Frankenstein and Chemistry

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In chapter 3 of the 1818 edition of *Frankenstein*, Victor Frankenstein declares that "natural philosophy, and particularly chemistry, in the most comprehensive sense of the term, became nearly [his] sole occupation," as he interrogated the secrets of vitality.[1] This essay investigates Mary Shelley's treatment of "chemistry, in the most comprehensive sense of the term," in the novel. For Shelley, and for Victor, chemistry is a science that incorporates not only the structures of inorganic compounds but also the functions and even vitality of living beings. A key term for the novel's discussion of chemistry is "galvanism," often taken by scholars to be Victor's means for animating his Creature. Shelley herself suggests as much in her 1831 "Author's Introduction" to the revised edition of the novel, noting: "Perhaps a corpse would be re-animated; galvanism had given token of such things: perhaps the component parts of a Creature might be manufactured, brought together, and endued with vital warmth."[2] But as this essay shows, Shelley's engagement with chemical discourse reveals that her uses of "galvanic" science are more complex than she suggests in 1831. In the "Author's Introduction" Shelley makes galvanism a byword for the electrical animation of dead matter, practiced by experimenters and showmen such as Giovanni Aldini, who toured London in 1802.[3] But galvanism of another sort is equally crucial for the science of the 1818 edition of the novel, namely the galvanic electrochemical work of Humphry Davy and William Nicholson, which reduced chemical compounds to their constituent elements and enabled unprecedented discoveries in chemistry. But though Davy works to maintain a clear distinction between his galvanic electrochemistry and the more disreputable investigations of galvanic "animal electricity" and vitality, such distinctions are often compromised in his work. Shelley takes full advantage of the way in which chemical discourse in the 1810s retained certain aspects of the vital and the occult, resulting in part from its retention of obscure alchemical practices but more importantly from the abstruseness of one of the most important tools of early nineteenth-century chemical practice, the galvanic battery or pile. A clearer understanding of the ambivalent status of chemistry in the early nineteenth century helps us to grasps the complexities of the science of the novel, in particular, Victor's animation of his creature. Shelley presents this animation as a chemical process, and an understanding of contemporary chemical science complicates the prevailing assumption that Victor uses an electrical battery to animate the creature. As we will see, chemistry, electricity and vitality are intertwined in many more interesting and complex ways in Shelley's narrative.

As historians of science like David Knight, Trevor Levere, and Jan Golinski have shown, the turn of the nineteenth century was a moment at which the science of chemistry and experimenters who practiced it achieved unprecedented fame, status, and notoriety.[4] Mi Gyung Kim declares: "Chemistry was then a vigorous, powerful, voguish science that made its way into the salons and drawing rooms of the upper bourgeoisie. Chemists seemed to wield magic in manipulating the powers of nature to practical and amusing ends. Chemical demonstrations for the lay public, portable chemical laboratories, hydrogen balloons, and electrochemical experiments all secured the place of chemistry in public culture and imagination."[5] Included in this much-expanded audience for chemistry were women and indeed girls: Jane Marcet's *Conversations on Chemistry* (1805) converted the chemical lectures of Davy into didactic dialogues outlining the principles of the science. Marcet seemed to intuit the power of chemistry to intrigue the imaginative as well as the rational faculties. As Richard Holmes notes, she "presented chemistry as a new form of education, a course in both logical reasoning and speculative imagination, for 'young persons.'"[6] Patricia

Fara notes that Marcet's *Conversations on Chemistry* is one of the texts that Mary Shelley may have read as a child in her father William Godwin's household.[7] But chemistry was not solely understood as wholesome educational fare for the young. In the 1790s in particular, the reformist political affiliation of leading British chemists like Joseph Priestley and the predominance and success of French chemists, most importantly Antoine Laurent Lavoisier, produced an association in the minds of conservative commentators between chemistry and political radicalism.[8] Such an association has lingered in some critical readings of the science of *Frankenstein*.[9] But I suggest here that the epistemological uncertainties as well as the sheer vogueishness of chemistry in the early part of the nineteenth century prevent such straightforward political readings of chemical discourse in the novel.

