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Chapter 11. Revitalising a Nineteenth Century Debate about Life (Which has been Done to Death): Or, How to Live with Historiographical Pluralism

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Reflecting on the relationship between History of Science (HS) and Philosophy of Science (PS), most in our field would admit that the latter can – perhaps should – draw fruitful lessons from the former. Philosophers want their theories about science to be borne out empirically, and to give a good account of the actual practice of science. Engagement with HS scholarship can help achieve these aims.¹ Perhaps less obvious is the value of PS for HS. Prominent iHPS scholar Theodore Arabatzis posed this question as the title for his 2017 article: ‘What’s in it for the Historian of Science?’² His answer begins with Norwood Russell Hanson’s observation that historical studies of science must grapple with metascientific concepts. Arabatzis urges that ‘philosophical reflection on those concepts can be (and, indeed, has been) historiographically fruitful.’³ He discusses the examples of ‘epistemic values’, ‘experimentation’, ‘scientific discovery’, and ‘conceptual change’, showing in each case how philosophical insights upon these matters can be (and have been) profitably deployed in historical scholarship. Scientific practices, past and present, often involve issues of philosophical weight, engagement with which can be invaluable in gaining thorough historical understanding. What I want to suggest is that PS can also inform HS externally to the specifics of the ‘metascientific concepts’ encountered during any particular HS project; at the more removed level of deciding which episodes to study historically, which methodologies to employ in doing so, and what we hope to gain from our investigations. Specifically, I will show how recent work in PS on pluralism and perspectivism can enhance HS. Section 1 sets out this approach in the abstract, whilst sections 2 and 3 apply it to a case-study from HS: a debate over the nature of life which took place at London’s Royal College of Surgeons in the early-nineteenth century. Reflecting on the results of this case-study, I end by summarising the ways in which applying lessons from pluralism and perspectivism in PS can benefit our historiographical practices.

Section 1. Pluralising Historiographical Perspectives: A Lesson for HS from PS

When we possess multiple differing accounts of a historical episode, we often see them as competing. Philosopher Katherina Kinzel asks in a 2016 essay how we might go about restricting such historiographical pluralism; which criteria should we apply in judging between competing accounts and how do we apply them? She concludes that, though most inadequate accounts may be fairly straightforwardly disposed with, we often lack strong enough criteria to neutrally adjudicate a single ‘best’ account. Consequently, ‘we will have to live with some degree of pluralism in historiography’.⁴ The heuristic guiding Kinzel’s rigorous study – a heuristic I will be contesting – is that historiographic pluralism is bad. Its presence, the reasoning goes, indicates that we have not yet arrived at the one best account of an episode; or if we have, that we nevertheless have been unable to demonstrate the inadequacy of its competitors. There is an analogy here with the sciences. The existence of alternative scientific accounts of the same phenomenon has tended to lead scientists and philosophers alike to ask which theory is ‘best’, and should hence be maintained at the expense of its ‘competitors’. The enduring centrality of the problem of ‘theory choice’ in PS is indicative of the value traditionally attached to the pursuit of monism in the face of pluralism. Increasingly, however, philosophers of science are urging that we turn a critical eye on our traditional commitment to monism, and even that we actively cultivate pluralism in science.⁵

One variety of scientific pluralism which can be of substantial value to HS, I suggest, is rooted in scientific perspectivism, which holds that a scientific theory or model only ever provides a partial account of its target phenomenon.⁶ Thus, scientists are only granted a perspective upon their object of study, among many which are possible. Competing scientific accounts will often provide alternative perspectives upon the phenomenon of interest, and will emphasise and illuminate (or obfuscate) different aspects of the target phenomenon to varying degrees. Once the partiality of scientific perspectives is acknowledged, monism appears a rather limiting virtue; a plurality of perspectives is required for anything approaching a ‘complete’ account of the phenomenon of interest.⁷ As perspectivist philosopher Michela Massimi has recently put it, ‘[t]here cannot be an

objective, unique, true description of the way the world is as soon as we acknowledge that our scientific knowledge is always from a specific vantage point'.⁸

My suggestion is that historians of science should heed these lessons from PS, for, as David Hull has noted, '[h]istory of science cannot be written from no perspective whatsoever'.⁹ The methodologies we adopt, and the historiographical frameworks we employ, influence which historical questions, and answers, we deem interesting and illuminating. Like science, HS is perspectival. Pursuing historiographical monism in the face of extant pluralism, then, appears misguided. We cannot hope for 'an objective, unique, true description' of any episode in the History of Science; hence, we stand to gain – as do scientists – from pluralising our perspectives. To be sure, historiographical pluralities already exist: else there would be little motivation for Kinzel's project.¹⁰ This is unsurprising, given the rapid turnover of what Jon Hodge in the introduction to this volume calls 'trends' in History of Science, and Hodge himself admits to being impressed by a 'very healthy pluralism' in the iHPS literature. Contra Kinzel, I am suggesting we embrace and learn from existing historiographical pluralism, and actively cultivate more.¹¹

Others before now have encouraged historiographical pluralism. Historian of science Robert Fox, for example, has written that, '[t]he more options we have as historians, the better. For different questions call for different methodological tools, and we need as broad a repertoire as possible.'¹² Yet, there is something about my plea for pluralising perspectives that differentiates it from calls to proliferate our 'methodological tools' or similar. We employ tools; we have perspectives on things. The latter and not the former implies the constancy of our target phenomenon, even as we pluralise perspectives. It is unclear whether Fox's 'different questions' relate to the same historical episode or different ones. Rather than merely suggesting that we practice in our field a variety of historiographical methodologies (hopefully an uncontroversial claim), the lesson historians of science should draw from scientific perspectivism is that we should focus many different methodological tools upon a particular case-study. Only by pluralising our historiographical perspectives upon some particular episode do we stand to gain a fuller account of that episode, as well as reflexive insights concerning the adopted perspectives themselves. The resultant plurality of accounts is not something we should aim to remedy à la Kinzel, but cultivate and learn from in the various ways I shall detail below.

Sometimes we may wish to apply this methodology of pluralising perspectives *de novo*, to a past scientific episode that is yet to be studied. Certainly, this is the surest way of gaining a ‘complete’ account of the episode. However, here I am concerned with revisiting episodes already explored from one (or more) historiographical perspective – even episodes which have apparently been ‘done to death’ – and consciously re-exploring them from an alternative perspective.¹³ The potential benefits of revisiting particular episodes in this way are many, including (but not limited to): the testing of historiographical/philosophical frameworks against known examples from the history of science (think of it as testing new kinds of microscope against existing kinds working on different principles); highlighting problems with our existing historiographical categories; alerting us to interesting historical and/or philosophical questions not obvious from existing perspectives; exposing shortcomings of, or errors made from, existing perspectives.

