Ben Woodard

Slime on a Wire

In 1853, the aging brig *USS Dolphin*, under the command of Otway Henry Berryman, tested the depths of the sea in a region of the North Atlantic. Dragging a partially hollowed cannonball fitted with hooks – a custom device designed by the military engineer John Mercer Brooke – across a great swath of the bottom of the ocean in a method called sounding, the crew mapped a massive and (supposedly) flat region previously studied by the American oceanographer Matthew Fontaine Maury. Berryman found the region far more geologically uneven than Maury had believed, much to the latter's displeasure. In 1857, at Maury's request, the British *HMS Cyclops* expanded the search, and in its soundings supported Maury's earlier claim of flatness. Thus the region kept its name: Telegraph Plateau. Captain Dayman of the *Cyclops,* who was also instructed to take samples for scientific research, reported a curious sludge on the sounding device's rope.

Soon after, the first of many attempts to construct a transatlantic telegraph cable began as a joint venture between the US, Canada, and England, funded largely by Cyrus West Field, an American businessperson who had been consolidating telegraph companies for years. The project had a short-term success lasting just over a month in 1858, followed later by a redesign and many more failures. The construction drama involved the support of elaborate economic syndicates and drew notable physicists such as Lord Kelvin into its service. Differing ideas about the proper design and operation (in terms of power level, construction materials, signal detection) and ever higher costs finally led to the completion of a fully functioning cable in 1866.[1] The endeavor combined industrial and naval feats and made large contributions to marine exploration, physics, and global politics (especially the military reach of the British Empire), including many shared congratulations, such as between Queen Victoria and President Buchanan.[2]

The cable also casts a peculiar shadow over the stock understanding of the conceptual links between physics and biology, as defined in the era of Darwin's rise to prominence. The typical historicization is that biology had begun to describe organisms in terms increasingly amenable to physics – that mechanical explanations took over materialist ones. Yet the historical episode of the telegraph exposes the more dialectic nature of the relation between materialism and mechanism as epistemological programs within the nascent science of biology and how biology in turn affected physics. In the nineteenth century, materialism was defined negatively as the refusal of nonnatural or irrational explanations of materially existent

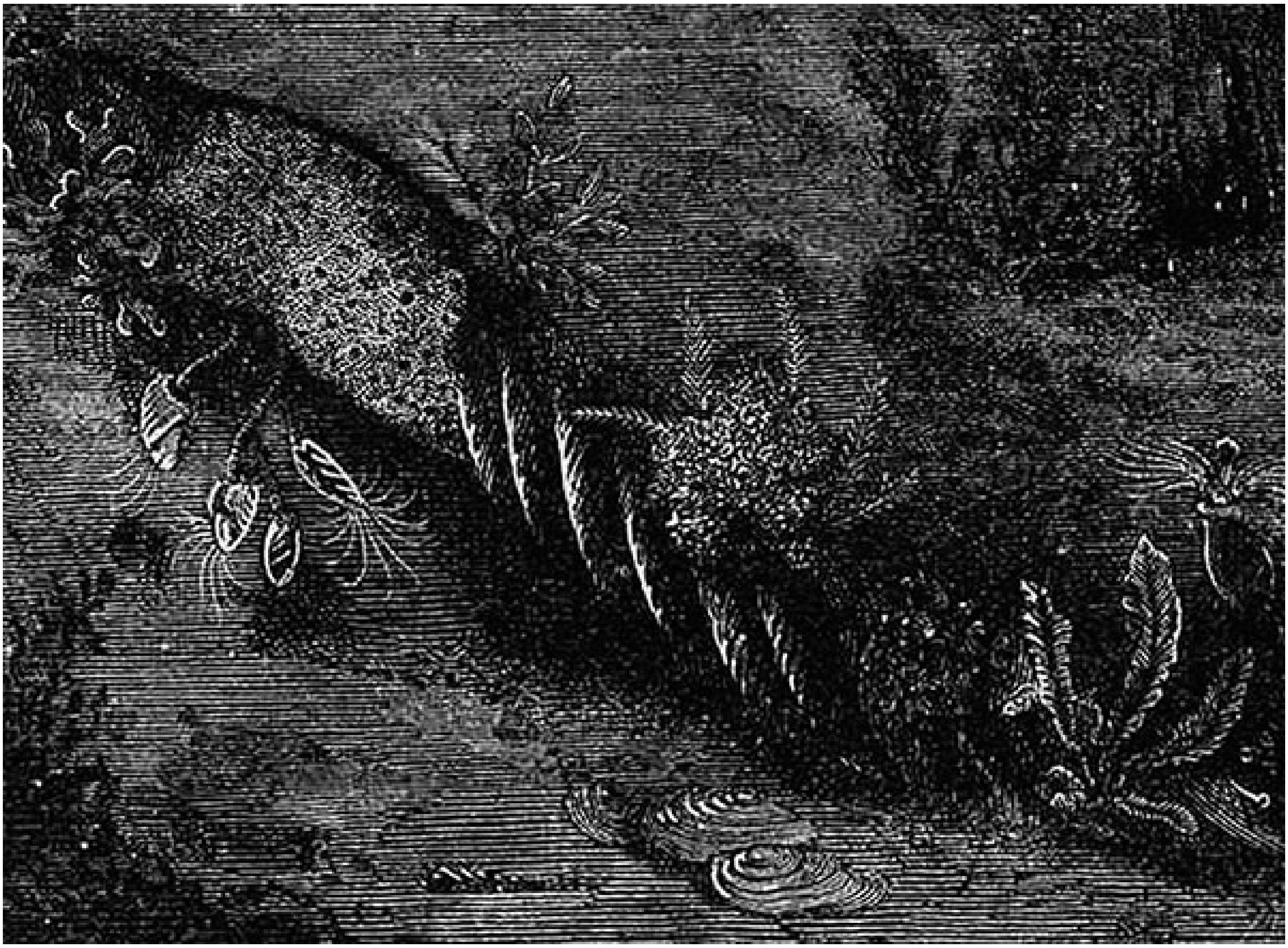


Illustration of a Sonrel, Leon (1872) *Bottom of the Sea*, New York City, NY: Scribner, Armstrong & Co. Image: Public Domain/Freshwater and Marine Image Bank, University of Washington.

