European Romantic Review

ISSN: 1050-9585 (Print) 1740-4657 (Online) Journal homepage: http://www.tandfonline.com/loi/gerr20

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To cite this article: Richard C. Sha (2012) Volta's Battery, Animal Electricity, and Frankenstein , European Romantic Review, 23:1, 21-41, DOI: 10.1080/10509585.2012.639182

To link to this article: https://doi.org/10.1080/10509585.2012.639182

Published online: 12 Jan 2012.

European Romantic Review
Vol. 23, No. 1, February 2012, 21–41

Volta's Battery, Animal Electricity, and *Frankenstein*

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Although *Frankenstein* critics generally agree that the battery gives life to the monster, they have missed the significance of Volta's invention to the novel. This essay situates *Frankenstein* within the Volta/Galvani debate about the existence of animal electricity. Since Volta invented the battery precisely to refute the existence of animal electricity, Mary Shelley harnesses the battery to undercut vitalism. In thinking about the battery and the curious material status of electricity, she wonders how experiments might distinguish between life and the mere appearance of life.

I here situate *Frankenstein* within the debate between Luigi Galvani and Alessandro Volta about whether Galvani had proven the existence of animal electricity. Where Galvani believed that he had discovered a new form of electricity, Volta insisted that such animal electricity was merely artificial, a man-made electricity caused by the connection between two metals. Thus what Galvani equated to life was really from Volta's perspective only mechanical electricity. Based on the fact that Galvani's nephew Aldini connected a battery to a recently decapitated criminal's head in 1803, causing the face to grimace, Shelley scholars have generally equated what Victor refers to as the "instrument of life" that "infuses a spark" to the battery (Holmes 327). Yet if she uses a battery to give birth to the monster, Mary Shelley highlights Victor's collapse of animal and man-made electricity, a collapse that is replicated in the tendency of modern critics (Mellor 105; Butler xxx) to refer to the "galvanic battery" when in fact the battery was invented by Volta precisely to refute the idea of animal electricity. And to the extent that the novel has been read as an allegory of what happens when a man tries to give birth without a woman, such a reading acquires considerable irony when the woman is replaced by a battery created to refute Galvanism as animal electricity. Talk about *coitus interruptus*! By understanding *Frankenstein* in relation to the Galvani/Volta debate, moreover, readers can attend to her concerns about the epistemology of biology – how does one know life when one sees it? Mary Shelley repeatedly warns readers not to be swept away by a vitalist logic of occult forces that enabled the collapse of man-made electricity with life.

Much as Volta separates animal and artificial electricity, Shelley understands animal electricity not as life but as a "token" for life, and thereby arrests the tendency of the Vitalists to make it an object and to mistake it for life itself.[1] She thus uses a figure against a figure to question how scientific demonstration relates to materiality and scientific knowing. I take seriously Shelley's wondering about whether electricity

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ISSN 1050-9585 print/ISSN 1740-4657 online

http://dx.doi.org/10.1080/10509585.2012.639182
http://www.tandfonline.com

can deliver the principle of life, and argue that she is after such larger epistemological questions as what are the relations among demonstration, materiality, language, and scientific knowledge?

After considering Shelley's engagement with these questions, I use the debate to show how electrical scientists turned to figuration to mediate the transient phenomena of electricity, giving it a materiality that on the one hand sought to fix electricity into an object of study.[2] On the other hand, if too fixed, physicists like Volta and physiologists like Galvani who sought to operationalize it might not be able to talk to one another. If scientists turned to language to gain a more flexible materiality, one that allows room for spirit and crossings between physics and physiology, then the politics of *Frankenstein* cannot be reduced to an initial endorsement of a radical science, pace Marilyn Butler, that is later tamed to bourgeois respectability (Butler xl–li). This flexible materiality also helps explain why animal electricity survived Volta's refutation of it. We have yet to understand the flexibility of Romantic materiality, and as the example of electricity will show, materialism could hardly straightforwardly equate to atheism or radicalism. Indeed, against materialist determinism, I turn to electricity to think about materialist possibility because that potential enabled the material to assist Romantic idealism, not obstruct it. In highlighting the essential figurality of electricity, then, Mary Shelley fingers the source of its power as its ability to cross back and forth between living and dead matter.

Batteries

Victor describes the genesis of the monster thusly: "I collected the instruments of life around me, that I might infuse a spark of being into the lifeless thing that lay at my feet" (Shelley 38). From Volta's perspective, the term "instruments of life" when used to describe his battery is an oxymoron. After all, if metallic plates could spark charges that one could taste on one's tongue or feel with one's hands, then Galvani's animal electricity was really a product of the combination of two different metals that was used to spark a contraction. What Victor refers to as "the instruments of life" was actually the instrument that attempted to sever any equivalence of animal electricity and life. Volta wrote that "je me vis obligé de combattre la prétendue électricité animale de Galvani, et de déclarer une électricité extrinsique, mué par le contact mutual des métaux de différente especè [I found it necessary to contest Galvani's claim of animal electricity, and to declare an extrinsic electricity, moved by the mutual contact of metals of different kinds]" (423). For Volta, when Galvani and his followers located "animal electricity" in dead animals – the severed frog's leg – they violated their own assumptions (Pancaldi, *Volta* 196). How could animal electricity exist in the dead? If animal electricity was in dead animals, then Galvanism was about the appearance of life.

Volta took pains to insist that animal electricity was metallic electricity and not some internal force of the animal. In reading Mary Shelley's use of the battery as a "sensationalist way of packaging aspects of the vitalist question for the multitude" (Butler xxx), Marilyn Butler sidesteps the issue of what Volta thought he was doing when he invented it, and misses some of Shelley's skepticism about vitalist logic. This, in turn, leads her to downplay the ways in which Shelley insists that the battery is a metonym for an instrument of life, not life, because it relies upon a chain of signifiers – battery, electricity, animal electricity, life – in order to connect the first term with the last. As an "artificial organ" modeled on the electric eel, Volta sees the battery in terms of the embodiment of the passive principle of electromotive action (Piccolino, "Taming" 141). Butler sees the battery experiment as an allegory for the "mature man's ambitions to found a family" (xli), but Volta insisted that nervous action could only be started by the will.

Volta polices the boundary between machine and life and he does so by (1) insisting his battery be artificial; (2) clarifying his indebtedness to nature; and (3) distinguishing between electrical principles and life. In his 1800 letter announcing his discovery of the battery in French and published in the London Royal Society's *Philosophical Transactions*, Volta referred to "la construction d'un appareil qui ressemble pour les effets, pour les commotions qu'il est capable de faire éprouver dans les bras, &c. aux bouteilles de Leyde [The construction of an apparatus that, with regard to its effects, with regard to the vibrations it can prove exist in the arm, etc. resembles a Leyden jar]" (403). Note Volta's language of appearance which insists upon a gap between perception and actuality. Moreover, Volta distances the apparatus from the effects which can be proven: his phrase "qu'il est capable de faire" not only exploits pronoun substitution, but also suspends any immediate felt effects under capability.[3] If calling the battery an "organ" threatened to breathe life into a collection of metal plates, Volta's modifier "artificial" insisted upon a gap between life and man's rendition of life even as he designed the stacked plates to look like the skeleton of the electric fish. Volta's view was that the will, a spiritual entity, acted through electricity only at the root of the nerve to activate energy appropriate to the relevant muscle or organ (Pancaldi, *Volta* 195). Despite having materialized the principle of nervous action, Volta left the door open to spirit in the form of a will that could not be anatomized.

