LIFE AS CONCEPT AND AS SCIENCE

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1 Related Topics

Biology, Medicine, Physiology, Soul

2 Introduction

What are early modern life sciences, the sciences of? What is the relation of philosophical considerations on living versus dead matter, or the possibility of animate matter, to such sciences? In this entry I examine such questions.

3 Life as concept or as scientific object: the problem

> *Hor*: What is Life?
> *Cleo*: Every body understands the Meaning of the Word, though, perhaps, no body knows the Principle of Life, that Part which gives Motion to all the rest (Mandeville 1729/1924, II, 167).

Life is a polysemous notion. Early modern thinkers, no less than us, moved imperceptibly between usage in which 'life' might be the life of a person, or the art of living well, or morally, and usage closer to what we might think of as a 'scientific' sense of life, i.e., the object of a science like biology (which only comes into being in the late eighteenth century). Scholarship on early modern philosophy has had less difficulty in picking out the specific issues concerning 'biological life', embodiment, organism and so on (see Smith (ed) 2006, Nachtomy and Smith (eds) 2017, Wolfe and Gal (eds) 2010), than the corresponding scholarship on early modern science, which has classically been determined by intellectual models deriving from the physico-mechanical sciences. That is, the idea of the Scientific Revolution and the historiography that studies (some would say constructs) this object, has almost entirely neglected the life sciences: they are simply not part of the story. Our concept of the Scientific Revolution does not include debates over generation, *semina rerum*, species, anatomy, vivisection, animal souls, irritability and so forth.[1] Some responded by declaring that there were no revolutions in the life sciences, perhaps until cell theory in the 19th century.

Yet early modern life science certainly exists, from physiology to theories of **generation**, from the chemical investigation of **blood**, aether and spirits to treatises on **fermentation** and fevers. As such, we can then inquire into its relation to the constitution and stabilization of other parts of natural philosophy, such as mechanics and atomistic physics. Figures such as Harvey, Descartes and Borelli, or Boyle, Pitcairn(e) and Malpighi, or Charleton and Boerhaave then loom large on the map and if our goal were to revise accounts of the Scientific Revolution so that they took account of such figures, it would seem reasonably easy to achieve. Indeed, some scholars seek to inscribe sciences like medicine, physiology, anatomy, notably (natural history is a more difficult case) into a mainstream, mechanistic-science friendly narrative **(**Grmek 1972**,** Bertoloni Meli 2008, 2011; see here **The Mechanization of Life)**.

Thus Domenico Bertoloni Meli elegantly emphasizes the interplay between the mathematical and medical disciplines: "when unraveling the intellectual world in the seventeenth-century, we can no longer separate the history of anatomy from the history of science as if anatomists and physicians inhabited a different world from not only mechanical and experimental philosophers, but also mathematicians" (Bertoloni Meli 2008, p. 709). Yet, even if we reinscribe Harvey or Malpighi into a 'mainstream' narrative of scientific development, this does not change the fact that there seems to be a deep discontinuity between the period 'before biology' and 'after'. One way to capture this discontinuity is with the distinction between ontologically driven theories of Life and a unified science of Life. This does not track a distinction like that between theoretical and experimental (Glisson's metaphysics of living nature also appeals to his 'experimental' work on irritability, while Treviranus' *Biologie* is very conceptual in motivation).

4 Life science

What is the science of life, a science of? Even this disarmingly simple way to put the question is itself something of a hornet's nest: what counts as a science? One should also pay careful attention to the dividing up of the disciplines in the early and mid-eighteenth century, which yielded results quite different, even foreign to our eyes. Besides the well-known fact that medicine was often called 'physick', one should also note that *physique* could be described as synonymous with natural philosophy (e.g. in the Jesuit *Dictionnaire de Trévoux*, first edition, 1704); Claude Perrault's 1680 *Essais de physique* is essentially a set of physiological essays). Thus **Fontenelle** (1657-1757)**,** the longtime Secretary of the Académie des Sciences, explained how such sciences were distributed across the sections of his academy: "That which pertains to the preservation of life belongs particularly to physic[s] . . . consequently it is divided across three parts of the Academy . . . anatomy, chymistry and botany."[2] For that matter, even if one reached a kind of consensus that the science of life, whether it is called 'biology' or not, studies living

[1] To my knowledge the first person to raise the issue was Salomon-Bayet 1978, pp. 12, 15, 112, 334 and in the Anglophone literature Cook 1990, pp. 401-404. Smith (ed.) 2006 is a notable attempt in the latter tradition to redress the balance, without particular focus on the Scientific Revolution paradigm itself; see also Pyle 1987 (which stresses the 'metaphysics of generation' more than the possible revision of a Scientific Revolution paradigm).

[2] Fontenelle 1702, Preface, n.p. (translations are mine unless otherwise indicated). The section of the Académie for 'physical sciences' (the non-mathematical, manipulable sciences) included anatomy, chemistry, metallurgy, mineralogy, botany, agriculture, and natural history; the absence of a section for physiology has led some commentators to assume that such researches were conducted outside the Académie: far from it.

beings, who gets to decide on the definition of these? (Is it 'ensouled', i.e. animate in terms of possessing an *anima*? What about plants?)