James Rieger famously notes that "Frankenstein's chemistry is switched-on magic, souped-up alchemy, the electrification of Agrippa and Paracelsus. . . . In other words, [Mary Shelley] skips the science."[10] But despite, or perhaps because of, Rieger's provocation, critics have for many years diligently explored the scientific contexts with which Shelley may have been engaging.[11] Such studies focus on Shelley's own reading and informal education at public lectures, noting that while she may have attended Davy's chemical lectures, she certainly went to those of André-Jacques Garnerin in 1814, and her journals record that she read scientific texts with Percy Bysshe Shelley while writing the novel.[12]

Marilyn Butler and Anne Mellor make important efforts to situate the novel in early nineteenth-century scientific debates. Butler argues in her critical introduction to *Frankenstein* that the novel interrogates the vicious and public professional argument over the nature of vitality between the London surgeons John Abernethy and William Lawrence from 1814 to 1817. For Butler, *Frankenstein* "acts out the debate between Abernethy and Lawrence, in a form close enough for those who knew the debate to recognise."[13] For Mellor, in contrast, *Frankenstein* plots a course between the competing visions for the role of science articulated by the chemist Humphry Davy, the doctor Erasmus Darwin, and the physiologist Luigi Galvani. Mellor notes that Shelley "distinguishes between those scientific researches [*sic*] which attempt to describe accurately the functionings of the physical universe and those which attempt to control or change that universe through human intervention. Implicitly, she celebrates the former, which she associates most closely with the work of Erasmus Darwin, while she calls attention to the dangers inherent in the latter, found in the work of Davy [and] Galvani."[14]

While arguing for different scientific influences on the novel, both Butler's and Mellor's studies shifted critical approaches to the science of *Frankenstein* by engaging forensically with the scientific discourses with which Shelley works. Here I follow this lead, but concentrate my analysis exclusively on the chemical discourse of the novel, which is not the focus of either Butler or Mellor's studies.

Critical accounts of chemistry in *Frankenstein* have tended to analyse the continuities between Victor's engagement with modern chemical science and his lingering attraction to the alchemical reading of his youth. Victor is urged by his father and his tutor at the university of Ingolstadt, M. Krempe, to lay aside the "sad trash" of Paracelsus, Cornelius Agrippa, and Albertus Magnus (23). Nonetheless their influence is sustained in Victor's later experimental work, not only in the grandeur of his ambition, but also, according to Markman Ellis and others, in some of the details of his practice.[16] Ellis notes that the scene in which Victor animates the Creature "summarises this ambivalent encoding of alchemy and science" and therefore complicates a reading of the animation as an electrical process.[17] I share Ellis's sense of the need to return to and reread the extremely brief animation scene, but in contrast to his reading of Victor's experimentation in alchemical terms, I suggest that modern chemical practice too is replete with obscurities, ambiguities, and blackspots, which Shelley intuits and exploits in her account of the Creature's animation.

My account of early nineteenth-century chemistry also responds to critical analyses which, though in less harsh terms than Rieger's, suggest that Shelley offers an ignorant or simplified account of Victor's science: Mellor for example notes that Shelley's "description of Victor Frankenstein's laboratory is both vague and naive; apparently Victor does all his experiments in a small attic room by the light of a single candle."[18] Shelley's account of the animation itself is indeed startlingly brief and devoid of detail. But as Alan Rauch argues, that lack of detail is intentional. Shelley "is deliberately unspecific about the details of [Victor's] scientific work. Aside from passing references to his techniques and to his instruments, there is little in the novel that actually describes Frankenstein's scientific activity, much less his scientific context."[19] Such lacunae of course generate the productive ambiguities that have proved so enticing to critics since the publication of the novel, but they also have an instrumental function for both the plot and the generic significance of *Frankenstein*. Shelley has Victor remark to Walton, "I see by your eagerness, and the wonder and hope which your eyes express, my friend, that you expect to be informed of the secret with which I am acquainted; that cannot be," for reasons not only of Walton's safety but also the reader's (35). Even beyond the demands of the plot, as Ellis reminds us, the novel is an apt medium through which Shelley can explore and exploit the obscurity of Victor's practice: "The novel form, and in particular the gothic mode adopted by Shelley, allows for the contradictions, confusions and errors of the science to be overlooked and underplayed, incorporated into the creative act of reading."[20] Despite this helpful intervention, however, Ellis retains the suggestion that Shelley misunderstands or simplifies the philosophical or scientific discourses on which the novel draws. I find more compelling Janis McClarren Caldwell's assurance that Shelley is in control of and deploying her material for certain ends: "if she hovers between philosophical positions, it can't be entirely from youthful confusion or a welter of influences. . . . The novel argues for—something."[21] In the case of chemistry, *Frankenstein* does not warp the certainties of chemical practice. Rather, part of the "something" for which it seems to argue is the radical uncertainty at the heart of chemical science in this period, which as Richard Sha notes, still "relied upon such elusive concepts as 'attraction' and 'affinity' because these suggested causality without specifying causes."[22] This is an uncertainty on which Shelley builds.