phenomena, while mechanists believed living things were composed of interdependent recognizable parts externally moved and motivated. Both materialism and mechanism attempted to slip between the long-standing rationalist and empiricist conceptions of the sciences, between the authority of hypothetical inquiry and that of experimental result. But beyond this general orientation, the historical approaches to these epistemologies have diverged significantly over time, especially as they apply to living phenomena.

Historian Jessica Riskin's 2016 *The Restless Clock* impressively demonstrates that for Descartes and those that preceded him, adhering to mechanism (via rationalism) did not mean to deprive organisms of life. Machinery implied a designer and that designer was either divine (the God of Christianity) or inspired by the divine (the rational soul). For Descartes, describing organisms as machines expressed the need to isolate the rationality of the soul from the sensitivity of the body in order to shift to a mechanistic *method* of science. The extended physical world could be parsed and understood, while the unextended rational mind could not, since it was not only god-given (and hence immaterial) but needed to be separate enough from the body in order to think the extended world rationally.[3] Descartes's famous doubt (how do I know I see what I think I see?) is the basic claim for the necessity of separating rationality from materiality in this way.

Following Cartesian rationalism, a swath of systematic approaches to life gave rise to biology around 1800, which then became associated with the more general principles of materialism and mechanism. *Naturphilosophical* investigations into the self-organization of matter and the dynamic movement of forces grounded materialism, while mechanism sprouted out of a rationalism freighted with teleological concerns about the capacity of living things to act spontaneously and with purpose. As biology advanced in the 1850s and '60s it became increasingly incompatible with theological articulations of life and mind, rational or not. As Riskin shows, mechanism could still be made compatible with even a "hands-off" deistic god, but materialism (especially in the form of Darwinian evolution) pressed even further against the divine – no god at all could be admitted into the natural world with its causes, forces, and matters.[4] But this did not mean Darwin accepted the strict opposition between materialism and mechanism. Darwin's great achievement was to synthesize these approaches (at least as they applied to biology) by emphasizing the materiality of inheritance (evident in variation between individuals shared in offspring) and the mechanism of competition (evident in the behaviors of populations).

But this epistemological difference is known predominantly through historical reactions to it rather than its specific positive content. Materialism invoked the wrath of the natural theologians because it submitted humans to the causal forces of nature, construing us as the evolutionary descendants of "lesser beings." Mechanism seemed to deny any purpose or inherent meaning to human existence other than the struggle for survival. While Darwin suppressed his materialist tendencies in print, T. H. Huxley, who I will discuss at length, pursued the materialist consequences of Darwinian evolution to the bottom of the sea. Huxley studied medicine and, like Darwin, spent a long sea voyage playing naturalist, as he was particularly interested in marine life. While initially unconvinced by any theory of species transformation, Huxley was immensely impressed by Darwin and was so swept up by *The Origin of Species* that he became not only a convert but a tireless defender of evolution and of Darwin. But despite this, Huxley was less interested in the complexities of variation and natural selection (the mechanistic aspect) and far more enthralled by the notion of common descent – that humans, and all other existent species, shared a common lineage.

In 1868, Huxley wrote a report on the dredging of the *Cyclops,* published in the *Quarterly Journal of Microscopial Science*. Huxley identified various new species of monera, single-celled organisms with no nucleus, sent to him from the *Cyclops*'s expedition (Captain Dayman was an old friend). Among the samples, Huxley noted an exceedingly primitive substance, which he identified as "protoplasm" (a concept first introduced by Lorenz Oken in 1802) but named, in honor of the concept's ressurector, the German biologist Ernst Haeckel, *Bathybius haeckelii*. Huxley believed this protoplasmic ooze was the basal matter of all life, that he had discovered the primordial substance proposed in various forms by the aforementioned *Naturphilosophie*.

Unfortunately Huxley made the very public error of becoming too enamored with the slime found by the *Cyclops* and therefore leaping to conclusions about its importance. In emphasizing the biological role of this generative scum, Huxley downplayed the mechanistic aspects of life, the understanding of populations, as well as the functional approach to living things. It is tempting to see Huxley's use of materialism here as the reduction of living beings to physics in such a manner that deprives them of their liveliness or vitality. But this not only contradicts Huxley's debts to physics, it also assumes a false opposition between the inorganic and the organic that Huxley never entertained.