The best way to be clear on what is meant by each of these benefits is through example. In section 2, I give an overview of my chosen case-study for re-exploration: the Abernethy–Lawrence controversy – a heated dispute in the 1810s over how best to explain vital phenomena, between two colleagues at London’s Royal College of Surgeons (RCS). This case serves my aims well, because the various accounts of it written last century – there are several, hence my titular ‘done to death’ phrase – represent but one well-developed perspective upon the episode. After a brief characterisation of this perspective, I proceed in section 3 to revisit the affair from an alternative one, namely by utilising a historiographical framework introduced by historian of science and medicine Andrew Cunningham for the purpose of thinking about the disciplines of anatomy and physiology in my period of interest. Though imperfect as applied to the Abernethy–Lawrence case, pursuing this perspective provides various benefits of the kinds set out above. Imperfections – and all perspectives are imperfect in some sense – can themselves be illuminating, and need not spell a perspective’s immediate dismissal, as part of the misguided search for a unique, ‘true’ account of our episode of interest.

Section 2. The Abernethy–Lawrence Controversy

In 1799 William Lawrence (1783-1867), a promising sixteen-year-old apprentice, came under the patronage of esteemed surgeon John Abernethy (1764-1831). As was customary, Lawrence lived in his mentor's household for the duration of his apprenticeship, after which he was appointed anatomical demonstrator at St. Bartholomew's Hospital in 1801, and a member of the RCS in 1804. It was here that, in 1814, Abernethy delivered a set of introductory anatomical lectures entitled *An Enquiry into the Probability and Rationality of Mr. Hunter's Theory of Life*.¹⁴ Extraordinary in scope, Abernethy's lectures tackled one of the most enticing problems of all: what is life?

According to Abernethy, what distinguished living from non-living matter was that, in the tradition of eighteenth-century 'Newtonian' ether-theories, the living was pervaded and animated by a subtle, immaterial, vital spirit.¹⁵ Drawing liberally upon contemporary investigations of electrical and chemical phenomena, Abernethy mobilised this notion to explain a wide range of the so-called 'vital phenomena' displayed by living organisms, such as animation, sensibility and irritability. Lawrence objected, vocally and publicly, to his former mentor's account. Though names went unmentioned, Lawrence's RCS lectures of 1816 – *An Introduction to Comparative Anatomy and Physiology* – amounted to a systematic rebuttal of Abernethy, ridiculing his invocation of a subtle life-giving principle.¹⁶ Lawrence, inspired by French anatomist Xavier Bichat, advocated instead a variety of vitalism which emphasised 'organisation', and located vital functions in particular tissues.¹⁷ Abernethy doubled-down on his position in his 1817 *Physiological Lectures*, which Lawrence responded to in turn in his *Lectures on Physiology, Zoology, and the Natural History of Man* of 1819.¹⁸

The personal nature of the dispute was not lost upon commentators in the specialist and general press. The conservative *Quarterly Review* blasted Lawrence for 'converting the lecture-room of the College into a school of materialism', whilst outrage was felt at his 'most coarse and virulent invective against his former patron'.¹⁹ Lawrence's defenders in the press held that moral and theological convictions should be set aside in discussing scientific matters. A failure to do so, one commentator reminded their readers, had left Galileo 'imprisoned in a dungeon for truths afterwards confirmed by Newton.'²⁰ In an effort to rescue his reputation, Lawrence withdrew his lectures from circulation (though they were pirated by various publishers after he lost the

copyright). Lawrence's retreat from the controversy had the desired effect, as he went on to enjoy a glittering medical career, culminating in his appointment in 1858 as Serjeant Surgeon to Queen Victoria.

Intensive social-historical study of the episode began in the 1960s by June Goodfield-Toulmin and Owsei Temkin, and continued two decades later by Stephen Jacyna and Adrian Desmond.²¹ Together, these authors successfully situated this pre-Victorian debate on the science of life within the context of religious, political, and class tensions in radicalising Britain. Roughly, the resultant perspectival account has it that Abernethy's principle-vitalism was aligned with the conservative political establishment, orthodox Christianity, and patriotism, whilst the Francophile Lawrence's doctrines reflected the politically dangerous, materialistic atheism emanating from the continent in the wake of the French Revolution. Elucidated in this way the Abernethy–Lawrence saga, according to Jacyna, 'merely constituted a fortissimo statement of a recurrent motif'.²²

This account of the affair is now standard, being cited regularly as an exemplary case-study of the relation between early-nineteenth century British science and the political upheavals of the time.²³ Yet the above is but one possible perspective on the Abernethy–Lawrence affair. Further, there are some concrete considerations which confirm our PS-informed suspicion that this perspective (like any) provides a less-than-complete account of the episode. Take, for instance, historian of biology Karl Figlio's 1976 criticisms of Goodfield-Toulmin and Temkin's accounts.²⁴ Figlio cites evidence of French resistance to materialism, British opposition to immaterial vital principles, and the 'deep appreciation of French thought in Scottish philosophical circles', in suggesting that Goodfield-Toulmin and Temkin's accounts overemphasised national differences.²⁵ Any one perspective is indeed liable to over- or under-emphasise certain aspects of the phenomenon under study.

Additional pressure can be applied to the received perspective by interrogating the supposed alignment of Abernethy's subtle-fluid-based physiology with his conservative politics and mainstream Christianity. Firstly, ether and God need not be inextricably linked, as John Christie has shown for the eighteenth century Edinburgh physician William Cullen, whose chemical ether replaced God as the effective causal agent in nature.²⁶ Secondly, Abernethy's invocation of electricity in discussing the vital fluid – on which, more later – puts pressure on the characterisation

of his doctrine as politically ‘conservative’, in contrast with Lawrence’s ‘radical’ views. On electricity in this period, Iwan Rhys Morus argues that, whilst the ‘plaything of fashionables’, the application of galvanic and electrical studies to life and the body carried materialistic and ‘radical’ undertones (as Mary Shelley brought to bear in her 1818 novel *Frankenstein*).²⁷ At worst, one could argue that the tight bundling of political persuasion, religious beliefs, and scientific views which is central to the received perspective is at risk of unravelling. At best, one must concede that the broad social-contextualisation perspective I have summarised is – like all perspectives – only partial.