Much of the promise but also the obscurity of early nineteenth-century chemistry arose from a newly urgent sense of the role of electrical forces in chemical phenomena, and a better understanding of the function of both electricity and chemistry in physiology. The association between chemistry and electricity was not itself new; Priestley had noted in 1767 that the importance of electricity for chemical practice was under-explored, declaring of chemistry: "Here seems to be the greatest field for the extension of electrical knowledge: for chymistry and electricity are both conversant about the latent and less obvious properties of bodies; and yet the relation to each other has been but little considered; few of our modern electricians having been either speculative or practical chemists."[23] In 1800 the gap Priestley diagnosed between the work of electricians and chemists was spectacularly bridged by the work of Alessandro Volta. But nonetheless, the opacity of electricity and chemistry that Priestley described still persists in nineteenth-century accounts.

In 1800 Volta took issue with Luigi Galvani's claim that he had detected a distinct form of "animal electricity" in the nerves and muscles of dissected frogs, and that this "nerve fluid, (an electric fire, as it were)," is distinct from electricity, though they have "qualities" in common.[24] Volta asserted in contrast that the twitching of Galvani's frogs was produced by the contact of metals in the electrical circuit. To prove this, Volta developed the "galvanic pile," a series of discs of different metals suspended in liquid, which was capable of producing a sustained electric current. In a letter to Joseph Banks, President of the Royal Society, Volta notes the "inexhaustible charge" of his pile, comparing it "to the Leyden flask

. . . acting incessantly."[25] But Volta also stresses the differences between the new apparatus and the older electrical technology of the Leyden jar or electrical condenser. He achieved his extraordinary breakthrough by studying the production of electricity in organic structures, namely the torpedo electric fish, and notes in his letter that "I would wish to give [it] the name of the artificial electric organ."[26] Though Volta developed his pile in order to rebut Galvani's claims for the production of a distinct "animal electricity," he too appeals to the evidence of the body to endorse the power of the pile, and anticipates that its primary uses will be in the work of "the anatomist, the physiologist, and the practitioner."[27] Experimenters in Britain soon observed a distinct use for the pile—in chemistry—but the physiological basis of Volta's instrument continued to inform its uses.

Banks shared news of Volta's invention of the pile with his colleagues, the chemist and inventor William Nicholson and the surgeon Anthony Carlisle. Nicholson and Carlisle built a pile according to Volta's design but put it to a new use, employing "the agency of electricity in chemical operations" by decomposing water into its constituent elements, hydrogen and oxygen.[28] In doing so, they demonstrated the application of the galvanic pile in chemistry, reducing compound substances to their constituent elements. And, crucially, they hinted at their dissent from Volta's view that the continual electric current was produced by the contact of the metals in the pile. Nicholson and Carlisle suggested instead that the chemical reaction in the pile was produced by electricity—and also that its electric force might be produced by the chemical reaction. Nicholson and Carlisle thus showed, as Priestley had proposed, that chemical reactions and the operations of electricity were innately but obscurely linked. And despite their demonstration of the pile's chemical action, commentators were still fascinated and convinced by its connection with the operations of the living body. The *Morning Chronicle* newspaper declared of a demonstration of the pile in May 1800 that its results "may throw light on several phenomena of the Animal Economy, as well as Chemistry and Electricity."[29] Such connections between electrochemistry and physiology were sustained in the aftermath of Nicholson and Carlisle's experiment.

