Why was there no controversy over life in the Scientific Revolution?

Charles T. Wolfe

"Of all natural forces, vitality is the incommunicable one"
(Fitzgerald 1945: 74)

1. Introduction

To ask why there was no controversy over Life – that is, debates specifically focusing on the status of living beings, their mode of functioning, their internal mechanisms and above all their 'uniqueness' within the physical universe as a whole – in the Scientific Revolution is to simultaneously run the risk of extreme narrowness of detail and/or of excessive breadth in scope. That is, if we take the question 'why?' at face value, a succinct answer can be given right away: the Scientific Revolution is an intellectual construct that we owe chiefly to the likes of Alexandre Koyré and Herbert Butterfield, and it was almost entirely focused on the physico-mechanical sciences; the latter focus was rarely challenged in the successive historiographic reassessments of this episode which emphasized notably its Puritan, gentlemanly or courtly roots,[1] and said not a word about the life sciences.[2]

1. A partial exception would be Kuhn 1976 precisely because he introduces a distinction between Baconian-inductive programmes in natural philosophy and more mathematically oriented programmes. As recently as Biagioli 1998 the standard picture which disregards the life sciences is still reiterated, only now with a constructivist flourish that has accents of *épater le bourgeois*: we learn that historians of science still need the concept of the Scientific Revolution to preserve their employment (Biagioli 1998: 144); but we are able to challenge the existence of this historical episode: "If we don't overdo it, we can safely bite the hand that feeds us" (ibid., 146).

2. Debus 1991, 2001 are exceptions, but they are precisely not 'mainstream' Scientific Revolution narratives. My point is not that no one has studied early modern life science (the bibliography of the present essay is filled with references to such studies) but that such studies never seem to impact on the picture we have of the Scientific Revolution. Put differently, if we consider as crucial a figure as Harvey and we look at what mainstream history of modern science has

Hence our concept of the Scientific Revolution does not include debates over generation, *semina rerum*, species, anatomy, vivisection, animal souls, irritability and so forth.[3] Conversely, the title question appears enormous and unmanageable once we realize that it implies several other interrelated questions:

(i) If Life was *not* a topic of controversy in and for the Scientific Revolution, when did it become one?

This question requires that we decide what counts as a controversy; for surely debates between Harvey and Riolan on the heart, or Whytt and Haller on irritability, do not meet the criteria for a 'strong' definition of a controversy in the history of science, i.e., in Helga Nowotny's definition, as "part of the collective production of knowledge the very lifeblood of science, one of the most productive factors in scientific development" (Mendelsohn 1987: 93; see also Dascal 1998).

(ii) How should we then understand the various activities that existed at the time, from anatomy and physiology (or the study of the 'animal economy') to medicine overall, as well as natural history, botany, or chemistry?[4]

Notice that even when we discard monolithic concepts of the Scientific Revolution and adopt a much more nuanced approach to the disciplinary status and diversity of natural philosophy, as Domenico Bertoloni Meli (2008: 709) does in an exemplary recent article, emphasizing the interplay between the mathematical and medical disciplines, so that "when unraveling the intellectual world in the

to say about him, here is a sample result: "Shapin's *The Scientific Revolution* has two derivative remarks, Gaukroger's comprehensive treatise on western scientific culture mentions him twice in passing, but only in the context of the science that came after him, and Dear's compilation of readings from *Isis* on early modern science omits him altogether… . Kuhn's celebrated analysis of radical disjuncture in the progressions of science sees Bacon, Copernicus, Lavoisier and Newton as revolutionary but not Harvey, who is excluded from his account entirely" (Salter 2010: Introduction). Smith 2009 is an interesting stock-taking of changes wrought in the Scientific Revolution narrative(s) over the past twenty years but also takes no notice of the effect a focus on the life sciences might have in this context.

3. It is a mark of the extreme provincialism of the history and philosophy of early modern science that it is so preoccupied with endless internal controversies over externalism and internalism, the role of the Church, or the replicability of an *experimentum crucis* that it takes absolutely no notice of recent (and original) work on the specifically 'biological' contribution to debates on substance, personal identity, species etc. in early modern thought, in which figures like Gassendi or Walter Charleton loom large (see notably Fisher (ed), 2003 and Smith (ed), 2006). National or linguistic provincialism (Anglocentrism) has been discussed elsewhere, notably with respect to Merton's and Shapin's theses.

4. For an early attempt to answer this sort of question see Roger 1980: 258f.

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,"[5] this still does not help us answer question (ii) above. We could extend the narrative of the Scientific Revolution to include debates on the circulation of blood, or the usefulness of the microscope (say, Borelli versus Locke), or the epistemological status of the 'animal economy' in relation to machine as well as soul.[6] Alternatively, we could be more faithful to the actual contents of the reports presented to the Royal Society or the *Académie des sciences* in their first fifty years of existence, which turn out to be much more biologically oriented than traditional historiography has led us to believe.[7] But in either case, these extensions would miss the dimension of 'crisis', that is, the sense that the existence of living beings suddenly again becomes an explanatory challenge or even a "scandal", whether from the standpoint of physics or on the contrary from the standpoint of the autonomy of biology.[8]

In addition, our title question also implies a historiographic claim about the Enlightenment, which follows from (i):

---

5. To my knowledge the first to raise the issue was Salomon-Bayet 1978: 12, 15, 112, 334 and in the Anglophone literature Cook 1990: 401–404. To mention one more example: out of fifteen essays by prominent scholars in a recent volume on 'Rethinking the Scientific Revolution' (Osler [ed], 2000), not a single one treats the life sciences even secondarily. Kiernan 1968 argues for a split between physical sciences and life sciences throughout the eighteenth century in France, which is very strange, if we consider figures such as Maupertuis, who sought to extend Newtonian concepts into the realm of generation, or Buffon, who translated Stephen Hales and sought to produce a kind of 'arithmetic' of life. Even Diderot declared that his essays on probability were, together with the *Rêve de D'Alembert*, his favourite amongst his writings (Diderot 1961: 126).

6. The first case is now too frequently discussed for citations to be necessary; on the latter two cases see Salter and Wolfe 2009 and Wolfe and Terada 2008.

7. E.g. Hahn 1971, a classic study of the Académie des Sciences, completely omits the life sciences; Kaplan 1993 fails to consider that 'embodied forms of knowledge' really were an issue for the Royal Society. Conversely, in a recent attempt to produce a historical survey of the philosophy of biology (Grene and Depew 2004), the authors bypass our era and thus our controversies entirely, by moving from Aristotle to Descartes and then to Buffon. That the seventeenth and early eighteenth centuries might have expressed something of a 'crisis' on topics such as body, species and the minimal constituents of living matter (e.g. Gassendi, Charleton, Lamy) is not an issue for this work.

8. Thus Jacques Monod described the discovery that motivated him to go into biology: "the scandal that certain objects exist with the properties of living beings and appearing to violate some physical principles or at least the general notion of the physical world. It seemed scandalous to me. I felt naïvely that one had to confront this scandal" (Monod 1970: 50).

(iii) Life is a controversial topic for the eighteenth century, not the seventeenth (regardless of the varied and significant contributions of Sanctorius, Harvey, Glisson, Malpighi, Baglivi, Descartes, Guillaume Lamy, Swammerdam, Van Helmont and others).

This incidentally seems to reverse Foucault's claim 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,[9] as well as the much more common claim, found typically in histories of physiology and related textbooks, that the 'modern', functionally specified concept of man as machine successfully banished concepts such as Life from science, especially once the 'machine' is augmented with Darwinian evolution and the modern synthesis.[10]

The irony here is that it is precisely after Cartesian or LaMettrian concepts of *bêtes-machines* or *hommes-machines* that Life becomes a locus of a kind of ontological crisis, either because natural philosophers worry about what it is, what its minimal conditions and components are, or because they worry about the boundaries between dead and living matter – such as when Buffon, in his comparison of the animal and vegetable kingdoms, ponders the exact nature of "le vivant et l'animé": whether Life is a metaphysical property of certain entities ("un degré métaphysique des êtres") or a "physical property of matter"; he ultimately opts for a kind of 'panspermist' hypothesis in which life is always potentially present in matter, notably in the form of organic molecules, so that "raw matter" merely means "dead matter".[11] Similarly, Gabriel-François Venel, in his long entry "Chymie" for the *Encyclopédie*, states that organic molecules and organized bodies are

9. Foucault 1966, including the claim that "l'histoire naturelle, à l'époque classique, ne peut pas se constituer comme biologie" (173). There has been much debate about what Foucault meant here, and rather than claim that my analysis rebuts his (for after all, I too am describing a series of inquiries into Life which are not constituted as biology), I will simply that my concern with Life as an object of controversy and/or crisis is not found in Foucault's discussion, nor is it affected by it. 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, which contains in-depth analyses of Buffon, Barthez and then Herder and the Humboldts, but is confusing taken as a whole since these figures do not seem to easily fit in one narrative.

10. The classic, and influential statement of this view is Loeb 1912; see also Smith 1976 for suggestive, but inconclusive discussion.

11. Buffon 1749, II, *Histoire générale des animaux*, Chapter 1, "Comparaison des animaux et des végétaux," in Buffon 1954: 238a–b; ibid.: Chapter 2, "De la reproduction en général," in Buffon 1954: 245b.

subject to laws that are "essentially different from" the laws of inert matter in motion; as sources, he refers both to Buffon and to the errors of iatromechanists with respect to the functioning of the "animal economy" (Venel 1753: 410).

Lastly, in addition to this revision of the notion of Enlightenment, our question also raises a specific disciplinary issue in close relation to point (ii) above:

(iv) 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. (Salomon-Bayet 1981; Caron 1988)

As I will try to show in closing, the emergence of a 'field of controversy' concerning the status of Life is hardly synonymous with the constitution of the science called biology. That does not mean it is not productive of forms of knowledge, such as medicine or natural history or in a very different kind of categorization, 'knowledge of the body' (see Wolfe and Gal 2010). But by the time the name 'biology' (or its close competitor, 'zoonomy') comes to the fore as a "synthetic, unitary science of life" (Singer [1929] 1958: 917) its concerns are quite different. Similarly, the question of the scientificity of medicine and anatomy in the late seventeenth century, or their disputed revolutionary status are again not to be confused with the existence of controversies over Life.