Victor Frankenstein, by contrast, recognizes neither that sight might merely deliver appearances, nor the potential connections between materialism and spirit; his failures speak to his own limitations rather than those of science itself. Indeed, Victor has the gall to refer to himself as "lifeless" under Clerval's care (Robinson, *Notebooks* 1: 115), a mistake that replicates Volta's criticism that Galvani had turned to dead animals and animal parts to deliver life. In the original manuscript Mary Shelley had first written "senseless," which would have made sense. Victor is not without life; he is without the appearance of life and his own refusal to notice this key distinction makes him senseless. He repeats this category mistake when crediting Clerval for his "unremitting attentions . . . [which] restored me to life" (Shelley 43).[4] Because Victor lacks protocols for separating appearance from reality, he tends to collapse life and the appearance of life, nervous electricity and life, thus playing the part of Volta's inept Galvani. Hence Mary Shelley has Victor wonder about "bestow[ing] animation upon lifeless matter" in one breath and pursuing this "*undertaking* with unremitting ardour" in the next (Robinson, *Original* 273). Her choice of "undertaking" deliberately confounds death with Victor's claim of life.

To make matters worse, almost every other character in the novel recognizes this gap between life and the signs of it. Walton knows better: describing the rescue of Victor from the ice floe in the Arctic, he claims that when Victor "showed signs of life," they wrapped him in blankets (Shelley 13). Walton notes in a letter to his sister that Victor is exhausted easily and "sinks again to apparent lifelessness" (Robinson, *Original* 420). And so does Alphonse, explaining to the young Victor that electricity is the "origin" of thunder and lightning and then goes on to detail the "various effects of that power" (Shelley 24). His use of "effects" allows for a gap between effects and any cause.[5] Shelley even endows the nameless monster with more sense. When he rescues the young girl who had slipped into an icy river, he remarks, "she was senseless; and I endeavoured, by every means in my power, to restore animation" (Shelley 115).

Mary Shelley herself insists upon "signs of life" as opposed to life itself. Her 1831 Preface recalls her waking dream, which featured "the hideous phantasm of a man stretched out, and then, on the workings of some powerful engine, show signs of life, and stir with an uneasy, half-vital motion" (Shelley 196). Much of this description acquires increased salience within the context of Volta's invention of the battery. For one, note how Shelley links "engine" – defined by the *OED* as "a complicated machine with moving parts, for producing a given physical effect, *esp*. the conversion of power into motion" – with "signs of life." Like an engine, a battery converts chemical power into electrical motion, but motion is not life. Metals are the engine of electricity while the frog's leg is merely a passive receptor of such electricity (Kipnis 119). Engines produce effects, which are remote from causes. Her insistence upon "then" and "on the workings of," moreover, rehearses Volta's claim that animal electricity was really the work of the battery: the temporal marker "then" insists that the signs of life only appear when connected to the engine. Shelley further distinguishes between life and "signs of life," and underscores her skepticism about vitalism with her double stress on "half-vital" (why sever vitality in half?) and her stipulation of "motion," not life. Here, Shelley implicitly but forcefully rejects Aldini's claim that "life is none other than a continued process of galvanism" (qtd. in Sleigh 232): Aldini may have produced somatic excitation of the murderer's facial features, but that was a long way away from genuine resuscitation (Sleigh 238).

When Mary Shelley herself insists in her 1831 Preface that "materials . . . can give form to dark, shapeless substances, but cannot bring into being the substance itself" (Robinson, *Original* 440), she credits materials with shape but not substance, and the very gap between shape and substance recalls Volta's charge that Galvani's animal electricity was really mechanical. The parallels between her thinking and Volta's are heightened when she comments that "supremely frightful would be the effect of any human endeavor to mock the stupendous mechanism of the Creator of the world" (Shelley 196). Like Volta who took pains to note that his battery was "similar its form to the natural electric . . . Torpedo," Shelley's choice of the term "mechanism" not only insists upon a deferential gap between the Creator and any mechanism that might be successfully mimicked, but it also implies a wavering commitment to vitalism, insofar as living form is antithetical to mechanism (Gigante 4). The battery as "engine" underscores the gap between mechanism and life. Shelley famously adds, "Perhaps a corpse would be re-animated; galvanism had given a token of such things" (Shelley 195). Circulating between something which serves as proof, a spot on the body which indicates disease, and a sign or indicator of something (*OED*), "token" shuttles back and forth between word and thing. In thinking about Galvanism as having given a token, Mary Shelley identified one of the most vexing problems in electrical science, its resistance to the stability of a scientific object. Her emphasis on Galvanism as giving a token serves to suspend any automatic connections between word and thing, and to question what experiments actually demonstrate. Not only does "token" insinuate a metonymical connection between Galvanism and reanimation, it reminds us of the battery as a metonym for life. The token does not directly symbolize but gives a part of a symbol. Shelley allegorizes the symbol and widens the gap between these two terms.[6] At the same time, her emphasis upon "token of such things" makes materiality not just the property of language but also the property of things. Shuttling back and forth between things and language, materiality once again has a flexibility that is far from determinative.

Indeed, in a scientific climate where electricity hovered between a sign of life and delivering life, Mary Shelley's and Volta's insistence upon a gap between forms and the things themselves highlights a real scientific problem. The London Royal Society bestowed upon Volta the Copley Medal, its highest scientific honor, for "having tested Galvani's experiments on animal electricity, which had seduced experts in Europe" (Pancaldi, *Volta* 179). He had of course announced his discovery of the battery in the Royal Society's 1800 *Philosophical Transactions*.[7] Waldman's claim that "the modern masters promise very little; they know that metals cannot be transmuted" (Shelley 30), alludes to Volta's recent invention of the battery and the fact that metals cannot be transmuted into life.[8] Although Waldman here distinguishes between alchemy and modern science, I underscore that Shelley frames knowledge of the refusal of metals to be transmuted as "modern" knowledge, making Volta the most likely referent since he sought to sever the connection between animal and metallic electricity. Hence Galvanism as animal electricity looked like another form of alchemy. Volta's work with metals, furthermore, enabled him to specify which metals would deliver more battery power.[9] The English chemists William Nicholson, Anthony Carlisle, William Cruikshank, and Humphry Davy all followed Volta's leads (Dibner, *Galvani – Volta* 37–40). Davy expressed caution in his 1800 "Outlines of a View of Galvanism," arguing that circumstances like "the appearance of galvanic action in living matter . . . afford analogies that render it probable that some phenomena similar to the galvanic phenomena, may be connected with muscular action, and other processes of life. These analogies, however, at present are very indistinct, and they ought to be considered of importance only so far as they are likely to lead to the discovery of new instruments of experimental investigation" (2: 207).[10] Davy tames the analogy by the conditional verb "may" and by experiment. In his later published writings, Davy was careful to treat the battery as an instrument, and to leave all theoretical implications of it, especially the issue of vitalism, behind (Pancaldi, "Hybrid Objects" 256–60).

