleological analysis; rather, these categories are 'inclusive', used to name accounts in which at least some vital properties or teleological explanations are thought to be required" (Berryman 2003, p. 346).

Rather than committing to either of these positions (which are very stipulative, and neglect both the hybridity inherent in mechanism or vitalism, and the specificity of their historical forms), I return to the animal economy as a concept which bridges mechanism and vitalism. With respect to the vitalist understanding of the animal economy, Roselyne Rey offers a concise formulation of the opposition between mechanism and its rivals, and how vitalism was meant to overcome it, when shed defines the vitalist concept of "organisation" as "machine plus sensitivity" (Rey 2000, p. 177). She explains that "this plus amounts to more than mere addition: a complex and autonomous system, endowed with multiple networks of relations, mutual interdependence, intimate correspondences and connexions, a system which can record external impressions and respond to them" (*ibid*.). This echoes my earlier emphasis on interrelation, systemic features, and relational properties (like the interrelation of 'little lives').

Yet the idea of the animal economy or 'organisation' as "machine plus sensitivity" suffers from its depreciation of what mechanism is, or could be. Rey states that Descartes (and La Mettrie, who is much less of a mechanist than what she claims) both "miss the specificity of living being" (*ibid*., p. 137). In fact, mechanism, e.g. in the case of Descartes, was definitely motivated to account for complex features of life, and had an implicit dimension of 'intrinsic finality' (Hatfield). Furthermore, it is unclear how vital properties could somehow be 'added on' to basic mechanical models. In addition, the animal economy concept is mechanism-friendly (as I have suggested in section 4). Just as the animal economy concept allows of more or less mechanist expressions, and the various mechanist / iatromechanist concepts are more or less pure, more or less expanded, and in that sense more or less weakly organismic, it is also the case that the different versions of the body-machine concept, such as notably La Mettrie's, integrate more or less higher-level properties, in their focus on circular causality (the system of actions and reactions), on health and sickness (precisely not 'atomistically' specifiable notions), and on functional explanations, building on developments already present in canonical earlier figures like Descartes and Harvey.

Our historiography and our intellectual categories need improving on, especially compared with the picture painted by Helmholtz – also because *there is no such thing as pure,*

blind, cold mechanism.[37] For one thing, when it came to projects for automata such as Vaucanson's 'defecating duck', the specific nature of organic life was the challenge, not what was denied, as I have sought to make clear above. And even when the body is treated mechanistically by the poster child of iatromechanism, Descartes, this still means explaining it "through whole systems" (Hutchins 2015, p. 671).

Conversely, core vitalist concepts such as the 'animal economy' are *not strictly, or wholeheartedly, anti-mechanist*. Supposedly pure mechanistic models exhibit sensitivity to functional properties (from Descartes and Boerhaave straight down to Haller's 'micromechanism'); supposedly anti-mechanistic models such as the positions here referred to as 'vitalist' exhibit a greater recognition of the role, pertinence and validity of mechanical explanations of particular phenomena than is generally believed. Not only are the mechanistic models of this period plural, diverse and variously defined; the interplay between 'mechanical models of life' and their various opposites (the Stahlian or Leibnizian organism; the vitalist animal economy and *organisation*, etc.) is complex, with blurry contours and shifting borders.

A question arises at this point: if vitalism is so mechanism-friendly, so focused on notions of structure (including structural integrity) and interrelation, what really differentiates it from mechanism? Don't they collapse into one larger view, or family of views?

One simple answer would be to reprise, once more, the opposition between mechanism and teleology and to show how the animal economy is a distinctly teleological concept, while the body as a set of funnels, pulleys and sieves (or 'worse', a bundle of atoms) is not. But that answer is not available to us. First of all, because of the presence of weakly teleological ideas throughout most forms of mechanism (here one could debate, again, whether there is such as a thing as *expanded* mechanism or whether *all of mechanism* is already complex, hybrid, pluralistic, etc.). Secondly, because there is so much more of 'machines', 'springs', 'motion', 'pressure', 'weight', 'expansion and contraction' in the animal economy than most discussions of vitalism seem to acknowledge.

Another possible core difference between the two would be the commitment to vital forces. After all, doesn't vitalism postulate some kind of entity, like a vital force or principle (if not a Stahlian *anima*), to explain the behaviour and self-maintenance of a living system? In fact, very rarely. (In earlier work I proposed the distinction between 'substantival' and 'functional' vitalism to support this point, i.e., arguing that Montpellier vitalism primarily tended to put

[37] A notion I do not use in this paper, that of embodiment, can also help show that the various early modern mechanist projects dealing with 'life' and 'body' were, not foreign to or in denial of embodiment, but viewed it more as a kind of explanatory challenge that, I suggest, spurs on the elasticity and ambition of the mechanistic project, as in the 'marveling' at Vaucanson's mechanical duck, but also in the irreducibly organic quality of La Mettrie's 'man-machine'. Paradoxically, it is in the vitalist models of animal economy that there is less interest in the 'lived-experiential' quality of *le vécu*.