In what follows I survey (§ 2) some of the possible candidates for 'controversies over Life' in early modern natural philosophy, and argue that we should not think of them in these terms. I then turn (§ 3) to the context for where I do believe Life as a problem emerges – in the interaction between chemical and metaphysical debates concerning organisms, substance and fermentation, notably between Leibniz and Stahl. In a conceptual development which may seem rather counter-intuitive to contemporary readers, who tend to believe that "materialists explain everything in terms of matter and motion" whereas so-called animists like Stahl or vitalists like Bordeu explain everything "in terms of the soul or vital force" (Wellman 2003), the specific preoccupation with the nature of organic Life that characterizes Stahl is taken up – in materialist terms – by thinkers such as Diderot, as I discuss next (§ 4). Lastly, I ask, here and in the conclusion, how this materialist focus on Life did and did not become or at least lead to the constitution of biology as a science. My analysis spans the periods we call the Scientific Revolution and the Enlightenment, but it does not seek to either challenge or rehabilitate these terms as historically explanatory categories, although a reader with particular interest in such questions might notice that the emergence of Life as a locus of ontological crisis (or controversy) roughly matches the shift from the former to the latter.

2. Was life a controversial topic in early modern natural philosophy?

If we can speak of early modern life science, from physiology to theories of generation, from the chemical investigation of blood, aether and spirits to treatises on fermentation and fevers, then we can 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, Pitcairne 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. However, if we hoped to find scientific discoveries which contribute to a unified notion of physiological function, we shall not; if we take, e.g., one century of analyses of digestion, from Francesco Redi and Giovanni Borelli in the 1650s–1660s to René de Réaumur and Théophile de Bordeu in the 1750s, none of the experiments on gizzards and their grinding power, discussed by many naturalists, produce any unified result, until Lazzaro Spallanzani conducts experiments on digestion in the 1780s (Salomon-Bayet 1978: 336f., 342–343, 355f., 348).

But, as I have suggested earlier, another problem arises, which is less easy to resolve. In the early 1700s Georg-Ernest Stahl, a court physician to Duke Johann Ernst of Saxon-Weimar and subsequently, as of 1694, a Professor of Medicine at the University of Halle, stated bluntly: in all these competing theories of the human body, notably the very successful mechanistic theories, "*Life* was never mentioned nor defined, and I could find no logical definition provided" (Stahl [1706] 1859, vol. 2: 224). To follow Stahl's suggestion, we could say that Life is either discussed but immediately dissipated into the entities and processes which subserve it, or promoted to the extent that vital spirits, vital heat, and animation are so coextensive to the field of investigation that Life as problem again dissipates into the analysis as a whole. There is discussion, but no controversy, in the sense that there is no polarization between Life and non-Life (with the notable exception of Stahl in his polemic with Leibniz, which I shall turn to in Section 3), nor the possibility of resolution between two positions, which implies *some* shared conceptual framework (Freudenthal 1998); resolution or conciliation requires at least the sort of quasi-paradigmatic framework into which particular cases such as circulation, generation, monsters can be fit, as will happen with Haller in the later eighteenth century. Let us consider some representative examples.

Boyle's corpuscularianism, despite its experimental attention to living bodies, the 'history of human blood', respiration and so forth, holds that both living and nonliving things are arrangements of a single universal matter, which is made up of corpuscles. Boyle does not want to trace vitality back to a faculty or a power, but rather to a certain arrangement of particles; hence vital processes may be considered as separations and re-combinations of material corpuscles. Blood does not possess an innate faculty which makes it 'alive' but, like sweat or snow, possesses its specific chemical properties "by virtue of the motion, size, figure and contrivance of [its]own parts," and new qualities are produced by "changing the texture or motion" of bodies' constituent corpuscles."[12] Now, in an interesting passage in his *Disquisition About the Final Causes of Natural Things* – a work in which Boyle describes the human body as a 'hydraulico-pneumatic' machine – he appears to grant that there is a kind of category difference between "Living Animals" and "Dead ones", in which the latter are more like stones, possessed simply of a static structure. But then he quickly returns to his 'micro-mechanical' view (even if, *qua* corpuscularian his mechanism is an enhanced mechanism possessed of chemical properties and explains that the difference lies not only in the innumerable "Liquors, Spirits, Digestions, Secretions, Coagulations" but also in the "Motions" of the body and its limbs, which are present in living bodies but not in dead ones; in other words, a purely structural difference (Boyle 1688: 74–75).

If we turn to mechanism, including its medical variant, iatromechanism (leaving aside here the irreducible variety of forms of mechanism, the incommensurability of their types of explanation, including the possibility that iatromechanism may have been "simply irrelevant to biology", and the distinction between a mechanistic *ontology* and a mechanistic *method*[13]), we might expect to find a straightforward elimination of vital properties in favour of size, shape and motion, including the classic rejection of final causes which is a mark of the Scientific Revolution, if we think of Galileo's description of the 'fool' in his *Dialogues*, Simplicio, as a *cause-finalier*, who thinks that horses are on earth for the sake of man, grass is for horses, clouds and rain are there for the grass (Galileo [1623] 1953: 71), or Bacon's exclusion from "Physick" of explanations such as "the firmness of the skins and hides of living creatures is to defend them from the extremities of heat and cold : or, … the leaves of trees are for protecting the fruit" (Bacon [1605] 2000: 86–87), and of course his 'barren virgins'. Equally well-known is Spinoza's contempt for the human ignorance which projects concepts of purpose onto the natural world, expressed notably in the appendix to *Ethics* I, where he asserts that "final causes are nothing but human fictions", and the preface to *Ethics* IV, where

12. Boyle, *Origin of Forms and Qualities* (1666), in Boyle 1772, vol. 3: 13; see also *Some Considerations Touching the Usefulness of Experimental Natural Philosophy, Second Tome* (1671), in ibid., vol. 3: 427; Hall 1969, vol. 1: 294.

13. For the former possibility see Westfall 1971: 104; for the latter distinction see Des Chene 2005: 249–250.

he writes that what we call final cause "is nothing but a human appetite" – the causes of which we tend to be unaware of (Spinoza [1675] 2002: 239–240, 321).[14]

It is known that the exclusion of final causes and thus purposive vital faculties, but also humors and elements (Anstey 2011), in favour of a mechanistic scientific program produced notable drawbacks, such as the difficulty in accounting for epigenetic processes. Thus 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: 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: 413). Indeed, Descartes' 'failure' to explain generation was notorious in the eighteenth century, e.g. Réaumur in the *Art d'éclore des poulets* said that it was worse than if Descartes had failed to explain the universe (Gasking 1967: 68). This much is well known; the point I wish to emphasize is that everything 'vital' is necessarily excluded from mechanistic models, ironically given Descartes' repeated insistence on health as an ultimate value and his ultimate, post-Cartesian doubt insistence on the survival value of our sensory organs. This exclusion is manifest in most of the celebrated pieces of iatromechanist propaganda, from Baglivi and Boerhaave:

> Since Physicians began to examine the Structure and Actions of a living Body, not by Physico-Mechanical and Chymical Experiments, but by Geometrico-Mechanical Principles, they have not only discovered an infinite number of things that were unknown to former Ages; but have made it out, that a Human Body, as to its natural Actions is truly nothing else but a complex of Chymico-Mechanical Motions, depending on such Principles as are purely Mathematical. For whoever takes an attentive view of its Fabrick, he'll really meet with Shears in the Jaw-bones and Teeth, … Hydraulick Tubes in the Veins, Arteries and other Vessels, a Piston in the Heart, a Sieve or Straining-Holes in the Viscera, a Pair of Bellows in the Lungs, … Pulleys in the Corners of the Eyes. And tho' the Chymists explain the Phaenomena of natural Things, by the Terms of Fusion, Sublimation, Precipitation &c. And so make a separate sort of Philosophy; yet all these

14. That Boyle, in his work on final causes which I mention, as well as Leibniz explicitly do *not* reject final causes does not make their denial by Galileo, Bacon, Descartes, Spinoza any less canonical for the Scientific Revolution (or indeed its ideological inheritance from Fontenelle and Voltaire onwards).

> ought to be imputed to the Force of a Wedge, Balance, Leaver, Spring, and such like Mechanical Principles … the natural Effects of an animated Body can't be accounted for with greater Facility and Clearness any other way.
> (Baglivi [1696] 1704: 135–136)

and

> 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 [1708] 1751: 81)

One can see why Stahl protested that Life had vanished from the bio-medical purview. Indeed, in a kind of unconscious echo of Stahl's concerns, Boerhaave declared in a much-cited lecture on the "use of mechanical methods in medicine" that "the human body is in its nature the same as the whole of the Universe" (Boerhaave [1703] 1983: 96), which I take less as a Renaissance-type statement of correspondences and more in the sense of a broadly mechanistic commitment to an ontology in which material particles and their interaction exhaustively account for the physical universe including ourselves.

In fact, these apparently pure statements of iatromechanism mask a more complex (and concrete) reality on the ground, where functional dimensions are never wholly absent from physiological explanations. Even Descartes, in a 1646 letter to Elisabeth will speak of the "office" of the liver (Descartes 1964–1976, IV: 407), and chemical explanations as used in medicine by figures such as Thomas Willis and Stahl blend, if not seamlessly, quantitative and qualitative definitions of fermentation, such that one no longer knows what is a strictly particulate explanation versus one on which invokes 'liquors', 'juices', 'heat', 'spirits' and so forth. Consider for instance this elegant statement on the body from Bernard de Fontenelle in 1707, presented 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 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 [1707] 1730: 16)[15]

Regardless, we cannot view these different variations on the mechanistic program as comprising a science of life – or if so, then it is one in which Life as in issue is completely absent. One notable exception to this narrative of the 'absence of Life' is Francis Glisson's *Tractatus de natura substantiae energetica, seu de vita naturae ejusque tribus facultatibus perceptiva, appetitiva, motiva* (Glisson 1672), usually referred to as *De vita naturae*. After publishing various significant medical works, such as *De rachitide* (1650) and *De anatomia hepatis* in (1654), Glisson produced this treatise on the "life of nature," describing life as immanent to matter: "life is the intimate and inseparable essence of matter" and "matter contains within itself the root of life."[16] Now, it would be easy to dismiss this as a kind of substance metaphysics, as indeed Albrecht von Haller 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 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.

However, it remains a challenge to integrate this aspect of Glisson into a Scientific Revolution narrative, since it is rather a species of matter theory; what is more, this very immanentism means that the nature of Life does not arise as a topic for controversy for Glisson. A converse attempt has been made recently by Guido Giglioni to present the existence of a 'vitalistic' strain no longer in a marginal but in a central figure, Francis Bacon, focusing on the theme of the 'appetites of matter' and the related fixation on the "prolongation of life" (Giglioni 2010; 2005). But on the issue of the demarcation of Life as an object (a) that requires a specific science or group of sciences and (b) which existing sciences do not adequately treat, it seems more relevant that when Bacon is outlining the contents of the *Sylva sylvarum* (published posthumously in 1627; in Bacon 1857, vol. II), he presents thirteen works as "physiological remains" (Bacon 1857: "Table of Contents"); out of these, seven concern minerals and six concern attractive force and

15. Translation mine (unless otherwise indicated all translations are mine).

16. Glisson 1672, § 8; I quote from a draft translation of *De Vita Naturae* by Guido Giglioni, which he was kind enough to share with me.

the transformations of inanimate bodies (even if Bacon discusses these in 'biological' terms). Thus Bacon does not attend to, or is not concerned with, a distinction between the living and the non-living.

