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Author(s): Barri J. Gold

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The Consolation of Physics: Tennyson's Thermodynamic Solution

BARRI J. GOLD

ALFRED, LORD TENNYSON'S *IN MEMORIAM* IS A STRANGE confluence of past and future. Without abandoning certain Romantic beliefs, especially the importance of poesy as a way of knowing, Tennyson embraces a characteristically Victorian investment in scientific modes of inquiry. By insisting on the consonance of the two cultures at a moment of their apparent divergence, *In Memoriam* not only evinces a deep concern with the science of the day but also disrupts expected patterns of influence. Even where readers have sought to explore the interaction between science and literature, they have tended to posit a unidirectional influence, considering almost exclusively the influence of science on literature. But for over a century, Tennyson's readership has remarked the poem's prescience in scientific matters. We are by now thoroughly familiar with *In Memoriam*'s struggles with the anxieties wrought by evolutionary narrative, such that, in spite of the poem's 1851 publication (preceding Darwin's *Origin of Species* by eight years), the phrase "Nature, red in tooth and claw" (sec. 56) has been "vested by historians with the power to sum up nothing less than the impact of evolutionary thought on Christian humanism" (Adams 7). We are similarly familiar with Hallam Tennyson's observation that "the sections of 'In Memoriam' about Evolution had been read by his friends some years before the publication of the *Vestiges of Creation* in 1844" (qtd. in Mattes 88n26). Thus, *In Memoriam* suggests, if nothing so simple as the influence of poetry on science, at least something more conversational: a mutual influence and common concerns leading to what we might call, borrowing from the scientists, a mode of simultaneous discovery.

Moreover, *In Memoriam*'s acuity regarding things scientific extends beyond Tennyson's investment in evolutionary biology and its precursors

BARRI J. GOLD is assistant professor of English at Muhlenberg College. Trained in literature and physics, she is interested in the intersection and mutual influence of nineteenth-century literature and thermodynamics. She has also written on the imagination of reproductive technologies as it is shaped by ideologies of gender and empire and redeployed in the production of feminist and sexual counternarrative.

in early-nineteenth-century geology. The 1850s witness the consolidation of two sciences; evolutionary biology and energy physics emerge in this moment as viable, indeed what Thomas Kuhn calls dominant, paradigms (*Structure*). But while Tennyson's engagement with biological and geological thought is well known, his conversation with the physical sciences has been largely overlooked.[1] Tennyson's oft-quoted to-do list—"Monday. History, German. / Tuesday. Chemistry, German. / Wednesday. Botany, German. / Thursday. Electricity, German. / Friday. Animal Physiology, German. / Saturday. Mechanics. / Sunday. Theology" (qtd. in Gibson 61)—coupled with the posthumous testimony of his friend the astronomer Norman Lockyer (see Lockyer and Lockyer), reveals an early and abiding interest in the physical sciences. Indeed, Thursday's regimen as well as Saturday's suggests that, in spite of Romantic antipathy to certain Newtonian ways of knowing, there is a place for physics in poetry.

My concern here, however, is less with what Tennyson knew than with what he could not possibly have known: the laws of thermodynamics. We are, indeed, hard-pressed to pinpoint when these laws were first articulated. For Kuhn, "the hypothesis of energy conservation [. . .] publicly announced by four widely scattered European scientists" between 1842 and 1847 is an exemplary case of simultaneous discovery ("Energy Conservation" 66). Some locate the genesis of energy physics considerably earlier. Thomas Young's 1803 lecture "On Collision" (75–82) seems to offer one of the earliest usages of the term *energy* in its modern physical sense (Peterfreund 24). But his rather Newtonian focus on the motion of macroscopic objects renders his formulation only a small subset of what *energy* (considerably transformed and expanded by the Victorians) eventually comprehends. Similarly, Sadi Carnot's 1824 paper "Reflections on the Motive Power of Heat" is often taken to be the earliest formulation of the second law of thermodynamics, which posits the inevitable loss of useful energy. That William Thomson, Lord Kelvin, will later call this work "a perfectly clear and general statement of the 'Conservation of Energy' " ("Dissipation" 316)—that is, of the first law of thermodynamics—suggests that Carnot's contribution is significant. What that contribution is, however, remains unclear for decades to come—perhaps until Thomson's landmark "On the Dynamical Theory of Heat" ([1851] 174–332), which seeks to reconcile the increasingly apparent contradiction between Carnot's work and James Prescott Joule's. The considerable conceptual work this reconciliation requires suggests that the scattered pronouncements of a principle here, a definition there, do not suffice to establish thermodynamics as a science or, more precisely, a physical theory (Rankine 209). It is not until 1854 that Thomson identifies this science as "thermo-dynamics" (Harman 45), not until 1865 that Rudolph Clausius coins the key term "entropy" (Clarke 73). A broad popularization of thermodynamic theory follows, marked not least by John Tyndall's *Heat Considered as a Mode of Motion* (1863) and by Balfour Stewart's *The Conservation of Energy* (1874). Thus, much of the development of thermodynamic theory coincides with—and virtually all its popularization succeeds—the writing and publication of *In Memoriam.*

Nonetheless, *In Memoriam* is saturated with the language of energy physics. Though "energies" appears only twice (40, 113), that which *energy* eventually comprehends (heat, light, power, force) surfaces again and again, as do images that suggest the concerns of thermodynamics more broadly (loss and gain, waste, systems, the behavior of gases, order and disorder, and changes of state or form). In Tennyson, as in the emergent science of energy physics, these terms overlap considerably and, like the things they represent, tend to transform into one another. As Joule will observe in 1847, "All three, therefore—namely, heat, living force, and attraction through space (to which I might also add *light*