Electrical Science and Figurative Things

Mary Shelley's use of a figure – the token – to bracket Galvanism as a suspect object acquires greater force when we consider that electrical science then relied heavily upon verbal figures: she recognizes how even scientific understandings of electricity were a token of something else. Hence she contrasts electrical violence with tamed experiments (Shelley 24). The ways in which verbal figures rendered a flexible materiality frustrate attempts to pigeonhole radical science from respectable science since the language of materiality crossed back and forth between them. Electricity was figured as a subtle fluid even though no one knew what it actually was, and it was only a short step from electrical fluids to nervous fluids. Unsurprisingly, Mary Shelley speaks of electrical "fluid" drawn down from the clouds (Robinson, *Original* 66). From the beginning, verbal figures loom so large in electrical science because it is a transient phenomenon that resists the forms of materiality that we can imagine. Even today, electricity has a polarity, yet "negative" and "positive" have no correspondence in reality beyond convention.[11] Figures thus offer a necessary and not just provisional ground.[12] In 1600, William Gilbert, later court physician to Queen Elizabeth, was the first to use the term "electricity," deriving it from the ancient Greek word for amber because the Greeks noticed that amber collects static electricity (Heilbron 174–75).[13] Thus electricity begins as a metaphor, one whose thingness – amber – is a metonym for electricity writ large.

In the eighteenth century, what made electrical science so powerful was Benjamin Franklin's thorough exploitation of the theory of the conservation of electrical charges which enabled the quantification of electricity.[14] Since there was no more electricity after the charging of a condenser, one side of it must gain what the other side loses. Franklin theorized that electricity was a fluid sui generis: it was unlike Newton's ether but modeled on it. Once again metaphor plays a key role in electrical science. These figural dimensions of electricity allow the control of traffic between the known and the unknown in much the same way that mathematics makes electricity look like an object of knowledge. And mathematics too is a language that complicates the thingness of electricity because quantification is not quite the thing. As Heidegger would later put it, "mathematics skips over the things" (92).

Scientists like Adam Walker, Percy Shelley's teacher, Benjamin Franklin, and Galvani all referred to electricity as both a fire and a fluid, and used analogy to switch back and forth between these metaphors which become more than metaphors because they clothe electricity in the language of materiality without forcing a commitment to one stable form of materiality. Such clothing further enabled materiality and spirit to co-exist. Even within the notion of electricity as a fluid, scientists finessed whether there was one or two fluids, a masculine or positive one and a feminine or negative one. By making it an imponderable fluid, too subtle to be realized, some electricians did not have to worry about the mysterious properties of this fluid because they bracketed those off from experiment. Nonetheless, electricity was hardly so imponderable that it could not be imagined to be a fluid. Once again materialism hardly necessarily precludes spirit, but one should not be too quick to conflate matter and spirit.

Monstrous Electricity

Although electricity has usually been taken as a sign of modernity, I emphasize its Romantic monstrous figural thingness because the language of modernity or enlightenment leaves behind all the unresolved scientific problems that endowed it not only with such power and mystery in the period, but also and paradoxically its very usefulness to science. Taken from physics, which understood electricity as the property of bodies to attract one another, electricity provided biology with one of the most powerful hypotheses about the principle and causes of nervous action and even of life (Kipnis 111). How does a property migrate into a cause? Here explanatory power trumped empirical experiment, and indeed, both supporters and opponents of animal electricity were often indifferent to the need to test it (Kipnis 113).

The issue of electricity as object was more vexed by the need to produce an "increasing array of experiments and instruments designed to make electricity visible" (Morus, *Physics* 98). If such visibility placed a primacy upon the spectacular so that audiences would be wowed, how much of this visibility was a contrivance? Electricity as object was complicated by what Philip Ritterbush called the "idea of immanence" surrounding electricity. Eighteenth-century assumptions that interrelated subtle fluids like electricity "caused all physical and vital phenomena" (17) meant that eighteenth century scientific electricity relied upon a metalepsis between cause and effect: was what could be seen an effect of electricity or a cause or both? Metalepsis is "the rhetorical figure consisting in the metonymical substitution of one word for another which is itself a metonym" (*OED*), and metalepsis is a capacious form for the monstrous thingness of electricity.[15] Indeed, similarity of effect came to stand in for an identity of cause (Ritterbush 17) even as the more analogies proposed between electricity, ether, and life consolidated themselves into identity (Ritterbush 16). Metalepsis was further helpful in the transition from thinking about electricity as a property of bodies to framing it as a cause: how does a property become a cause? Since electricity could short circuit the relation between effect and cause, and because the fluid analogy grounded the identity of electricity and life, electricity provided science with the tools of metalepsis.

Metalepsis can be such an effective rhetorical tool even within science because it is "subsumed by two terms between which it provides a link" (Menon 73). Here those two terms are natural and man-made electricity, which encompass passive and active, the living and the dead, the material and the seeming immaterial, and the visible and the invisible. Because Galvani thought that natural and man-made electricity were functionally the same (Finger and Law 162), function tamed any differences between them and this allowed Galvani to substitute a relationship between animal and man-made electricity for life itself. The figure of analogy provides other terms to feed the metalepsis; since metalepsis specifies a relation between two things as opposed to distinct objects, nervous electricity through metalepsis connects two sliding things rather than embodying one stable object. Despite Volta's care to separate natural from artificial electricity, even he takes advantage of this metalepsis because he models his battery on the electric fish and then in turn thinks of that fish as a Leyden jar, "a bottle filled with water and containing a metal rod which projected through the neck [that] would, when held in the hand and the rod presented to an electrical machine, receive a powerful charge (Meyer 18). The problem here is that the Leyden jar has no electricity of its own, and must be charged by an electrical machine. If biologists recognized an insuperable barrier between the living and the dead, they minimized the trauma of this new category distinction by accelerating the traffic between the two by generating such metaphorical terms as power, principle, and even organization.[16] Such acceleration culminates in the fact that Galvani and Volta have become somewhat interchangeable.

Indeed, Galvanism is metalepsis writ large in that animal electricity is given a scientific name that renders the "convulsions" (Galvani 47) of a frog's leg into a demonstrable scientific object before Galvanism as animal electricity has been conclusively proven to exist.[17] In September 1786, Galvani noticed that when a recently prepared frog's leg was in contact with an object in contact with the earth, the leg would twitch when an electrical discharge occurred nearby (Dibner, *Galvani – Volta* 10). Ironically, the term "Galvanism" was coined by Volta, and he meant by this term electro-physiological effects caused by bi-metallic currents (Dibner, *Galvani – Volta* 13).[18] In his 1791 *Commentary on the Effects of Electricity*, Galvani turned to experiments to "reveal about nerves and muscles … their hidden properties" (45). Much was hidden: Galvani confesses that he knows neither what "kind" of electrical force the frog's thigh reveals (50), nor the basis of nervous substance (74). He writes, "since this nerve substance, which is present throughout the fiber, neither constitutes a nerve nor is perceptible to the eye but is perceived only by feeling, what hinders our supposing that it is at least partially dissimilar to the substance of the visible nerve, or is arranged in a different way, and for this reason has perhaps an electrical nature" (74). As Galvani strives to make the hidden visible through experiment, he redefines experimental evidence as that which forecloses certain avenues of speculation, not that which reveals truth. In shifting experiment from the demonstration of facts to the offering of hindrances to certain speculations because he cannot make animal electricity visible, and only has the possibility of showing its effects, Galvani enhances the figurative powers of electricity and electrical demonstration. Simply put, how many instances of negation disprove the negative? Galvani's main mistake of course was not in the argument about the existence of animal electricity, but in his claim that the kick of the frog's leg was caused by animal electricity (Dibner, *Galvani – Volta* 29).