Even the term 'life science' itself was initially used (e.g. as *science de la vie* or *Lebenswissenschaft*) more in the sense of an 'art of living'. Only by the early nineteenth century is 'life science' used in the sense of a specifically biological (or medical, or physiological) body of knowledge, in the first sentence of the Chevalier de Richerand's physiology textbook.[3] As for 'biology', it is not an early modern term although it occurs earlier than is commonly thought (people usually point to the same occurrences in Treviranus and Lamarck, both in 1802), by the 1770s, but not with a meaning we would recognize today. For example, Linnaeus uses it to mean something close to 'biography', but also speaks of 'biologi' to mean scientists studying plant reproduction.[4] At the same time one witnesses real, explicit concern with the need for a specific science of life, the names of which vary (biology, zoonomy, biogeography, and often, 'physiology' used in a broader sense as the umbrella discipline in this study of life). Thus the French chemist Gabriel-François **Venel**, in his article "Chymie" in Diderot and D'Alembert's *Encyclopédie*, speaks of "changes" which bodies undergo, such that they "move from the non-organic state to the organic state," and suggests that the "phenomena of organisation [*i.e. organism, organic phenomena, CW*] should be treated by a science separate from all other parts of Physic" (Venel 1753, p. 410); curiously, his long entry on chemistry is really about the chemistry of life.

Neither biology nor chemistry exist as stable theoretical entities in the early modern or Enlightenment periods, even if chemistry had existed for a long time, but on unstable methodological and conceptual bases, that are only unified with Lavoisier. (The term 'chymistry' is now standard in scholarly usage: it is meant to highlight the fact that there is no non-arbitrary and historically justified analytic division between 'chemistry' and 'alchemy' in the early modern period: Principe and Newman 1998. However, for the purposes of my emphasis on 'vital chemistry', such historiographical concerns are not directly relevant.) Yet the constitution of an autonomous ontological region corresponding to 'the science of living beings', i.e. biology, is significantly affected by chemistry, as we have seen. One way to describe this is to say that chemistry is, at least at this time, the science which "allows for an understanding of matter as something that – at least provisionally – cannot be reduced to calculation" (Starobinski 1999, p. 86).

Now, Foucault claimed influentially in *The Order of Things* that "Life did not exist" before the emergence of biology as a science bearing that name, in the nineteenth century, a claim which I think should be taken with a considerable grain of salt (Foucault also makes the less controversial claim that early modern natural history could not constitute itself as biology).[5] My concern here is not with the conditions of that emergence, which come together in the decades immediately following the period this Encyclopedia examines, explicitly in the 1790s. But, contra Foucault, the obsession with Life and the growing recognition that a specific science will be required to study, is a striking 18th-century development. Further, as Jacques Roger observed, if there was no biology, there could also be no biologists (Roger 1980, p. 258). Yet there were many naturalists, philosophers, natural philosophers

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[3] de Richerand 1817, Prolégomènes, p. 1; the first edition of Richerand's textbook appeared in 1801, but does not include this expression, even if it does include long discussions on the nature and scope of physiology, understood as the science that studies the entirety of properties of the animal economy, i.e., the science of life. See Toepfer, "Physiologie," in Toepfer 2011.

[4] On the history of the term 'biology', see Barsanti 2000; Toepfer, "Biologie," in Toepfer 2011; Bognon-Küss and Wolfe, "Philosophy of biology before biology: a methodological provocation," in Bognon-Küss and Wolfe (eds) 2019.

[5] Foucault 1966, pp. 139, 173. For an excellent, less tendentious discussion of the shifting meanings of 'biology' and its predecessors, 'physiology' and 'natural history', and an analysis of the relation between 'philosophy' and these terms, see Gayon 1998. For the newer view that the eighteenth century *was* significantly concerned with 'vital' matters, see Reill 2005, Bognon-Küss and Wolfe (eds) 2019.

fixated on Life and the properties of living beings. To step back into the seventeenth century, well before Venel's entry, is to be confronted with a variety of *theories* of Life. Life could be explained in terms of

- Fermentation and/or vital heat (Fernel, Descartes, Gassendi, Willis)
- An emergent feature of chemical *mixtio* (Stahl)
- Organic molecules (Buffon, Maupertuis)
- Fibre architecture / gluten (Haller)
- As a property of organic bodies, which are bodies composed, not of organs *qua* inanimate parts but of 'small [sensitive] lives' (Bordeu, Diderot)

However, we should take such theories with caution. It is by no means clear that early modern thinkers asked the question 'what is Life?' in the way that we have become familiar with – not just that their possible answers to the question were different (vital heat, fermentation, Descartes' 'fire without light' and so on) but even what it would mean to ask such a question. They could also, of course, reject the idea that Life had to have an essential definition, as Locke did:

> Life is a term, none more familiar. Any one almost would take it for an affront to be asked what he meant by it. And yet if it comes in question, whether a plant that lies ready formed in the seed have life; whether the embryo in an egg before incubation, or a man in a swoon without sense or motion, be alive or no; it is easy to perceive that a clear, distinct, settled idea does not always accompany the use of so known a word as that of life is (Locke 1701/1975, III.x.22).

5 Ontology of Life

In some cases, Life is understood, in more or less explicitly Aristotelian (or post-Aristotelian) fashion, as the life of the soul: life as animation. As Gassendi writes, "Life corresponds to the presence of the soul in the body, and death to its absence" (Gassendi, *Syntagma philosophicum*, in Gassendi 1658, II, pp. 250a-b). This can be taken in an increasingly materialistic direction, in which soul is understood in more Lucretian terms as 'material soul'; the idea of soul or life as a 'little flame' is again an instance of this, in Gassendi (Gassendi 1658, II, p. 251a) and in a variety of **clandestine manuscripts** of the next decades, including the *Treatise of the Three Impostors*. Ideas such as these are often neglected by scholars who think there is a kind of switch or black-and-white oppositional choice between Cartesian models and non-Cartesian models, as in when T.S. Hall writes, "to interpret the body without invoking a soul required a compensatory extension of the role assigned to matter, since matter now must carry the full explanatory load" (Hall 1982, p. 69). In fact, it is not just 'soul or matter' as options, but a material soul.