But does Huxley's materialism, suspended between reason and evidence, allow the same object to be both epistemic and material, to be a formal explanation and a biological thing to be explained? For Huxley, protoplasm was simply the first emergence of living matter from the nonliving, the first result of abiogenesis.[5]

In "On the Physical Basis of Life" (1868) Huxley follows very much in Descartes's spirit and disentangles materialist philosophy from materialist science. While he allows that materialism in biology implies a chain of causes, he maintains that there is an empiricist limit to rational speculation, due to human ignorance surrounding the full complexity of matter. While Descartes maintains a metaphysical separation between mind and matter as part of his mechanistic methodology, for Huxley the materiality of the living world requires (albeit in a limited fashion) the divisions and categorizations of empirical science. Huxley writes:

> Protoplasm, simple or nucleated, is the formal basis of all life. It is the clay of the potter: which, bake it and paint it as he will, remains clay, separated by artifice, and not by nature, from the commonest brick or sun-dried clod. Thus it becomes clear that all living powers are cognate, and that all living forms are fundamentally of one character.[6]

Huxley asks us to imagine what could possibly be shared between beasts as colossal as whales and animalcules so small as to be invisible to the eye, and suggests that what they have in common is the most basic organic matter and the physical forces it receives, transmits, and modifies. As historian Robert Brain points out, Huxley's protoplasm is not only foundational matter (in a formal sense) but also a medium for waves of energy and of flowing biological material.[7] Brain argues that Huxley's protoplasm functioned as an epistemic object, as an experimental site for testing the boundaries between physics and biology. This is supported by Huxley's use of the word "formal" – protoplasm as the "formal basis of all life" – and yet, his remarks on the slime on the telegraph cable potentially push this particular instance of protoplasm beyond merely an epistemic form.

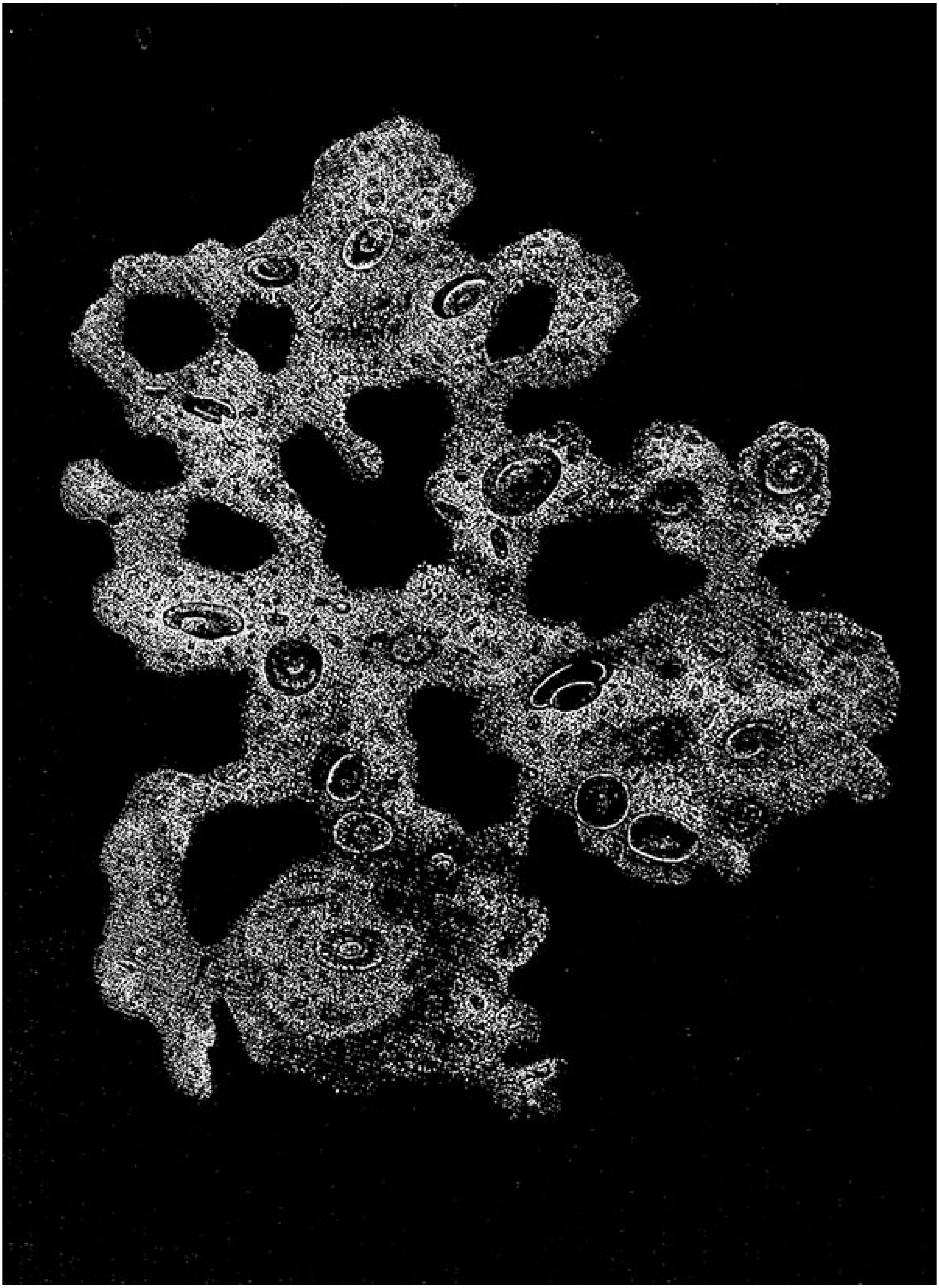
However, Huxley's identification of the substance as protoplasm was due to an experimental error, the result of an unexpected reaction between the inorganic materials scraped from the ocean floor and the preservation agent used to keep organic samples intact. In 1872, during its four years studying the seas, the *HMS Challenger* confirmed that *Bathybius haeckelii* was an inorganic byproduct that appeared alive because of the chemicals used in laboratory preservation. Huxley accepted his mistake; Haeckel did not.[8] At the time, Huxley's error was seen as a grave injury to the young discipline of evolutionary theory and it has served as a cautionary tale for attempting to explicitly ground biological claims with philosophical ones, for using outdated models of biological thinking, or for being too zealous about one's hypotheses.[9]

While Huxley admitted his laboratory error, he did not seem to see a flaw in his overall reasoning; the coincidence of an actual biology entity and a model of biological life was, according to him, a necessary avenue, in particular for studying the porosity of the membrane between the physical and the biological.[10] Over a decade after the *Bathybius haeckelii* coated the dredging lines of the *Cyclops,* Huxley continued to wonder about the possibility of protoplasm being the first form of life generated from inorganic matter. The difficulty in thinking through the problem of Huxley's slime in its historical context essentially is this: the status of a theory, or model, or form in a fully materialist biology (one that is ultimately an exchange of matter and force) must itself be the result of matter and force. Of course this could potentially be avoided if one distinguishes between materialism and mechanism (as a philosophy) and materialism and mechanisms as scientific epistemologies. But then this in turn raised the question: Which epistemic tool should one then use to make that distinction?