Section 3. A New Perspective: The Pen and the Sword

My crude summary of the works of Goodfield-Toulmin, Temkin, Jacyna and Desmond represents but one possible perspective on the Abernethy–Lawrence affair, albeit an illuminating one. These authors attempted – successfully – to situate this dispute at the RCS within a historiographical framework emphasising a nexus of national, political, and religious tensions at the turn of the nineteenth century. Yet, as I have suggested, there are likely alternative perspectives from which we can give an account of the episode, which will be fruitful in different and complementary ways.

The alternative perspective I will pursue, based on work by historian Andrew Cunningham, takes different categories as historically significant, compared with the received perspective.²⁸ Ultimately, it will be clear that the new perspective is far from perfect.²⁹ No matter: no perspective is. This was a benefit of pluralising perspectives that I listed in the introduction: the testing of historiographical frameworks against known examples. In spite (and partly because of) its limitations, the perspective pursued here is still productive in the various ways suggested: it highlights problems with existing historiographical categories; alerts us to new and interesting historical and/or philosophical questions not obvious from other perspectives; exposes errors made from other perspectives; and, most straightforwardly, renders our understanding of this episode from the history of science more ‘complete’.

The perspective takes the nature and role of certain scientific disciplines as its historiographical category of interest. In the early 2000s, historian of science and medicine Andrew Cunningham

set out in a pair of articles – and later at book-length – a framework for ‘recovering the disciplinary identity of physiology and anatomy before 1800’.³⁰ The decades after 1800 were, for Cunningham, a watershed moment during which the disciplines of anatomy and physiology were transformed beyond recognition, taking on roughly the identity they retain to this day. Before this radical transformation, anatomy was the great experimental science of life, being a much richer and more active pursuit than we now conceive it to be. Physiology in this period was purely theoretical; the ‘old-physiologist’ was a philosopher, who weaved together

the anatomical and other evidence he had acquired from experiment, observation and reading, and reasoned his way to understanding how it all functioned together in life [...] He took the anatomical facts and on them built his physiological speculations.³¹

To capture the relations between ‘old-anatomy’ and ‘old-physiology’, Cunningham re-deploys the adage of the pen and the sword. The philosophising physiologist required only the former, and allowing himself the rhetorical flourish, Cunningham bestows the latter upon the knife-wielding anatomist. These disciplinary identities were transformed out of recognition, Cunningham explains, by the emergence in the early-mid-nineteenth century of ‘experimental physiology’, in the mould of pioneering Frenchmen François Magendie (1783-1855) and Jean Pierre Flourens (1794-1867). Far from the philosophical interpretation of facts provided by anatomists, physiology of the Magendie School was itself an active, experimental, interventionist discipline. Experimental physiology replaced ‘old-anatomy’ as the great experimental science of life, the major difference being that it intervened not in the dead, but the living body.³² Anatomy, meanwhile, became demonstrative, losing its active, interventionist, and experimental identity.

The Abernethy–Lawrence saga was already underway by the time Magendie penned the first textbook of his new experimental physiology in 1816, which would take some time to exert an appreciable influence in the generally Francophobic British context.³³ The timing of the affair, then, places it just within the remit of Cunningham’s proposed framework of the nature of and relationship between the disciplines of anatomy and physiology. Both men drew liberally upon both disciplines in explicating their accounts of vitality, and as such, the doctrines they espouse in

their lectures provide a tantalising test-case for Cunningham's framework, which he set out at a rather general level, and is hence lacking in applications to concrete episodes.

Adopting Cunningham's framework as an alternative historiographical perspective, I will show that a good deal of Abernethy and Lawrence's disagreement over the nature of life can be made sense of in terms of disparities between each man's notions of good physiological practice. Different disciplines are (and were) defined by different, sometimes conflicting, sets of methods, aims and approaches, that encapsulate, shape and constrain the research undertaken under their banners. A physiologist might pose questions or solutions that a comparative anatomist would not dream of, or regard as important, or even coherent. Through adopting Cunningham's discipline-centred perspective, we will see that the attitudes our protagonists held concerning the disciplinary scopes of anatomy and physiology, and particularly their relationship to one another, elucidates a great deal of the disparity in their respective conceptions of life.

The case is not as simple as one man 'doing old-anatomy' and the other 'doing old-physiology'; both men wielded pen and sword. Despite this, Cunningham's characterisation of these disciplines appears promising, as we read Lawrence stating that comparative anatomy, 'furnishes the data, which constitute the basis of general physiology, of which the object is to determine the laws that regulate the phenomena exhibited by organized beings'.³⁴ Abernethy also held that knowledge of vital processes must be based upon facts ascertained by comparative anatomy. He instructed his audience that to gain knowledge of vital processes in the exemplary manner of the late, revered surgeon John Hunter, 'it is necessary to refer to the facts contained in his Museum'; in other words, examination of the structures of various animal forms is a prerequisite to theorising about the actions and functions of animate beings and their parts.³⁵

Both parties in the dispute, and indeed most of the wider scientific community, subscribed to the view that particular functions were localised in particular bodily structures.³⁶ Lawrence's commitment to this methodological heuristic is clear in his 1819 entry in *Rees's Cyclopaedia*, on the topic of 'monsters', or, individual organisms, 'in whom the body in general, or some large and conspicuous part of it, deviates remarkably from the accustomed formation'.³⁷ Such instances presented the researcher unrivalled opportunities:

Monsters, in which considerable parts are wanting, seem peculiarly likely to assist in the prosecution of physiological researches. If we never saw animals, except in a perfect state, we could not form just ideas of the comparative importance of the different organs.³⁸

Lawrence, eyes peeled for information pertaining to the localisation of functions, recounts the tale of a particular ‘monster’ patient:

In one case, where [...] an imperfect cerebrum seemed to exist, the child lived six days. The child was perfectly formed, excepting the head, and of usual size. It took no food, and had no evacuation. Respiration went on naturally: it did not cry, but often made a hideous whining noise [...] No signs of voluntary motions appeared, and the mother had less feeling of the child in utero, than in her former pregnancy.³⁹

From such a case, Lawrence explained, one may deduce that the coordination of functions including nutrition, excretion and voluntary motion – but excluding respiration, vocalisation, and growth – are localised in the portion of the brain disrupted.