Another case which also seems to belong to the genre of a 'metaphysics of Life' is the English physician Francis Glisson's (c.1597-1677) ideas about "life [as] the intimate and inseparable essence of matter," and matter as "contain[ing] within itself the root of life" (Glisson 1672, § 8).[6] In fact, Glisson also speaks at length about the idea of material soul, in his *Tractatus de natura substantiae energetica, seu de vita naturae ejusque tribus facultatibus perceptiva, appetitiva, motiva* (1672), usually referred to as *De vita naturae*. After publishing various significant medical works, such as *De rachitide* in 1650 and *De anatomia hepatis* in 1654, Glisson produced this treatise on the 'life of nature'. Now, it would be easy to dismiss this as a kind of substance metaphysics, as indeed Albrecht von Haller (1708-1777) did when he both credited Glisson with the discovery of the property of muscular irritability and excluded him from the history of science proper (Giglioni 2008); but clearly Glisson reflects on the nature of our organic

[6] I quote from a draft translation of *De Vita Naturae* by Guido Giglioni, which he was kind enough to share with me.

structure (*organizatio*, § 11), its relation to our sense organs, and how animal spirits are not a sufficient explanation of the features of 'animation' and complex perception which our sense organs display. The great scholar of Glisson, Guido Giglioni, has also stressed the presence of related ideas of the "appetites of matter" in a more apparently mainstream figure, Francis Bacon, together with a sustained interest in the "prolongation of life," particularly in his posthumous *Sylva Sylvarum* (Giglioni 2005, 2009). Thinkers such as **Margaret Cavendish** are often classified as vitalists, because of their vision of matter as possessed of internal dynamism, and sometimes Life depending on the passage quoted. But their type of engagement with the life sciences of their day is quite remote, and so I have not included them in this survey.

The ontological dimension here makes the question 'what is Life?' different from when thinkers like Erwin Schrödinger ask it in the 20th century, typically answering with a set of biological criteria (or ones derived from physics, e.g. thermodynamics, like Schrödinger). If one asks 'what is Life?' today, definitions vary widely – including even a lack of consensus on whether or not definitions are desirable or possible – but tend to emphasize that living beings grow, metabolize, reproduce and die, producing lineages that provide increased adaptive fitness in changing environments (Weber 2011). It's not just that the lists of relevant properties were different (vital heat versus self-reproduction, or fermentation versus inheritance). But rather, that conditions for a science of 'biology' explicitly respond to the existence of phenomena which did not conform to the laws of mechanics, like parthenogenesis, muscular reactivity, the behavior of animal spirits (soon to be reconfigured in terms of the equally surprising 'animal electricity') (Barsanti 2000, p. 124), or microscopical discoveries (or rather, phenomenologically revised and refreshed assessments of what was seen under the microscope), in terms of life.

However, this is not an entry on 'proto-biology' but on the concept of Life. And it is striking that despite, first, the presence of a variety of such *theories*, and second, the existence of sciences such as medicine and physiology, it is a striking fact that 'Life itself', the nature of Life, the status of living beings in the physical universe, is not a problem in early modern texts. In their introduction to their volume on the life sciences and early modern philosophy, Ohad Nachtomy and Justin Smith suggest an analogy. The problem of life in the early modern period, in their view, "imposed itself" on early modern thinkers in much the same way that the "hard problem" of consciousness has in philosophy of mind, since the work of David Chalmers in the 1990s (Nachtomy and Smith 2014, p. 2). But contrary to this otherwise interesting analogy – and indeed issues concerning 'Life and Mind' reward further exploration – it seems that, notably until the writings of the Halle professor Georg-Ernst Stahl in the early 18th century, including his debate with Leibniz, which he published in full after Leibniz's death (Duchesneau and Smith, eds. and trans. 2016), one doesn't find early modern natural philosophers reacting to the existence of living beings as an explanatory (or ontological) scandal; life is not a problem, hard or otherwise.

That is, in early modern discussions of the nature, function and operation of organic bodies (animal or human), including comparisons of these with various sorts of machines, both real and imagined, it is extremely rare to find distinctions between the two being made on the basis of ontological claims about 'Life' itself or the nature of the frontier separating the living from the non-living, animate matter from inanimate matter. Life itself is not the object of controversy. The Leibniz-Stahl debate stands out in this regard, in the sense that there, Life has become a core issue itself – particularly, the specific status of organized bodies (i.e. organisms). Notably because Stahl himself, particularly in his treatises collected as *Theoria medica vera* (1708), explicitly criticizes rival theories of the human body for not sufficiently defining Life, including in 'foundationalist' terms (Stahl speaks of logical definitions). In his treatise *Paraenesis ad aliena a medica doctrina arcendum* (1706), Stahl repeatedly asks 'what we call Life', 'what purpose does it serve', within and outside the body?