Though the importance of Nicholson and Carlisle's work to the development of chemistry has often been noted by historians of science, their connection with the author of *Frankenstein* has been less often remarked. But, as Maurice Hindle has noted, both Nicholson and Carlisle were close friends of Shelley's father.[30] Nicholson, in particular, had been closely associated with Godwin since the 1780s; Nicholson and his wife attended Godwin during the days in which Mary Wollstonecraft was dying, offering to take care of the children on her death, and they remained close until Nicholson's death in 1815.[31] In her unpublished memoir of her father, Shelley singled out Nicholson as one of Godwin's most "dear & valued friends for many years" and praised his scientific work, noting, "In these days Nicholson would probably have risen to greater eminence. During the period when he lived he knew the world was chiefly alive to the progress of mind & political science—now the external universe obtains far more consideration. As a man of invention, of acquirement—of mingled theory & practice, Nicholson would have prospered in these days of mines, tunnels, railroad & steam engines."[32] Nicholson and Carlisle's chemical decomposition of water was indeed largely received, and contested, as a theoretical rather than a practical achievement; indeed there was little consensus as to whether they had indeed managed to separate water into hydrogen and oxygen, or whether there was an alternative explanation for the effects they witnessed.[33] But Nicholson's work certainly demonstrated the aspects of chemistry emphasized by recent historians and critics: it was a practice which, while offering few secure answers, opened up further avenues for both experimental and theoretical, even imaginative, investigation.

The most celebrated beneficiary of Nicholson and Carlisle's experiment was another visitor to the Godwin household in the late 1790s, though he later played down such radical connections: Humphry Davy.[34] Despite the controversy over the findings of Nicholson and Carlisle's experiment, Davy quickly accepted that Volta's instrument could indeed decompose chemical compounds, and he used it as a tool for further electrochemical work. Davy was circumspect about the precise operation of the galvanic pile, and focused instead on its effects, but he seemed to believe, like Nicholson and Carlisle, that the electric current in the pile might be produced by a chemical reaction.[35] Looking back in 1812, in his *Elements of Chemical Philosophy*, he declared: "it was not till the era of the wonderful discovery of Volta . . . that any great progress was made in chemical investigation by means of electrical combinations."[36] Davy made Volta's pile the symbol of his self-appointed task to modernize and standardize chemical methods in the first fifteen years of the new century.

Davy used the pile to divide chemical compounds into their constituent elements, isolating elements like potassium and sodium. He also oversaw the production of larger and more advanced equipment, connecting separate piles into "batteries" and noting of his "great battery" at London's Royal Institution that "it consists of two hundred instruments, . . . each composed of ten double plates arranged in cells of porcelain . . . so that the whole number of double plates is 2000, and the whole surface 128000 square inches."[37] Though he avoided speculation on the operation of the pile, Davy even claimed that chemical affinity is itself electrical, showing "the dependence of the chemical arrangements of matter upon electrical functions."[38] In making such claims, Davy was careful to distinguish between his electrochemical work and the galvanic practice of experimenters like Aldini.[39] But despite his emphasis on the modernization and professionalization of chemistry, Davy's electrochemical writings demonstrate a sustained interest in the physiological origins and applications of the galvanic pile, an interest which Shelley seems to echo in her descriptions of Victor Frankenstein's chemical work.

Davy engages with the debate over galvanic phenomena in living bodies throughout his career, even declaring in his final published paper in 1829 that "it is surprising to me that the electricity of living animals has not been more an object of attention, both on account of its physiological importance, and its general relation to the science of electro-chemistry."[40] Still, as Sharon Ruston has shown, the connection between animal life and electro-chemistry was not a given for Davy: from 1812 on he was a member of the conservative Animal Chemistry Society, which aimed to demonstrate that vitality "could not be reduced to or explained by chemistry" because its causes were divine.[41] Davy never seems to have lost his interest in the bodily applications of chemistry, and he suggests on several occasions that electrochemical techniques might be applied to organic matter. Among his authoritative claims for electricity's power to isolate inorganic chemical elements we thus find suggestive hints, and important hints for *Frankenstein*, that it operates on living matter too.

The term galvanism itself signals a connection between Davy's electrochemical experimentation and Galvani's animal electricity; indeed, in Davy's first uses of Volta's pile a distinction between the two practices is not always clear. Davy's letter published in *Nicholson's Journal* dated 23 January 1801 declares: "there exists in living matter galvanic action independent of all influence generated by metallic oxidation. I have produced the phenomena of taste and muscular irritation by means of metals, in cases where they were apparently incapable of undergoing chemical change."[43] Davy thus introduces the possibility that galvanic forces arise from and affect physiological structures in a way distinct from its chemical operation, but arising from the same causes. According to such understandings of galvanism, Victor's animation of the creature could arise from the manipulation of galvanic physiological forces.[44]