Abernethy, unlike Lawrence, invoked an immaterial principle of vitality pervading the organism. However, this was seemingly no deterrent to believing that vital functions could be mapped to specific structures and organs. Indeed, Abernethy explained that, ‘[a]s what is deemed the complexity of animal life increases, we find distinct organs allotted for each of these functions’. He later instructs his audience that ‘it is generally believed that all sensation is in the brain, and that all volition proceeds from that organ’.⁴⁰ He mobilised various empirical results supporting the conclusion that the brain is the seat of volition, including ‘that the perceptions and intellect of animals increase in proportion as the brain becomes larger and more complex’, and the observation that, ‘[i]f a certain degree of pressure be made upon the brain, both feeling and voluntary motion cease whilst it continues and return when it is removed’.⁴¹ Epitomising Abernethy’s conception of anatomical knowledge, and its standing relative to the high theorising of physiology, he starts from the basis of localising volition in the brain, and argues henceforth for the existence of a subtle, vital fluid:

If then it be admitted that sensation exists in the brain, and that volition proceeds from that organ, it necessarily follows that motions must be transmitted to and from along the nervous chords, whenever they take place [...] Physiologists were

therefore led to conjecture that the nervous fibrils were tubular, and that they contained a subtile fluid, by means of which such motions were transmitted.⁴²

Both men, then, preached and practised localisation in research. However, only in Lawrence's case was the resultant anatomical knowledge invoked to ground his physiology on a strongly observable and empirical bedrock. For Abernethy, anatomical knowledge was a springboard for conjectural hypothesising.

For Lawrence, the facts of comparative anatomy made clear and obvious the conclusion that life relies upon organisation, even in the somewhat controversial case of mental processes. If it was not the brain that performed our mental functions, but rather an immaterial principle attached to or housed within it, then why, Lawrence mused, is the former so large and complex? If the brain itself is redundant with respect to mental processes, then the fact it is 'better fed, clothed, and lodged than any other part, and has less to do' is quite inexplicable.⁴³ Moreover, the tight correlation of mental powers and cerebral size and complexity throughout the 'great chain of being' represented, for Lawrence, anatomical facts demonstrating the importance of organisation to vital functions. True, most vital functions are present throughout the living kingdom, in creatures of disparate organisation. However, Lawrence emphasised that these properties of life were manifested to degrees and levels of perfection that varied just as widely, and importantly, in a manner that correlated with organisational gradations. The 'bare facts' of anatomy, were employed by both Abernethy and Lawrence; by the former to downplay the centrality of organisation, and by the latter to uphold it.

Localisation was a tool of Cunningham's 'old-anatomist'. Lawrence rarely departed from the programme of general anatomy forwarded by his idol, Xavier Bichat, who desired what Jacyna has described as 'a topographical or natural-historical account of tissues to which was subjoined an analysis of their vital properties'.⁴⁴ Lawrence, like Bichat, was content to rest his doctrine on a level that he saw as, at least presently, irreducible:

To say that irritability is a property of living muscular fibres, is merely equivalent to the assertion, that such fibres have in all cases possessed the power of contraction. What then is the cause of irritability? I do not know, and cannot conjecture.⁴⁵

Lawrence professed a strong disinclination to going beyond anatomical facts; he might be read as an ultra-empiricist ‘old-physiologist’. His physiology was ‘shackled’ by anatomy. The divergence between his and Abernethy’s approach is clear, and concerned the extent of each man’s empiricism; how far they were willing to conjecture, to physiologise, beyond anatomical facts. For the most part, Lawrence merely anatomised; he localised vital functions, classifying tissues by their status as the seat of a particular vital property. His physiology did not go much further, nor did he desire it to. For Abernethy, however, a physiology overly shackled by anatomy simply did not tell us enough of interest about the workings of organisms.

Because of this divergence, Lawrence and Abernethy reached an impasse when seeking to elucidate the causes of vital phenomena. Lawrence entertained a ‘constant-conjunction’ view of causation.⁴⁶ He wrote in his Introduction to Comparative Anatomy and Physiology that:

Experience can only exhibit the order and rule of succession of the phenomena, which indicate the action of the cause. When one event is observed constantly to precede another, the first of these is called cause, and the latter effect; and we believe that the preceding event has a power of producing that which succeeds; although, in reality, we know only the fact of succession.⁴⁷

With such a humble epistemology of causation in place, there was little opportunity for Lawrence’s physiological speculations to roam too far from anatomical matters-of-fact. But what was for Lawrence a safeguard against unfounded conjecture represented for Abernethy a restrictive shackle upon knowledge-making. Abernethy despaired:

If ... [Lawrence and other such thinkers] mean to insinuate, that we have no knowledge of cause or effect beyond that which results from mere observation, they publish at the same time, a libel on the human understanding; a prohibition to rational enquiry, and a most severe satire, on themselves.⁴⁸

Certain of the ‘common-sense’ Scottish philosophers to whom Lawrence owed so much were also at this time beginning to recognise within science a constructive role for analogy and hypothesis.⁴⁹ Unlike the constant-conjunction view of causation, this latter development was one which Abernethy could get firmly behind:

[F]ormation of an hypothesis excites us to enquiries, which may either confirm or confute our conjectures; and which may, by enabling us to discover the deficient facts, convert our hypothesis into a theory.⁵⁰

Indeed, Abernethy thought it

highly probable that it was [Hunter's] hypothesis respecting life which incited him to enquiries by which he has been able to supply the deficient facts, so as to establish his conjectures, or convert his hypothesis into a theory.⁵¹

Hypothesising, for Abernethy, was a justified movement beyond the facts; only through conjecture can we drive our researches forward and learn new things from enquiries we might not otherwise have considered pursuing. Lawrence was not wholly opposed to hypotheses, but only thought them warranted when

they are adduced with the array of philosophical deduction, because they involve suppositions without any ground in observation or experience, the only sources of our information on these subjects.⁵²

Lawrence's attitude left open the possibility that vital spirits could be employed as a heuristic principle for guiding research, though he rightly interpreted Abernethy as wanting his vital principle to do much more.⁵³