In the debate with Leibniz, the uniqueness of organisms is a shared tenet; what the authors disagree on is how to justify this uniqueness. Stahl typically argues for it in terms of the presence of the soul, and specifically its purposive, goal-directed action; Leibniz in terms of complexity of structure (machines of nature, as he terms organisms, are machines all the way down to infinity, unlike artificial machines). These aspects of Leibniz's thought occur, as very often with him, in dialogue or confrontation with other thinkers – here, notably Ralph Cudworth's 'plastick natures' and Stahl's *anima*. Due to the law of the conservation of force among other reasons, Leibniz refuses to allow for any type of extra-causal influence on bodies of a vital principle that would be separate from bodies as a whole. Hence he denies a concept of 'soul' as the motive force or controller in the body, which is what Stahl put forth. Leibniz insists that everything that happens in Nature happens according to mechanical laws.

Leibniz, like Aristotle, drew heavily on his observations (and reports from microscopists such as **Leeuwenhoeck**) concerning living beings in the formulation of his metaphysics of substance. It is not that monads possess uniquely vital properties, but that their definition is inspired by the self-maintaining, self-regulating, autonomous features of living beings. This aspect of Leibniz – that there is something unique about living beings, and this uniqueness is metaphysically grounded – was strongly brought to the fore by a series of his biologically inclined disciples who focused, increasingly on the difference between organic and inorganic entities: Louis Bourguet (1678-1742) in the 1720s and, better-known, the Genevan naturalist Charles Bonnet (1720-1793) a generation later.

Bourguet, in the course of an extensive analysis of crystals, developed an original notion of "organic mechanisms" which functioned in a different way than ordinary mechanisms, and directly influenced Buffon's idea of "organic molecules." Bourguet describes "organic mechanisms" in Leibnizian terms as a combination of various types of molecules – from aether, water, earth, the air, etc. – which are subordinate to a "dominant Monad or Activity" (Bourguet 1729, pp. 164-165).[7] Bourguet suggested that there was a difference between the growth of crystals by "juxtaposition" or the apposition of new parts, and the organic process of "intussusception" by which new molecules are integrated into the organic body and form a part of it – a distinction repeated almost exactly in the second half of the eighteenth century by Linnaeus, Lamarck and others.[8] In other cases, as in Maupertuis or Diderot, it is no longer at all Leibniz's substance metaphysics which is being appropriated, but rather a series of deliberate, materialistically and/or biologistically inclined versions of monadology that were produced notably in France during the early Enlightenment (Canguilhem 2008, Wolfe 2010).

Why are living beings special? Stahl's 'animism' earned him the ridicule of many prominent scientists, such as Haller, who suggested that Stahlians, who rejected interventionist medicine in the face of disease, were to mechanist physicians like a half-naked ancient German warrior was, compared with a Roman centurion, armed and in uniform (Haller, cit. in Reill 2005, pp. 123-124). Yet Stahl noticed something important, in pointing to the absence of a concept of Life. For, if we extend his observation, we could say that in the earlier context, Life is either everywhere, promoted to the extent that vital spirits, vital heat, animation and the like are so co-extensive to the field of investigation that Life dissipates into the analysis as a whole, or nowhere, because it is immediately dissipated into the entities and processes which subserve it, for instance in classic mechanistic reduction, e.g. Hobbes' "Life is but a motion of

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[7] Nutrition will become an increasingly important topic, with authors including Bonnet insisting that nutrition and organic development (including embryogenesis) are the products of forces different from mechanical forces (Bonnet 1779, vol. V, p. 192).

[8] Bourguet 1729, 4th letter; Linnaeus, Introduction to the *Philosophia botanica*: "Stones grow, plants grow, and live, animals grow, live and feel" (I, §3, in Linnaeus 1751, p. 3).

limbs," or Archibald Pitcairn's more medically articulated version: "Life consists in the Circulation of the Blood produced by the Motion of the Heart and Arteries."[9]

Does this emerging ontological concern about Life reflect the constitution of a science? Is it a precondition for a science? The concern and its various verbal expressions clearly predate the coinage of the word 'biology' in German and French (and its establishment as a science) by roughly a century. Duchesneau nicely speaks of the "tight correlation between philosophical invention and the empirical, experimental and conceptual considerations which tend to make up the elements of a theory of Life," and he emphasizes, as I do here, that the chain of influence could run both ways, between philosophy on the one hand, and 'life sciences' (notably, medicine, physiology, natural history) on the other hand (Duchesneau 1998, p. 11). However, without opting for the (too-neat) radical solution of Foucault, and stipulating: no biology before actual biology, it would not be desirable either to insist that such ontologies of Life either *are* life science, or are some kind of precondition thereof. For instance, the interest in vital minima in the 17th and 18th centuries (from Gassendi's *semina rerum* to Isaac Beeckman's "molecules" and Maupertuis' more Leibnizian version of the latter: Wolfe 2010) cannot be said to flow into the constitution of biology, although it tells us something about the vital coloration of such ontologies. A different kind of narrative would explore the links between early modern mechanism, its increasing focus on organization, and the concomitant rise in importance of generation (what we would today call development); it is to this which I now turn.

6 Two stories about mechanism

The mechanist approach to life, which is in fact not one but many, has exercised a peculiar degree of fascination over scholars, whether they denounce it as the crudest, most reductionist denial of the relevant properties of living beings, or they applaud it as the only legitimate instantiation of scientific method. (In an interesting case of the latter, Joseph Schiller, in a little-known short book on the history of the notion of organization in biology (Schiller 1978), denounces 'vitalism' for being scientifically worthless and takes the example of one Montpellier vitalist, Paul-Joseph Barthez, who in addition to his major writings on the topic, had also published a more standard study of muscular motion.[10] Schiller seizes on the latter text and insists that when Barthez analyses the power of muscles he is obliged to be a mechanist like any other legitimate scientist.) Peter Hans Reill takes a slightly different angle, neither denouncing nor applauding, but nevertheless trying to seize on a kind of constitutive weakness of the mechanistic approach, stating "if mechanism could, e.g., explain the pumping action of the heart, it was incapable of saying why the heart continually kept pumping without running down" (Reill 2005, p. 135).