Davy reiterates his interest in the physiological operation of galvanic forces in his new employment at the Royal Institution in London. Davy began his lecturing career there in 1802, with a series on chemistry. His introduction to that series has been much discussed by scholars of *Frankenstein*, and I turn to it below. In the syllabus to the lecture series, Davy signals his continued interest in the connection between galvanic chemistry and physiology: "The general connection of electricity with physiology and with chemistry, which is at present involved in obscurity, is probably capable of experimental elucidation; and the knowledge of it would evidently lead to novel views of the philosophy of the imponderable substances."[45] The obscure connection between galvanic forces in chemical compounds and in living matter is a useful problem for Davy, because it suggests the potential for future progress in electrical science. But it also demonstrates that the brilliant clarity of Davy's electrical decomposition of chemical compounds is never far removed from the more uncertain provenance and operation of galvanic forces in living bodies. This enables an obscure, creative space in chemical experimentation, which Shelley exploits.

Davy's "A Discourse, Introductory to a Course of Lectures on Chemistry" (1802) has been the subject of detailed analysis by *Frankenstein* scholars since Laura Crouch pointed out that it was this text Shelley referred to in October 1816 when she noted in her journal, "Read the Introduction to Sir H. Davy's Chemistry."[46] Crouch argued that the strongest influence of Davy on the novel was registered in the enthusiastic rhetoric of Victor's professor at Ingolstadt, M. Waldman, who closely echoes Davy's claims for the potential influence and reach of chemical science in the "Discourse."[47] In a celebrated passage, Davy declares of chemistry:

> By means of this science man has employed almost all the substances in nature. . . . Not contented with what is found upon the surface of the earth, he has penetrated into her bosom, and has even searched the bottom of the ocean for the purpose of allaying the restlessness of his desires, or of extending and increasing his power. He is to a certain extent ruler of all the elements that surround him, and he is capable of using

> not only common matter according to his will and inclinations, but likewise of subjecting to his purposes the ethereal principles of heat and light.[48]

As Crouch suggests, Davy's words do not anticipate the details of Victor's achievements in the novel, but they foreshadow the "scientific optimism" by which he is driven.[49] Such "optimism" is certainly evident in the words of M. Waldman, who in Victor's first class lectured on "the history of chemistry . . . , took a cursory view of the present state of the science, and . . . concluded with a panegyric upon modern chemistry" in which he declares: "These philosophers, whose hands seem only made to dabble in dirt, and their eyes to pour over the microscope or crucible, have indeed performed miracles. They penetrate into the recesses of nature, and shew how she works in her hiding places. They ascend into the heavens; they have discovered how the blood circulates, and the nature of the air we breathe. They have acquired new and almost unlimited powers; they can command the thunders of heaven, mimic the earthquake, and even mock the invisible world with its own shadows" (30). Here Waldman echoes Davy's claims for the scope of chemical science, which includes the investigation of vitality. But the importance of Davy's electrochemical work for the novel goes beyond these rhetorical connections.

Davy's argument for the cultural and intellectual reach of chemistry and his account of the complex operation of electricity in chemical science is echoed in Victor's declaration that in Ingolstadt "natural philosophy, and particularly chemistry, in the most comprehensive sense of the term, became nearly my sole occupation" (32). Shelley reminds the reader at several points in her account of Victor's education at Ingolstadt that it is chemistry in particular, and not an undefined science, that Victor pursues. He not only excels in the theory, but also "at the end of two years . . . made some discoveries in the improvement of some chemical instruments, which procured me great esteem and admiration at the university"

(33). Shelley's phrase "chemistry, in the most comprehensive sense of the term" chimes with Davy's "Discourse" but she deliberately does not clarify its precise meaning.

The nature of the connections between Victor's work and Davy's chemistry has therefore been the subject of much discussion. Mellor notes that Victor is steered toward a broad field of study by Waldman, who in the previous chapter echoes Davy again, declaring: "Chemistry is that branch of natural philosophy in which the greatest improvements have been and may be made. . . . [But a] man would make but a very sorry chemist, if he attended to that department of human knowledge alone. If your wish is to become really a man of science, and not merely a petty experimentalist, I should advise you to apply to every branch of natural philosophy, including mathematics" (31). But though she signals the connection with Davy, Mellor also seems to narrow Victor's "comprehensive" field by declaring that it refers to "the newly established field of chemical physiology; thus, he must be familiar with recent experiments in the disparate fields of biology, chemistry, mechanics, physics, and medicine."[55] "Chemical physiology" was indeed a novel and intriguing field of study in the early nineteenth century, but if Victor is a chemical physiologist, this distances his practice from that of Davy, who aligned such work with Aldini, and indeed criticized it. Davy notes in the "Discourse" that "A reproach . . . has been thrown upon those doctrines known by the name of chemical physiology; for in the applications of them, speculative philosophers have been guided rather by the analogies of words than of facts. Instead of slowly endeavouring to lift up the veil concealing the wonderful phaenomena of living nature, they have vainly and presumptuously attempted to tear it asunder."[56]