[. . .])—are mutually convertible into one another. In these conversions, nothing is ever lost" (271). Similarly, in Tennyson, light and heat (life, attraction) will prove interconvertible and will be governed by the same principles. And when read through the lens of constructive anachronism—the same kind of vision that enables us to identify retroactively the significance of contributions such as Young's and Carnot's—the poem's apparently disconnected returns to these concerns emerge as a coherent thermodynamic narrative. Drawing on the same culture of science that enables the physicists, Tennyson (reading Laplace and Kant, among others) can be said to have discovered—poetically—not only the terms but also the principles and processes of the nascent science of energy physics, especially the poetic evocation of the tension between conservation and dissipation that haunts the first and second laws of thermodynamics.[2]

In this way, *In Memoriam* becomes exemplary of poetic discovery simultaneous with—even prior to—scientific discovery. As such, the poem requires us to reexamine our expectations of the relation between Victorian poetry (or religion, for that matter) and science, especially physics. Far from being antagonistic or mutually exclusive endeavors, poetry and science draw on the same language and wrestle with the same worrying contradictions as each develops the principles physics will call the laws of thermodynamics. Working out how Tennyson anticipates these laws, we also elicit the means by which he reshapes what seem like familiar tropes of Romantic elegy. As he deploys these in the context of his scientific concerns, they resonate in important physical, as well as spiritual, ways. At the same time, *In Memoriam*'s conversation with energy physics leads us to revisit our ideas about relations in and between the branches of Victorian science: we find elegiac echoes in the discourse of energy physics, and we discover that Victorian physics and biology may have enjoyed an affective relation counter to what we have come to expect.

A Brief Scientific Interlude: The Laws of Thermodynamics and the Paradox of Heat

In this essay the "affective relation" between physics and biology refers to the emotive weight attached to each as they come to permeate popular conversation. By the second half of the nineteenth century—significantly, in the wake of the publication of *In Memoriam*—evolutionary theory is suffused with optimism. Victorians invest evolution with the promise of progress (a promise, biologists insist, by no means inherent to the theory); the concept is taken to imply an onward and upward development—of individual, species, race, and nation—toward perfect forms. Thermodynamics, in contrast, is widely experienced as the scientific basis for universal pessimism; it promises only decay, dissipation, degradation, and death. As George Levine observes, "[T]he second law seemed from the start to run counter to the optimistic 'progressivist' directions of most contemporary science, particularly evolution" (157). This affective opposition finds reinforcement in a professional one: Thomson and his followers were the most vocal scientific opponents of Darwinism. Indeed, Thomson remarks on the impossibility of Darwinian evolution within the universal time scales allowed by thermodynamic theory ("Age" 391–92).

In Memoriam, however, is not limited by late-century expectations of thermodynamic pessimism, and the poem requires us to revisit the laws of thermodynamics without the pressure of late-Victorian affect. The simple statement of these laws, originally articulated by Clausius in 1865, persists: "1. The energy of the universe is constant." The first law implies that energy can be neither created nor destroyed. In a closed system, though energy may change forms, the total energy is always conserved. "2. The entropy of the universe tends towards a maximum" (Clausius 365). *Entropy* is the term given to the measure of disorder in a system. The second law thus implies that in a closed system, energy always changes to increasingly less orderly, less usable forms.

The first law, the conservation of energy, seems to promise that nothing can be lost. It operates in affective opposition to the second law, which, in threatening the perpetual and irreversible increase of entropy, suggests that everything must be lost. Nonetheless, the combination suggests not only a tension but also a careful balance, an elegant parallelism. Indeed, Clausius "intentionally form[s] the word *entropy* so as to be as similar as possible to the word *energy*" (357). Both laws emphasize that closure is necessary to their validity; failing other modes of closure, the universe acts as the ultimate closed system. And both are implicitly, though centrally, concerned with change—the *dynamics* in *thermodynamics*. Identifying, articulating, and resolving the apparent contradiction between loss and conservation was nothing short of the work of consolidating important but loosely connected observations into the science of energy physics (more on this later), but we may understand the physical resolution, simply, as follows: Yes, energy is conserved. It can take many forms, including heat and mechanical work. But once it has transformed into heat (more exactly, into heat at uniform temperature), no work can be done with it. Thus, energy is conserved, but it becomes unavailable for use.

Heat is a central term in the resolution of the two laws. *Heat*, in physics at least, generally represents energy in its least useful, most entropic or diffuse state. *Heat death* then refers to a state of things in which all energy has been, not lost, but transformed, albeit irrecoverably and uniformly, into heat. Of course, in popular parlance, heat death tends to be attributed to the loss, rather than the excess, of heat. *Heat* is its own opposite; its popular usage suggests usable energy, what scientists and engineers call heat sources, bodies at higher temperatures, from which we can derive warmth or run steam engines. However, *heat* in technical parlance as often evokes the heat sink, "waste places" (Tennyson 3) that form the repositories of energy that is past its usefulness.[3] Thus, *heat* proves a "contradiction on the tongue" that reproduces linguistically the tension between the first and second laws (125).

Thus, while there is no fundamental physical contradiction between the first and second laws (a resolution that becomes clear only in retrospect), thermodynamics is laden with tension. And the interplay between conservation and dissipation structures a central tension in Tennyson's poem, as in Victorian thought more broadly. But where (except for diehard optimists such as B. Stewart and P. G. Tait) the second law comes to dominate a Victorian mind-set increasingly concerned with dissipation and degradation, Tennyson's willed optimism shapes itself according to a first-law sensibility that renders the second law not merely palatable but hopeful. *In Memoriam*, I shall argue, is finally able to find consolation by subordinating the loss that drives the poem to the larger concept of change, by holding loss and conservation in careful balance. In this way, the intellectual work done by *In Memoriam* parallels that done by the founders of thermodynamics—both are the work of sustaining contradiction, of holding apparent oppositions in well-balanced tension. Section 1 (c. 1834) lays out this consolatory program, suggesting (in terms that look uncannily thermodynamic) that the poem's work will be to "find in loss a gain to match," to soothe second-law anxieties through the promise of first-law compensation.