In this section I want to look briefly at what we might call the 'standard mechanist picture' of the body and show how it quickly becomes more complex, yielding something we might call 'expanded mechanism' (Duchesneau 1982, Wolfe forthcoming), roughly from the time of Descartes and Italian iatromechanism onto Boyle, Boerhaave, Fontenelle, Haller and later authors. As mechanism grows more

[9] Hobbes 1651/1996, p. 9; Pitcairn, "A Dissertation Upon the Circulation of the Blood Through the Minutest Vessels of the Body," in Pitcairn 1727, p. 99.

[10] Vitalism in this context refers to doctrines in medicine and other life sciences which seek to grasp the particular nature of – vitality, in some cases (but not all) positing a kind of 'vital force' or 'vital principle' to explain the difference between a living and a dead body in general, and processes such as digestion, assimilation and self-preservation in particular. The word 'vitalist' appears at much the same time as does the word 'biology', a fact that has not so far been discussed much, if it all. On the history of the former, see Wolfe 2017 and on the interrelation of the two, Wolfe forthcoming.

complex, integrating organizational and structural features, it also, in an unexpected turn of events, becomes much less of a canonical 'opposite' to vitalist ideas (*if* the latter are also understood as calling attention to the structural features of the body rather than strictly its components). Some might see this process of expansion as an *ontological* expansion (e.g., the way authors like Boyle and Fontenelle integrate chemical features into their 'basement level' mechanism); others could emphasize the way mechanism morphs, if anything, into a *less ontological*, more *heuristic* set of claims (as is explicit in Steno and in Haller).

6.1. Mechanism: expansionist or puppet régime?

In the standard mechanist picture, which we often associate with Descartes (and the popularity of the animal-machine image for at least a century after the appearance of the *Treatise on Man* is not irrelevant here), the body is understood as a system of pulleys, funnels, sieves, pipes, bellows and the like. Boerhaave gives a detailed version of this in his 1708 *Institutiones medicae*:

> 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 ; we find some of them resemble Pillars, Props, …, some like Axes, Wedges, Leavers and Pullies, others like Cords, Presses or 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*, and by them only are intelligible (Boerhaave 1742, § 40, p. 81).

Sometimes an idea of self-motion is invoked, as when Descartes describes the difference between the body of a living man and that of a dead one in the *Passions of the Soul* (1641) as

> the difference between a watch or other automaton (that is a self-moving machine) when it is wound up and contains in itself the corporeal principle of the movements for which it is designed, together with everything else required for its operation; and, on the other hand, the same watch or machine when it is broken and the principle of its movement ceases to be active (Book I, §6, AT XI, p. 331).

Sometimes, the mechanistic approach seeks to remedy the limitations in its original formulations (this corresponds to the tensions the older scholarship on the Scientific Revolution highlighted, between mechanism and the 'mechanical philosophy'), by insisting that the (living) body is not an ordinary machine, but a *hydraulic*, indeed, *hydraulico-pneumatic* machine. Thus Robert Boyle, in *A Free Inquiry into the Vulgarly Receiv'd Notion of Nature* (1686), explained that he did not

> look on a human body as on a watch or a hand-mill, i.e., as a machine made up only of solid, or at least consistent parts; but as an hydraulical, or rather hydraulo-pneumatical engine, that consists not only of solid, and stable parts; but of fluids, and those in organical motion. And not only so, but I consider that these fluids, and the liquors and spirits, are in a living man so constituted, that in certain circumstances the liquors are dispos'd to be put into a fermentation or commotion, whereby either some depuration of themselves, or some discharge of hurtful matter by excretion, or both, are produc'd… (Boyle 1772, vol. 5, p. 232; cf. p. 236)

Significantly, in his *Disquisition About the Final Causes of Natural Things* (1688), Boyle recognizes that "living animals" and "dead ones" differ not in their basic components but at the level of their vital fluids (secretions, etc.) and motions (Boyle 1772, vol. 5, p. 410). Yet at the fundamental, corpuscularian level, Boyle does hold that living and nonliving things alike are arrangements of a single universal matter, which is corpuscular, despite all his experimental attention to living bodies, the 'history of human blood', respiration and uniquely vital properties. Vital processes may be considered as separations and recombinations of material corpuscles, as Boyle does not want to trace vitality back to a faculty or a power, but rather to a certain arrangement of particles (the example of blood, here as also in Pitcairn, is paramount, since various earlier thinkers had insisted on a kind of innate vitality of the blood; Harvey, who of course also promotes the heart, not wanting the blood to be possessed of a kind of total magical power, nevertheless describes it as "a kind of treasure of life": Harvey 1628, ch. 8, p. 42).