forth *functional-vitalist* arguments on the nature of living systems, rather than *substantival-vitalist* arguments on the ontological uniqueness of a vital force: see Wolfe and Terada 2008, Wolfe 2017a and 2019a). Bordeu, Ménuret and Grimaud do not want to reduce the workings of the body to mechanics as a known science, yet the properties they invoke are dependent on mechanistic concepts, they supervene on them. These vital properties are rarely presented in terms of laws (including due to some suspicion towards quantification and overall, mathematization: cf. Wolfe 2017c); let's say that although they tend to reject mechanical laws, they will sometimes speak of the laws of the animal economy.[38] In this sense, vitalism as discussed here, namely its mechanism-friendly form (defended by non-negligible figures, chief representatives of 'Montpellier vitalism') is a "weak organicism" (Beckner 1974), i.e., an approach to organisms that stresses the specificity of their functional properties, without insisting on the ontological autonomy of this specificity (which would be "strong organicism"). It is thus very close to the later forms of expanded mechanism I discussed in sections 2 and 3.

Yet vitalist explanations are, nevertheless, not *componential* explanations (recall the case of the glands, and the beeswarm metaphor). That is, the animal economy is not explainable in strictly reductionist terms (as in 'decomposition' explanations). In contrast, mechanism does explain 'the complex by the simple'.[39] Vitalist analyses seek to articulate an idea of complex organization which integrates mechanical explanations. However – depending on how strong a teleology they incorporate – they can hold that mechanical explanations have limits, and thereby allow that "within the organic realm the various empirical regularities associated with functional organisms can be investigated" (Lenoir 1981, p. 30). Indeed, Bordeu in particular speaks of a force of self-preservation, although he is explicitly agnostic as to its ontological status

> It is difficult . . . to explain oneself, when it comes to speaking of the force which so carefully directs a thousand singular motions in the human body and its parts . . . all living parts are directed by an ever-vigilant self-preserving force; does this force belong, in certain respects, to the essence of a part of matter, or is it a

[38] Grimaud 1776 is an instance of vitalist approval of laws of irritability (referring to Fontana and Haller) (p. 12). But the notion of 'law' receives no particular focus or investment here; simply, Grimaud acknowledges that there are quantitative regularities – indeed, laws – in the functioning of the organism, or in this case, in the convulsions at the moment of death.

[39] In J. Schiller's (outdated and anachronistic, but interesting) study on the history of physiology (Schiller 1978), 'mechanism' is the hero, diversely instantiated by Descartes, Lamarck and Claude Bernard, and vitalism is the enemy, less so because of the historical figures known as vitalists, and more because of what Schiller perceives as a kind of postmodern relativism defended by Roger, Foucault and Canguilhem, in favor of vitalism. He would doubtless not be happy at the enthusiasm with which the Montpellier vitalists invoked Hippocrates, notions like the *enormon*, or Van Helmont's *archaeus* (e.g. for Grimaud, Van Helmont had "des idées si sublimes" on the animal economy: Grimaud 1776, p. 9). But moreover, Schiller would neglect the fact that these apparently 'archaic' invocations are necessarily reactions to a modern mechanistic scheme and thereby are in interaction with this scheme.

> necessary attribute of its combinations? (Bordeu 1751, § CVIII, in Bordeu 1818, vol. 1, p. 163)

And he acknowledges that he cannot answer this question (is the self-preserving force part of matter or an attribute of some particular material arrangement?) directly but must be content with "metaphorical expressions and comparisons" (*ibid*.)

Vitalism as we have encountered it here is not a holistic philosophy of nature which rejects the scientific pertinence of mechanistic explanations, but rather an 'expanded mechanism'. But it's not just a matter of the occurrence in vitalist vocabulary of 'machine', 'mechanism', 'structure', 'causality' and the like. The animal economy conveys to us something like a 'structural vitalism': rather than "machine plus sensibility," as Rey put it, I would suggest it is 'vital materiality plus structure'. I thus disagree with the formulation of the theoretical biologist Robert Rosen, namely, that the reductionist approach to living systems is to "throw away the organization and keep the underlying matter," whereas what he calls (following Nicolas Rashevsky) the "relational approach" in biology, recommends that "when studying an organized material system," one should "throw away the matter and keep the underlying organization" (Rosen 1991, p. 119).

The vitalists I have discussed here would not want to throw away the matter; they, like Bordeu discussing the glands, would insist on the *particular material properties* of the system they are studying. The fact that each gland has its distinctive sense of 'taste', i.e. a distinctive chemical (and, some would add, biosemiotic) communication system, does not make it immaterial. It means that the expanded mechanist needs to take on board considerable elements from the chemical and physiological toolbox (so much so that she may start calling herself a vitalist) if she is to do justice to organic structure, to the circle of action.

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