"Spring No More": Waste, Death, and the Second Law

William Thomson's 1862 announcement in *Macmillan's Magazine* of "the age of the sun's heat" triggered a widespread cultural anxiety that encompassed no less than the cooling of the world and the death of all things as the sun burned itself out. And while such an event had been predicted "by poets and lunatics from time immemorial" (Stoppard 65), the second law of thermodynamics brought new urgency and new form to this ancient fear. To a public just recovering from the fossil-induced anxiety of extinction that Tennyson articulates so nicely—"From scarped cliff and quarried stone / She [Nature] cries, 'A thousand types are gone' " (56)—the death of the sun seemed not only inevitable but frightfully immediate. Gillian Beer traces the ways depictions of the sun's death (depictions newly energized by scientific authority) "passed rapidly into an uncontrolled and mythologized form" (228). Two fin de siècle texts stand out as particularly troubled fictional manifestations of Thomson's concern "that inhabitants of the earth cannot continue to enjoy the light and heat essential to their life, for many million years longer" ("Age" 393): Camille Flammarion's short story "The Last Days of the Earth" (1891) and H. G. Wells's *The Time Machine* (1894), in which the unnamed time traveler "watch[es] with a strange fascination the sun grow larger and duller in the westward sky, and the life of the old earth ebb away" (98).

Tennyson, too, depicts a dying sun. As Sorrow whispers:

> The stars [. . .] blindly run;
> A web is woven across the sky,
> From out waste places comes a cry,
> And murmurs from the dying sun [. . .]. (3)

This evocation of Pierre-Simon Laplace's nebular hypothesis evinces a decidedly second-law sensibility. Though Laplace postulates a mechanism for galactic origins, Tennyson here focuses on the theory's implications for endings. The death of the sun is linked to an anxiety about the blindness and cruelty of nature evident in the poem's evolutionary narrative, even as Tennyson evokes a broader cosmological concern through the image of waste space. The term *waste*, which has not yet given way, in physical theory, to *dissipation*, *disorder*, or most especially *entropy*, also anticipates a further Victorian anxiety, attached to the second law. Added to the increasing conviction that the sun was a limited power supply was the realization that most of the sun's energy was wasted: how little of the sun's heat and light (late Victorians calculated) would be intercepted for use on earth; how much would dissipate uselessly into space!

This moment is also an interesting (and readily traceable) example of the poem's contribution to scientific thought. James Clerk Maxwell—in writing to Michael Faraday about whether Faraday can transfer his methods for modeling the behavior of electrical interactions to a model of gravitation—formulates this possibility in words self-consciously evocative of Tennyson: "then your lines of force can 'weave a web across the sky'" (qtd. in Kargon xv).

The generalized waning of power, suggested above by the transformation of a "cry" into mere "murmurs," returns emphatically in a later image of heat death: "I dream'd there would be Spring no more. / That Nature's ancient power was lost: / The streets were black with smoke and frost [. . .]" (69). This moment exemplifies how Tennyson operates at the intersection of Romantic poetry and Victorian physical theory. The dreamed end of the universe echoes Byron's "Darkness": "I had a dream, which was not all a dream. / The bright sun was extinguished, and the stars / Did wander darkling in the eternal space [. . .]" (lines 1–3). But the ultimate waning of power, the end of heat and light in nature, more nearly anticipates the scientifically driven fictions of Flammarion and Wells. The concern with the failure of the workings of nature, at least implicitly scientific by this time, is emphatically so in the light of the way this poem's "Nature" always evokes the anxieties wrought by science, most especially the threat of science to faith (e.g., "Are God and Nature then at strife [. . .]?" [55]). That Nature's "power" is lost here resonates in present-day as in Victorian physical theory; alongside force, work, and energy, "power" rings peculiarly thermodynamic. Indeed, at this moment, *energy* has yet to take its central place in thermodynamic language. *Motive power* (*puissance motrice*) is the term Carnot, for one, uses in the 1824 essay so evocative for those who build on his work ("Reflections").

Not only does Tennyson's use of language place him in conversation with emerging physical theory, his impulse to identify analogous phenomena at vastly different scales suggests how his poetic methods dovetail with the methods of his contemporaries in physics. The same concern with the loss of heat that colors Tennyson's cosmos applies to the death of the individual and to the metaphoric death of day with nightfall. This mode of analogy is characteristic of thermodynamic conversation: physiologists were among the earliest advocates of energy theory, and by the end of the century, the depiction of the body as thermodynamic system or of nightfall or an eclipse as a mini heat death will become familiar, if not commonplace.[4] Indeed, for one prominent Victorian physicist, this mode of thinking distinguishes a physical theory, such as energetics, from an abstract science, such as Newtonian mechanics: grounded in the observation of a wide range of phenomena, the principles of a physical theory must be reduced "to the form of a science"; in turn, this reduction is "the better the more extensive the range of phenomena whose laws it serves to deduce" (Rankine 209, 211). Eventually, Tennyson's friend the physicist John Tyndall will claim for thermodynamics a "wider grasp and more radical significance" than Darwinian evolution (qtd. in Dale 130), which becomes merely one manifestation of the concept of energy (Dale 132).