Mechanism's piecemeal treatment of reality – in which reality is made of separable parts, or at least treated as such – appears to better evade these difficulties above. But whereas the concept of material continuity risks error when overzealously applied, the mechanistic model contains an inverse problem. If the problem for biological materialism is the materiality of the concept or model, for the mechanistic view the problem is the choice and applicability of the model organism.

The tension between the mechanistic and the materialist approach was not apparent only in biology, but attempts to resolve it within biology showed possible solutions for problems in materials physics and electrical engineering. While the potentially primordial sludge of the soundings and dredgings may have seemed like only a byproduct of the surveys to pave the way for the telegraph's construction, it indicated a deep affinity between the electrical and the material that cut across the divide of the inorganic and the organic.

When the final and longer lasting



Thomson, C. Wyville, *Depths of the Sea: An account of the General Results of the Dredging Cruises of H.M.SS. 'Porcupine' and 'Lightning' During the Summers of 1868, 1869, and 1870 under the Scientific Direction of Dr. Carpenter, F.R.S., J.Gwyn Jeffreys, F.R.S., and Dr. Wyville Thomson, F. R. S.*, (1873). London: MacMillan and Co. Image: Public Domain/Freshwater and Marine Image Bank, University of Washington.

construction of the transatlantic cable was made in 1866, it was in no small part due to Lord Kelvin, then known by his birth name William Thomson, a British engineer and physicist who was knighted partly in thanks for the task. In particular, Thomson's use of a measuring device called the mirror galvanometer proved central. His device was a more precise update of a preexisting version constructed by Hermann von Helmholtz, which could detect minute electrical signals by receiving current that charged a coil, turning it into an electromagnet. Helmholtz's version utilized a fixed needle and was designed to measure the speed of nerve impulses. Thomson paired the electromagnet with a small mirror with magnets fixed to it, suspended on a silk string (which reduced resistance extensively). The polarity differential caused the mirror to spin, which then projected light from a lamp or other source onto an external ruler. Looking at Helmholtz's device takes us deeper into the materialism/mechanism relationship.

Helmholtz was a physicist and physician who, among his many accomplishments, spent 1849–50 attempting to measure the signal speed of nerve impulses. He did this by connecting a detached frog leg with an exposed sciatic nerve to a myograph – a device (pictured above) that Helmholtz adopted and updated to provide a demonstration and a proper measurement of the time required for a nerve impulse to travel through the muscle fibers, coupled with the effect of the reaction. The device used a fine needle attached to the exposed nerve that, when receiving the impulse given to the other end of the frog leg, caused the leg to contract and thus move the needle along a rotating glass tube that had been blackened with smoke – thus making the two lines etched by the needle easier to read.

Helmholtz's frog-writing device (as he referred to it in a letter to the physician and physiologist Emil du Bois-Reymond)[11] is part of a long history of the use of amphibians as model organisms. As the French physiologist Claude Bernard put it, the frog had long been the Job of experimental physiology.[12] At least since the experiments of Luigi Galvani and Alessandro Volta, frog bodies functioned as an experimental site and a temporal circuit, which was interpreted in terms of organically produced chemical electricity (Galvani's animal electricity) or in terms of chemical and physical energy that was thought to be independent of organic bodies (Volta's electromagnetism). Helmholtz's myograph not only measured the speed of the reaction of the frog muscle to the electrical pulse but also indexed a complex process of action and reaction, rather than a straightforward cause and effect, in the curve's rise and fall.

While the frog-writing device demonstrated the material and mechanical complexities of nerve action, it also opened a gap between forms of life as physically or materially conditioned, which ran against the notion of the frog's "neutrality" as a model organism. Namely, the results suggested that the action and perception of an organism (including temporal perception) could be conditioned by the interior fine-scaled composition as well as the bulk and mass of a living thing. This was noted by Helmholtz himself, when in a lecture titled "On the Methods of Measuring Very Small Portions of Time" (1853) he invited his audience to feel pity for the harpooned whale, who would not learn of the harpoon in its tail for a second or so after it was pierced.

Thomson and the telegraph's electrician, E. O. Whitehouse (a surgeon by training), repeated the amphibian drama between Volta and Galvani noted above about the circuit of propagation, the signal, material composition, and power level. Even before constructing his mirror galvanometer based on Helmholtz's frog machine, Thomson argued that Whitehouse's approach of increasing voltage to guarantee the telegraph signal made it across the ocean ignored the problem of noise if the cable was simply large and high-powered. Thomson proved that variations in frequency in the line would "pile up" and cause exponential interference.