Descriptions of the living body as not merely an inert machine but one possessed of internal motions involving the dynamics of fluids ("Liquors, Spirits, Digestions, Secretions, Coagulations," as Boyle would have it) become more common in subsequent decades, typically with further chemical elaboration, whether in this extremely clear statement by Fontenelle in 1707 (it is especially useful as it seems to give a short ontogenesis-recapitulates-phylogenesis history of the evolution of mechanism itself), ostensibly in the context of a discussion of the pituitary gland:

> 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[11]

or in way Leibniz rather idiosyncratically uses "pyrotechnic" language to describe bodies as systems of combustion:

> by the circulation that is brought about all of the parts are subject to enter into the fire little by little, such as we see happening in a flame, and as remains hidden from us in the body of an animal. We will thus rightly assert that an animal is not only a Hydraulico-Pneumatic machine, but also in a certain respect a Pyrotechnic one. (Leibniz (1680-1683) in Smith 2007, p. 161)

As noted by Justin E.H. Smith, for Leibniz, bodies should be understood "not so much as hydraulic-pneumatic machines, but rather *pyrotechnic* machines, to the extent that their functioning is maintained by the conversion of fuel (i.e., food), into a vital heat analogous to fire" (Smith 2007, p. 147).

Can mechanism, thusly boosted or enhanced with these hydraulic, pneumatic and pyrotechnic additions, say why the heart pumps, or starts pumping? It is not my interest here to turn back to the old mechanism vs. teleology debate, and in any case, contrary to those who see a stark opposition, there as

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[11] Fontenelle 1730, p. 16. In the early nineteenth century, William Cullen is still using this language: the body is both a chemical mixt and a hydraulic machine (and, he adds, an "animated nervous frame"): Cullen 1827, vol. 1, p. 409, cit. in Demeter 2016, p. 44.

well, it is quite patent that card-carrying mechanists like Descartes use teleological language in their physiology (e.g. speaking of the 'office' of an organ, or repeatedly insisting on health as an ultimate value[12]), just as patented teleologists like the (self-proclaimed) Montpellier vitalists are not afraid to integrate a degree of componential analysis into their reflections on organization, so long as it is taken in a structural sense. Thus Jean-Joseph Ménuret de Chambaud, the underappreciated author of scores of medical entries in Diderot and D'Alembert's *Encyclopédie*, has his own version of enhanced mechanism, which we might call *vital mechanism*:

> 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 1765, p. 435b, emphasis mine).

What we see in this gradual shift from funnels and pulleys to springs and their interaction (and the higher-level properties that result, like health) is, first, a process of complexification, whereby the properties of the living body, mechanistically analyzed, gradually become determined by the properties of the system as a whole (Duchesneau 1982, Hutchins 2015). Granted, just because Ménuret first uses mechanistic language and then moves upwards, as it were, to health doesn't mean that all such levels merge in a night in which all cows are grey. For instance, as an instance of much more overt reductionism, the Galenic physician George Castle declares, in his *The Chymical Galenist* (1667), that health is just the regularity of the machine's functioning: "It is not, I think, to be question'd, that a man is as Mechanically made as a Watch, or any other Automaton; and that his motions, (the regularity of which we call Health) are perform'd by Springs, Wheels, and their Work from those pieces of Clock-work, which are to be seen at every Puppet-play" (Castle 1667, pp. 5-6)

Thus mechanistic approaches to Life should not be caricatured as they sometimes are, e.g. by Richard Westfall, who described medical mechanism as "the puppet regime set up by the mechanical philosophy's invasion," as he argued that iatromechanism may have been "simply irrelevant to biology" (Westfall 1971, p. 104). For one thing, one should distinguish more carefully between a mechanistic *ontology* and a mechanistic *method* (see Des Chene 2005, pp. 249-250); and both of these end up taking on varied, increasingly complex forms, as I described above. Additionally, these approaches are not blind to the nature of vital processes, but seek to heuristically model them. One instance of this which I do not discuss here is the production and celebration of **automata** in the early modern period. Another can be summarized with the slogan: mechanism is worth pursuing if it works, as Steno will argue about Descartes, a case to which I turn below. One can also see this more heuristic approach as downplaying ontological matters in favor of methodology, modelling and explanation.

6.2. Heuristic mechanism

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[12] Descartes speaks of the "office" of the liver, e.g. in a letter to Elisabeth, May 1646 (AT IV, p. 407); on health, he asserts for instance, in a letter to the Marquis of Newcastle of October 1645, that "the preservation of health has always been the principal end of my studies" (AT IV, p. 329).

The great brain anatomist Nicolas Steno (1638-1686) proposes quite a nuanced approach to Cartesian mechanism,in his well-known *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). On the one hand, he challenges Descartes' detailed views on the brain, including what we might call his excessively figural mechanistic commitments (strings, ropes, pulleys, funnels, sieves, etc.), stressing that Descartes' mechanical construction of the body is anything but empirical. On the other hand, Steno 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). But 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 – we might also say too ontological (as in Alan Gabbey's comment that seventeenth-century mechanism "tried to explain everything, which was too much by a long chalk": Gabbey 1985, p. 13).

But on the other hand, what is noteworthy for our purposes in this text is that Steno is also (deliberately) using the idea of a machine as a heuristic. That is, he says that it is precisely because Descartes realized he could not explain or describe cerebral anatomy exhaustively that he chose instead to "explain [*i.e. describe, CW*] to us a machine that can perform all the actions which humans can" (Steno 1669, p. 12). He accepts the mechanistic program concerning the brain, on the grounds that it is impossible to grasp the internal structure of a machine by observing its outer motions, because those motions could be performed in different ways. But here, 'machine' is now functioning as a heuristic:

> Now since the brain is a machine, we should not hope to find its artifice [*artifice*] by other ways than those one uses to find the artifice of other machines. There is therefore nothing left to do besides what would be done to any other machine, I mean to dismantle piece by piece all its parts [*ressors*, sic] and consider what they can do separately and together (Steno 1669, pp. 32-33).