Tennyson, too, applies his principles to a wide range of systems. Personal death echoes the structures of this cosmological death. Loss ties to waste on the personal scale, for where space is figured as entropic—a waste place—so is the end that the poet anticipates for himself: "somewhere in the waste, / The Shadow sits and waits for me" (22). In the absence of faith in an afterlife, "earth is darkness at the core, / And dust and ashes all that is" (34). Waste and entropy seem fundamental and final. Repeatedly throughout *In Memoriam*, the speaker's death is figured as the loss of heat, light, and even electricity. He anticipates, "How dwarf'd a growth of cold and night, / How blanch'd with darkness must I grow!" (61), and implores the spirit of his friend to "be near me when my light is low" (50). And in the spirit of transformability central to the subsequent development of thermodynamics, death also manifests itself as the loss of electricity, a time when "this electric force, that keeps / A thousand pulses dancing, fail[s]" (125). Thus, Tennyson not only evokes the physiological imagination that animates Frankenstein's monster but also links "electric" to "force"—a term relatively well defined under Newton but in flux when the poem was written. Though a principle that finally cannot hold in the face of emerging physical evidence, the conservation of force (something Newton never dreamed of) is a key precursor to the first law; such uses of *force* illustrate how it functions as an early synonym of *energy*, though not the final word. Nor is *waste* the last word in Tennyson; "dust and ashes" are not "all that is." As I shall argue, Tennyson's cognizance of what will become the first law of thermodynamics, in many ways rooted in Romanticism, enables his famous consoling gesture, on the personal and the popular scales—for the loss of his friend and for the rift between God and Nature, faith and science, produced by evolutionary and geological concerns.

Meaningful Metaphor: The Progress of *Energy*

The repeated evocations of light, heat, and electricity, were these isolated from the transformations they (and death with them) undergo as the poem progresses, might leave us comfortably enough in the realm of poetic tradition. After all, even *energy*, the keystone term of thermodynamic language, carried metaphoric and social weight before physicists took it up. As Greg Meyers aptly demonstrates, "[P]hysicists had already borrowed the language and authority of social prophets," and, indeed, the concept of entropy was built on the foundation of an ancient commonplace of decline, irreversibility, and disorder

(308). Similarly, Tennyson's redeployment of Romantic tropes suggests the influence of Romantic thought on Victorian energy physics, an influence of poetry on science often imagined but rarely traced. Several scholars have, however, explored the connection between Romantic philosophy and Victorian natural science. Peter Allan Dale finds "that the break between romantic aestheticism and positivist science was far from radical" (7). He identifies nineteenth-century positivism ("something we may fairly call a religion of science") as "the true nineteenth-century successor to the romantics' efforts at totalization" (7, 6). Stephen Brush holds that the Romantic "doctrine of the essential unity of all forces in nature leads directly to the law of conservation of energy" (20), and he identifies the shift in thermodynamic affect from mid to late century:

> The first law of thermodynamics (conservation of energy), inspired in part by the philosophy of romanticism, provided an organizing principle for the science of the realist period. Likewise the second law of thermodynamics (dissipation of energy), which arose from the technical analysis of steam engines, provided a *dis*organizing principle which turned out to be highly appropriate for the neoromantic period. (29)

Brush makes a distinction generally glossed over in literary treatments of thermodynamics—a shift from first- to second-law dominance, which correlates with the difference between early- and late-century depictions of cosmological burnout and the consolatory potential that, as I shall argue, Tennyson is able to find in thermodynamic principles at mid century.

It is, perhaps, not surprising that the desire for Romantic wholeness should run strong in Tennyson, seeking consolation for the loss of a friend and restoration of a shaken faith. Similarly, it is not surprising that he should resurrect Romantic uses of *energy* to achieve these ends. Indeed, the potential for elegiac consolation inheres in Romantic conceptions of energy; *In Memoriam* in many ways echoes Shelley's "Adonais"—a poem Tennyson particularly admires, though he later declares that "Shelley had no common sense" (Viswas 4–5). Even more striking is the way Tennyson's closing "One God, one law, one element" (epilogue, line 142) evokes Coleridge's "Religious Musings": "one Mind, one omnipresent Mind, / Omnific" (lines 105–06). When Stuart Peterfreund explores how energy, after a long period of disrepute in science dating from Newton's *Principia*, "re-emerged [. . .] for reasons primarily metaphysical, and especially religious, rather than physical," he notes that Coleridge connects energy to this "one Mind" and "declares it to be 'Nature's essence, mind and energy!' subsequently confiding that ''tis God/Diffused through all, that doth make one whole . . .'" (24, 34, 40–41).

This religious character, resonant in Tennyson's "full-grown energies of heaven" (40), makes the Romantics' use of *energy* attractive to Tennyson and, at the same time, begins to mark the divergence between his deployment of *energy* and theirs. What distinguishes Tennyson's use of *energy* in his elegy—and locates him squarely in conversation with the emerging science of energy physics—are the place of faith and the place of figurative language, especially in relation to knowledge of the physical world. Although Coleridge, "a Victorian doubter before his time," may well have appealed to Tennyson because both men wrestled with the increasingly visible gap between the truths of science and those of religion (J. Beer 1–2), "Coleridge realizes that to proclaim is not to prove, and that the *sine qua non* for a faith such as the one he wishes to articulate is an unquestioning belief in God strong enough to lay aside any nagging questions [. . .]" (Peterfreund 40–41). Tennyson, by contrast, begins with huge nagging questions. And far from reacting against the certainty of science (as the Romantics were wont to do), he will draw on it as he formulates a response to his explicit questioning of faith. Moreover, where Romantic energy is decidedly extraphysical (what would a physicist make of Blake's "Energy is

Eternal Delight" [70]?), the energetics of *In Memoriam* attempt to marry the physical to the spiritual, to imagine the "soul, / In all her motion one with law" (122). Similarly, where the Romantics make claims for separate, poetic knowledge—what Dale has called "romanticism's [. . .] supreme privileging of the artist as prophet-deliverer of a moribund social order" (7)—Tennyson does not strive to dissociate his way of knowing from other, especially scientific, ones. Though Tennyson resists any simple materialism, the knowledge he seeks is knowledge not of the extraphysical but of the physical and extraphysical as ultimately inseparable.