The elder surgeon's hypothesising was analogy-driven, and it provoked some of Lawrence's most devastating retorts. Abernethy habitually compared his vital principle with the mysterious force of electricity, also purported to operate via a subtle and mobile fluid, urging his audience that, '[t]he phænomena of life and electricity correspond'.⁵⁴ Choosing a vital property that the Swiss anatomist Albrecht von Haller had localised in muscular tissue, irritability, for comparison with the electrical force, Abernethy argued that '[t]he motions of electricity are characterized by their celerity and force; so are the motions of irritability. The motions of electricity are vibratory; so likewise are those of irritability'.⁵⁵ Abernethy took great heart from Humphry Davy's recent work in electrochemistry, believing that the great chemist had 'solved the great and long hidden mystery of chemical attraction', showing its dependence upon 'the electric properties which the atoms of different species of matter possess'.⁵⁶ The bearing of these conclusions upon Abernethy's case was indirect. He believed they showed that electricity, this subtle and powerful principle, was pervasive

in nature, ‘and that it enters into the composition of everything, inanimate or animate’.⁵⁷ Hence, he reasoned, electricity or something similar, ‘pervades organized bodies’ and produces the vital processes within them, as electricity underpins the chemical changes undergone by inanimate matter.⁵⁸ Analogy, for Abernethy, pointed to the probability and rationality of his theory of life.

Lawrence ridiculed his adversary’s approach:

To make the matter more intelligible, this vital principle is compared to magnetism, to electricity, and to galvanism; or it is roundly stated to be oxygen. ’Tis like a camel, or like a whale, or like what you please.⁵⁹

These analogies, Lawrence maintained, did not enlighten: the nature of electricity was as mysterious as that of any purported vital principle. Moreover, the analogies proposed were without foundation. For Lawrence, ‘[i]dentity or similarity of cause can only be inferred from identity or resemblance of effect’, but vital processes like digestion, growth, and sensibility differ vastly from the effects of the electrical force.⁶⁰ Abernethy’s analogical flourishes represented moves which Lawrence’s philosophy simply did not permit; going beyond the observable anatomical facts. According to the received perspective, Lawrence’s distaste for Abernethy’s vital principle had its foundations in morals and politics. It is true, one of his objections to a ‘vital principle’ was its supposed affirmation of a transcendental power controlling human freedom; it was intended to ‘impose a restraint upon vice stronger than Bow street or the Old Bailey can apply’.⁶¹ However, it is equally clear that the invocation of a subtle, immaterial agent of vitality violated many of the rules bounding what was, for Lawrence, proper physiologising.

Taking Cunningham’s lead, I have asked what light the roles of anatomy and physiology can shed on the Abernethy–Lawrence affair. We have seen that our two authors’ conceptions of the scope of anatomical and physiological practices significantly diverged, in ways which illuminate the discrepancy in their respective accounts of life. The works of these men differ in the degree to which they exhibit what Cunningham suggests was the relationship between the ‘old’ styles of anatomy and physiology. Abernethy’s propensity to hypothesise and analogise meant he deviated from the ideal of a physiology based exclusively upon anatomical fact. Abernethy was willing to go further beyond the brute facts than Lawrence’s strict empiricism would allow. The Cunningham-inspired perspective pursued here has led us to consider issues neglected by the

received social-contextualisation perspective, as well as telling us useful things about Cunningham's framework itself. The final section discusses these various fruits of pluralising our perspectives upon the Abernethy–Lawrence case.

Section 4. A Productive Pluralism

At the close of section 2, we saw Karl Figlio accuse the received perspective of overemphasising national differences, with Abernethy and Lawrence painted as Francophobe and Francophile, respectively. I also suggested that certain aspects of Abernethy's principle-vitalism cause problems for interpreting his doctrine as consonant with conservative politics and orthodox Christianity. The upshot was that social, political, and religious considerations – upon which the received perspective focuses – are alone insufficient to fully capture Abernethy and Lawrence's disagreement over the nature of life. This is unsurprising, I suggest, because HS – like the science it investigates – is perspectival. Recent movements in PS acknowledge the perspectival nature of our knowledge-making practices, and thus recommend we pluralise our perspectives. We should do the same in HS. The resultant historiographical pluralism differs from existing calls for pluralism in HS; it is not simply a matter of tolerating and maintaining various methodological approaches within our discipline more broadly, but rather actively and consciously training a variety of such approaches upon particular episodes, in order to yield multiple perspectives. Besides gaining greater 'completeness' in our historical understanding of an episode, the potential benefits of my approach are several, including: (A) problematising our existing historiographical categories; (B) alerting us to new and interesting questions not obvious from other perspectives; (C) exposing errors or mischaracterisations made by other perspectives. Additionally, there is the reflexive benefit that, (D) via application to known cases in the history of science, we can develop and improve the adopted framework itself. By way of concluding this chapter, I will show how each benefit is manifested in our perspectival re-exploration of the Abernethy–Lawrence affair.

Our chosen perspective has trained our attention upon the ways in which each man thought about the proper scope, methods, and aims of the disciplines they practiced, as well as the relationship between them. In turn, this has led us to explore the competing epistemologies and notions of causation at play in the debate. It turns out that a coherent, illuminating account of the disagreement

between these practitioners can be offered at this level. To tell such a story does not, however, invalidate those already told at the level of the political, the social, and the religious. Rather than competing, we can view these different perspectives as complementary. The fact that Abernethy and Lawrence held differing epistemological commitments, including the proper relations they perceived to exist between anatomical and physiological practices, does not at all suggest that their political and religious differences were inconsequential. Indeed, further investigation may reveal interesting interrelationships between these two sets of considerations (Benefit B). Confessedly, Cunningham's pen-and-sword framework purposefully paints the state of 'old-anatomy' and 'old-physiology' in a 'somewhat static way', in order to emphasise the contrast with what came after.⁶² Thus, Cunningham underplays the heterogeneity within these disciplines, and in the relations between them. The case of Abernethy and Lawrence – figures united geographically, temporally and institutionally, but who nevertheless negotiated the relations of anatomy and physiology quite differently – can add some welcome nuance of a quite subtle kind to Cunningham's framework (Benefit D).

The perspectival account I have offered also highlights certain errors or mischaracterisations in the received accounts (Benefit C). As we saw, Lawrence sought to localise vital functions in particular tissues, and go no further; upon the causes of the functions, he could 'not conjecture'. He elaborated at length his views upon the properties of living and non-living matter, specifying that the former is

governed by physical laws, such as attraction, gravitation, chemical affinity; and it exhibits physical properties, such as cohesion, elasticity, divisibility, &c. Living matter also exhibits these properties, and is subject in great measure to physical laws.