Mechanism, corpuscularianism, Baconian natural philosophy (to which one could add Locke's Helmontian medical reflections but also his philosophical consideration of the Life that is the unity and identity of a plant, animal or a man[17]) do not address the question of Life; they do not see it as a problem, or *a fortiori* an ontological crisis. If it is historically insensitive to leave out the life sciences from all accounts of the Scientific Revolution, as so many do, it is also mistaken to completely gloss over the problem. Thus Harvey is sometimes simply described as a bona fide member of the intellectual construct called 'Scientific Revolution', as in Gasking (1967: 40): "Harvey … tended to stress the importance of observation and experiment, an increased emphasis on which was a vital part of that change in outlook which is sometimes called the Scientific Revolution".[18] Another way of sweeping the problem under the rug is to state, as Peter Dear has more recently, that there is "no reason in principle" to "ignore the sciences of life", since 'physics' in the early modern period is conceived as inquiry into nature in general (Dear 1998: 190). Something is missing from this picture. Some scholars, particularly in the humanities, would say that what is missing is *the body* – and an entire subdiscipline of cultural history has devoted itself over the past twenty-plus years to studying the historical constitution of the body, with particular attention given to its Renaissance and early modern formations (see Brown 1988; Turner 1984; Sawday 1995; Mandressi 2009; the section on 'Bodies' in Cooter and Pickstone 2000; Wolfe and Gal 2010). But what precisely differentiates a living body from a corpse – a leitmotiv in the concern with Life – is heavily determined by the natural-philosophical engagement involvement with chemistry. It is to this, via Leibniz, that I now turn.

17. See Locke [1701] 1975, II.xxvii.4–6 on the Life qua identity of plants, animals and humans in mereological terms. His last word on the question (ibid., III.x.22) does not advance the issue very much: the term Life is obvious for everyone, but when one turns to the status of a plant in a seed, a chicken in an egg, or a dying man, its sense is harder to grasp.

18. Rather more à propos is that, whatever Harvey's epistemological approach towards circulation was (mechanistic? Aristotelean? empiricist? Paduan? hypothetico-deductive?), "he did not attempt to formulate any general laws of life on a purely mechanical basis" (Ackerknecht 1982: 114).

3. Machines of nature, ferments, and chemical metaphysics

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" (Westfall 1971: 104). Whether in its earliest phases or – most evidently – in its late and complexified form such as von Haller's 'micro-mechanical' analysis of physiological structure, combining structural and functional explanations, these approaches are not blind to the nature of vital processes, but seek to heuristically model them, e.g. by the usage of automata, which Borelli cleverly described as having "a certain shadowy sameness (*umbratilem similitudinem*) to animals" (Borelli 1680, vol. II: § viii).

And yet something has changed by the time of Buffon and Diderot in the late 1740s. Life, 'organized bodies' (*corps organisés, organisierte Körper*) and gradually 'organisms' are everywhere. The *Encyclopédie* discusses matters pertaining to biological Life far more, proportionately, than its predecessor and inspiration of fifty years earlier, Chambers' *Cyclopedia*. Conversely, the Encyclopédie has no article on Galileo (whereas Galileo features prominently, e.g. in Brucker's *Historia critica philosophiae*, which is a major source of the *Encyclopédie*; Salomon-Bayet 1978: 384). In § 4 of his 1753 *Pensées sur l'interprétation de la nature*, Diderot gave an exhortatory dimension to this state of affairs, and declared that

> We are on the verge of a great revolution in the sciences. Given the taste people seem to have for morals, belles-lettres, the history of nature and experimental physics, I dare say that before a hundred years, there will not be more than three great geometricians remaining in Europe. The science will stop short where the Bernoullis, the Eulers, the Maupertuis, the Clairaut, the Fontaines and the D'Alemberts will have left it… . We will not go beyond. (Diderot 1994: 561)

Similarly, Buffon asserted in his methodological discourse "De la manière d'étudier l'Histoire Naturelle" that "mathematical truths are merely mental abstractions, which lack anything real" (Buffon 1749: 53). Diderot also gave an explicitly vital or biologistic inflexion to metaphysics, declaring in his commentary on Helvétius' *De L'Homme* [1773–1775] that "It is very hard to think cogently about metaphysics or ethics without being an anatomist, a naturalist, a physiologist, and a physician" (Diderot 1994: 813; Wellman 1987: 89, n. 43). What were the roots of this 'vital' change? Conceptually, Leibnizianism plays a key role – not necessarily the substance metaphysics of Leibniz as he intended it, but the series of deliberate, materialistically and/or biologistically inclined misreadings that were produced notably in France during the early Enlightenment, when thinkers such as Maupertuis, Bordeu and Diderot explicitly make use of concepts such as the monad but turn them into descriptive tools for the theory of generation, deliberately ignoring Leibniz's own distinction between the physical and the metaphysical (Canguilhem 1980; Wolfe 2010). In a sense it is ironic for this turn towards Life to involve Leibniz so strongly, since he notably described organisms as 'machines of nature', which are machines down to their smallest parts and rejected extra-causal, mysterious vital forces. What did he mean by this?

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. In addition, Leibniz seems to have coined the term 'organism' in a technical sense to mean a type of entity different from machines, and synonymous with 'organized body'. (I say 'technical sense' because the term is used even after Leibniz, e.g. in the *Encyclopédie*, where it does occur, contrary to the claims of earlier scholars, in a yet undefined sense of the word, as synonymous with 'mechanism'.[19]) But mostly, Leibniz speaks of living beings as "machines of nature." The term first appears in his *New System of Nature*, published in 1695 in the *Journal des savants*. Machines of nature are machines in their "most minute parts" ("moindres parties"), contrary to machines created by human artifice (Leibniz 1978, vol. 4: 482); they are machines to infinity also in the sense that bodies contain seeds which can never be destroyed (ibid.: 475). He also specifies that it is living bodies which are machines of nature (*Monadology*, § 64 and for a full discussion of this notion in Leibniz, Fichant 2003). This is where the terminology of 'organism' starts to appear: "The organism of a living being (*organismus viventium*) is nothing other than a divine mechanism which is more subtle than an ordinary mechanism in the infinity of its subtlety" (Leibniz [1903] 1981: 16; Leibniz 1978, vol. 1: 15). 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. Of course, Leibniz also holds that Life stems from a "deeper source" than the ontological level of mechanically specifiable Nature, which remains at the level of passivity (letter to Hoffmann, 27 September 1699, Hoffmann 1749: 49a–b).[20]

---

19. In the *Encyclopédie* articles "Fibre" and "Nutrition" (VI: 670; XI: 288) the terms "méchanisme" and organisme" are used interchangeably, e.g. "the mechanism or organism of nutrition."

20. Discussed in Duchesneau 1982: 82; Leibniz's reply to Stahl in Stahl [1720] 1864: 14. For further discussion of the Leibniz-Stahl exchange as precisely a *controversy* see Carvallo 2010.

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 disciples precisely concerned with 'biophilosophy' and, increasingly, with the difference between organic and inorganic entities: Louis Bourguet in the 1720s and, better-known, Charles Bonnet a generation later. Bourguet, in the course of an extensive analysis of crystals, developed an original notion of "organic mechanisms" (*méchanismes organiques*) which functioned in a different way than ordinary mechanisms, and directly influenced Buffon's idea of "organic molecules". He 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, Bonnet, Lamarck and others.[21] The distinction between 'apposition' and 'intussusception' is between two forms of growth, the former characteristic of minerals (such as crystals), and the latter characteristic of plants and animals, which is the "intussusception of a new matter" (Maupertuis 1746: 44). Bonnet plays on the French word for organic growth (the verb *croître*) and says that crystals merely agglomerate (*accroître*) rather than actually grow (*croître*) (Bonnet 1768, vol. 1, ch. XII, §§ 170, 210: 143, 189, 191). Bourguet describes "organic mechanisms" in Leibnizian terms as a combination of various types of molecules – from aether, water, earth, air, etc. – which are subordinate to a "dominant Monad or Activity" (Bourguet 1729, 4th letter: 164–165). Bonnet explicitly declares that "nutrition, development and the formation of a new organized being are the products of an *unknown force* … which has nothing in common with *mechanical forces*" (Bonnet 1764: 92; italics mine) and more humorously, that "I have always led my reader back to the Being of beings, and shown his handiwork in all the products which had falsely been traced back to purely mechanical causes, as if an animal had the same origin as a cheese"[22] (Bonnet was Swiss, after all).

But let us return to the discussion with Stahl, since it is essentially here that Leibniz develops a concept of organism, because Stahl, in a combination

21. Bourguet 1729, 4th letter, 73, 165–166; see Cheung 2006, § 2; also Duchesneau 2003; Linnaeus, Introduction to the *Systema naturae* (and of course in his celebrated aphorism that 'Stones grow, plants grow, and live, animals grow, live and feel', in the *Philosophia botanica*); Lamarck in the *Système des Animaux sans vertèbres*, discussing the formation of the shell in mollusks (Lamarck 1801: 55).

22. Letter to Malesherbes of October 30, 1762, quoted in Savioz 1948: 214; Bonnet is admittedly protesting against the ban of his *Considérations*.

of medico-physiological and chemical reflection, insists repeatedly on *Life*. To put it differently, the recognition of Life as a problem (which goes hand in hand with the formulation of 'organism' as a concept) is an effect of Leibniz's debate with Stahl, since their disagreement specifically centres on Stahl's assertion that the organism obeys causal laws which are different from those operating in mechanical nature overall, an assertion Leibniz cannot accept *although* he too wishes to defend a concept of organism (Duchesneau 1995; Carvallo 2010). And, especially on Stahl's part, the conceptualization of what an organism is and how it differs from a mechanism (or, which is much the same, how a living body differs from a dead body) centrally involves chemistry (or 'chymistry'[23]); hence Life becomes an object of controversy. I shall now discuss this chemical contribution to the emergence of Life as an ontologically problematic entity (notably with the concept of fermentation, and the consequent role of analyses of digestion) before turning, in Section 4, to the radical materialist appropriation of these inseparably chemical and 'biophilosophical' elements, and its relation to the constitution of 'biology'.