Galvani's turn to metalepsis is more pronounced when he frames his experiments as the cause of his hypothesis. He writes, "consequently, when these different problems were investigated and their results confirmed in a long series of experiments, we felt permitted not only to attribute the phenomenon of muscular contractions to electricity, but even to consider the conditions of the experiment as certain laws by which it was bound" (50–51). Despite his linking of experiments with "consequently," he needed to have the hypothesis of nervous electricity before he could direct experiments towards proving its existence. Galvani's initial "attribution of muscular contractions to electricity" is screened by a belated set of experiments whose conditions become the laws by which animal electricity is bound. The effect (experiments) has become a cause of the attribution when in fact the attribution caused the experiments. Whereas in his reclamation of Galvani, Piccolino stresses Galvani's pursuit of a "coherent and rational explanation of neuromuscular physiology" ("Galvani's Path" 310), I highlight the metalepsis between cause and effect, hypothesis and experiment, that make such experiments possible. After all, the ground for these experiments is based upon a linkage between electricity and nerves that stands in for the concept life which resists demonstration.

To make matters worse, could effects reveal causes? And to what extent might experiments show the hidden, especially when the hidden involved the interiority of the nerves and muscles.[19] Galvani recognized the existence of an "extremely mobile principle" and thought that electricity might explain the quickness and mobility of the principle (Piccolino, "Animal" 386). Modifying Haller's theory of muscular irritability, Galvani thought of the muscles in terms of having intrinsic electrical properties that were set into motion by external current (Piccolino, "Animal" 384): the flow of a fluid between muscle and nerve explained the contractions of the frog's leg (Kipnis 107). I underscore the power of metalepsis by noting that in much the same way at Volta based his artificial organ upon an electric fish, which in turn, was imagined to be like a Leyden jar,[20] Galvani considered the frog to be equivalent to a Leyden jar (Piccolino, "Animal" 387). Thinking about the frog's leg as if it were a Leyden jar enabled him to frame the nerve as a simple conductor of positive electricity and the muscle as the reservoir of negative electricity (Piccolino, "Animal" 387), homologous to the outer and inner surface of a Leyden jar.[21] The jar, then, supplements the nervous force, and delivers the physiological explanation that Galvani cannot otherwise show, but this is despite the fact that a Leyden jar must be connected to an electrical machine in order to have a charge. His nephew, Aldini, exacerbated this mistake when he began to refer to "animal Leyden flasks" (181). Writing back to Volta in 1803, President of the Royal Society, Joseph Banks, made clear where he stood by calling Galvani's "animal electricity" the "Voltaique Fluid" (Banks 5: 289).

As my reading of the Leyden jar already suggests, I want to contest the historian of science Marco Piccolino's claim that Galvani "swept away from life sciences mysterious fluids and elusive entities like 'animal spirits'" ("Animal" 381) because such a view underestimates the elusiveness of Galvanism as object. Piccolino's reclamation of Galvani as the father of electrophysiology through the stabilization of Galvanism as a scientific object reaches towards a future science, one that has securely given electrophysiology objects of study. Yet it could not conclusively be that object until the instrumentation capable of measuring nervous electricity existed. In gesturing to a future that envisions Galvanism as the foundational moment in the science of electrophysiology, Piccolino sweeps away Galvanic metalepsis to tidy up Galvani's place in scientific history but with a metalepsis of his own. The current measurable object stands for the past occult object and suppresses the ambiguities of Galvanism. Because Galvani has no real way of proving the existence of nervous electricity without the instrumentation necessary to capture very fine electrical differences, he must turn to metalepsis and other figures to make animal electricity an object. Effects prove causes. Experiments negate the negative as opposed to proving the positive. Nervous force is conceptualized in terms of the Leyden jar which has no electricity of its own. Experiments prove hypotheses, but hypotheses drive the experiments. Let us also recall that Volta means by the term "Galvanism" artificial electricity while Aldini means by it animal electricity. The word "Galvanism" is itself metaleptic, shuttling back and forth between mechanical and animal electricity.[22] Even for Galvani, the problem was intractable. He did not know how to explain the "innate capacity" for contractions and consequently referred to this as "what" capacity (61). Animal electricity was literally thought to be a continuously streaming fluid, as electricity was considered a fluid, but no one really knew what it was.[23]

Indeed, "animal electricity" literally supplanted animal spirits, making the former concept more scientific. Much as Volta left the door open to spirit by thinking about how a living and spiritual will provided the impulse to an otherwise passive electrical nervous system, Galvani replots animal electricity on the old explanation of animal spirits which are manufactured by the brain, the locus where the soul resides. The certainty with which scientists identified the seat of the nervous fluid as the brain screened their inability to specify the nature of this occult fluid. Both Galvani and Volta, then, offer scientific forms of materiality that do not refute God and show the manifold ways in which materiality need not preclude spirit. Insofar as animal electricity literally supplements animal spirits, it inherits the older concept's baggage and hydraulic language.[24] When Galvani speculates that the source of the electrical fluid is the cerebrum, and bases this thinking on the idea that "physiologists indicated [it] as the source of the animal spirits" (78), we witness the return of the repressed, and the ways in which science turns to even outdated concepts but gives them, through figures, new clothing so that they do not appear outdated.[25] Although animal spirits allegorized the soul, and Galvani transforms animal spirits into animal electricity, he still relies upon a physiology of the soul when he invokes the cerebrum as the maker of this electricity. Despite their differences, both Galvani and Volta think of material thingness as a complement to the spirit, and thus make Romantic science less of an oxymoron. Unfortunately for Galvani, new evidence showed that nerves were not hollow inside, and this created obstacles to hydraulic theories of nervous fluid (Pancaldi, *Volta* 194).

Was this movement of a frog's thigh a result of animal electricity, or was it a result of a battery? Galvani thought he had "in various ways prevent[ed] the electrical fluid from the electrical machine from passing (in whatever way this may be done), into the animal and its conductors" (53). Indeed, he excluded both atmospheric electricity by submerging the leg in water, and static electricity by using a glass handle to provide the communicating arc (Kipnis 115). Galvani's "whatever way this may be done" relies on his ability to imagine the ways it could be done, and he could not have imagined that Volta's bi-metallic stimulus opened up the nervous membrane's ion channels (Piccolino, "Galvani's Path" 316). And yet when it came to discovering the seat of animal electricity, Galvani admitted that "it became evident to us that this problem, which could not be sufficiently clarified by experiment, must be left primarily to conjecture" (65). Galvani repeated his experiments on living animals, and concluded "all of this seems to establish the postulation that animal electricity operates in essentially the same way in living as in dead animals" (70). Yet if animal electricity worked in the dead by the same principle, then how could it be life? He claimed that he had been the first "to hold in his hands, as it were, this electricity which is concealed in the nerves, and to draw it forth from the nerves and to set it practically before our eyes" (79). Despite his material metaphors, and despite his conversion of his audience into virtual eye-witnesses, Galvani's metalepses resist such delivery. The frog's leg cannot securely deliver animal electricity until the origin for the convulsion has been demonstrated.