So far, so standard from a man accused by his contemporaries of physicalist-materialism. But he continues:

But living bodies are endowed moreover with a set of properties altogether different from these, and contrasting with them very remarkably.⁶³

Indeed, Lawrence frequently derided crude attempts by some physiologists to reduce vital processes to mathematics and the physical sciences:

One estimated the force of the heart as equal to 180,000lbs.; another reduced it to 8oz.; and both these conclusions are deduced from reasonings clothed in all the imposing forms of the exact sciences.⁶⁴

It is unsurprising, given the socio-political milieu explored in the received perspective, to find Lawrence's views misrepresented by politically-motivated conservative quarterlies. More recent commentators, though, are also guilty of misreading Lawrence along similar lines. Adrian Desmond, for instance, explains that Lawrence 'believed that the ordinary laws of physics and chemistry were quite adequate to explain this life-giving organization'.⁶⁵ This mischaracterisation is puzzling in light of the quotations given just above, in which Lawrence explicitly details his anti-reductionism concerning vital phenomena. But such are the subtle hazards that come with Desmond's ambitious perspective, seeking as it does to contextualise thinkers within the broad political, social and religious tensions of their time. If Abernethy's political conservatism and patriotism are wedded to his vitalism, Lawrence's perceived radicalism and Francophilia might push us too far in interpreting his doctrines as reductionist and materialist. The perspective explored in this chapter, which encourages close engagement with the philosophies and methodologies subscribed to by our historical figures of interest, guards against the kind of error made by Desmond (though it surely leaves us exposed to many others of a different nature).

Given our augmented understanding of Lawrence's position, we can be confident that, by any measure, it was a 'vitalist' one. As we have seen, he conceived of vital functions as residing irreducibly in particular tissues of the body. Living matter was distinct from ordinary physical matter. But in view of Lawrence's vitalism, the fact that both he and his adversary – who differed so significantly – are united under the 'vitalist' label certainly puts pressure on its historiographical utility. In the 1970s, Edward Benton proposed that, instead of labelling thinkers as 'vitalists', 'mechanists', or whatever, based upon a superficial glance at the opinions they professed in print, we produce a scheme in which 'vitalist' theories are classified according to variance along the 'dimensions' of: epistemological scepticism; the formal character of the explanations they propose; the fields of study in which different sorts of vitalist explanations were proposed, etc.⁶⁶

More than forty years on, and despite some efforts in this direction, we are still without such a scheme.⁶⁷ The entry on ‘Materialism and Vitalism’ in *The Oxford Companion to the History of Modern Science* is symptomatic of our failings, as we hear that ‘[m]aterialists make the ultimate principles matter and motion; vitalists, the soul or an irreducible life force’.⁶⁸ Certainly there is no room for Lawrence in this dichotomous characterisation. Hasok Chang has suggested that, when we are without ‘ready-made philosophical concepts through which a given historical episode can be properly understood, the historian needs to craft new abstract philosophical concepts’.⁶⁹ The perspective adopted in this chapter has not been productive enough to provide such concepts, but it has certainly underscored our need for them (Benefit A).

The kind of interplay between HS and PS forwarded in this chapter adds to the variety already advocated in the iHPS literature. Arabatzis’ exploration of the benefits of integrating PS into historical work, focuses upon issues ‘internal’ to the process of writing HS in particular cases. My complementary suggestion holds that lessons from PS can be integrated into HS ‘externally’ to the particularities of any case-study; PS can guide our choice of case-studies, the methodologies we adopt in studying them, and open our eyes to new possibilities concerning the kinds of lessons we stand to learn from such studies. The lessons PS teaches us about the nature of science and its practice can fruitfully inform our practices in HS.

This chapter began with Kinzel’s discussion of historiographical pluralism in HS. Guiding her analysis was the assumption that pluralism in our historical accounts of scientific episodes is an obstacle to be overcome – eradicated so far as is possible – in the pursuit of (the one) historical truth. By reflecting on the lessons of the perspectivism movement in PS, and applying those lessons to a historical case-study, I have contended that historiographical pluralism is – far from something we simply ‘have to live with’⁷⁰ – something we should actively cultivate. This conclusion should be especially welcome in a volume devoted to iHPS, as the attempt to integrate HS and PS is itself an alternative to mainstream modes of doing the History of Science (and the Philosophy of Science, for that matter). It is an alternative approach for which, in spite of suspicion from some quarters, my call for historiographical pluralism makes ample room. Furthermore, even within this small snapshot of iHPS scholarship, we can notice a great plurality of methods, approaches, and perspectives. I hope I am correct in suggesting that my fellow contributors do not wish that their

own (perspectival) approach – however productive it might be – straightforwardly replace other approaches to understanding science, but rather that our wealth of perspectives may complement, rather than compete with, one another.

¹ Some, though, question whether any philosophical lessons can be drawn from historical case-studies. For discussion of these issues, see: Joseph C. Pitt, 'The Dilemma of Case-studies: Toward a Heraclitian Philosophy of Science', *Perspectives on Science*, 9.4 (2001) 373-382; Jutta Schickore, 'More Thoughts on HPS: Another 20 Years Later', *Perspectives on Science*, 19.4 (2011) 453-481; cf. Katherina Kinzel, 'Narrative and Evidence: How can Case Studies from the History of Science Support Claims in the Philosophy of Science?', *Studies in History and Philosophy of Science Part A*, 49 (2015) 48-57.

² Theodore Arabatzis, 'What's in It for the Historian of Science? Reflections on the Value of Philosophy of Science for History of Science', *International Studies in the Philosophy of Science*, 31.1 (2017) 69-82.

³ *Ibid.*, p. 69.

⁴ Katherina Kinzel, 'Pluralism in Historiography: A Case Study of Case Studies', in *The Philosophy of Historical Case Studies*, ed. by T. Sauer and R. Scholl (Dordrecht: Springer, 2016) pp. 123-149 (p. 146).

⁵ Stephen Kellert, Helen Longino and Kenneth Waters, eds, *Scientific Pluralism* (Minneapolis; London: University of Minnesota Press, 2006); Hasok Chang, 'Cultivating Contingency: A Case for Scientific Pluralism', in *Science as It Could Have Been: Discussing the Contingency/Inevitability Problem*, ed. by L. Soler, E. Trizio, and A. Pickering (Pittsburgh: University of Pittsburgh Press, 2015) pp. 359-382. Wonyong Park and Jinwoong Song's chapter in the present volume explores how scientific pluralism can be beneficially mobilised in science education.