6.3. Whither mechanism?

Another development which is less directly part of the 'Life' story if the latter is understood in more scientific terms, because it belongs more to the purely philosophical corner of the battlefield, is the potentially materialist outgrowth of Cartesian mechanism, with figures like Descartes' erstwhile disciple **Henricus Regius** (1598-1679) and Spinoza. Regius, in what is perhaps the first of the heretical and/or unfaithful moves within and outside of Cartesianism, argues for soul as mode of body, with consequences including a kind of 'organic' view in which there is no purely mental act of contemplation without the intervention of the body (given the soul's dependence on the body), the two forming an 'organic' whole. Spinoza's emphasis on interrelation between bodies and their organization or structure yields what some see as a more complete organismic theory (Andrault 2016).

So far I have discussed a kind of uneasy parallel development of theories of Life, on the one hand, and contributions to a science of Life that is not yet called biology, on the other hand (indeed, it is not yet called anything at all in a unified sense, but with an eye to the various accounts of mechanism I've summarized above, we might say it reflects an increasing focus on *organization* and the combination of structural and functional features thereof). Whether or not they can tell us why a heart keeps pumping, neither of these are reducible to a vacuous or purely ideological 'puppet régime', whether they are viewed as grasping the phenomena or as pushing a reductionist program which cannot ultimately grasp the phenomena yet plays an important heuristic role.[13] However, without one needing to speak of a 'collapse of mechanism', there is a sense in which the focus on organization gradually turns to *self*-organization (including the generative and transformative properties of living matter), and the chemical properties of organisms reveal a kind of interconnection and plasticity which mechanism *per se* (however varied) could not grasp: part of this situation can be described as the emergence and coalescence of an organism concept. (Further discussion of this point would require that one compared the earlier models I've discussed in this section, to more 'network'-oriented models of the nervous system such as those inspired by string instruments and their vibratory properties, in authors such as **David Hartley** and Diderot.) It is also at this point that the figure of vitalism rears its head.

7 Do you see this egg?

In a provocative passage of his unclassifiable work *D'Alembert's Dream* (1769), Diderot asks,

> Do you see this egg? With this you can overthrow all the schools of theology, all the churches of the world. What is this egg? An unsensing mass, prior to the introduction of the seed [*germe*]; and after the seed has been introduced, what is it then? Still an unsensing mass, for the seed itself is merely an inert, crude fluid. How will this mass develop into a different [level of] organisation, to sensitivity and life? By means of heat. And what will produce the heat? Motion (Diderot 1975-, vol. XVII, pp. 103-104)

In a few lines, Diderot is boldly and efficiently connecting a theory of biological development, epigenesis (according to which the embryo develops by successive addition of material 'layers' rather than any preexisting 'information' as in preformationism) to a materialist philosophical project (and to boot, he is presenting this piece of biological reality, "this egg," as having immediate ideological consequences, in the way some Darwinists will eagerly claim about their own favorite biological phenomena in the centuries following). Endless commentaries have been written on the impact of microscopy on early modern metaphysics, and in this particular case, the way in which tiny living entities, from the polyp to the spermatozoa, could be seen as unseating various (inseparably biological and metaphysical) hierarchies – or as further exemplification of a naturalized-Leibnizian monadology, as in Bonnet. Here, I simply wish to emphasize that it is not only voyages of discovery to the New World which shake up hierarchies (taxonomies, human/animal boundaries, etc.): it is also, so to speak, voyages to the interior, to the microworld. The latter, as Diderot's invocation of "this egg" shows, suddenly puts self-organization and the generative potential of matter on center stage.[14]

Living nature could be destabilizing on its own, without having to confront the existence of platypuses. This could be because of the increasing attention paid to monsters, which challenged core conceptions of Nature as normative (which philosophers such as Locke and Leibniz reflected on in terms of 'species'). Jonathan Swift wrote in a 1708 letter to Sterne regarding the two Hungarian conjoined twins who were travelling throughout Europe, that "the sight of two girls joined at the back causes a great many speculations and . . . raises abundance of questions in divinity, law and physic" (Swift 1767, p. 13), and

[13] For the older, somewhat Whiggish version of the pro-mechanist view, see Schiller 1978; for the newer, more subtle version see Bertoloni Meli 2011, Andrault 2016. For more pro-organismic views, often apparent in scholars whose narrative gives an important place to Kant, see e.g. McLaughlin 1990, Mensch 2013.

[14] Lack of space means I cannot go into detail into another celebrated case in which life science (here, anatomy as well as embryology) and metaphysics become, so to speak, conjoined, namely **monsters**.

the surgeon Georges Arnaud de Ronsil wrote in an essay on hermaphrodites that in the contemplation of such cases, "it is only with difficulty that we can recognize Nature in Nature itself" (de Ronsil 1768, p. 246). But it could also be because of in-between beings like the polyp. This concern is much earlier than Diderot's (or Abraham Trembley's, the discoverer of the polyp): Robert Hooke, too was concerned with what he called "skips" from the mineral to the plant to the animal, and spoke in this case of "Plantanimation" (Hooke 1665, p. 127).