To Galvani, a metallic arc allowed for the discharge of electricity "accumulated in a condition of disequilibrium inside the animal tissues" (Piccolino, "Galvani's Path" 316). To Volta, who assumed that the disequilibrium was caused by the metallic contact, the contraction of the frog was simply a response to external electricity (Piccolino, "Galvani's Path" 316). Because each understood electrical disequilibrium to reside in different objects, each thought he had proven his version of electricity. Volta thus designed experiments specifically to return even nervous electricity to the domain of physics, a passive scientific object that could be delivered by physics, not physiology, because it was essentially passive.[26] Untrained as an anatomist, Volta used the entire frog rather than the frog's thigh, and he did not think this was a meaningful switch and yet it was much more difficult to see animal electricity in the entire body. From the vantage of his training in physics, Volta thought Galvani had mistaken animal electricity for what was really metallic electricity: Volta thought the frog's legs only served as an indicating electroscope (Dibner, *Luigi Galvani* 11). And because he did not specify exact distances between the electrical device and the frog's thigh, Volta found Galvani's language imprecise (I. Cohen 30). Nor could Galvani account for why different metals produced stronger contractions than similar metals (Kipnis 118). In a 1796 letter, Volta noted that there was nothing "magical about galvanism": indeed, he declared, "it is simply an artificial electricity, which acts under the impulse of contacts between different conductors" (Mertens 304). And yet despite Volta's experimental success, the magic of Galvanism would not be tamed because of its explanatory and healing powers. Galvani undeniably spurred other scientists to work on animal electricity (Kipnis 141). In actual fact, both Volta and Galvani believed that the presence of one – either metallic or animal electricity – excluded the other, and while both animal and metallic electricity existed, both denials of the one or other were incorrect (Kipnis 123).

Frankenstein, **Electricity and the History of Science**

Mary Shelley's bracketing of Galvanism, therefore, highlights the gaps between Galvanism and electricity as stable natural objects and anticipates the ways in which thing theory now helps critics to see the ways in which the materiality of things accrue a shifting intelligibility. Indeed, her use of "token" undercuts the seemingly self-explanatory thingness of electricity. Heidegger demonstrates the ways in which things seem to cohere with propositions of truths (45), and asks pointedly "Has man read off the structure of the proposition from the structure of the things, or has he transferred the structure of the proposition into the things? (46). By distinguishing between the thing and the proposition, Heidegger hoped to historicize things. Anticipating Heidegger, Shelley explicitly refers to the "lifeless thing" that is given a "token of things" like animation, and thingness designates some material excess that only seems to provide continuity between the dead and living. Sometimes she figures life as a kind of occult force as when she comments that "the arrival of the Arrabian [sic] now infused new life into [Felix's] soul" (Robinson, *Original* 337). Other times she has Victor appear to be a staunch materialist who demands "of what materials was I made that I could resist so many shocks" (Robinson, *Original* 385). "Shocks" once again frame electricity as external to the body. When taken together, we can see how Mary Shelley explores what life is and how it can be known.

More recently, in *We Have Never Been Modern*, Bruno Latour has turned to things/quasi objects to think about how they rupture neat dichotomies between looking subjects and objects, especially within science. Since Romanticism immediately preceded the rise of objectivity (Daston and Galison), when the gap between objects and subjects became the primary means of guaranteeing scientific truth, and since scientists then were bound by what Jessica Riskin has called a sentimental empiricism, Romanticism is when things deliberately refused the neat modernity marked by clear distinctions between nature and culture, things and objects. Wordsworth, we might recall, demanded that we "see into the life of things." Whereas objects betray the gaze of the subject since objects need subjects to look at them, things exceed the subject's gaze. Riskin demonstrates the extent to which sentimental empiricism underwrote attacks against mechanistic theories: because mechanism restricted physics to moving "bits of matter" (70), scientific "sensibilists" like Franklin "personalized" matter so that one "could have sympathy" towards it (70). Adela Pinch has argued that Hume defined the emotions as a kind of Newtonian force (33), and this meant that the emotions paradoxically could bridge the external and the internal. Even Victor Frankenstein recognizes the demand for scientists to espouse a sentimental empiricism when he apologizes for having fixed his morbid attention "upon every object the most insupportable to the delicacy of the human feelings" (Shelley 34). Franklin's personalization of matter and Hume's rendering of the emotions into a Newtonian force make possible a chiasmus between science and emotion that helps explain how Victor can frame this dead matter as having the power to destroy human sympathy. His apology shows that he recognizes that it was wrong to have suppressed these feelings, yet he did so anyway. His guilt and shame over his suppression of feelings resurfaces when he confesses that he had "tortured the living animal to animate the lifeless clay" (Shelley 36). Shame highlights a precarious porousness to the scientific self, a self open to the world's influence.[27] Because science was tied to feeling, giving it an ethics, Romanticism, we might say, is when scientific things and figures retained their monstrous powers to mediate nature and culture, mediations that Latour argues current science stubbornly resists (*Modern* 28–29). By highlighting such mediations, Mary Shelley asks are monsters born or made? Is electricity the ground for life or merely the stimulus to life or the appearance of life?

All these problems in locating electricity in nature or culture are amplified when electricity stands in for life. Was life a scientific object? Indeed, Walton records the fact that Victor "talks as if life were a thing which he loved" (Robinson, *Original* 420). Shelley inserts Walton's "as if" to inject some needed skepticism. The answer to this question was hardly simple in part because electricity was used to explain the nerve force and possibly the life force. Electricity made the speed of nervous transmission intelligible because the speed of electricity was demonstrably instantaneous. Under natural philosophy, intelligibility – which Peter Dear defines as "feeling at home in the world" (14) – was a sufficient criterion for scientific knowledge. Here the object of natural philosophy is an object of culture, not nature, because it is about societal understanding of it.[28] Under "science," Dear explains, the emphasis moves from explanation to instrumentality, where instrumentality "seems to justify an image of truthfulness" (6), and here too the natural object becomes societal insofar as it exists to serve society. Read in such a light, Victor's acquired "disgust" with natural philosophy can be taken as Shelley's criticism of the incompleteness of a science that leaves behind causes, explanations, and ethics in favor of utility: after expressing his disgust with natural philosophy, Victor holds onto Pliny and Buffon for their "utility" (Shelley 25).[29] Victor's embrace of "utility" yet complete disinterest in how electricity might offer cures, not only flies in the face of a contemporary electrical science driven by the medical implications of it, but also smacks of his own narcissism because utility applies only to himself. This is the man, after all, who counts on the creature's "blessing" of him well before his "new species" has hatched (Shelley 36).