⁶ Ronald Giere is the main advocate of perspectivism. See Giere, *Scientific Perspectivism* (Chicago: University of Chicago Press, 2006).

⁷ Ronald Giere, 'Perspectival Pluralism', in Kellert et al., *Scientific Pluralism*, pp. 26-41.

⁸ Michela Massimi, 'Perspectivism', in *The Routledge Handbook of Scientific Realism*, ed. by J. Saatsi (London; New York: Routledge, 2018) pp. 164-175 (p. 165).

⁹ David Hull, 'Testing Philosophical Claims about Science', In *PSA: Proceedings of the Biennial Meeting of the Philosophy of Science Association Vol. 2* (Chicago: University of Chicago Press, 1992) pp. 468-475 (p. 472).

¹⁰ Kinzel's examples include Harry Collins and Allan Franklin's alternative accounts of efforts to detect gravitational waves, and Alan Musgrave and Hasok Chang's differing reconstructions of the Chemical Revolution; Kinzel, 'Pluralism in Historiography', Section 7.3.

¹¹ During the preparation of this volume, two articles appeared whose recommendations are happily consilient with my own, though arrived at and elaborated in interestingly different ways. See: María del Rosario Martínez-Ordaz and Luis Estrada-González, 'May the Reinforcement Be with You: On the Reconstruction of Scientific Episodes', *Journal of the Philosophy of History*, 12.2 (2018) 259-283; Adrian Currie and Kirsten Walsh, 'Frameworks for Historians & Philosophers', *HOPOS: The Journal of the International Society for the History of Philosophy of Science* (2018 [online, ahead of print]), <https://doi.org/10.1086/699797>.

¹² Robert Fox, 'Fashioning the Discipline: History of Science in the European Intellectual Tradition', *Minerva*, 44 (2006) 410-432 (p. 412).

¹³ Hasok Chang has urged that '[t]here is much to be gained from a pluralist retelling of even those historical episodes that are widely considered to have been "done to death" already'; 'Cultivating Contingency', p. 380. His active pluralism consists in writing careful histories of the 'losers' in scientific controversies rather than simply celebrating the winners, and combatting the focus upon 'consensus points and explanations of closure'. To the extent that we can view these as alternative 'perspectives', Chang's program can be easily accommodated within my own. I owe to Chang the 'done to death' phrase in the title of this chapter. Klodian Coko's historicist-hermeneutic study of Jean Perrin's famed molecular work (in the preceding chapter of the present volume) well exemplifies the benefits of training new perspectives upon much-studied episodes from the History of Science.

¹⁴ John Abernethy, *An Enquiry into the Probability and Rationality of Mr. Hunter's Theory of Life*, being the Subject of the first two Anatomical Lectures delivered before the Royal College of Surgeons of London (London: Longman, Hurst, Rees, Orme and Brown, 1814); On John Hunter's influence in the period, see Stephen Jacyna, 'Images of John Hunter in the Nineteenth Century', *History of Science*, 21.1 (1983) 85-108; On teaching practices in this period, see Pauline Mazumdar, 'Anatomy, Physiology, and Surgery: Physiology Teaching in Early Nineteenth-Century London', *Canadian Bulletin of Medical History*, 4.2 (1987) 119-143.

¹⁵ On ether-theories, see Geoffrey N. Cantor and M. J. S. Hodge, eds, *Conceptions of Ether: Studies in the History of Ether Theories, 1740-1900* (Cambridge; New York: Cambridge University Press, 1981)

¹⁶ William Lawrence, *An Introduction to Comparative Anatomy and Physiology: Being the Two Introductory Lectures Delivered at the Royal College of Surgeons* (London: J. Callow, 1816).

¹⁷ Stephen Jacyna, 'Romantic thought and the origins of cell theory', in *Romanticism and the Sciences*, ed. by Nicholas Jardine and Andrew Cunningham (Cambridge: Cambridge University Press, 1990) pp. 161-168.

¹⁸ Abernethy, *Physiological Lectures*, exhibiting a General View of Mr. Hunter's Physiology and of his Researches in Comparative Anatomy, delivered before the Royal College of Surgeons (London: Longman, Hurst, Rees, Orme

and Brown, 1817); Lawrence, *Lectures on Physiology, Zoology, and the Natural History of Man*, delivered at the Royal College of Surgeons (London: J. Callow, 1819).

This latter work has been analysed in some detail, with a particular focus on Lawrence's views on biological inheritance; Kentwood D. Wells, 'Sir William Lawrence (1783-1867): A Study of Pre-Darwinian Ideas on Heredity and Variation', *Journal of the History of Biology*, 4.2 (1971) 319-361.

¹⁹ George, D'Oyley 'Abernethy, Lawrence &c. on the Theories of Life', *The Quarterly Review* (July 1819), vol. 22 (London: John Murray, 1820) pp. 1-34 (pp. 6, 5).

The accusation of 'materialism' seems misplaced, given that Lawrence's Bichatian approach was in truth a variety of vitalism, as I discuss in section 4.

²⁰ Philostratus (Foster of Chelmsford), *Somatopsychonologia*, Showing that Body, Life and Mind Considered as Distinct Essences cannot be Deduced from Physiology (London: R. Hunter, 1823) p. 116.

²¹ June Goodfield-Toulmin, 'Blasphemy and Biology', *The Rockefeller University Review* 4 (1966), 9-18; 'Some Aspects of English physiology: 1780-1840', *Journal of the History of Biology*, 2.2 (1969) pp. 283-320; Owsei Temkin, 'Basic Science, Medicine, and the Romantic Era', *Bulletin of the History of Medicine*, 37 (1963) 97-129; Stephen Jacyna, 'Immanence or Transcendence: Theories of Life and Organization in Britain, 1790-1835', *Isis*, 74.3 (1983) 311-329; Adrian Desmond, 'Artisan Resistance and Evolution in Britain, 1819-1848', *Osiris*, 3 (1987) 77-110; *The Politics of Evolution: Morphology, Medicine, and Reform in Radical London* (Chicago; London: Chicago University Press, 1989).

²² Jacyna, 'Immanence or Transcendence', p. 311.

²³ For example, Sharon Ruston, *Shelley and Vitality* (Basingstoke: Palgrave-Macmillan, 2005) p. 2.

²⁴ Karl Figlio, 'The Metaphor of Organization: An Historiographical Perspective on the Bio-Medical Sciences of the Early Nineteenth Century', *History of Science*, 14 (1976) 17-53 (p. 20).