In their respective mediums, both Helmholtz and Thomson argued that a purportedly continuous process of excitation or transmission was in fact saltational: a series of jumps and variegated events indicated multiple simultaneously operating processes, indexing different materials as well as different forces. In this regard, the synthesis of the mechanical and the material approaches checks the debilitating excesses of both: the continuity of material composition pushes against the limitations of mechanical focus, while the partition of living or mechanical things into components or organs emphasizes the localization of forces relative to their material grounds. In terms of their respective conceptual investments, materialism reigns in the teleological temptations of mechanism, while mechanism localizes the massively wide field of forces for materialism.

Thus the construction of the telegraph and its operation exhibit these differences not only as a engineering problem but also as concepts that have been redeployed into other fields.[13] Helmholtz embodies this place of synthesis, and it is telling that both Thomson and Huxley, who drew from his results, took from them mechanistic ramifications on the one hand (Thomson) and materialist ones on the other (Huxley). For instance, Helmholtz's reverse-engineering of the physiology of the human

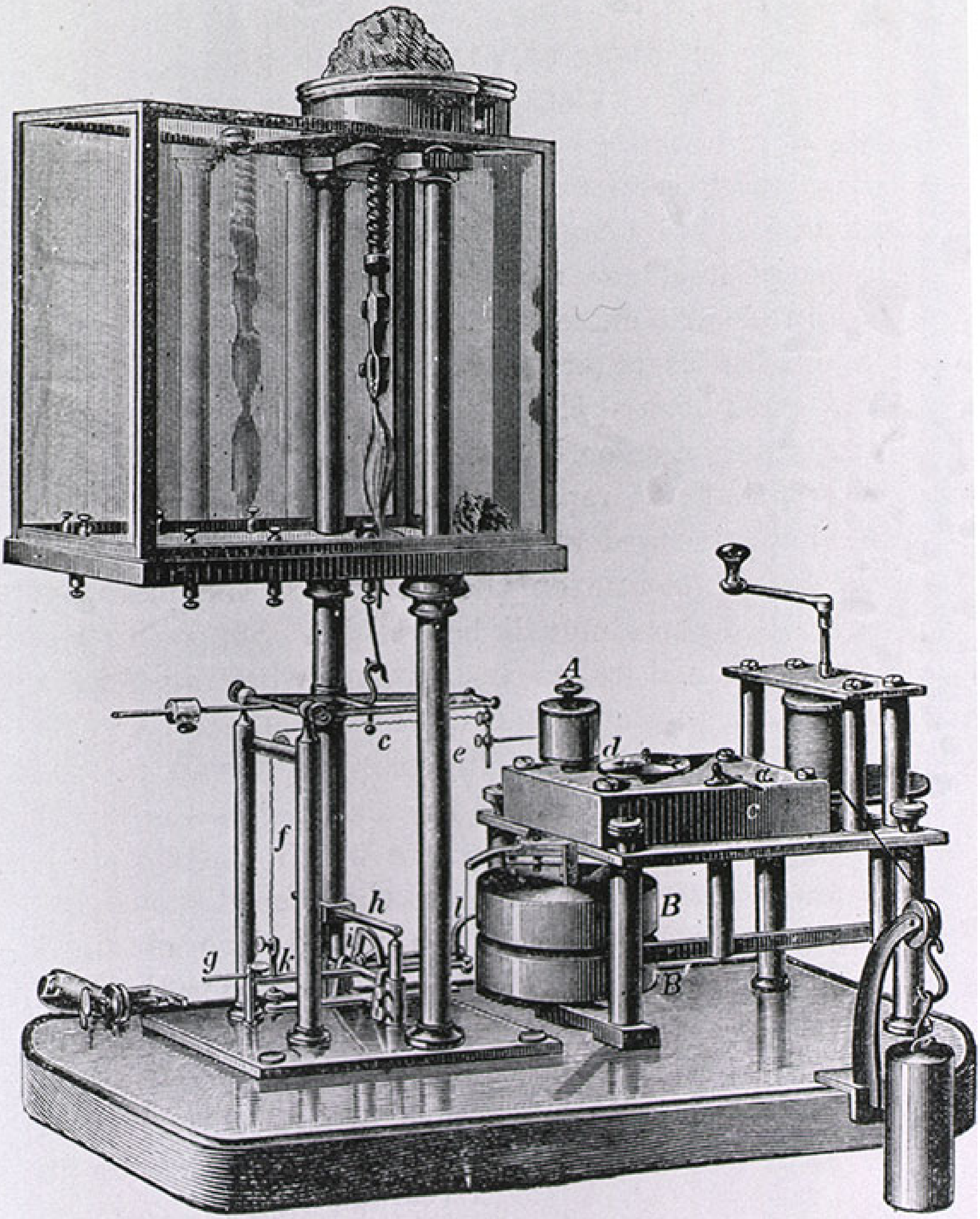


FIG. 17. MYOGRAPH OF HELMHOLTZ.
(One quarter natural size.)

Illustration of *Myograph of Helmholtz,* New York, 1881. Image: Public Domain/The National Library of Medicine.

eyeball (and of sight) dethroned the visual organ as a bastion against the evolutionary explanation wielded by the natural theologians that had haunted Darwin. While working feverishly on modifying Helmholtz's galvanometer for the laying of the telegraph, Thomson wrote a letter to Helmholtz with the following postscript:

> P.S. When will your book on the eye be completed, or is it so already? I find people greatly interested in it, especially regarding the adjustments.
>
> I was out with a shooting party a few days ago at Largs, and looked into the eyes of various birds immediately after death. I saw the three images of the sun well in a woodcock's eye, but was puzzled by the position of the image by reflection at the posterior surface of the lens. I had a very curious view of the interior by simply pressing my eyeglass on the front of the cornea so as to nearly flatten it. Have you seen an owl's eye? It is a splendid thing. I cut one open, but learned nothing more than that the cornea is very tough.[14]