Between Natural Philosophy and Science

Mary Shelley's oscillations between "science" – used eight times in the 1818 edition – and "natural philosophy", which occurs seven times, betray the ambiguous place of chemistry and electricity with the sciences and the need to adjudicate between intelligibility and instrumentality. Volta's battery is after all a chemical reaction. "Natural philosophy" in the novel is linked to discussions of "potassium and boron, of sulphates and oxyds" (Shelley 25). Despite Lavoisier's attempts to modernize chemistry through technical precision and measurement, it relied upon such elusive concepts as "attraction" and "affinity" because these suggested causality without specifying causes, and because these concepts endowed an otherwise vulgarly commercial science – chemistry is tethered to trade – with intellectual pretensions.[30] These oscillations may also hint at competing ways of thinking about forms of scientific truth, as well as the ways in which objects both embody and resist those truths. To what extent did intelligibility have the power to produce objects that could enable such knowledge to condense around a thing, much less a scientific or natural philosophical thing?[31] In the case of nervous electricity, the fact was that then forms of instrumentation were not yet sophisticated enough to register it, and in the absence of such machinery, were explanations enough to render objects? The fact that medical electricity was successful in its treatment of rheumatism and sleep walking, helped to solidify the links between nerves and electricity and to make nervous electricity seem a thing before cell theory, concepts of ion channels, and notions of action potentials. Indeed, Galvani hopes his electrical experiments will enable the treatment of the "ailments" of the "nerves and muscles … with more safety" (45), and he ends this treatise by speculating on new treatments for paralysis, epilepsy, rheumatism, and insanity (85–86). So too did electrical theories help explain why, despite the vast interconnectedness of neural networks, nervous transmission of signals occurred only within specific pathways. Galvani hypothesizes that nervous fibers were conductors surrounded by insulators, and this explained why a nervous signal did not go everywhere.[32] If natural philosophy understood that things provided causal explanations, and if science understood things to have efficacy, electricity became such a powerful object to the science of the nineteenth century because it seemed to do both. In fact, Volta's battery made electricity both portable and harnessable, and therefore far less frightening because it could be controlled.[33]

To connect the Romantic period to current science, some historians like Piccolino have emphasized the role of experiment within Romantic science. However, such a view ignores not only that the period was fundamentally ambivalent about scientific experiment, but also that the period had good reason to be skeptical about experiment.[34] When Mary Shelley has Waldman contrast the "man of science" with "petty experimentalists" (Robinson, *Notebooks* 1: 65), she captures the period's skepticism about experiment, hints that a scientist needed to know more than just experiment, and recognizes that life and materiality may resist experiment. Whether Shelley meant "petty" as was printed in the 1818 version or "pretty," as Robinson has noted in the manuscript (*Original* 73), she trivializes experiment as a form of knowledge. Some of this skepticism offers a useful corrective to a science of today, for example, intent upon collapsing brain scans with cognition or brain states with emotion. In the Romantic period, experiments could mean a vulgar form of knowledge that was underwritten by the mere mechanical labor of one's hands.[35] When Galvani applies his experiments quite by rote to all then-known forms of electricity to see if he achieves the same results, we witness the gap between empiricism and knowledge. Even such an esteemed scientist as Benjamin Franklin thought of experiment as a means of proving whether something worked or not (Finger 251) and since the how or why of why something worked could not be addressed by the then forms of technology, one needed a flexible object that was open to future technologies.[36] Because so many animals died in the name of science, experiment, moreover, seemed a form of barbarous cruelty.

If we recall that the Romantic period immediately preceded the rise of objectivity as the consolidation of scientific truth (Daston and Galison argue that objectivity does not become secure within science until the 1860s), we are prepared to see another deeper level of figuration within electrical science: a chiasmus between subject and object. Although science demands "objects which have been rendered 'able' to object to what is told about them" (Latour, "When Things Strike Back" 115), Leon Chai has argued that the radical otherness of objects becomes a threat to our subjectivity and therefore we conceptualize objects and thereby make them subjective (169). At the same time, Chai submits, because external forces put pressure on the mind, we theorize the external as a way of avoiding "complete submission to external forces" (184).[37]

By conceptualizing electricity as a scientific object, Volta and Shelley help to internalize it, even as its object status shows awareness of the dangers of such internalization. Shelley does so when she recounts Alphonse's educating Victor in the principles of electricity through "a small electrical machine … [and] a kite, with a wire and string, which drew down that fluid from the clouds" (Shelley 24). She contrasts the taming of electricity through experiment with its natural violence (Shelley 24). Such taming or objectification was especially necessary to a notion of science that was becoming intent on the suppression of subjectivity. The stability of the object enhances the stability of the subject looking at the object. Indeed, Shelley's monster allegorizes an electrical thingness, both active and passive, that defies the subject/object binary, a defiance whose name is Galvanism because it seems both external (mechanical) and internal (animal). And by linking Victor Frankenstein with a kind of egregious affectivity – so much so that the very medical electricity thought to offer cures against nervous diseases becomes in Victor's hands the reason for his own nervous collapse – Shelley addresses the need for scientists to find a way outside of their own subjectivities even as the suppression of subjectivity runs the danger of cutting the scientist off from moral and ethical concerns.

Because scientific demonstration then recognized two incommensurate forms of demonstration – one, before colleagues, that requires "sophisticated instrumentation and careful measurement" and another, before a wider public, involving "spectacular effects" (Mertens 306) – what counted as demonstration in science further complicated the kind of object science could deliver. Was the object to be defined by precision, or was it to deliver a visual bang for the buck that had emotional appeal? Since Volta originally lacked the instrumentation, he turned to the latter, even providing bowls of water connected to his battery so that people could feel the electricity.[38] Victor, perhaps unsurprisingly, is drawn to the spectacular: "the catastrophe" of a shattered tree (Shelley 24) is what attracts him towards electricity in the first place.[39] So was Percy, and in fact, in his revision to Shelley's manuscript, he insists that Victor's questions about "the origin of thunder and lightning" were "suggested by natural objects" (Robinson, *Original* 66). Objects that "suggest" seem to talk, and here Percy Shelley registers the ways in which electricity exceeds its neat object status.

I have emphasized the ways in which Shelley turns to figures and things to bracket a scientific object and suspend its being rendered into a stable object. That is, while figures and things rupture the objects that were necessary to the work of Romantic electrical science, the failure to grasp the object of thought allows the targeted object to be encircled, and its contours thereby become discernible.[40] I now highlight how even scientists figuralize things because I consider the ways in which scientific objects require figurality to be operationalized between various branches of science so that the object if not stabilized can be encircled. In so doing, I want to stress that deconstructive accounts of language and of materiality have only told us half the story. Latour perceptively noted that deconstruction made "language a mediator independent of nature and society alike" (*Modern* 62). Deconstruction further desubstantializes matter by defining it in terms of its relation to impossibility (Cheah 76), but electricity makes such maneuvers seem belated. Figures not only enhance intelligibility and communication, thereby connecting objects to speakers, but figuration also links materiality and intelligibility without essentializing any one link. If, to the detriment of science, figuration compromises the scientificity of objects, figuration more positively allows science to continue in the absence of the requisite technology. Thinking about electricity as a fluid explained some of the phenomena about it and allowed scientists to concentrate elsewhere and to invent experiments. Moreover, figuration grants scientific objects both intelligibility and the elasticity they need to be open to future technologies that might otherwise render them historical waste products.[41] Indeed, scientific objects must resist their status as stable objects if they are to bend to future technologies, and if they are to bring together seemingly disparate phenomena under one term, as did electricity. Behind the elusive stability of scientific objects like electricity, then, is thingness, their resistance to the looking subject. Bill Brown puts it this way:

> You could imagine things ... as what is excessive in objects, as what exceeds their mere materialization as objects or their mere utilization as objects – their force as a sensuous presence or as a metaphysical presence, the magic by which objects become values, fetishes, idols, and totems. Temporalized as the before and after of the object, thingness amounts to a latency (the not yet formed or the not yet formable) and to an excess (what remains physically or metaphysically irreducible to objects). But this temporality obscures the all-at-onceness, the simultaneity, of the object/thing dialectic and the fact that, all at once, *the thing seems to name the object just as it is even as it names something else*. (5)

Galvanism thus is a perfect example of the thing that seems to name the object even as it tries to name the location of the soul or life. Mary Shelley put it best, Galvanism had "given a token of such things." Thing theory, thus, helps restore to our view a Romantic view of materiality, the ability of things to exceed the ability of consciousness to process objects. This excess both makes the material resist consciousness, spurring subjectivity. But it also, much as electricity helps explain the action of the nerves, grants materiality a dynamism that brings it in line with consciousness.[42] By leaving open such a wide berth for things, Romantic materiality, thus, paradoxically embodied within itself possibility. This excess need not create problems for science so long as experiment is the final arbiter of things, and so long as, in Bruno Latour's words, objects have the power "to object" to the narratives that surround them ("When Things Strike Back" 115). Thing theory furthermore helps us to see how science has a method for dealing with things that resist object status: an empirical futurity by which technologies yet to be invented will allow science to deliver securely the object sometime in the future. Such a future allows scientists to violate the empirical imperative by seeming to hold onto it because it will be demonstrated.

In her 1817 draft of *Frankenstein*, Mary Shelley contrasts the fact that chemical lectures in Geneva "never failed to attract" Victor's attention with the fact that he "did not understand them" (Robinson, *Notebooks* 1: 15), and thus explicitly frames a gap between specular things and intelligible objects. Shelley's concern with a thingness that straddles the gaps between specularity and intelligibility acquires greater resonance in light of the fact that she plays with the terms "monster" and "demonstration": it is the "theory which he [Cornelius Agrippa] attempts to demonstrate" (Shelley 22) that helps give rise to the monster. Whereas "monster" goes back to the Latin "monere" meaning to warn, "demonstrate" derives from the Latin "demonstrare" meaning to show or point out (*OED*). Of course, Mary Shelley's point is to warn readers about the difference between a show and proof, and to worry about the extent to which demonstration as specularity or as instrumentation were both forms of blindness. What threatens to make demonstration truly monstrous is the forgetting of the gaps between appearance and reality, objects and things, which could be occluded by a language of mathematical or technological precision. Rather than asking us to choose between the hideous/visible and the hidden/invisible, Shelley instead wonders what is the meaning of the visible in a world so governed by the ways in which one perceives. Even Galvani admitted "in experimenting, it is easy to be deceived and to think we have seen and detected things which we wish to see and detect" (59). Galvani's remark offers a useful gloss on the fact that Victor "clap[s] his hands with joy" (Shelley 42) when he finds the monster has fled; it is as if his disappearance to Victor means the problem has gone away. Shelley concludes her novel with "he was soon borne away by the waves, and lost in the darkness and distance" (Shelley 191). Just because the monster is no longer visible, Shelley warns, does not mean that it does not exist.[43] Appearances are not truth.

Galvani's concept of animal electricity is driven by his desire to find medical cures for nervous diseases. Within a context of an electrical science driven by the need to cure, Victor represents a parodic reversal of what should have taken place. Much of Victor's education occurs in his native Geneva, and Geneva, was not coincidentally the place where M. Jallabert, Professor of Philosophy at Geneva, in February of 1748 first achieved a successful cure using medical electricity (*Encyclopedia*, s.v. "electricity"). Shelley notes that the very sight of a "chemical instrument renewed all the agony of [Victor's] nervous system" (Robinson, *Notebooks* 1: 139): not only has the cure become the disease, but also Victor's objectification of his instrument suppresses his subjectivity and absolves him of guilt. Likewise, when he refers to his "hideous narration" (Shelley 167), Victor deflects attention away from his own hideousness by making the narration the object of that hideousness. As science moves in the direction of objectivity, Mary Shelley recognizes the potential of objectivity to eliminate Victor's blinding "enthusiastic frenzy" (Shelley 137). Nonetheless, she worries that objectivity will throw the baby out with the bathwater: sure, enthusiastic frenzy will be contained but in so doing, all sensibility will be left behind and science, because it is now divorced from feeling, will lose its connection with ethics. The fact that objects still require subjects to perceive them, moreover, means that the costs of objectivity include blindness to the ways in which objectivity demands both the suppression of the self, ignorance of how objects can paradoxically insulate the subject so that he or she remains pure, and a world in which matter may be indifferent to human beings. However, if physicians turned to electricity for cures, unlike Victor, they were often not interested in explaining why electricity could cure, and their desire for outcomes over knowledge was not unlike that of Victor's desire for fame.

Born from a voltaic battery designed to prove the existence of Galvanism in the sense of artificial electricity caused by bi-metallic currents and not in the sense of animal electricity, Frankenstein's monster, thus, allegorizes the ontological liminality of nervous electricity in the Romantic period.[44] Was nervous electricity an active and living principle as Galvani thought, but one that was built upon the notion of animal spirits? Or was it a passive principle, and therefore essentially dead, activated by a spiritual will? By asking what it would mean if a battery could give life, Mary Shelley encourages readers to ironize Victor Frankenstein and the novel itself, and move in the direction of skepticism rather than belief. She also thereby wonders about the epistemology of science, about the dangers and uses of demonstration.

In terms of the scientific debate, despite having materialized nervous action, both Galvani's and Volta's notions of materiality leave the door open to spirit, and therefore both demand more nuanced accounts of both scientific materiality and demonstration in the Romantic period. Again the flexibility of materiality belies neat categories of radical or respectable science. Romantic scientific objects have spiritual dimensions that historians suppress in the name of science; indeed, this suppression serves as a metonymy for the very suppression of subjectivity that objectivity entails. Losing sight of these dimensions has not only made science seem more of an enemy to Romantic idealism than it needs to be, but also it has tidied up that science so much so that we have lost sight of how the language of scientific materiality enables the material to become about conditions of possibility rather than material determinism. It is precisely these forms of monstrous liminality that Frankenstein, Romantic scientists, and current historians of science strive to resist or contain.

Acknowledgements

For advice, I thank Roswitha Burwick, Stuart Curran, Tilottama Rajan, Marilyn Gaull, the members of George Washington University's Nineteenth-Century Study Group, and Russell Wyland. Thanks also to Aaron Long, my research assistant.