²⁵ *Ibid.*, pp. 33-38, 33.

²⁶ J.R.R. Christie, 'Ether and the Science of Chemistry: 1740-1790', in *Conceptions of Ether*, ed. by Geoffrey N. Cantor and M. J. S. Hodge (Cambridge; New York: Cambridge University Press, 1981) pp. 85-110 (p. 94).

²⁷ Iwan Rhys Morus, *Shocking Bodies: Life, Death and Electricity in Victorian Britain* (Stroud: The History Press, 2011) pp. 32-38.

²⁸ One could of course pursue a multiplicity of other perspectives. Another more 'philosophical' option would be to conceive the affair as, at base, a dispute over scientific explanation; in this case, how best to explain the relationship between organised bodies and the vital phenomena they exhibit. It may turn out that our current philosophical concepts of scientific explanation can capture Abernethy and Lawrence's disagreement in illuminating ways (which fall outside of the aims or possibilities of the social-historical perspective summarised above). If not, iHPS scholars might follow Hasok Chang's suggestion essay that, when we are without 'ready-made philosophical concepts through which a given historical episode can be properly understood, the historian needs to craft new abstract philosophical concepts'; 'Beyond Case-Studies: History as Philosophy', In *Integrating History and Philosophy of Science: Problems and Prospects*, ed. by Seymour Mauskopf and Tad Schmaltz (Dordrecht: Springer, 2012) pp. 109-124 (p. 111).

²⁹ For criticism of Cunningham's framework, see Carin Berkowitz's review of his *The Anatomist Anatomis'd* for the *British Journal for the History of Science*, 44.2 (2011) 291-293.

³⁰ Andrew Cunningham, 'The Pen and the Sword: Recovering the Disciplinary Identity of Physiology and Anatomy Before 1800: I: Old Physiology—The Pen', *Studies in History and Philosophy of Biological and Biomedical Sciences*, 33.4 (2002) 631-665; '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*, 34.1 (2003) 51-76; *The Anatomist Anatomis'd: An Experimental Discipline in Enlightenment Europe* (Farnham: Ashgate, 2010).

³¹ Cunningham, *The Anatomist Anatomis'd*, p. 157.

³² *Ibid.*, p. 372.

³³ *Ibid.*, p. 371.

³⁴ Lawrence, *Lectures*, p. 8.

³⁵ Abernethy, *Physiological Lectures*, p. 5.

³⁶ William Bynum, 'The Anatomical Method, Natural Theology, and the Functions of the Brain', *Isis*, 64.4 (1973) 445-468 (p. 445).

³⁷ Lawrence, 'Monsters', in *The Cyclopaedia: or, Universal Dictionary of Arts, Sciences, and Literature*, Vol. 24, ed. by Abraham Rees. (London: Longman, Hurst, Rees, Orme & Brown, 1819) pp. 1-16 (p. 1).

³⁸ *Ibid.*, p. 8.

³⁹ *Ibid.*, pp. 7-8.

⁴⁰ Abernethy, *Enquiry*, p. 46.

⁴¹ *Ibid.*, pp. 65, 67.

⁴² *Ibid.*, pp. 67-68.

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- ⁴³ Lawrence, Introduction, p. 106.
- ⁴⁴ Jacyna, 'Origins of cell theory', p. 162.
- ⁴⁵ Lawrence, Lectures, pp. 81-82.
- ⁴⁶ Lawrence's view of causation was inspired by the Scottish common-sense school, particularly Thomas Brown's, *Inquiry into the Relation of Cause and Effect*, 3rd edn (Edinburgh: Archibald Constable & Co., 1818); Lawrence's debt to Brown is evinced by a lengthy footnote on p. 78 of his Lectures.
- ⁴⁷ Lawrence, Introduction, p. 149.
- ⁴⁸ Abernethy, *Physiological Lectures*, p. 97.
- ⁴⁹ Richard Olson, *Scottish Philosophy and British Physics, 1750-1880: A Study in the Foundations of the Victorian Scientific Style* (Princeton, N. J.: Princeton University Press, 1975) p. 96.
- ⁵⁰ Abernethy, *Enquiry*, p. 8.
- ⁵¹ *Ibid.*, p. 13.
- ⁵² Lawrence, Introduction, p. 177.
- ⁵³ On vital spirits as heuristic principles, see: James Larson, 'Vital forces: Regulative Principles or Constitutive Agents? A Strategy in German Physiology, 1786-1802', *Isis*, 70.2 (1979) 235-249.
- ⁵⁴ Abernethy, *Enquiry*, p. 42.
- ⁵⁵ *Ibid.*, p. 48.
- ⁵⁶ *Ibid.*, p. 48.
- ⁵⁷ *Ibid.*, p. 49.
- ⁵⁸ *Ibid.*, p. 51.
- ⁵⁹ Lawrence, Introduction, p. 169.
- ⁶⁰ *Ibid.*, p. 171.
- ⁶¹ Lawrence, Lectures, p. 10.
- ⁶² Cunningham, *The Anatomist Anatomis'd*, p. xxi.
- ⁶³ Lawrence, Introduction, p. 121, emphasis added.
- ⁶⁴ *Ibid.*, p. 72, emphasis added.
- ⁶⁵ Desmond, *Politics of Evolution*, p. 117.
- ⁶⁶ Edward Benton, 'Vitalism in Nineteenth-Century Scientific Thought: A Typology and Reassessment', *Studies in History and Philosophy of Science Part A*, 5.1 (1974) 17-48 (pp. 21-23).
- ⁶⁷ See, for example, the work of Charles Wolfe, especially: 'From Substantial to Functional Vitalism and Beyond: Animas, Organisms and Attitudes', *Eidos*, 14 (2011) 212-235; 'Varieties of Vital Materialism', in *The New Politics of Materialism: History, Philosophy, Science*, ed. by S. Ellenzweig and J. H. Zammito (London; New York: Routledge, 2017) pp. 44-65.
- ⁶⁸ Kathleen Wellman, 'Materialism and Vitalism', in *The Oxford Companion to the History of Modern Science*, ed. by J. H. Heilbron (Oxford: Oxford University Press, 2003) pp. 490-491.
- ⁶⁹ Chang, 'Beyond Case-Studies', p. 111.
- ⁷⁰ Kinzel, 'Pluralism in Historiography', p. 146.

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