Huxley provided similar descriptions of Helmholtz's experiments described as "beautiful methods" before summing up the measure of nerve signals in his "On the Present State of Knowledge as to the Structure and Functions of Nerve" (1854):

> Science may be congratulated on these results. Time was when the attempt to reduce vital phenomena to law and order was regarded as little less than blasphemous: but the mechanician has proved that the living body obeys the mechanical laws of ordinary matter; the chemist has demonstrated that the component atoms of living beings are governed by affinities, of one nature with those which obtain in the rest of the universe; and now the physiologist, aided by the physicist, has attacked the problem of nervous action – the most especially vital of all vital phenomena – with what result has been seen. And thus from the region of disorderly mystery, which is the domain of ignorance, another vast province has been added to science, the realm of orderly mystery.[15]

For Thomson, the eye's mechanisms could eventually be fully understood, albeit with difficulty, while for Huxley, the impact of his myograph experiments deepened the understanding of the dynamic richness of matter and its effects in and on living things. For Huxley (and Darwin), Helmholtz's work on the eye provided a great weapon against the natural theologians and other purveyors of design – the eye was far from perfect and vision was a shoddy physiological and cognitive patchwork that bore no fingerprints of divinity.

A materialism as thorough as Huxley's and Darwin's could still be (and was) recombined and audited in ways that attempted to reinstall human importance, naturalize progress, or otherwise bring back some form of direction or development. In the decades following Darwin, this was done by retroactively justifying existent hierarchies between cultures, often mediated by technological capacity, while remaining blind to decidedly contingent conditions of material wealth, climate, fortuitous landscapes, and so on. Cultural and technological outputs could then be read back into the structures of living matter – in terms of dispositions, habits, and capacities. "Playing god" should not be an accusation reserved for Dr. Frankenstein but rather a description of the national pastime of self-appointed superiority.[16]

But the externalization of supposed "inborn" capacities via technology is not motivated solely by interhuman dominance; it is also a condition of thought. It results from collectivized knowledge and its subsequent epistemological programs (like mechanism and materialism). To see technology only as a form of anthropogenic violence would again ignore the generative synthesis of mechanistic analysis and materialist supposition. The denial of progress, even if limited to the technological output of human beings, requires treating technological objects both mechanically and materially, as well as demonstrating particular forces and matters. Or as philosopher Gilbert Simondon approached it, technology can be defined as a designed tool on the one hand and as having a life of its own on the other.[17]

A matrix arises between the intentional and unintentional effects of mechanistic design, and between the intended and unintended ramifications of technology. If the rationality of the mechanistic approach can no longer be isolated from its own mechanisms, then the effects of intentional and unintentional design can be mapped onto, or extrapolated from, the human mind. The theme of technology as organ projection, heavily employed by the geographer and arguably the first philosopher of technology Ernst Kapp, treated tools and devices as externalized sections of human anatomy and physiology.

Writing in 1877, Kapp refers to the recent transatlantic telegraph as the globalization of the human nervous system. But in line with the tension between the intentional and unintentional aspects of technological design, Kapp sees this feat as exhibiting both conscious and unconscious tendencies. He finds that the designed artifact revealed both forms of knowledge simultaneously and believes technological objects (and therefore human beings) can only emerge in situ:

> Our point of departure is the human being, who, in all he thinks and does, unless he breaks with himself entirely, can proceed from nothing other than his thinking, acting self. We are not dealing with a hypothetical bathybius-being nor with a hypothetical ideal human being, but with the human to whose being may attest only the traces of and changes in the things he has made with his own hands.[18]

Kapp sees himself as poised between mechanism and materialism, as occupying a position like Helmholtz, whom he often cites approvingly. But by operating from a technological position rather than a biological one, Kapp essentially restores the mechanist position as a means to return to the anthropocentric and teleological mode of thought. He misrepresents Darwin as essentially Lamarckian and insists upon “original dispositions” teleologically necessary in humans, such as for speech, mind, and toolmaking. Simondon’s position can be taken as a materialist alternative to Kapp’s, as Simondon sees technology as a crystallization of labor. For Simondon, the human interpretative capacity relevant to technology is to construct devices that maximize this materialist open architecture of formed matter.[19]

As a further counter- and materialist reading of the telegraph, one might follow cultural historian Wolfgang Schivelbusch’s well-known portrait of the earlier railway telegraph, which inaugurated the modern trope of technology as the annihilation of space and time:

> The landscape appeared behind the telegraph poles and wires; it was seen through them. As we noted earlier, the rail traveler’s perceptions were changed by the intervention of the machine ensemble between him and the landscape; there was a material demonstration of that intervention in those poles and wires, which were a part of the machine ensemble. They interposed themselves, both physically and metaphorically, between the traveler and the landscape.[20]

The panoramic effect of the visible telegraph does not apply to the underwater cable. The underwater cable more strongly represents the archaic and submerged nature of the physiological system, since we receive messages but do not see the structures that deliver them. While Schivelbusch notes that when riding on a train one embodies the nerve flash across the muscular landscape (because the train follows the telegraph wire’s path), in the submerged cable one exists on a shoreline, waiting for a signal and also uncertain that one has comprehended what was heard. Living in a world of measured temporality, we are in many senses more like Helmholtz, observing the lost time of the electrophysiological curve, or like his wound-ignorant whale – lived time is somewhere between a measure of time and the knowledge that the signal’s path determines our very sense of time – temporality is conditioned by materiality.[21] This marks the central difference between Kapp and Schivelbusch. The feats of engineering involved in measuring mechanistic and material time externalize communication so time and space are folded up in such a manner that our bodies or voices can cut across the earth in mere minutes with or without our bodies moving through space. If Kapp sees the technological object as a prosthesis, Simondon sees it as a fossil. Both views invite regular reinterpretation but for the former, the mode runs from anthropological to psychological, while for the latter it goes from technological to cultural.