If we recall Bourguet's distinction between the formation of crystals by juxtaposition of their components, versus organic entities which are formed by the intussusception of their molecules, the issue with chemistry – particularly the notions of fermentation and 'seeds' (what Gassendi called, using a Lucretian term, *semina rerum*; the difference is that for Lucretius these 'seeds' were simply atoms, whereas for Gassendi they were composites or compounds of atoms[24]) – revolves around a distinction between beings that are merely 'formed' and beings that are 'generated'. It is only in the late seventeenth century that this distinction becomes crucial – both because the list of candidates for the latter gradually gets defined more narrowly, so it can no longer include metals, crystals and minerals, and because the iatrochemical Paracelsian–Helmontian–Sylvian–Stahlian tradition of

23. The term 'chymistry' is increasingly preferred in current scholarly usage, as it emphasizes the absence of a non-arbitrary and historically justified analytic division between 'chemistry' and 'alchemy' in the early modern period. While there was certainly a range of theories and practices in the science of matter, 'chemistry' and 'alchemy' do not pick out a meaningful division within that range, and so the term 'chymistry' is used as a general term for all such theories and practices, following Principe and Newman 1998. (Thanks to Lydia Barnett whose work helped me see this more clearly.)

24. Bloch 1971: 252, n.75. On the shifting meanings of vital *minima*, notably 'molecules', in seventeenth-century chemistry, matter theory and philosophy see, in addition to Bloch 1971, Clericuzio 2000: 63–71, and for the impact of *semina rerum* on early modern matter theory overall, Hirai 2005.

'chymistry' strongly focuses on the processes that are unique to organic beings, such as fermentation.[25]

A major source for this idea of fermentation is Thomas Willis (1622–1675), who taught natural philosophy at Oxford and medicine in London; he was best known perhaps for his discovery of the 'circle of Willis' and his great work on the anatomy of the brain, *De cerebri anatome* (1664) (richly illustrated by Christopher Wren). But the work that concerns us is his *De fermentatione* (1659), translated as *A Medical-Philosophical Discourse of Fermentation; or, Of the Intestine Motion of Particles in Every Body*. *De fermentatione* was meant to be the introduction to his theory of fevers, which in fact he explained as the outcome of a vitiated fermentation of blood (Willis also says that he added a treatise on fever to the one on fermentation in order to apply his fermentation theory to fever). "Every disease acts its Tragedies by the strength of some Ferment" (Willis; in Debus 2001: 69). Is fermentation chemical or mechanical? The iatrochemical answer should be straightforwardly the former, since it describes all material bodies as being composed of the principles of Spirit, Sulphur, Salt, Water and Earth and the mixture and proportion of these.[26] But Willis complicates matters by sometimes speaking of fermentation in more purely iatrochemical terms, sometimes in more mechanical terms, as a motion of the parts. Ferments helped kindle the particles of spirit and sulphur in the blood into a flame, a combustion that was also called effervescence of the blood, which is how Willis explains body heat and fever. The fermentation in the heart heats the blood like "Water Boyling over a Fire",[27] and this heat is distributed to the whole body through blood circulation, constituting the common cause of ordinary body warmth as well as febrile heat. Our body heat is the effect of a chemical cause – specifically, of fermentation.[28] And, most

25. I thank Justin E. H. Smith for this suggestion. Joly 2004 observes that Renaissance and early modern chymical treatises frequently describe minerals and metals in terms which we would only use for living beings ("seeds and germination, growth and rot, death and resurrection"); he suggests that this is less because the chemists were intellectually chaotic and more because a doctrine of living being was simply absent.

26. According to Clericuzio (ms., 2009), spirits, sulphur and salts are the active principles (with spirits being the most active), while earth and water are passive. Spirits affect various properties of the body, from heat to conservation to preventing putrefaction; e.g., the digestive system is described as a process of fermentation in the stomach. For a discussion of chemical vs. mechanical explanations of fermentation, see Mendelsohn 1964: 380; Chang 2002: 56, 59f.

27. Willis, *Of Feavers*, in Willis [1659] 1681, Chapter I, § 1: 59 (pagination continuous with *Of Fermentation*); Chang 2004: 785.

28. Bates 1981 suggests that "for Fernel [and all traditional Galenists], the essence of fever was preternatural heat whereas for Willis it was an inordinate motion of the blood" (49).

relevantly for us, "The first beginnings of life proceed from the spirit fermenting in the heart" (Willis [1659] 1681, Chapter V: 13).

Stahl, too, viewed the body as composed of organic matter in a process of fermentation, which in fact meant it was vulnerable to putrefaction – indeed, always in a process of putrefaction in some sense. Some parts of the body are more vulnerable than others, notably the blood; hence Stahl describes circulation as a process which preserves the *mixtio* of the blood and thereby maintains the stability of the whole. This is a good example of how his system renders the chemical and the metaphysical almost indissociable, in his description of the living body as a kind of dynamic equilibrium which constantly has to be maintained. On the one hand this equilibrium is chemically specified, both at the level of the concept of fermentation and with the description of the body as a chemical *mixtio*, not a mere aggregate: since aggregates are merely mechanical combinations of portions of matter in motion, whereas mixts imply a notion of qualitative diversity above and beyond the spatial proximity between particles. (This distinction, which is crucial for Stahl, will be wholly appropriated by Diderot who uses it to define the relation between matter in general, living, sensing individual molecules and the 'sensitivity of the whole'). Leibniz reiterated this in his own terms: "a mass of matter is not properly what I call a corporeal substance, but rather an aggregate of an infinity of such substances, like a pack of sheep or a pile of worms."[29] On the other hand, Stahl famously describes the body and its organs as literally mere instruments of the soul, a position sometimes revised so that "organs are not, as the name might suggest, mere instruments", but nevertheless, "it is the soul that makes the lungs breathe, the heart beat, the blood circulate, the stomach digest, the liver secrete" (Stahl 1859: 347). Put these two together and you have the notion of a "highly fermentable organic body [which] has to rely on a vigilant *anima* to discharge the corrupt and harmful materials from the vital economy in a timely manner" (Chang 2002: 63).[30]

These concepts of fermentation are closely linked to concepts of Life, and indeed were actively taken up in the second half of the eighteenth century by vitalists, notably when dealing with the phenomenon of digestion. Whereas mechanists or 'solidists' (who held that illness is due to a pathological change in the solid parts of the body, as opposed notably to humoralists), but also Newtonian-inspired physicians including Boerhaave and Pitcairne reduced digestion to a quantitative process of 'trituration', of spatial relations between masses, or more

29. Leibniz, "Éclaircissement sur les Natures Plastiques et les Principes de Vie et de Mouvement" (1704), in Leibniz 1978, vol. 6: 550.

30. It's not always so clear-cut, though, because chemistry for Stahl is both something foreign to the *theoria medica vera* and nevertheless that which explains life (Roger 1979: 45).

specifically the expansion and contraction of muscles, iatrochemical physicians and post-Stahlian chemists like Venel – in his articles for the *Encyclopédie* including "Chymie", "Chaleur", "Digestion" and "Mixte" – emphasized the chemical transformations of the substances involved in the digestive process. Thus François Boissier de Sauvages, in his *Nosologie méthodique* of 1763, explains that the faculties of the body are equivalent to the properties of matter in general (e.g. gravity, elasticity and attraction), but that *within the organism* these produce processes of fermentation and putrefaction which seem to be restricted to living beings (Sauvages [1763] 1771, I, §§ 150–154, 261, 266).

Of course, the mechanical explanations of digestion are augmented with processes such as heat, vibration, the action of the spirits, and continuous compression, recalling our earlier point that it is not always appropriate to fully distinguish the 'mechanical' and the 'purposive' or the 'functional', either in seventeenth- or eighteenth-century physiology and natural philosophy. Sauvages believed that the fully self-contained nature of his calculations on the body's energy proved the existence of an independent soul which was the source of this motion, and – surprisingly, we would think, for someone who stresses the causal role of the soul in vital functions (i.e., what came to be called an 'animist') – praised the discoveries of Baglivi, Pitcairne, Newton and Boerhaave precisely for their calculations as applied to the body (Sauvages 1731: 2). As Roger French comments, "it is something of an 'ism' paradox that the eighteenth-century 'mechanists' generally described the body in non-quantitative terms whereas the 'animists' used mathematics to demonstrate the need of a soul to power the machine of the body" (French 1990: 103). A missing term in this opposition between mechanism and animism is vitalism.

Organisms, ferments and digestive systems all have some more or less obvious, more or less intuitive relation to an idea we might call Life, and indeed gradually, from the iatrochemists to Stahl, and onwards to his disciples in the mid-eighteenth century and their *Auseinandersetzungen* with the group of physicians who come to be called vitalists by the dawn of the next century,[31] these kinds of phenomena, together with more broad research programmes such as physiology (as opposed to anatomy), are being presented as specifically vital. Venel, in the article "Chimie" in the *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] should be treated by a science separate from all other parts of Physic", namely, chemistry (Venel 1753: 410). Where is the crisis, then? What happened to the ontological

31. 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 and Terada 2008; on the latter, see Caron 1988 and Barsanti 2000.

controversy? Remember that Stahl had spoken in fairly strong terms, if not of scandal then at least of shock: “What shocked me above all was that in this physical theory of the human body, *Life* was never mentioned nor defined, and I could find no logical definition provided” (Stahl [1706] 1859, vol. 2: 224). And throughout the collection of essays entitled *Theoria medica vera* (Stahl [1708] 1860), he asks about what we call Life and what purpose does it serve within and outside the body? Stahl is challenging a dominant, and vast set of views partly encapsulated under the notion of *mechanism*, or specifically *iatromechanism*. He does not respond with a coherent model, program, or unifying concept, such as ‘organicism’ which other physiologists and teaching physicians could both apply and improve on, as Haller precisely did with *his* physiological model (usually referred to as the Göttingen school; see Steinke 2005). Had Stahl done so we could possibly study various tensions between mechanistic medicine, physiology and chemistry and organicist medicine, physiology and chemistry as *bona fide* controversies.