This meeting of physical and spiritual correlates with the changing uses of figurative language in poetic as well as in scientific inquiry. Romantic uses of *energy* are subject to what John Ruskin will later call the pathetic fallacy; indeed, the term *energy* seemed to many "a covert attempt to humanize the object-world through a species of anthropomorphic projection" (Peterfreund 43). Tennyson, in contrast, while refusing to privilege the poetic as the superior way of knowing, nonetheless retains metaphoric, or analogical, thinking as a powerful tool for knowing the natural world. Similarly, though opponents of the new physics will continue to object to *energy*—opting, by the 1870s, for the term *force* to signal their belief that, however useful, the concept is still merely a "logical fiction" (Dale 135)—analogy and metaphor become increasingly acceptable tools for thinking in science. Richard Butts illustrates this shift in the nineteenth century from univocal to equivocal modes of thought: from an insistence that scientific theories can and should reveal truths about nature to an understanding of scientific hypotheses as symbolic constructs. For Butts, the analogical mode, characteristic of Tennyson and Tyndall, represents a compromise between these extremes. From a slightly different angle, Patricia O'Neill marks "Tyndall's sympathy with the Romantic poet's task to humanize the experience of nature" (106). Even Joule, as early as 1847, is hardly troubled by the figurative baggage attached to the label "*vis viva*, or *living force*. The term may be deemed by some inappropriate, inasmuch as there is no life, properly speaking, in question; but it is *useful* [. . .]" (266–67).

The usefulness of energetic metaphor extends beyond what Joule suggests here, and several scholars have noted the connection between the structures of energetics and those of metaphor. Eric Zencey describes the readiness of the concept of entropy to become a deeply embedded and widely used cultural metaphor. Bruce Clarke locates this readiness in the structure of energy transformation itself. Clausius coins the term *entropy* "after the Greek word 'transformation' " (qtd. in Clarke 74); Clarke argues that in "[b]orrowing the root of the term 'trope'—the linguistic torsion that produces nonliteral uses," the word *entropy* implies a continuity between the metamorphic capacity of language and that of matter: "In the name of entropy, energic and linguistic transformation became metaphors for each other [. . .]" (74). Transformation—refiguration—characterizes poetic and scientific ways of knowing, because it inheres in the natural world both seek to know. Tennyson's use of language thus proves not merely (as "pathetic fallacy") or exclusively (as "supreme privileging") but meaning-fully metaphoric, a real way of coming to know the physical world and, indeed, deeply apropros, even mimetic of the physical world he at once describes and investigates.

"Power in Darkness": The Consolation of the First Law

The phenomenon qua metaphor that grounds Tennyson's investigation is heat. While images of heat loss dominate the early sections of the poem, determining whether heat can also generate and be generated is key to Tennyson's development of thermodynamic principles. As the poem progresses, heat figures increasingly as source, as that which can provide light or even life, that which generates and warms: "life is not as idle ore, / But iron dug from central gloom, / And heated hot with burning fears [. . .]" (118). Even in absence, heat figures as usable energy. The poem imagines the absent Hallam, for instance, sitting among his family "[a] central warmth diffusing bliss" (84). Even the failure to realize life, light, and heat figures, rather strangely, as something akin to what physicists will call potential energy: the "unborn faces [of Hallam's children] shine / Beside the never-lighted fire" (84). Thus, Tennyson develops contrasting notions of heat sources and heat sinks (what Carnot calls "the source and [. . .] the refrigerator" [10]), notions that Tennyson, like a good physical theorist, then applies to a broad range of phenomena. As he returns to Laplace's nebular hypothesis, he shifts his attention to its implications for beginnings. Replacing "I dream'd there would be Spring no more" with "They say, / The solid earth whereon we tread / In tracts of fluent heat began [. . .]" (118), the poem now suggests the process through which (Laplace theorized) our sun and planets were formed. Looking at heat from both sides, Tennyson illustrates a central dilemma in the resolution of thermodynamic principles, even as he moves toward an increasingly optimistic vision of what those principles imply.

Similarly, much of Tennyson's energetic language—especially the developing topos of light—which was previously marked by loss, attaches increasingly to the capacity to generate or change. Thus, for a while, darkness signals predominantly loss and lack as Tennyson worries about a time "when my light is low" and imagines himself "on the low dark verge of life" (50). The poem, however, becomes increasingly sure that the loss of light or electricity need not imply the loss of power. Darkness now evinces a power of its own: "And Power was with him in the night, / Which makes the darkness and the light, / And dwells not in the light alone" (96). This development of faith out of doubt, a conventional feature of elegy, is described in distinctly thermodynamic terms. Steeped in the spiritual concerns of Romantic energetics, this passage also suggests a physical revelation—that dark and light are both power, differently manifested. Conversely, where darkness may figure as source, light may figure as sink. Thus, "'Farewell! We *lose* ourselves in light'" (47; my emphasis). Tennyson's most complex thinking on light in its various manifestations occurs in the 1849 prologue to the poem: "Our little systems have their day; / They have their day and cease to be: / They are but broken lights of thee [. . .]." Resonating with the poem's physical concerns (as in "star and system rolling past" [epilogue, 122]), "our little systems" suggests not only our belief systems (Butts 206–07) but also our physical systems, our all-too-temporary bodies. In a move worthy of Einstein, these prove material manifestations of light itself. "[B]roken lights," moreover, implies at once disorder and transformation; in life or in death, our existence proves an entropic manifestation of divine light.