In the mechanistic view, any disparity between time scale and its perception is an engineering mistake or limitation, and an apparatus can smooth out the differences through measuring and averaging. But from the materialist perspective, the effect of externally measured temporality, as it involves structures that redirect and situate the measure and perception of time, is not reversible – it is a historical change in how time and space are understood and experienced. Without the checks and balances of materialism, mechanism can cast drastic differences as essentially calibration problems (inciting the design of finer instruments) without questioning the relative ground of human perception.

Kapp’s displacement of the mechanistic/materialist difference from its older teleomechanistic perspective allows him to utilize Helmholtz to reinstate a radical split between organism and machine, and to claim that the mechanists of the past foolishly thought that living beings were automatons that needed no winding up.[22] For Kapp, by way of his reading of Helmholtz, mental work must remain qualitatively separate from physical work: the body can be a machine but the mind cannot. In this regard, Kapp essentially restates the mechanistic program but in terms of the codependency of anthropology and technology as the naturalistic emergence of human thought – the human machine is made of special purposive parts that can be materially exported but not materially grounded.[23]

Again, following Riskin, the clockwork of life did in fact require winding, but the clock key was turned by divine fingers.[24] What is insidious about Kapp's view, and what Riskin critiques in twentieth and twenty-first century biology (especially in cybernetics), is that mechanism in biology increasingly disavowed its teleological roots by attacking any epistemological program in biology that would grant agency or intentionality to living things as materially intrinsic to their organic nature. This classical mechanistic paradigm, Riskin argues, continuously foreclosed any possibility of naturalized agency, of the possibility that disquiet could be a central part of living things, of the possibility that organisms could be viewed as restless clockwork. But the question of how to articulate this restlessness divided even Thomson and Huxley.

Thomson calculated that the age of the earth was not sufficient to allow for evolution to take place. Huxley refuted this in his address to the Royal Geological Society in 1868. Since neither party had any inkling of nuclear fusion, the debate was in many ways about experimental certainty between calculations regarding types of known energy. The disagreement raised the issue of whether the evolutionists were in fact suggesting some force unique to living beings, something that could cheat the laws of physics. Huxley's main point was that Thomson's calculations assumed a relatively stable world devoid of catastrophe, while evolutionary time was the synthesis of temporal forms:

> It is very conceivable that catastrophes may be part and parcel of uniformity. Let me illustrate my case by analogy. The working of a clock is a model of uniform action; good time-keeping means uniformity of action. But the striking of the clock is essentially a catastrophe; the hammer might be made to blow up a barrel of gunpowder, or turn on a deluge of water; and, by proper arrangement, the clock, instead of marking the hours, might strike at all sorts of irregular periods, never twice alike, in the intervals, force, or number of its blows. Nevertheless, all these irregular, and apparently lawless, catastrophes would be the result of an absolutely uniformitarian action; and we might have two schools of clock-theorists, one studying the hammer and the other the pendulum.[25]

August Weismann's theories of the mechanisms of inheritance, combined with the rediscovery and development of genetics by the early botanist and geneticist Hugo Marie de Vries, formed the proper synthesis of the material and the mechanical for the theory of evolution to operate. This solidified form of Darwinism, however, became increasingly mechanical (in the sense of measurable and predictable) at the beginning of the twentieth century (in the so-called "modern synthesis").[26] Both Huxley and Darwin's materialisms were retroactively painted as foolhardy by those who eventually gave rise to population genetics and those who placed a heavy emphasis on DNA-based explanations. The historical element of evolution became antithetical to the genetic program as evolution was cut off from its structural-mutationist and historical-epigenetic roots. The relevant paths of evolution became genetic information and not the forms and histories of species nor the radical contingency of how the branches of life on earth took shape. Huxley's dreams of generative slime were a means of maintaining this material continuity as a research program to explore the maximal possibilities of Darwinian evolution, regardless of what it did to human stature.

Riskin is also concerned with the twentieth-century emphasis on information by way of cybernetics, piggybacked on the modern synthesis in evolutionary biology and later integrated in the discovery of DNA.[27] With cybernetic information, agency becomes an appearance of negative feedback, since to say any more would be to theologize or philosophize. At the same time, the critics of these tendencies tend to draw a straight line from Descartes to Darwin to Dawkins, as if the reduction of life to machines or information has been a well-organized march towards modernity – as if what we think by "machine" has not radically changed in the last five hundred years.

Yet mechanism in biology, without its materialist accompaniment, is not a blanket reductionist program but a formalization of life that desperately, and often disastrously, leaves open a path by which one can decide the relevant timescales and the desired contingencies in advance – a desire to be a machine that can wind its own key in the name of progress.[28]

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[1] Arthur C. Clarke dramatizes this in his *Voice Across the Sea: The Story of Deep Sea Cable-laying, 1858–1958* (Muller, 1958). See also John Griesemer, *Signal & Noise: A Novel* (Picador, 2004).

[2] There have also been several fictional and historical accounts of the *Great Eastern*, the ship that unspooled the cable. See Griesemer's *Signal and Noise* as well as Howard Rodman's *The Great Eastern* (Melville House, 2019).

[3] Jessica Riskin, *The Restless Clock* (University of Chicago Press, 2016).

[4] Riskin, *Restless Clock*, 70–71.

[5] T. H. Huxley, "Biogenesis and Abiogenesis," 1870 https://mathcs.clarku.edu/huxley/CE8/B-Ab.html.