From an external standpoint, as historians or onlookers in general, the problem is not so much to find a definition – at the present time we still have not agreed on a definition of Life, or what constitutes its exact origin (see Deamer and Fleishaker 1994) – as to understand why it becomes a problem and what the effects of this problem are. One response, a fairly rhetorical one, is that of the Montpellier vitalist physician Théophile de Bordeu: “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 [1764] 1818, vol. 2: 670). Another possible answer to the ‘why?’ question is suggested less rhetorically by Peter Hans Reill: “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: 135). Obviously, for Stahl a major part of the answer lay in the soul, and specifically its purposive, goal-directed action, a view which 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 an armed Roman centurion, in uniform.[32] One can also try and reconstruct Stahl’s often unnecessarily obscure argumentation in a charitable way, and point out that he never denies the basic laws of physics and chemistry, nor the fact that living bodies, too, obey the laws of motion. As we saw with fermentation, the idea is rather to articulate a

32. Haller 1751: 956 (a review of Volters’ *Gedancken von Psychologischen sachen*), as quoted in Reill 2005: 123–124.

kind of 'emergentist' view in the weak sense that certain arrangements of particles exhibit complex, goal-directed behavior.[33]

However, Stahl is quite adamant that the above be attributed to the soul, which then controls the various mechanically specifiable parts of the body as so many *instruments*. Stahl is a teleologist, who definitely believes, not unlike his twentieth-century compatirot Wilhelm Reich (1968: 45), that "The question, '*What is life?*' lay behind everything I learned. Life seemed to be characterized by a peculiar reasonableness and purposefulness of instinctive involuntary action for both an *anti-reductionist* interpretation (his own), and a *reductionist* interpretation – which is not specifically mechanistic, as we shall see – with materialists such as Buffon and Diderot. And in this reductionist approach, the vital dimension is not discarded.

4. Constitutive materialist ontology of life or gradual constitution of biology?

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. 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: 86). Recall Buffon's and Diderot's anti-mathematical proclamations of a new science of Life ("natural history", but also the study of the "animal economy" in medicine), or the prominence of vital matters in the *Encyclopédie*.

Iatrochemical, Stahlian concepts that merge the chemical and the metaphysical are turned into reductive materialist concepts by Diderot (reductive notably in the sense that they are meant to replace explanations that appeal, e.g. to the soul). *Yet* these concepts are not themselves meant to be mechanically or ultimately, mathematically specifiable. This takes several interrelated forms: Diderot's enriched atomism of vital *minima*, in which the 'atoms' or 'molecules' of living matter are themselves *alive*; his transformation of Hallerian irritability via Bordeu's

33. T. S. Hall describes certain theories of Life in the eighteenth century (notably that of Maupertuis) as 'emergentist' (Hall 1968, vol. 2: 26–28); for additional discussion of how eighteenth-century models of organic life can be understood as 'organizational' and thus beyond the split between reduction and emergence, see Wolfe and Terada 2008: 558–574.

concept of sensitivity (*sensibilité*) into a concept of organic sensitivity which is itself a property of living matter. The difference between irritability and sensitivity in Haller is that the former is fully mechanically specifiable and is strictly a property of muscle fibres, while the latter has a functional component as it is directed towards the organism's survival, and it presupposes the existence of the 'soul'.

In Diderot, this difference is collapsed into one property of living matter, with some waverings as to whether this property occurs in the elements or only in organized wholes, but he seems to opt ultimately for the latter. Sensitivity and therefore Life require, according to Diderot, the presence of organic "continuity" rather than mere spatial "contiguity" (Diderot's terms, which map onto Stahl's distinction between aggregate and mixt; Diderot 1994: 625–628; Boury 2006; Wolfe 2006). The difference between the life of an organic being and the life of a wooden automaton, or a watch, is not that the former possesses a soul, or is free, whereas the latter is not. The difference is, one might say, a structural one, between two different types of arrangements of parts. This is what Leibniz, a favourite author of Diderot's, meant when he declared that "a feeling or sensing being is not something mechanical like a watch or a windmill" (Preface to the *New Essays*, in Leibniz 1978, vol. 5: 59) or, in Diderot's version, which reflects his annoyance with the prevalent clock metaphor: "What a difference there is, between a sensing, living watch and a golden, iron, silver or copper watch!" (*Elements of Physiology*, in Diderot 1994: 1283).

It is for this reason that the concept of 'mechanistic materialism' is so problematic, and perhaps downright false (Kaitaro 1987): because most materialists, unlike Descartes, do not claim that physical nature is essentially specifiable in mechanistic terms. Diderot's challenge is to be able to do justice to the difference between organic and inorganic beings, without having reference to a concept of 'soul', anima, as the basis of animation, given that the distinction between 'animate' and 'inanimate' initially means 'possessed-of-soul' versus 'not-possessed-of soul' (Cunningham 2003: 58). This will be the concept of active, sensing matter. Hence his materialism is significantly focused on the concept of Life. It is in this sense that his "revolutionary" fervour (the *Thoughts on the Interpretation of Nature*'s "We are at the dawn of a revolution", Diderot 1994: 561) is not just a way of participating in the emergence of biology as a science, since it is also a philosophical project. Consider the article "Spinosiste" of the *Encyclopédie*, by Diderot:

> Spinosist: follower of the philosophy of Spinosa. One must not confuse the ancient Spinosists with the modern Spinosists. The general principle of the latter is that matter is sensitive; they demonstrate this by the development of the egg, an inert body which by the sole means [*instrument*] of graduated heat moves to the state of a sensing, living being, and by the growth of any animal which in its inception [*principe*] is merely a point, and through the nutritive assimilation of

> plants and – in one word – of all substances that serve the purpose of nutrition, becomes a great sensing and living body in a greater [expanse of] space. From this they conclude that only matter exists, and that it is sufficient to explain everything. For the rest, they follow ancient Spinosism in all of its consequences. (*Encyclopédie*, vol. XV: 474; Diderot 1994: 484)

No one has ever produced a satisfactory explanation as to why Diderot chooses to place an affirmation of his biologically motivated metaphysics within an entry on a philosopher (or a derivative of the philosopher) who did not himself think there was anything metaphysically unique about living beings. The first scholar to call attention to it, Paul Vernière, invented "neo-Spinozism", as a category to describe precisely this biologically reconceptualized Spinozism. Vernière meant by this a form of holist materialism founded on the life sciences rather than on a priori metaphysical speculation (Vernière [1954] 1982: 529); what "neo-Spinozism", which he attributes not just to Diderot but to Maupertuis as well, does is "refashion a monism more in accordance with the findings of science" (ibid.: 533). In the present context I will content myself with the observation that the difference between "ancient Spinosists" and "modern Spinosists" effectively maps onto the historical narrative I have been suggesting: whereas ancient Spinosists are essentially substance metaphysicians, their modern descendents are essentially focused on Life, specifically, the radical implications of the biological theory of epigenesis.

Harvey, who is supposed to have coined the term, defines epigenesis as "the superaddition of parts out of the power or potentiality of the pre-existent matter" (Harvey 1653: 223). More specifically, epigenesis is the theory of generation (or development as we would now call it) in which the characteristics and structure of the mature organism may be pre-determined in the embryo, but are not "preimprinted" in it. Rather, they are acquired during the course of a gradual development, in which the embryo undergoes transformations under the influence of the environment. In this sense, it is opposed to the preformationist theory, according to which all the characteristics of the developed organism correspond directly to characteristics "imprinted" in the embryo. Thus 'epigenesis versus preformationism' seems like the basis for a controversy in the theory of generation. We might think that we have finally encountered a proper controversy over Life; but in fact it does not become one until Diderot takes hold of it. Or rather, to introduce a distinction, if 'preformationism versus epigenesis' is a controversy in the life sciences, beginning fitfully in the early 1700s in the *Académie des sciences* and reaching full velocity with Haller, Wolff, and Blumenbach in the late years of the century, what happens with Diderot is that it becomes, precisely in the wake or rather the vein of Stahl, an ontological controversy. This is most explicit if we add to the entry "Spinosiste" a passage from *D'Alembert's Dream*, the first sentence of which François Jacob in fact used as an epigraph for his *La logique* du vivant (Jacob 1970):

> 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 1994: 618)

Aside from its stated radical dimension (to overthrow all schools of theology), there is also clearly something 'vital' about the commitment to epigenesis, or even vitalistic, since "All believers in epigenesis are Vitalists", as Hans Driesch observed (Driesch 1914: 39; see Oyama 2010).

The transformative, 'epigenetic' dimension of living beings, which fascinates Diderot ("Voyez-vous cet œuf ?") or La Mettrie (who uses Lucretian motifs to describe the living Earth as like a womb (*utérus*) which has now grown barren, so that new species do not arise[34]), which also fuels the fascination with monsters, is very far removed from the set of possible criteria for the science of biology by the early nineteenth century, which include a reductive constraint on explanations of living beings in terms of their physico-chemical nature, a unification criterion which states that all living entities (including plants and animals) possess properties such as development, reproduction, nutrition, respiration, beginning in a basic substance (protoplasm) and ultimately arriving, by the middle of the nineteenth century, at the study of development, focusing on structure and function (morphology and anatomy versus physiology); at this point biology also requires cell theory in order to explain cellular division and conjugation, and has to incorporate evolutionary and ecological components (Singer [1929] 1958; Caron 1988; Barsanti 2000). It is no surprise that Cuvier by 1810 can declare that "the anatomical portion of the general problem of life has been resolved for a long time, at least as concerns the animals which interest us the most" (Cuvier 1810, "Histoire naturelle", II: 207).

To reiterate the point otherwise, the various instances of an emerging 'life science' in the eighteenth century, from the renewal of theories of generation to Haller's work on irritability, to pieces of 'folk biology' such as Trembley's polyp or Bonnet's aphids (Roe 1981; Lenhoff and Lenhoff 1989) are not themselves identical with an ontological concern with the status of Life. To conflate these two would be to create a monolithic concept of vitalism which would somehow lead inexorably to the constitution of biology as a science. As much as Buffon, Haller, Barthez, Blumenbach, Bordeu, Venel, Diderot and especially Ménuret de

34. La Mettrie [1750] 1987, Sections 8–11; he thinks the moderns can improve experimentally on this view, but does not reject it wholeheartedly.

Chambaud insist on the separation between life sciences and physical sciences – a separation which formally culminates in Bichat, Cabanis, and Bernard – it is not clear that all these figures, and certainly not Bichat or the 'founders' (or at least coiners) of biology Lamarck, Treviranus and Carl Christian Erhard Schmid (the author of *Physiologie philosophisch bearbeitet*, 1798–1801)[35] care about ontology. After all, no less a figure than the head of the Montpellier vitalists, Paul-Joseph Barthez, declared "I am as indifferent as could be regarding *Ontology* considered as the science of entities" (Barthez 1806, vol. 1: 96, n. 17).

It is true that some of these figures viewed these episodes of the coming-to-be of biology as not conforming to the laws of mechanics (or even violating them), and thus placing "in serious difficulty the traditional paradigm, based on the sovereignty of physics" (Barsanti 2000: 124). Thus the geologist Jean-Claude Delamétherie declared that the living being was "a machine that confounds all our ideas of mechanics".[36] But the more a science of biology emerges the less it is concerned with the ontological crisis about Life. My interest here is more in the problematic status of Life in between historical categories such as the Scientific Revolution and the Enlightenment, and less to produce some ahistorical typology of controversies; but one is tempted to venture a distinction between an *ontologically* controversial moment (Stahl, and its materialist version in Diderot) and a *functionally* controversial moment that emerges with the positive science of life.