Notes

1. On vitality as the "distinguishing feature of Romantic aesthetics," see Gigante 1–48.

2. Peer argues that Romanticism "is the first movement in Western Culture to question the ontological primacy of the sensible object" (2). He considers how the raising of the imagination came at the expense of objects.
3. Noting that the torpedo can use electricity to stun its prey, Galvani argues that these fish have "a greater abundance of electricity" but that such electricity was not of a dissimilar nature to that of other animals (78).
4. In the 1800s, the main boundary was between life and not life. In today's science, the boundary has shifted to between unicellular and multi-cellular organisms (Morange 54).
5. Veeder defends Frankenstein's father and points to the ways in which Victor tries to blame his father for helping to cause his downfall (375). Ketterer suggests that Mary and Percy revised this passage on the blasted tree to signal Frankenstein's conversion from alchemy to modern science ("Frankenstein's 'Conversion'" 63). See also Thame.
6. Shelley had good reason to be more skeptical in 1831. The famous neurologist Charles Bell in 1829 "insisted that the theatrical use of electricity to make hanged felons move again ... fooled nobody – it held out no promise of the key to life" (Desmond 227).
7. Fred Burwick (in a personal communication) reminds me that 1800 is also the year that the University of Ingolstadt closed, and thus Victor's training there must have occurred by this date. Volta's essay was translated in Alexander Tilloch's *Philosophical Magazine* for 1800 (Knight 130).
8. Shelley originally wrote, "they know that metals cannot be transmuted and that the elixir of life is a chimera" (Robinson, *Original* 72).
9. Levere begins his history of chemistry by thinking about why the seventeenth-century scientific revolution allowed alchemical traditions to continue (1–13). Shelley recognized that alchemy played an important role in the history of chemistry, despite any Lavoisierian claims to the modernity of chemical science.
10. "Outlines" was originally published in the *Journal of the Royal Institution*. In his 1802 "Essay on the Progress of Galvanism," Davy reviews Aldini's experiments, and supposes that "the animal organs are capable, in certain cases, of exerting an action similar to the metals" (2: 222).
11. I am indebted to my physicist colleague, Nathan Harshman, for this point.
12. Daston traces how theories of electricity "cheerfully recycled the subtle spirits of sixteenth- and early seventeenth-century preternatural philosophy" (34–35).
13. On the history of electricity, see I. Cohen, Whittaker, Meyer, Piccolino ("Galvani's Path"), Morus, Newton, Pancaldi (both works in the References), Dibner (both works in the References), and Heilbron especially. David Ketterer credits Peter Haining for having shown that Mary Shelley attended Andrew Crosse's lecture on electricity on 28 December 1814 at Garnerin's lecture hall ("Alchemy" 396). On Crosse's theatrical and enthusiastic electrical experiments, see Morus, *Frankenstein's Children* 132. On medicine and electricity, see Rowbottom and Susskind.
14. Heilbron corrects the common error that Franklin had invented this concept (330).
15. Madhavi Menon unpacks the implications of metalepsis in *Wanton Words* (73–78). Rhetoricians prefer not to speak of metalepsis, and this results in the fact that metalepsis has no clearly defined ontology (73).
16. Holmes explicitly calls the battery "Voltaic" (327). Natural and man-made electricity facilitate this traffic between the living and the dead.
17. Piccolino defends Galvani's status as scientist because he attends to experimental conditions, and he learns from his mistakes ("Galvani's Path" 306–7). The Institute of Science at Bologna "followed the scientific concepts of Malpighi who wrote about 'rational medicine' based on scientific study using new instruments and new methodologies" (Cajavilca 160).
18. In "Outlines of a View of Galvanism," Davy asserts, by contrast, that "Galvanism was at first limited in its application to organized bodies; ... it has gradually become connected with chemistry and general physics" (2: 189).
19. Faraday sought to prove that electricity from various sources produced the same effects, and thereby might be considered identical (I. Cohen 77).
20. Piccolino examines Galvani's journals and traces how Galvani initially compares the muscles to tourmaline because they produced signs of double electricity upon heating. He abandoned this analogy for the Leyden jar ("Galvani's Path" 313).

21. Galvani writes "An observation that a kind of circuit of a delicate nerve fluid is made from the nerves to the muscles when the phenomenon of the contractions is produced, similar to the electric circuit which is completed in a Leyden jar" (*Commentary* 60). The Leyden jar analogy allowed Galvani to understand "the passive conduction of the electrical signal in nerves," but not the more prevalent active conduction (Piccolino, "Galvani's Path" 315).
22. Dibner (1952) credits Volta and Galvani with a joint discovery, and suggests whether it is called "Galvanism or Voltaic electricity," enough honor should accrue to them both (*Galvani – Volta* 40).
23. According to the *Encyclopedia Britannica* (1771), entry on electricity, "We are entirely ignorant of the nature of this fluid ..."
24. Given how frequently scientists referred to electricity as fire, "Modern Prometheus" should be seen as a code for Electrical Scientist (Goodall 119).
25. Galvani elaborates: "we believe therefore, that the electric fluid is produced by the activity of the cerebrum; the nerves ... are carriers for a very fine ... subtle fluid which is secreted from the cortical substance of the brain, as many believe. If this be the case, perhaps at last the nature of animal spirits, which has been hidden and vainly sought after for so long, will be brought to light with clarity" (79). On electricity as "spiritualist science," see Kirkby.
26. Heilbron cautions that the boundaries between physiology and physics were indefinite and frequently crossed (29–30).
27. On shame, see Sedgwick (61–65).
28. Latour credits Ian Hacking with the nifty distinction between objects of nature and objects of society ("When Things Strike Back" 115).
29. Heidegger claims that the greatness of science during the Scientific Revolution was due to the fact that scientists were philosophers: "they understood that there are no mere facts, but that a fact is only what it is in the light of a fundamental conception" (67).
30. See Chapter One of Klein and Lefevre.
31. Heidegger explores the ways in which thingness has an intelligibility that seems natural.
32. Piccolino notes that this formulation of the nerves was "a basic assumption of the Leyden jar hypothesis of neuromuscular physiology" ("Galvani's Path" 309).
33. Morus demonstrates how electricity became practical in the nineteenth century as it was harnessed by the telegraph and factory machines (*Physics* 54–86).
34. Morus's "Radicals, romantics and electrical showmen" highlights the connections Tories made between experiment and French radicalism. Romantic skepticism about experiment is informed both by French Radicalism, and by the vulgarity of mechanic labor.
35. See Cunningham.
36. Heilbron presents Franklin as more of a bungler in electrical science (336–40).
37. Chai warns against reading what happens in the novel primarily as a comment on the Natural Sciences (184). However, because this novel takes place in the period immediately before the rise of objectivity as the major criterion of science, his analysis has unintended resonance for thinking about science and the novel.
38. In 1796, Volta announced his success in making "metallic electricity" instrument detectable (Pancaldi, *Volta* 182).
39. Vernon mentions Volta in passing – "it is presumably a Voltaic battery which is the 'powerful engine' mentioned" (279). James and Field also lend a surface overview of electricity and the novel. Jackson overviews electricity as a science of spectacle, arguing that this kind of showmanship led to a defensiveness about electricity as science (15–16). Against the optimism of these electricians, Jackson finds Shelley to be deeply pessimistic (164).
40. My phrasing here is very much indebted to Žižek (88).
41. Morange (37). Hull notes how scientists rely upon "weasel words" to finesse differences.
42. On the manifold ways in which materiality functions as an Other to consciousness, see Oerlemans.
43. I am indebted here to Mellor (*Mary Shelley* 139–40).
44. Ontological liminality is one of Jeffrey Cohen's seven theses on monsters. I thank Corie Schweitzer for pointing me to him.

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