[6] https://mathcs.clarku.edu/huxley/CE1/PhysB.html#note1.

[7] Robert Michael Brain, *The Pulse of Modernism: Physiological Aesthetics in Fin-de-Siècle Europe* (University of Washington Press, 2015).

[8] Haeckel spent several years of his life documenting the thousands of species of microorganisms sent to him by the *Challenger* Expedition. On this, see the short film *Proteus*.

[9] For a critique of this "dangerous" mixing of philosophy and biology, see the preface to Peter Brian Medawar and Jean S. Medawar, *Aristotle to Zoos: A Philosophical Dictionary of Biology* (Harvard University Press, 1983). For a critique of Huxley being too old fashioned (and mechanistic), see Loren Eiseley, *The Immense Journey: An Imaginative Naturalist Explores the Mysteries of Man and Nature* (Vintage, 2011). For a closer analysis of Huxley's error and what it came to represent in evolutionary science, see Donald J. McGraw, "Bye-Bye Bathybius: The Rise and Fall of a Marine Myth," *Bios* 45, no. 4 (1974): 164–71.

[10] There are of course many ways a model can be wrong, and an incorrect or incomplete model can, and has, led to significant gains in scientific knowledge. For a helpful overview of the importance of false models, see chapter 6 of William C. Wimsatt, *Re-engineering Philosophy for Limited Beings: Piecewise Approximations to Reality* (Harvard University Press, 2007).

[11] Cited in Alison Abbott, "Lost Curve Hits a Nerve," *Nature*, no. 464 (2010): 681–82.

[12] Henry Schmidgen has written extensively on Helmholtz's myograph experiments and has noted how, when working in Paris, Helmholtz referred to the curve made by the needle as "*le temps perdu*" (an utterance of "lost time" some hundred years before Proust). Such treatments of animals and especially model organisms has a long and ugly history. Both Claude Bernard and his teacher François Magendie describe some of the most sickening reports of vivisection I have encountered. In terms of frogs, the happiest report I have found is the work of the great Lancelot Hogben who devised a quick pregnancy test for women by injecting their urine into the frog species called *Xenopus*. The frogs would then lay eggs within hours, thereby confirming a woman's pregnancy. This did not harm the frog and replaced dissections of injected rabbits and mice which were previously used to identify pregnancies in women. Huxley's own "Has a Frog a Soul?" is steeped in details of frog torture and dissection over the ages.

[13] Too often the figure of the engineer is caricatured as the pragmatist against the theoretician. Mark Wilson's work on the philosophy of engineering is very helpful in this regard as he demonstrates how engineers utilize theoretical concepts but treat them as pliable in a way that too often philosophers of science do not. See, for instance, *Physics Avoidance* (Oxford University Press, 2018).

[14] Cited in Silvanus Phillips Thompson, *The Life of William Thomson, Baron Kelvin of Largs* (Cambridge University Press, 2011).

[15] https://www.tandfonline.com/doi/abs/10.1080/00222935709487876?journalCode=tnah08.

[16] Peter Bowler and Stephen Jay Gould have documented the decades following Darwin and the various forms of progressive or directed evolution. See Bowler's *The Eclipse of Darwinism* (Johns Hopkins University Press, 1992) and Stephen Jay Gould's *Ontogeny and Phylogeny* (Belknap Press, 1977).

[17] See chapter 1 of Gilbert Simondon, *On the Mode of Existence of Technical Objects* (University of Minnesota Press, 2017).

[18] Ernst Kapp, *Elements of a Philosophy of Technology: On the Evolutionary History of Culture* (University of Minnesota Press, 2018), 29–30.

19
Here I am following Henning Schmidgen's text "Inside the Black Box: Simondon's Politics of Technology," *SubStance* 41, no. 3 (2012): 23–24.

20
Wolfgang Schivelbusch, *Railway Journey* (University of California Press, 43).

21
Henri Bergson's portrait of the intuitive mind as caught between thought and perception seems structurally not far off from Helmholtz's perch between rationalism and empiricism (although their motivations for such an island are opposed). *In Matter and Memory*, Bergson attempted to avoid idealism and materialism, even describing the conscious mind as a telegraph operator suspended between waiting for a message and sending one. For Bergson the brain is a bureaucratically boring central office, while for Helmholtz it is the ship that navigates the unknown. Bergson's metaphor has been criticized, notably by Catherine Malabou, as there is no central power anymore, nor is the mind best understood as a computer when one takes into account the plastic nature of synaptic activity. Incidentally, Bergson gave the Huxley lecture "Life and Consciousness" in 1911.

22
Kapp, *Elements of a Philosophy of Technology*, 97.

23
In this sense Kapp is quite Kantian in maintaining a difference between a constitutive and a regulative role regarding purposiveness in human organisms. But while the split for Kant was at least in part to engender a normative dimension regarding the treatment of living things as non-mechanical, for Kapp it is about using the productions of thought to strengthen the case for a human or non-divine teleological program.

24
Riskin, *Restless Clock*, 370–74.

25
Huxley, "Geological Reform," 1869
https://mathcs.clarku.edu/huxley/CE8/GeoR.html.

26
The term "modern synthesis" was coined by the evolutionary biologist and eugenicist Julian Huxley, grandson of T. H. Huxley as well as brother of the writer Aldous Huxley.

27
Riskin quotes Ernst Schrödinger as an exception to the strict mechanist trend and cites a passage about the chaos of clockwork that is very much in line with Huxley's reasoning.

28
I am of course speaking of the eugenics programs which were overwhelming the product of the biometricians and biostatisticians of the early twentieth century such as Ronald Fisher, Walter Weldon, and Karl Pearson.