5. Conclusion

Why was there no controversy over Life in the Scientific Revolution? This episode, or absence thereof, is very difficult to make sense of in terms of familiar concepts such as 'paradigms' or 'normal science', for at least two reasons. First, since the sciences involved in the constitution of Life as a problem are not unified, discursively, experimentally or by their objects, whether we speak of alchemy, natural history, iatrochemical medicine or 'metaphysical' reflections on vital *minima* and the relation of body and soul; as Claire Salomon-Bayet nicely suggests, it would then have to be a "permanent revolution" (Salomon-Bayet 1978: 15; Salomon-Bayet 1981: 36, 39) lasting one hundred and fifty years (in her case the object is the study of life

35. Schmid 1798–1801, I: 140, cit. in Risse 1972: 153–154. See Schiller 1980: 85–87; Caron 1988: 231–232 for further indications on the early uses of 'biology', 'zoonomy' and the older 'physiology' to designate the same science.

36. Delamétherie 1787, II: 292, cited by Barsanti 2000: 124.

in the *Académie des sciences*; we could just as well say 'from Harvey to Pasteur'[37]). Second, by the time it (biology, medicine, etc.) is a science and is perhaps on the way to producing normal vs. abnormal patterns of discourse,[38] it has already lost its ontological dimension and thus its sense of being a crisis or a "scandal" – even if figures such as Hans Driesch at the end of the nineteenth century can effectively replay Stahl versus mechanism, invoking Aristotelian entelechies just like Stahl did. This lack of fit between the various strands of the Life narrative in early modern science, and Kuhnian concepts such as paradigms, is sometimes used to demonstrate that Kuhn's concepts might not work here (Salomon-Bayet 1981), even if some attempts have been made, unsuccessfully, to interpret notably Haller's enhanced mechanistic model for physiology as precisely a "paradigm shift" (Toellner 1977). What it tells us here is not so much a matter for Kuhnian philology as a problem for understanding the development of biology as a discipline and how it relates to the more ontologically oriented discussions of the previous century, from the core years of the Scientific Revolution to the *Spätaufklärung*.

If, then, Life and the investigation into Life is not manageable as a Scientific Revolution narrative, we can of course revise the latter to include more discussion of animal spirits, of Newton's queries on sensation and their influence on biomedicine in the next generation, and of course of the shift from a notion of 'soul' to various embodied and cognitive concepts. We can also insist on the presence of quantitative experimentation, notably in the Italian anatomists. But we will not able to reconstruct a controversy over Life within the frame of the development of biology. In the seventeenth century Life is either everywhere, as in Gassendi or Glisson, but it is immediately dissipated into the entities and processes which mechanistically subserve it, or promoted to the extent that vital spirits, vital heat, ferments, seeds and other forms of animation are so co-extensive to the field of investigation that Life again dissipates into the analysis as a whole. There is discussion, but no controversy, in the sense that there is no polarization between Life and non-Life. In the eighteenth century, with Stahl and Diderot, Life becomes a 'crisis' concept – with anti-reductionist and reductionist trajectories, respectively – until by the early nineteenth century it resolves into being a structural concept with no ontological component. This is patently the case in Claude

37. Cuvier provides his own capsule history of the birth of life science *qua* science (i.e. as a system allowing for causal explanations): we have known the causal processes at work in digestion for centuries; the absorption of substances, since Pecquet, Rudbeck et Ruysch; the process of circulation, since Harvey. "The work of the English and Italian anatomists on the lymphatic system has … completed everything that remained to be said in this regard" (Cuvier 1810: 208).

38. Say, Pasteur versus Pouchet on spontaneous generation or Cuvier versus Geoffroy Saint-Hilaire on the the *plan d'organisation* (mentioned in Dascal 1998).

Bernard – a careful reader of Diderot, who left behind an unpublished manuscript on the latter's medical and physiological writings (Barral 1900) – for whom vitality is an effect of a particular type of physical organization, and nothing more: "l'élément ultime du phénomène est physique; l'arrangement est vital."[39]

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: 487). But what about the "revolutionary" force of epigenesis? The sense Diderot had that he and others were "on the verge of a great revolution in the sciences", but not a revolution that was subsumed under an autonomous science of biology? As I have tried to describe, this "great revolution" which did not happen at least as envisaged by Diderot, combines the ontological *crisis* component of Stahlian animism with the new materialist focus on epigenesis and other key features of biological entities ("modern Spinosism", as Diderot calls it). It is neither a feature of the Scientific Revolution nor of the Enlightenment per se; it is more of a *Sattelzeit*, Reinhart Koselleck's term for epochs which lie in between the recognized stages in our historical narratives, whether as transitions or as inassimilable moments (Zammito 2004). This *Sattelzeit* of Life as a scientific and philosophical problem, prior to the emergence of biology as a positive science in the nineteenth century, combines both a mechanistic interest in structures, components and 'how things are put together' with a recognition of the challenge created by new concepts of organism, body, animal economy etc.; and yet it does not hypostatize these concepts into transcendent entities beyond the reach of natural science. It is this radical, ontologically controversial aspect of Life that I have discussed here.[40]

Acknowledgements

Thanks to Guido Giglioni, Justin E. H. Smith, Sean Dyde and Randall Albury for assistance and suggestions; to the editors of the volume for helpful commentary and clarifications.

39. Bernard 1879: 524, cited and discussed in Métraux 2004: 44–46.

40. This is part of a broader project to examine the relationship between materialism and embodiment in early modern science and the Enlightenment – moving away from stereotypical schemas such as 'mechanistic materialism' but also from certain theories of embodiment which oppose it to the concepts of natural science. See further Wolfe and Gal (eds) 2010, Huneman and Wolfe (eds) 2010, Wolfe and Terada 2008, Salter and Wolfe 2009.

References

Ackerknecht, E. 1982. *A Short History of Medicine*, 2nd ed. Baltimore: Johns Hopkins University Press.

Anstey, P. 2011. "The Matter of Medicine: New Medical Matter Theories in Mid-Seventeenth-Century England". In P. Anstey and D. Jalobeanu (eds), *Vanishing Bodies. The Philosophy of Matter from Descartes to Hume*. London: Routledge, 61–79.

Bacon, F. 1605/2000. *The Advancement of Learning*, ed. M. Kiernan. Oxford: Clarendon Press.

Bacon, F. 1857–1874. *Works*, eds. J. Spedding, R. L. Ellis and D. D. Heath, 14 vols. London: Longman.

Baglivi, G. 1696/1704. *De praxi medica*, trans. G. Sewell & J. T. Desaguliers, *The Practice of Physick*, 2nd ed. London: A. Bell et al.

Barral, G. 1900. "*Diderot et la médecine*. Un ouvrage projeté par Claude Bernard". *Chronique médicale* (February 15): 126–128.

Barsanti, G. 2000. "Lamarck: Taxonomy and Theoretical Biology". *Asclepio* 52: 119–131.

Barthez, P.-J. 1806. *Nouveaux éléments de la science de l'homme*, 2nd edition, 2 vols. Paris: Goujon & Brunot.

Bates, D. G. 1981. "Thomas Willis and the Fevers Literature of the Seventeenth Century". In W. F. Bynum and V. Nutton (eds), *Theories of Fever from Antiquity to the Enlightenment*, Supplement 1 to *Medical History*. London: Wellcome Institute for the History of Medicine, 45–70.

Bernard, C. 1879. *Leçons sur les phénomènes de la vie communs aux animaux et aux végétaux*, tome II. Paris: G. Baillière.

Bertoloni Meli, D. 2008. "The Collaboration Between Anatomists and Mathematicians in the Mid-Seventeenth Century with a Study of Images as Experiments and Galileo's Role in Steno's *Myology*". *Early Science and Medicine* 13(6): 665–709.

Biagioli, M. 1998. "The Scientific Revolution is Undead". *Configurations* 6(2): 141–148.

Bloch, O. R. 1971. *La Philosophie de Gassendi. Nominalisme, matérialisme et métaphysique.* The Hague: Martinus Nijhoff.

Boerhaave, H. 1708/1752. *Institutiones medicae*, translated as *Dr. Boerhaave's Academical Lectures on the Theory of Physic, being a Translation of his Institutes and Explanatory Comments*, vol. 1 of 6. London: W. Innys.

Boerhaave, H. 1703/1983. *De usu ratiocinii mechanici in medicina*, translated as *Oration on the Usefulness of the Mechanical Method in Medicine*, in *Boerhaave's Orations*, trans. and ed. E. Kegel-Brinkgreve and A. M. Luyendijk-Elshout. Leiden: E. J. Brill / Leiden University Press.

Bonnet, C. 1764. *Contemplation de la Nature*, vol. I. Amsterdam: Marc-Michel Rey.

Bonnet, C. 1768. *Considérations sur les corps organisés*, 2nd edition. Amsterdam: Marc-Michel Rey.

Bordeu, T. 1764. *Recherches sur quelques points d'histoire de la médecine*. Paris: Cailleau.

Bordeu, T. 1818. *Œuvres complètes*, précédées d'une Notice sur sa vie et ses ouvrages par Monsieur le Chevalier de Richerand, 2 vols. Paris: Caille et Ravier.

Borelli, G. 1680. *De motu animalium*, 2 vols. Rome: A. Bernabò.

Bourguet, L. 1729. *Lettres philosophiques sur la formation des sels et des crystaux et sur la génération et le méchanisme organique des Plantes et des Animaux*. Amsterdam: F. l'Honoré.

Boury, D. 2006. "Contigu, continu." In S. Audidière, J.-Cl. Bourdin et al. (eds), *L'Encyclopédie du Rêve de D'Alembert*. Paris: Éditions du CNRS, 104–106.

Boyle, R. 1688. *A Disquisition About the Final Causes of Natural Things*. London: John Taylor.

Boyle, R. 1772. *The Works of the Honourable Robert Boyle*, 6 vols., ed. Thomas Birch. London: J. and F. Rivington et al. Reprinted 1965. Hildesheim: Georg Olms.

Brown, P. 1988. *The Body and Society: Men, Women, and Sexual Renunciation in Early Christianity*. New York: Columbia University.

Buffon, G. L. M. L. de. 1749. *Histoire naturelle, générale et particulière*. Paris: Imprimerie Royale.

Buffon, G. L. M. L. de. 1954. *Œuvres philosophiques*, ed. J. Piveteau et al. Paris: PUF.

Canguilhem, G. 1980. "Note sur les rapports de la théorie cellulaire et de la philosophie de Leibniz". Appendix II in *La connaissance de la vie*, revised edition. Paris: J. Vrin, 187–189.