Davy's account of the presumptuous experimenter attempting to roughly tear away the "veil" concealing the works of nature at first glance seems to anticipate Shelley's account of Victor's work, and thus to set Victor and Davy in opposition. But I suggest that Victor's chemical work is indeed closely connected with Davy's electrochemistry. The tendency of critics to align Victor with the vitalist experiments of Aldini arises from a limited reading of the significance of galvanism for Victor's practice. Victor does perhaps adopt galvanist techniques (Shelley never gives us enough information to be sure), but it is Davy's electrochemical galvanic practice that seems to inspire Victor's chemistry.

In the animation of the Creature at the opening of volume 1, chapter 4, Victor declares: "With an anxiety that almost amounted to agony, 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. It was already one in the morning; the rain pattered dismally against the panes, and my candle was nearly burnt out, when by the glimmer of the half-extinguished light, I saw the dull yellow eye of the Creature open; it breathed hard, and a convulsive motion agitated its limbs" (38–39).

This is a deliberately oblique passage in which Shelley leaves various interpretations open to the reader. According to contemporary discussions, Victor could be administering a galvanizing electrical shock in the manner of Aldini, and this is certainly the explanation favored by many scholars, who declare that not only is the "spark of being" electrical, it is also produced by a galvanic pile. Butler is typical when she notes that "Frankenstein's 'instruments of life' capable of infusing the 'spark of being' suggest the galvanic battery used in real life to try to bring a poisoned cat or hanged criminal back to life."[58] Peter Vernon uses different terms to describe the same instrument, declaring that Victor animates the Creature "presumably using a gigantic Voltaic battery."[59] The novel's plot, as I discuss below, seems to demand that Victor cannot be using "gigantic" equipment of any kind, but there are other objections to be made to the assumption that the animation is a galvanic process in the manner of Aldini.

Richard Sha has offered an important rejoinder to such claims, reminding us that Volta's pile was of course developed in order to counter Galvani's claims for "animal electricity." Thus, Sha notes, "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 . . . to refer to the 'galvanic battery' when in fact the battery was invented by Volta precisely to refute the idea of animal electricity. . . . 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."[60] Sha usefully notes that Shelley's laconic account of the Creature's animation gestures to the figurative qualities of contemporary descriptions of electricity, and warns readers not to literalize the connection between electricity and life.[61] Yet despite his caution, Sha too reaches the conclusion that Victor uses a voltaic battery to animate the Creature: he is "[b]orn 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."[62] I want to build on Sha's destabilizing of scholarly assumptions about Victor's electrical vitalist methods, to consider whether Shelley's animation scene need be powered by galvanic equipment at all. Sha's focus on the electrical technology of the animation scene perhaps necessarily places the galvanic pile at the center of his analysis. But a focus on chemistry "in the most comprehensive sense of the term" suggests that chemistry can relate to electricity and even physiology in ways that do not issue only from galvanic equipment.

As we have seen, both Nicholson and Davy argued, against Volta, that the electricity produced by Volta's pile was a result not of the contact of metals, but of a chemical reaction. In this account, electricity is found to be a fundamental driver of chemical activity, but chemical compounds also produce electricity. This account of the chemical production of electricity was disseminated in the early years of the nineteenth century, to the extent that Marcet discusses the phenomenon in *Conversations on Chemistry*. But Marcet stresses caution about the precise connection between chemical reactions and electricity. Her instructor, Mrs. B, declares: “The action of the fluid on the metals [in the pile] is entirely of a chemical nature. But whether electricity is excited by this chemical action, or whether it is produced by the contact of the two metals, is a point upon which philosophers do not yet perfectly agree.”[63] So while electricity is understood to be fundamental to chemical processes, radical uncertainty still remains about the limits of their operation. Mrs. B notes: “I should not omit to mention, that some doubts have been entertained whether electricity be really a material agent, or whether it might not be a power inherent in bodies, similar to, or, perhaps identical with, attraction.”[64]