Beyond colorful and evocative cases like polyps and monsters, generation itself and concerns with organism in terms of what was called "general physiology" (in authors like **Lazzaro Spallanzani**) was as important as the focus on species. Descartes, who actively promoted the use of mechanical models as heuristics in studying the body, famously admitted his inability to account for the processes of generation in terms that were compatible with the mechanistic program he had set out for himself: "The formation of all the parts of the human body … is something so difficult that I dare not attempt (to explain it) yet" (Descartes to Elisabeth, May 1646, AT IV, p. 407); as Dennis Des Chene comments: "Among the phenomena of life, generation offers, along with the apparently reasoned behavior of higher animals, the greatest challenge to a science based on Cartesian principles" (Des Chene 2003, p. 413). Even a century later, Bonnet could write that "generation is one of those secrets that Nature seems to have kept for herself. Yet I think that it will be torn from her some day" (*Considérations sur les corps organisés*, ch. III, § 17, in Bonnet 1779, vol. III, p. 7; vol. V, p. 93).

This "secret," and the conceptual-and-scientific changes that come with it, has a real impact. Something has changed by the time of Buffon and Diderot in the late 1740s. 'Life', 'organized bodies' and gradually 'organisms' are everywhere. Where the *Encyclopédie* devotes a long entry to "Life" ("Vie"), its predecessor and inspiration of fifty years earlier, Chambers' *Cyclopedia*, has none. In his essay on the right manner of studying natural history, Buffon asserted that "mathematical truths are merely mental abstractions, which lack anything real" ("De la manière d'étudier l'Histoire Naturelle," in Buffon 1749, p. 53). Even some self-proclaimed mechanists, like Albrecht von Haller, also felt that the *rage de calcul*, the zeal for quantification, had gotten ahead of actual empirical work. But this was also an insight of vitalism. When Théophile de Bordeu, a celebrated Montpellier vitalist and collaborator of the *Encyclopédie*, who Diderot also made into a fictional character in *D'Alembert's Dream*, wrote, in a 1764 work on the history of medicine, "Spare us, once and for all, all these tiny fibres, pressures, globules, thick substances, sharp angles, lymph, hammers and all the rest of the equipment from mechanical workshops with which [earlier doctors] filled the living body – they were the playthings of our fathers" (Bordeu 1818, II, p. 670), he was not criticizing the 'truth' or 'falsity' of mechanism, but its obsessive completeness. Further, with this antimathematical attitude came an increasing emphasis on the fact that every living being is exposed to sickness and death: this is the crucial difference between the science of living beings and the other physical sciences. There is no pathology of planets or stars, of solids or fluids. And here we get to a kind of ontological specificity of life.

Kevin Chang, referring to vitalist theories in the Renaissance (although the term is a late eighteenth-century coinage), helpfully suggests a distinction between "cosmic vitalism" and "immanent vitalism." Cosmic vitalism holds that the cosmos itself is alive, permeated by a universal spirit, the idea of which derived from Plato's 'world-soul' and the Stoic *pneuma*, ultimately propounded by Marsilio Ficino (1433–1499) in the Renaissance. Immanent vitalism, on the other hand, "presumed a principle of life that was intrinsic to matter," an immanent principle that was considered to be "a soul, a spirit, or a form, often visualized as a 'seed' implanted in the basic unit of the living substance" (Chang 2011, p. 324). But curiously, a number of these Enlightenment vitalists including Bordeu and Ménuret were more than reluctant to posit a soul or life-force as a fundamental explanatory principle. To use a distinction different from Chang's, which I have proposed elsewhere, they were more *functional* than *substantival* vitalists: rather than arguing that life was a special substance (like Stahl did about the soul), they were more geared towards describing life's *functions* (and its organizational complexity, often articulated in terms of "animal economy," to use a term of the period), including by appealing to analogies with Newtonian gravitation in the realm of physics.

8 Conclusion

Is the concept of Life a motivating factor or not in the constitution of 'life sciences'? We could conclude, following a hint of François Duchesneau's, that the concept of 'Life' is an artificial construct, an *être de raison* created when rationality runs up against the speculative limits of a physiological theory that experience cannot wholly circumscribe (Duchesneau 1982, p. 487). To summarize, (i) Life and its status is not a neutral issue in early modern science – from the Scientific Revolution to the Enlightenment. Yet (ii) it seems to be 'nowhere to be found' as an issue in prominent natural philosophers, physicians and others – Willis, Locke, Bacon, Harvey, Hobbes, or Galileo, Newton, Boyle, etc.; that is, they do not view the investigation of Life as a 'problem' or a 'challenge'. (iii) It becomes a 'problem', including in the sense that it is ontologically present, in the Leibniz-Stahl debate, in the early 1700s. Thereafter, and markedly by the mid-18th century, one witnesses a kind of biologistic obsession. (iv) Not necessarily on the part of experimental scientists calling for the autonomous development of a separate science (as will be the case by the end of the century). But strikingly, in authors like Buffon and Diderot, in service of what at times resembles a metaphysics of living matter, and at other times seems like a massively expanded program for natural history with potential materialist implications. However, it would be an act of great internalist hubris to claim that this increased metaphysical and/or conceptual focus on the status of living beings – of organisms – directly leads to the emergence of biology as a science. Despite the increasing visibility of vitalism, and the almost Freudian way in which mainstream life scientist (from Haller to Claude Bernard) try to repress it, the increasing complexification of mechanistic models and the emergence of a broad-minded general physiology are better candidates in the latter story.

9 Cross-References

Biology, Generation, Health, Medical Materialism, Physiology, Soul, The Mechanisation of Life, Vitalism

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