Caron, J. 1988. "'Biology' in the Life Sciences: A Historiographical Contribution". *History of Science* 26: 223–268.

Carvallo, S. 2010. "Leibniz vs. Stahl: A controversy well beyond medicine and chemistry". In M. Dascal (ed), *The Practice of Reason. Leibniz and his Controversies*. Amsterdam: John Benjamins, 101–136.

Chang, K. M. 2002. "Fermentation, Phlogiston and Matter Theory: Chemistry and Natural Philosophy in Georg Ernst Stahl's *Zymotechnia Fundamentalis*". *Early Science and Medicine* 7: 31–64.

Chang, K. M. 2004. "Motus Tonicus: Ernst Stahl's Formulation of Tonic Motion and Early Modern Medical Thought". *Bulletin of the History of Medicine* 78: 767–803.

Cheung, T. 2006. "The Hidden Order of Preformation: Organized Bodies in the Writings of Louis Bourguet, Charles Bonnet and Georges Cuvier". *Early Science and Medicine* 11: 11–49.

Clericuzio, A. 2000. *Elements, Principles and Corpuscles: A Study of Atomism and Chemistry in the Seventeenth Century*. Dordrecht: Kluwer.

Clericuzio, A. ms. 2009. "The Organical Motions of Body Fluids. Mechanical and Iatrochemical Theories in 17th-Century Physiology". Presentation to Workshop on Embodied Empiricism, Unit for History and Philosophy of Science, University of Sydney, February 20–22.

Cook, H. 1990. "The New Philosophy and Medicine in Seventeenth-Century England". In D. Lindberg and R. Westman (eds), *Reappraisals of the Scientific Revolution*. Cambridge: Cambridge University Press, 397–436.

Cooter, R. and Pickstone, J. (eds). 2000. *Medicine in the Twentieth Century*. Amsterdam: Harwood.

Cunningham, A. 2003. "The Pen and the Sword: Recovering the Disciplinary Identity of Physiology and Anatomy Before 1800, II: Old Anatomy – The Sword". *Studies in History and Philosophy of Biological and Biomedical Sciences* 34: 51–76.

Cuvier, G. 1810. *Rapport historique sur les progrès des sciences naturelles depuis 1789, et sur leur état actuel*. Paris: Imprimerie Impériale.

Dascal, M. 1998. "The Study of Controversies and the Theory and History of Science". *Science in Context* 11: 147–154.

Deamer, D. W. and Fleishaker, G. R. (eds). 1994. *Origins of Life: The Central Concepts*. Boston: John and Bartlett.

Dear, P. 1998. "The Mathematical Principles of Natural Philosophy: Toward a Heuristic Narrative for the Scientific Revolution". *Configurations* 6: 173–193.

Debus, A. G. 1991. *The French Paracelsians: The Chemical Challenge to Medical and Scientific Tradition in Early Modern France*. Cambridge: Cambridge University Press.

Debus, A. G. 2001. *Chemistry and Medical Debate. Van Helmont to Boerhaave*. Canton, Mass.: Science History Publications.

Delamétherie, J.-C. 1787. *Principes de la philosophie naturelle, dans lesquels on cherche à déterminer les degrés de certitude ou de probabilité des connoissances humaines.* Geneva: n.p.

Descartes, R. 1964–1976. *Œuvres*, eds. C. Adam and P. Tannery, 11 vols. Paris: Vrin (cited as AT followed by volume and page number).

Des Chene, D. 2003. "Life After Descartes: Régis on Generation". *Perspectives on Science* 11: 410–420.

Des Chene, D. 2005. "Mechanisms of Life in the Seventeenth Century: Borelli, Perrault, Régis". *Studies in History and Philosophy of Biological and Biomedical Sciences* 36: 245–260.

Diderot, D. 1961. *Correspondance*, recueillie, établie et annotée par G. Roth, vol. 9. Paris: Éditions de Minuit.

Diderot, D. 1994. *Œuvres complètes*, éd. L. Versini, vol. 1. Paris: Robert Laffont, coll. 'Bouquins'.

Driesch, H. 1914. *The History & Theory Of Vitalism*, revised ed., trans. C. K. Ogden. London: Macmillan.

Duchesneau, F. 1982. *La physiologie des Lumières. Empirisme, modèles et théories*. La Haye: Martinus Nijhoff.

Duchesneau, F. 1995. "Leibniz et Stahl: divergences sur le concept d'organisme". *Studia leibnitiana* 27: 185–212.

Duchesneau, F. 2003. "Louis Bourguet et le modèle des corps organiques". In M. T. Monti (ed), *Antonio Vallisneri. L'edizione del testo scientifico d'età moderna*. Florence: Leo Olschki, 3–31.

Fichant, M. 2003. "Leibniz et les machines de la nature". *Studia leibnitiana* 35: 1–26.

Fisher, S. (ed). 2003. *Early Modern Philosophy and Biological Thought*, special issue of *Perspectives on Science* (11:4).

Fitzgerald, F. Scott. 1945. "The Crack-Up". In *The Crack-Up*, ed. E. Wilson. New York: New Directions.

Fontenelle, B. de. 1699/1702. *Histoire de l'Académie royale des Sciences*. Paris: Imprimerie royale / J. Boudot.

Fontenelle, B. de. 1707/1730. "Sur la glande pituitaire". In *Histoire de l'Académie Royale des Sciences* pour 1707. Paris: Martin, Coignard et Guérin.

Foucault, M. 1966. *Les mots et les choses*. Paris: Gallimard.

French, R. K. 1990. "Sickness and the soul: Stahl, Hoffmann and Sauvages on pathology". In A. Cunningham and R. French (eds), *The Medical Enlightenment of the Eighteenth Century*. Cambridge: Cambridge University Press, 88–110.

Freudenthal, G. 1998. "Controversy". *Science in Context* 11: 155–160.

Galilei, G. 1623/1953. *Dialogue on the Great World Systems*, ed. G. de Santillana. Chicago: University of Chicago Press.

Gasking, E. B. 1967. *Investigations into Generation, 1651–1828*. London: Hutchinson.

Gayon, J. 1998. "La philosophie et la biologie". In J.-F. Mattéi (ed), *Encyclopédie philosophique universelle*, vol. IV: *Le Discours philosophique*. Paris: PUF, 2152–2171.

Giglioni, G. 2005. "The Hidden Life of Matter: Techniques for Prolonging Life in the Writings of Francis Bacon". In C. Gimelli Martin and J. Robin Solomon (eds), *Francis Bacon and the Refiguring of Early Modern Thought. Essays to Commemorate* The Advancement of Learning *(1605–2005)*. Aldershot: Ashgate, 129–144.

Giglioni, G. 2008. "What Ever Happened to Francis Glisson? Albrecht Haller and the Fate of Eighteenth-Century Irritability". *Science in Context* 21: 465–493.

Giglioni, G. 2010. "Mastering the Appetites of Matter. Francis Bacon's *Sylva Sylvarum*". In C. T. Wolfe and O. Gal (eds), *The Body as Object and Instrument of Knowledge. Embodied Empiricism in Early Modern Science*. Dordrecht/New York: Springer, Studies in History and Philosophy of Science, 149–167.

Glisson, F. 1650. *De Rachitide sive Morbo Puerili, qui Volgò The Rickets Dicitur, Tractatus … Adscitis in Operis Societatem Georgio Bate, & Ahasuero Regemortero Medicinae quoque Doctoribus, & pariter Sociis Collegii Medicorum Londinensium*. London: W. Du-gard for Laurence Sadler and Robert Beaumont.

Glisson, F. 1654. *De Anatomia Hepatis. Cui Praemittuntur Quaedam ad Rem Anatomicam Universe Spectantia*. London: Typis Du–Gardianis, Impensis Octaviani.

Glisson, F. 1672. *Tractatus de natura substantiae energetica, seu de vita naturae ejusque tribus facultatibus perceptiva, appetitiva, motiva*. London: Flesher.

Grene, M. and Depew, D. 2004. *The Philosophy of Biology: An Episodic History.* Cambridge: Cambridge University Press.

Hahn, R. 1971. *The Anatomy of an Institution: The Paris Academy of Sciences, 1666–1803*. Berkeley: University of California Press.

Hall, T. S. 1968. "On Biological Analogs of Newtonian Paradigms". *Philosophy of Science* 35: 6–27.

Hall, T. S. 1969. *Ideas of Life and Matter. Studies in the History of General Physiology*, 2 vols. Chicago: University of Chicago Press.

Haller, A. von. 1751. Review of Volters, *Gedancken von Psychologischen sachen*. In *Göttingschen Gelehrten Anzeige*.

Harvey, W. 1653. *Anatomical Exercitations Concerning the Generation of Living Creatures*. London: James Young.

Hirai, H. 2005. *Le concept de semence dans les théories de la matière à la Renaissance de Ficin à Gassendi*. Turnhout: Brepols.

Hoffmann, F. 1749. *Operum omnium physico-medicorum supplementum primum*, vol. I. Geneva: Fratres De Tournes.

Huneman, P. and Wolfe, C. T. (eds). 2010. *History and Philosophy of the Life Sciences* 32: 2–3, special issue: *The Concept of Organism: Historical, Philosophical, Scientific Perspectives*.

Jacob, F. 1970. *La logique du vivant. Une histoire de l'hérédité*. Paris: Gallimard.

Joly, B. 2004. "Le modèle du vivant dans la chimie à l'âge classique". Presented at seminar on "L'Analogie dans les sciences – fécondités et obstacles," Centre commun d'histoire des sciences et d'épistémologie de Lille I, online at http://stl.recherche.univ-lille3.fr/archives/archivesset/seminaires/sem/analogie0304.pdf. Accessed September 15, 2009.

Kaitaro, T. 1987. "The eighteenth century French materialists and 'mechanistic materialism". In J. Alavuotunki, A. Leikola, J. Manninen and A.-L. Räisänen (eds), *Aufklärung und Französische Revolution II*. Publications of the Department of History, University of Oulu, 3: 66–83.

Kaplan, B. 1993. *"Divulging of Useful Truths in Physic": The Medical Agenda of Robert Boyle*. Baltimore: John Hopkins Press.

Kiernan, C. 1968. *The Enlightenment and Science in Eighteenth-Century France*. Oxford: Voltaire Foundation.

Kuhn, T. S. 1976. "Mathematical vs. Experimental Traditions in the Development of Physical Science". *Journal of Interdisciplinary History* 7: 1–31.

Lamarck, J.-B. 1801. *Système des Animaux sans vertèbres, ou Tableau général des classes, des ordres et des genres de ces animaux ; présentant leurs caractères essentiels et leur distribution d'après les considérations de leurs rapports naturels et de leur organisation, et suivant l'arrangement établi dans les galeries du Muséum d'Histoire naturelle, parmi leurs dépouilles conservées*. Paris: Déterville.