In terms increasingly distinct from Romantic elegy, death, too, figures as change—physical change—rather than loss: "I wage not any feud with Death / For changes wrought on form and face [. . .]" (82). Tennyson thus shifts from second-law anxiety to first-law hope, even as he proliferates thermodynamic language: *form*, *state*, *process*, *power*, and even *diffusion*. One of the many ways change is wrought, death is merely one part in an "[e]ternal process moving on[.] / From state to state the spirit walks" (82). But change is not a sufficient—though it is a necessary—condition of conservation:

> But thou art turn'd to something strange
> And I have lost the links that bound
> Thy changes; here upon the ground,
> No more partaker of thy change. (41)

Change here clearly still implies loss. What, then, enables the shift from "I have lost the links" to the principle of conservation that eventually governs even the mechanics of friendship, such that "The all-assuming [all-destroying] months and years / Can take no part away from this" (85)? How is the second-law threat of an all-assuming entropic decay subordinated to the first-law promise that no part can be taken away?

As the poem reimagines death-as-change in a manner more consoling, it reconciles the problems wrought by this dissipative model by reconceiving these changes as bound within a larger system:

> What are thou then? I cannot guess;
> But tho' I seem in star and flower
> To feel thee some diffusive power,
> I do not therefore love thee less [. . .]. (130)

The links are not lost; Hallam's "diffusive power" can still be felt; it is "bound" upon the ground—in flower as well as in star—and is marked by a love that is not less. Tennyson's phrasing echoes Wordsworth's Immortality Ode but with important differences; Tennyson, it seems, can bring back the "splendour in the grass [and] glory in the flower" (Wordsworth, line 178), through his distinctive deployment of the notion of diffusion. Though profoundly implicated in the development of the second law (a precursor to which may readily be found in Fourier's diffusion equation), the concept of diffusion nonetheless allows Tennyson to conceptualize transformation without loss. All he need do now is imagine a system that, though it may (as in Clausius) encompass the whole of the universe, is nonetheless closed. Where once "Nature's ancient power was lost," Hallam's is conserved, and Nature, as well as Hallam, persists in a threefold mixing with God:

> My love involves the love before;
> My love is vaster passion now;
> Tho' mix'd with God and Nature thou,
> I seem to love thee more and more. (130)

The critical shift from *waste* to *vast*[*ness*]—etymologically linked words, sharing the Latin source *vastus*—marks a rethinking of the universe, not as waste space, but as a large closed system, still accessible, in which things are diffused rather than lost. This vastness, moreover, ultimately proves not only conservative but also productive, since "star and system rolling past, / A soul shall draw from out the vast / And strike his being into bounds" (epilogue, 122–24), a negentropic development hardly conceivable in science until the advent of chaos theory.

The Consolation of Physics

Tennyson's development of thermodynamic concepts in and from a tradition of poetic elegy raises a complementary question: to what extent do we find elegiac traces in the development of physical theory? There are striking analogies between the conceptual work done by Tennyson and that done by Victorian energy physicists. In addition to the prominent place of analogical reasoning in both, we see the significant workings and reworkings of faith and faithlike convictions in the development of thermodynamic concepts among physicists—processes strongly reminiscent of the religious consolation for which *In Memoriam* is well known. All these seem to circulate around the reconciliation of apparently contradictory uses of *heat*, a reconciliation effected by the reconception of loss (and generation) as transformation and accompanied, as in Tennyson, by the restoration of faith.

Although the belief that "God [is] love indeed" (56) is not explicitly at issue in their scientific investigations, Thomson and Joule repeatedly evoke a creator, distinguished by the unique capacity to generate or annihilate matter. Joule's 1847 lecture "On Matter, Living Force and Heat" (265–76), presented at St. Ann's Church Reading Room, is emphatic regarding the place of God in scientific reasoning: "We might reason, *à priori*, that such absolute destruction of living force cannot possibly take place, because it is manifestly absurd to suppose that the powers with which God has endowed matter can be destroyed any more than they can be created by man's agency [. . .]" (268–69).

Much of the language Thomson uses is less explicitly religious but undoubtedly faithlike in its structure, for while he cannot say with Carnot (regarding Carnot's belief that any heat loss is precisely compensated by an equivalent gain) that "[t]his fact has never been doubted [. . .]" (qtd. in Thomson, *Papers* 115), Thomson observes that "[t]he truth of this principle is considered as axiomatic by Carnot [. . .]" and that in spite of doubts raised by Joule's work, "I shall refer to Carnot's fundamental principle [. . .] as if its truth were thoroughly established" (115, 117). However, where Carnot's confidence rests on his contention that heat is a substance—caloric—and therefore subject to conservation laws associated with matter, Thomson's belief has no such backing. By mid century, the caloric view of heat is well on the wane, and belief in the conservation of what will eventually be comprehended in *energy* (heat, force, vis viva) must be sustained as faith—indeed, as faith under siege by increasingly visible evidence in nature.