Electricity, and with it chemical affinity or attraction, is apparently an agent inherent in matter, but whether it is a material substance itself, or an immaterial power, is unknown. Such speculation is common to discussions of electricity at this moment, as Sha suggests. But the work of Davy, and by extension Marcet, helps us see the extent to which this speculation also informs chemical discourse. Victor is an adherent of modern chemistry after all, but in the imagination of Shelley, this science presents the possibility of demonstrating and harnessing the electrical forces inherent in organic and inorganic matter. The uncertainty of the operation of chemical reactions is no obstacle for Shelley; rather she appropriates it to ensure the obscurity and potency of Victor’s methods for animating the Creature.

We have seen that in the animation scene itself Shelley offers few textual suggestions for the nature of the “instruments of life” that Victor employs. But in the aftermath of the Creature’s birth and Victor’s subsequent breakdown, he declares that “when I was otherwise quite restored to health, the sight of a chemical instrument would renew all the agony of my nervous symptoms. Henry saw this, and had removed all my apparatus from my view” (48). While avoiding detail, Shelley reiterates that the Creature’s animation was a chemical process, and also, importantly, that Victor’s “apparatus” is unlikely to be “gigantic,” but rather is portable enough that his friend Clerval can remove it from sight.

This suggestion of the nature of Victor's equipment is reinforced in volume 3 of the novel, when he sets out with Clerval for England with the aim to correspond with "the philosophers of that country, whose knowledge and discoveries were of indispensable use to me in my present undertaking," the construction of a female mate for the Creature (126). Though distressed at his task and his "exile," he says "I remembered only . . . to order that my chemical instruments should be packed to go with me: for I resolved to fulfil my promise while abroad, and return, if possible, a free man" (128). Those instruments travel with Victor through northern Europe and his tour of "Windsor, Oxford, Matlock, and the Cumberland lakes," as well as Edinburgh. "I packed my chemical instruments, and the materials I had collected, resolving to finish my labours in some obscure nook in the northern highlands of Scotland" (132). Shelley doesn't specify the nature of either the chemical instruments or other materials, though the narrative gestures to a rather grim spectacle of Victor's British tour proceeding with luggage filled with chemical instruments and perhaps also body parts, as the chapter makes no other mention of Victor gathering bodily "materials" for the female Creature. Though Shelley sustains the mystery of Victor's actual practice, she clarifies that he is able to complete his work with the smallest of mobile laboratories, in marked contrast to Davy's "great battery" of galvanic piles at the Royal Institution. And as Rauch notes, the mobility of Victor's equipment introduces doubt about his claim to have abandoned his chemical work. Though he has destroyed the female Creature, he then "sat upon the beach, employed in cleaning and arranging my chemical apparatus," packing them for their next use.[69] Victor's ongoing relationship with his chemical instruments thus also alerts the reader to the limits and deceptions of his self-justifying narrative.

Critical discussion of the animation science in *Frankenstein* remains a remarkably open and diverse field, and this is a result of the radical openness of Shelley's description of Victor's practices. It would be unwise and unhelpful to make categorical statements about the nature of Victor's scientific "secret," as he himself points out, not just to prevent efforts to replicate the project but also because, as Fred Botting notes in a deconstructionist reading of the novel, it would compromise the novel's radical indeterminacy: "The quest to uncover the secret of the text's nature, to unfold once and for all its living presence, its principle of life, does not reveal the unequivocal or authorised voice, but discloses only monstrous doubles, different and distant from any unifying figure."[70]

I would suggest that to focus on Shelley's statements about Victor's practice as chemical is not to look for a unifying figure or explanation, but rather to note that the science of chemistry itself is a discourse which at the opening of the nineteenth century still embodied fundamental mysteries. Despite the breakthroughs and the pretensions of figures like Nicholson and Davy, chemistry remained something of an occult science whose operations were unexplained and the limits of whose powers were thrillingly indistinct, taking in organic as well as inorganic material. Galvanic experimentation has proved a useful cultural context for scholars of the novel, but I suggest that Shelley's representation of galvanic chemistry does not merely provide a single model for the animation of the Creature. Rather, it confirms the mysterious operation of electricity in inorganic and organic materials, and thus opens up a range of possible techniques for Victor, which the novel's studiedly laconic descriptions of his practice encode and sustain.