La Mettrie, J. O. de. 1750/1987. *Système d'Épicure*, in *Œuvres philosophiques*, ed. F. Markovits, vol. 1. Paris: Fayard, collection "Corpus".

Leibniz, G. W. 1903/1988. *Opuscules et fragments inédits de Leibniz*, ed. L. Couturat. Reprint, Hildesheim: Georg Olms.

Leibniz, G. W. 1978. *Die Philosophischen Schriften*, ed. G. J. Gerhardt, 7 vols. Reprint, Hildesheim: Georg Olms.

Lenhoff, H. M. and Lenhoff, S. G. 1989. "Challenge to the Specialist: Abraham Trembley's Approach to Research on the Organism – 1744 and Today". *American Zoologist* 29: 1105–1117.

Locke, J. 1701/1975. *An Essay Concerning Human Understanding*, ed. P. Nidditch. Oxford: Oxford University Press.

Loeb, J. 1912. *The Mechanistic Conception of Life. Biological Essays*. Chicago: University of Chicago Press.

Mandressi, R. 2009. "Le corps et l'histoire, de l'oubli aux représentations". In D. Guillo et al. (eds), *La tentation du corps. Corporéité et sciences sociales*. Paris: EHESS.

Maupertuis, P.-L. Moreau de. 1746. *Vénus physique*. La Haye: J.-M. Husson.

Mendelsohn, E. 1964. "The Changing Nature of Physiological Explanation in the Seventeenth Century". In *L'aventure de la science. Mélanges A. Koyré*, vol. 1. Paris: Hermann, 367–386.

Mendelsohn, E. 1987. "The Political Anatomy of Controversy in the Sciences". In H. T. Engelhardt, Jr., and A. L. Caplan (eds), *Scientific Controversies: Case Studies in the Resolution and Closure of Disputes in Science and Technology*. Cambridge: Cambridge University Press, 93–124.

Métraux, A. 2004. "1064332 atomes et un cercle de vie". *Multitudes* 16 (Majeure *Philosophie de la biologie*): 41–47.

Monod, J. 1970. "Le scandale de la vie". Interview in *Le Nouvel Observateur*, November 2.

Principe, L. and Newman, W. 1998. "Alchemy versus Chymistry: The Etymological Origins of a Historiographic Mistake". *Early Science and Medicine* 3: 32–65.

Osler, M. J. (ed). 2000. *Rethinking the Scientific Revolution.* Cambridge: Cambridge University Press.

Oyama, S. 2010. "Biologists Behaving Badly: Vitalism and the Language of Language". *History and Philosophy of the Life Sciences* 32: 2–3, special issue on *The Concept of Organism: Historical, Philosophical and Scientific Perspectives*, eds P. Huneman and C. T. Wolfe, 401–423.

Reich, W. 1942/1968. *The Function of the Orgasm: Sex-Economic Problems of Biological Energy*, trans. T. P. Wolfe. London: Panther.

Reill, P. H. 2005. *Vitalizing Nature in the Enlightenment*. Berkeley: University of California Press.

Risse, G. 1972. "Kant, Schelling, and the Early Search for a Philosophical 'Science' of Medicine in Germany". *Journal of the History of Medicine* 27: 145–158.

Roe, S. A. 1981. *Matter, life and generation. Eighteenth-century embryology and the Haller-Wolff debate*. Cambridge: Cambridge University Press.

Roger, J. 1979. "Chimie et biologie: des molécules organiques de Buffon à la physico-chimie de Lamarck". *History and Philosophy of the Life Sciences* 1: 41–64.

Roger, J. 1980. "The Living World". In G. S. Rousseau and R. Porter (eds), *The Ferment of Knowledge. Studies in the Historiography of Eighteenth Century Science*. Cambridge: Cambridge University Press, 255–284.

Roger, J. (ed). 1984. *Médecine et sciences de la vie au XVIIIe siècle*, *Revue de Synthèse* 105: 113–114.

Salomon-Bayet, C. 1978. *L'institution de la science et l'expérience du vivant: méthode et expérience à l'Académie Royale des Sciences, 1666–1793*. Paris: Flammarion.

Salomon-Bayet, C. 1981. "1802. 'Biologie' et médecine". In H. N. Jahnke and M. Otte (eds), *Epistemological and Social Problems of the Sciences in the Early Nineteenth Century*. Dordrecht: Reidel, 35–54.

Salter, A. 2010. "William Harvey. A Study in Empiricism". PhD Dissertation: University of Sydney.

Salter, A. and Wolfe, C. T. 2009. "Empiricism contra Experiment: Harvey, Locke and the Revisionist View of Experimental Philosophy". *Bulletin de la Société d'histoire et d'épistémologie des sciences de la vie* 16: 113–140.

Sauvages, F. B. de. 1731. *Nouvelles classes des maladies dans un ordre semblable à celui des Botanistes, comprenant les Genres et les Espèces de toutes les Maladies*. Avignon: D'Avanville.

Sauvages, F. B. de. 1763/1771. *Nosologie méthodique, dans laquelle les maladies sont rangées par classes, suivant le systême de Sydenham, & l'ordre des Botanistes*, trans. Nicolas, 3 vols. Paris: Hérissant fils.

Savioz, R. 1948. *Mémoires autobiographiques de Charles Bonnet de Genève*. Paris: Vrin.

Sawday, J. 1995. *The Body Emblazoned: Dissection and the Human Body in Renaissance Culture*. London: Routledge.

Schiller, J. 1980. *Physiology and Classification–Historical Relations*. Paris: Maloine.

Schmid, C. C. E. 1798–1801. *Physiologie philosophisch bearbeitet*, 3 vols. Jena: Akademische Buchhandlung.

Singer, C. 1929/1958. "Biology, History". In *Encyclopedia Britannica*, vol. 3. Chicago: Encyclopedia Britannica.

Smith, C. U. M. 1976. *The Problem of Life: An Essay in the Origins of Biological Thought*. New York: Wiley.

Smith, J. E. H. (ed). 2006. *The Problem of Animal Generation in Early Modern Philosophy*. Cambridge: Cambridge University Press.

Smith, P. M. 2009. "Science on the Move: Recent Trends in the History of Early Modern Science."*Renaissance Quarterly* 62(2): 345–375.

Spinoza, B. 1675/2002. *Ethics*, in *Complete works*, trans. S. Shirley et al., ed. M. L. Morgan. Indianapolis: Hackett Books.

Stahl, G.-E. 1706a/1859. *On the Difference Between Mechanism and Organism* (*Disquisitio de mecanismi et organismi diversitate*), in *Œuvres médico-philosophiques et pratiques*, trans. T. Blondin, ed. L. Boyer, vol. 2. Paris: J.-B. Baillière.

Stahl, G.-E. 1706b/1859. *On The Necessity Of Eliminating Anything Foreign From Medical Doctrine* (*Paraenesis ad aliena a medica doctrina arcendum*), in *Œuvres médico-philosophiques et pratiques*, trans. T. Blondin, ed. L. Boyer, vol. 2. Paris: J.-B. Baillière.

Stahl, G.-E. 1708/1860. *Theoria medica vera*, in *Œuvres médico-philosophiques et pratiques*, trans. T. Blondin, ed. L. Boyer, vol. 3. Paris: J.-B. Baillière.

Stahl, G.-E. 1720/1864. *Negotium Otiosum, seu σκιαμαχια adversus positiones aliquas fundamentales theoriae verae medicae*, *Œuvres médico-philosophiques et pratiques*, trans. T. Blondin, ed. L. Boyer, vol. 6. Paris: J.-B. Baillière.

Starobinski, J. 1999. *Action et réaction. Vie et aventures d'un couple*. Paris: Éditions du Seuil.
Steinke, H. 2005. *Irritating Experiments. Haller's Concept and the European Controversy on Irritability and Sensibility, 1750–90*. Amsterdam and New York: Rodopi.
Toellner, Richard. 1977. "Mechanismus – Vitalismus: Ein Paradigmawechsel? Testfall Haller". In A. Diemer (ed), *Die Struktur wissenschaftlicher Revolutionen und die Geschichte der Wissenschaften*. Meisenheim am Glan: Anton Hain, 33–65.
Turner, B. S. 1984. *The Body and Society*. Oxford: Blackwell.
Venel, G.-F. 1753. "Chymie". In D. Diderot and J. le Rond D'Alembert (eds), *Encyclopédie ou dictionnaire des arts et métiers*, vol. III. Paris: Briasson, 408–421.
Vernière, P. 1954/1982. *Spinoza et la pensée française avant la Révolution*. Paris: PUF.
Wellman, K. 1987. "Medicine as a Key to Defining Enlightenment Issues: The Case of Julien Offray de La Mettrie". *Studies in Eighteenth-Century Culture* 17: 75–89.
Wellman, K. 2003. "Materialism and vitalism." In *The Oxford Companion to the History of Modern Science*, editor in chief J. L. Heilbron. Oxford: Oxford University Press. Accessed at *Oxford Reference Online*. September 15 2009. http://www.oxfordreference.com.
Westfall, R. S. 1971. *The Construction of Modern Science. Mechanism and Mechanics*. Cambridge: Cambridge University Press.
Willis, T. 1659/1681. *De fermentatione*, translated as *A Medical-Philosophical Discourse of Fermentation; or, Of the Intestine Motion of Particles in Every Body*, trans. S. Pordage. London: Dring, Harper, Leigh, and Martin.
Willis, T. 1664. *Cerebri anatome nervorumque descriptio et usus*. Amsterdam.
Wolfe, C. T. 2006. "Agrégat". In S. Audidière, J.-Cl. Bourdin et al. (eds), *L'Encyclopédie du Rêve de D'Alembert*. Paris: Éditions du CNRS, 36–38.
Wolfe, C. T. 2010. "Endowed molecules and emergent organization: the Maupertuis-Diderot debate". *Early Science and Medicine* 15, special issue: *Animals, Humans and Machines, 1600–1800*, ed. T. Cheung, 38–65.
Wolfe, C. T. and Terada, M. 2008. "The Animal Economy as Object and Program in Montpellier Vitalism". *Science in Context* 21(4), special issue: *Vitalism without Metaphysics? A Reevaluation of Enlightenment Vitalism*, ed. C. T. Wolfe, 537–579.
Wolfe, C. T. and Gal, O. (eds). 2010. *The Body as Object and Instrument of Knowledge. Embodied Empiricism in Early Modern Science*. Dordrecht/New York: Springer.
Zammito, J. 2004. "Koselleck's Philosophy of Historical Time(s) and the Practice of History". *History and Theory* 43(1): 124–135.