The development of physical theory is marked by a resistance to evidence and theory that threaten the conviction of conservation, a kind of denial stage, traces of which appear in Thomson and Joule.[5] Although Thomson is prepared to adopt Carnot's view, the contradictory implications of Joule's work surface, first as a footnote: "This opinion seems to be nearly universally held by those who have written on the subject. A contrary opinion however has been advocated by Mr Joule of Manchester [. . .]" (Thomson 102n). A similar observation, now promoted from the footnotes to the main body of the text, appears the following year in his "Account of Carnot's Theory of the Motive Power of Heat [. . .]" (113–55): "The extremely important discoveries recently made by Mr Joule of Manchester, that heat is evolved in every part of a closed electric conductor, moving in the neighbourhood of a magnet, and that heat is *generated* by the friction of fluids in motion, seem to overturn the opinion that heat cannot be *generated* [. . .]" (116–17). Significantly, the most troubling and most provocative part of this discussion is again relegated to the margins:

> When "thermal agency" is thus *spent* in conducting heat through a solid, what becomes of the mechanical effect which it might produce? Nothing can be *lost* in the operations of nature—no energy can be *destroyed*. What effect then is produced in place of the mechanical effect which is lost? A perfect theory of heat imperatively demands an answer to this question; yet no answer can be given in the present state of science. (118–19n; my italics)

Why footnote such an elegant assertion of the conservation of energy and such a clear imperative for the goals of energy physics? For one thing, it has become increasingly clear that this is a reassertion of faith rather than an articulation of well-substantiated scientific principles. Even the observation that "no energy can be destroyed" is deceptively simple and deceptively assured, since it is not clear what *energy* comprehends. That Thomson still seeks "a perfect theory of heat" suggests that the relation between heat and energy is as yet unsettled. And, of course, this statement is emphatically about the absence of answers. It is noteworthy that though generation and loss threaten the principle of conservation in logically equivalent ways, this moment is marked at once by anxiety and by the dominance of the language of loss.

No one, it seems, wants to be responsible for loss. Even Joule, whose research points Thomson inexorably toward loss, dissociates himself from this position. Indeed, his objection to Carnot's theory is marked by a similar pattern of resistance:

> I conceive that this theory, however ingenious, is opposed to the recognized principles of philosophy, because it leads to the conclusion that *vis viva* may be destroyed by an improper disposition of the apparatus [. . .]. Believing that the power to destroy belongs to the Creator alone, I entirely coincide with Roget and Faraday in the opinion that any theory which, when

> carried out, demands the annihilation of force, is necessarily erroneous. (188–89)

That Joule's objection is to the loss of vis viva (living force or kinetic energy), where Thomson's is to the loss of mechanical effect or, alternatively, to the generation of heat, suggests the definitional challenges central to the consolidation of energy physics, especially the shifting uses of *heat*.

For Joule, heat resolves the threat to conservation. In Joule, as in Tennyson, heat enables the reconceptualization of loss as transformation: "wherever living force is *apparently* destroyed, an equivalent is produced which in process of time may be reconverted into living force. This equivalent is *heat*" (269). Thus reconciled, Joule expresses a faith fully in keeping with the workings of the physical world: "we find a vast variety of phenomena connected with the conversion of living force and heat into one another, which speak in language which cannot be misunderstood of the wisdom and beneficence of the Great Architect of nature" (272). As Joule evokes the metaphor of language, these interconversions become a physical metaphor that attests to the goodness of God. For Joule, as for Tennyson, "[l]arge elements [are] in order brought" (Tennyson 112); loss and disorder prove merely superficial, subordinated to the larger truth: "Thus it is that order is maintained in the universe—nothing is deranged, nothing ever lost, but the entire machinery, complicated as it is, works smoothly and harmoniously. [. . . E]very thing may appear complicated [. . .] yet is the most perfect regularity preserved—the whole being governed by the sovereign will of God" (Joule 273).

Similarly, once Thomson has reconciled Carnot with Joule through the dynamical theory of heat (a theory that understands heat not as substance but as molecular motion), he, too, reconceives loss—here "waste"—as transformation. And, as in Tennyson, this reconceptualization enables the restoration of faith: "As it is most certain that Creative Power alone can either call into existence or annihilate mechanical energy, the 'waste' referred to cannot be annihilation, but must be some transformation of energy" (511). This assertion, however, indicates a transition for Thomson regarding the affective resonance of thermodynamics. For this clear statement of faith—now consistent with physical theory—is his opening to a surprisingly short but important piece that marks the beginning of the end of his thermodynamic optimism: "On a Universal Tendency in Nature to the Dissipation of Mechanical Energy" (*Papers* 511–14).

Diffusing Ambivalence: Sexuality, Gender, and Evolution

Dissipation—or its near synonym in physical discourse, *diffusion*—serves Tennyson rather more gently. As discussed above, the concept of diffusion enables Tennyson to conceive of conservation in the face of apparent loss. The poet's capacity "to feel thee some diffusive power," moreover, suggests the usefulness of Tennyson's energetics for diffusing the explosive potential of his feelings for Hallam. For all that Tennyson may "seem to love [him] more and more," the poet's passion for Hallam, however vast, is not without ambivalence. Christopher Craft, identifying the poem's "strategic equivocation," explores how in *In Memoriam* "[t]he elegiac mode disciplines the desire it also enables," at once articulating and sublimating Tennyson's longing for Hallam (85, 88). Jeff Nunokawa, in contrast, locates the poem's homoerotics as a stage in the sexual evolution of the individual—an early phase that the individual leaves behind on reaching (hetero)sexual maturity. I would argue that the poet's capacity "to feel thee some diffusive power"—a capacity that speaks to the conservation of energy and love—intersects with these important readings of the text's homoerotics. This passage is conservative and dissipative, not only thermodynamically but also sexually. By diffusing the power of Hallam's attraction, thermodynamics consoles the poet for the loss of his friend, even as it disperses the poet's uneasiness with the nature of his affection. Though not lost, Hallam's power is diffused; it is spread out and therefore less useful, more entropic. Similarly, the poet's passion may be "vaster," but it is certainly less usable. Deploying a thermodynamic metaphor, Craft notes that "the elegy negotiates its problematic desire less by a centering of its warmth than by the dispersion of its bliss" (85). Providing a way for Hallam to survive pointedly disembodied, the mechanics of energy transformation allow the poet to insist that Hallam's attraction is eternal, even as he renders it lukewarm.