NOTES

1. Shelley, *Frankenstein*, 32. Subsequent page references will be included in the main text.
2. Shelley, "Author's Introduction" (1831), *Frankenstein*, 195–96.
3. See Aldini, *Account*.
4. Knight, *Natural Science Books*; Levere, *Poetry Realized*; Golinski, *Science as Public Culture.*
5. Kim, *Affinity*, 2.
6. Holmes, "Humphrey Davy," 1629.
7. Fara, "What Mary Knew," 19.
8. See Crosland, "Image of Science," 277–307.
9. See for instance Schummer, "Historical Roots," 116.
10. Rieger, Introduction, xxvii.
11. The first dedicated study of this kind was perhaps by Vasbinder.

12. Hindle, “Vital Matters,” 32; Rauch, “Monstrous Body,” 241–42; Shelley, *Journals*, vol. 1, 96, 142–44.

13. Butler, Introduction, xx. For more on the Abernethy and Lawrence debate, see Ruston, *Shelley and Vitality*, 6–21.

14. Mellor, “*Frankenstein:* A Feminist Critique,” 288.

16. Ellis, “Fictions,” 1–20. As critics have noted, while early nineteenth-century chemical science is tested through public experimentation and discussion, Victor’s practice remains a deadly secret. Schummer, “Historical Roots,” 100; “*Frankenstein*: Science and Electricity,” 276; Rauch, 234; Friedman and Kavey, *Monstrous Progeny*, 19.

17. Ellis, 15.

18. Mellor, 288.

19. Rauch, 288.

20. Ellis, 1.

21. Caldwell, *Literature*, 29.

22. Sha, “Volta’s Battery,” 32.

23. Priestley, *History and Present State*, 463.

24. Galvani, *Commentary*, 62.

25. Volta, “On the Electricity,” 36. Volta’s letter was published in French in *Philosophical Transactions* in June 1800, and translated into English for the *Philosophical Magazine* in December 1800.

26. Volta, “On the Electricity,” 37.

27. Volta, “On the Electricity,” 45, 47.

28. Nicholson, “Account,” 183.

29. *Morning Chronicle*, 30 May 1800.

30. Hindle, “Vital Matters,” 32; see also Marshall, *William Godwin*, 86–87.

31. Godwin’s diary offers a full record of those days 30 August–10 September 1797. Nicholson is mentioned 516 times in the diary, Carlisle 298 times; see *Diary of William Godwin*. .

32. Shelley, “Life of William Godwin.”

33. Golinski, 206–7.

34. Hindle, “Vital Matters,” 32.

35. Knight, *Humphry Davy*, 40.

36. Davy, *Collected Works*, vol. 4, 37.

37. Davy, *Collected Works*, vol. 4, 110.

38. Davy, “Lecture I, Introductory to Electro-Chemical Science” delivered in 12 March 1808, in *Collected Works*, vol. 8, 284.

39. See for instance Davy, “An Account of the Late Improvements,” 194–98.

40. Davy, “An Account of Some Experiments,” 15.

41. Ruston, “Resurrecting Frankenstein,” 100. See also Levere, 53; Sha, 25.

43. Davy, “Letter to Mr Nicholson,” 527.

44. Fullmer, *Young Humphrey Davy*, 316.

45. Davy, “A Syllabus of a Course of Lectures on Chemistry,” in *Collected Works*, vol. 2, 409.

46. Shelley, *Journals*, vol. 1, 142; Crouch, 35–36. Mellor notes that the *Elements of Chemical Philosophy* was the likely source for the chemical lecture that Victor witnesses as a child in Geneva. See Shelley, *Frankenstein*, vol. 1 ch.1, 25; Mellor, 289.

47. Crouch, “Davy’s *A Discourse*,” 38–39; Mellor, 288–92.

48. Davy, “A Discourse,” in *Collected Works*, vol. 2, 318.

49. Crouch, 36, 38.

55. Mellor, 288.

56. Davy, “A Discourse,” in *Collected Works*, vol. 2, 314.

58. Butler, Introduction, xxx.

59. Vernon, 275, 279.

60. Sha, 21.

61. Ibid., 22, 25.

62. Ibid., 36.

63. Marcet, *Conversations*, 165.

64. Ibid., 25.

69. Ibid., vol. 3 ch. 3, 142; Rauch, “Monstrous Body,” 233.

70. Botting, *Making Monstrous*, 3.

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