Nor is Hallam's the only disconcerting power diffused in this way. Ultimately, Tennyson will also diffuse the power of a fiercely feminized mother nature—not only "red in tooth and claw" but ravenous and, though reproductive, distinctly unmotherly (56). It is no wonder, then, that in his early cosmology, Tennyson retroactively endows Nature with power only in the moment that he imaginatively divests her of that power (recall "Nature's ancient power was lost"). But by the end of the poem, Tennyson manages to diffuse the power of this frightful female without the gloomy sacrifice of spring. When, in his diffusion, Hallam becomes "mix'd with God and Nature," he enters an androgynous being already extant. And this blending is marked by Tennyson's prethermodynamic studies, for, formerly "at strife," God and Nature now meet "in light" (55, 111).

Thus, the consolation of physics proves remarkably adaptable, and the principles of simultaneous conservation and dissipation that permeate Tennyson's personal consolation are reiterated in the poem's popular consolation. Conserving Hallam's love while diffusing the power of his attraction, dissipating Nature's frightful femininity through a mixing with God, Tennyson's thermodynamic solution—his answer to death and the second law—also heals the rift between science and faith wrought by science's depiction of a ruthless nature. And insofar as this picture of nature accompanies the poem's evolutionary angst, the consolation of thermodynamics enables Tennyson's reformulation of the implications of evolution as well. For if, as Susan Gliserman contends, "literature is especially designated in a society [. . .] to express and shape affective meanings" (279), *In Memoriam* forces us to revise our picture of the antagonism between Victorian thermodynamic and evolutionary narratives. A poem driven, at the outset, by a sense of overwhelming loss, *In Memoriam* produces a narrative of evolutionary progress only through the kind of willed optimism that attaches, as I have argued, to Tennyson's maintenance of a first-law sensibility. Such a narrative must derive from the same capacity to imagine conservation in the face of dissipation, transformation in the place of loss. *In Memoriam* manifests this capacity in spades—even in its geological narrative. For while early in the poem geology is marked by waste and decay as the speaker hears erosion in "The sound of streams that swift or slow / Draw down Aeonian hills, and sow / The dust of continents to be" (35), this geological image gives way to another:

> The hills are shadows, and they flow
> From form to form, and nothing stands:
> They melt like mist, the solid lands,
> Like clouds they shape themselves and go.
> (123)

In this image, geology is marked by the dominance of change over loss. Hills no longer erode into dust; they flow from form to form, from a solid to a mist, perhaps, but are still present, still shaping themselves, and, like clouds, increasingly capable of transformation. The poem's ability to reshape anxieties of (here, geological) loss and dissipation into hopes of transformation and conservation suggests the power of Tennyson's increasingly present first-law optimism, a discourse sufficiently strong that it could not fail to inform the poem's evolutionary narrative as well.

As these two scientific subtexts become entangled, physics—counter to late-century expectations—offers a solution to the problems of waste wrought by biology. The earlier parts of the poem imply that in biology, as in geology, there is little progress and much waste. Manifestly concerned with the careless waste of resources in the reproduction of species, the speaker fixes on the profligacy of Mother Nature and "find[s] that of fifty seeds, / She often brings but one to bear" (55). But evolutionary biology, the poem suggests, is able to transform waste into progress because it grows up alongside and in conversation with the notion of transformation central to the development of thermodynamics, especially the first law. The evolutionary thinking of *In Memoriam* follows a now-familiar pattern, as this early vision of waste is eventually replaced by a vision of human progress wherein the species and the individual "Move upward, working out the beast, / And let the ape and tiger die" (118). We can then see in Tennysonian evolution—"evolution as transformation, maintaining identity but bringing about change" (Fulweiler 315)—the undertones of the first and second laws of thermodynamics. If "Tennyson's concept demanded transformation" (313), the nascent principles of thermodynamics provided a mechanism for answering that demand, for finding transformation where the senses perceive loss and waste. Thus, the triumph at the end of the poem of a progressivist evolutionary narrative is the triumph of first-law optimism and the fantasy of transformation over second-law anxieties of inevitable loss.

These simultaneous triumphs, moreover, merge with the renewal of faith and the reconciliation of science and religion on which the poem ends. Transformation explains apparent loss; religious, evolutionary, and thermodynamic optimism converge in the final lines of the poem: "One God, one law, one element, / And one far-off divine event, / To which the whole creation moves" (epilogue, 142–44). This passage marks, once more, Tennyson's debt to and divergence from his Romantic predecessors. Like and unlike Coleridge, Tennyson expresses a belief in divine unity, but one that has become markedly scientific. Romantic wholeness has been reconciled with Victorian science. Undoubtedly the confirmation of faith that readers have always taken it to be, the "one far-off divine event" is emphatically overdetermined. While it represents a union with God, this union is also figured as the culmination of upward evolutionary progress, a time when, having "moved thro' life of lower phase," we will evolve into a species "no longer half-akin to brute," the "crowning race" for whom Hallam was the herald, "[a]ppearing ere the times were ripe" (epilogue, 125–39). But when read in the light of the poem's thermodynamic concerns, God comes to look remarkably like a heat sink. No longer "somewhere in the waste" (22) or even lost "in light" (47), "that friend of mine [now] lives *in* God" (epilogue, 140; my emphasis). Nature's power safely diffused, God alone remains, the repository of all energy that has passed, irrecoverably, to the other side.

"One law" also reemphasizes the wish, characteristic of *In Memoriam* and thermodynamics alike, for the widespread application of physical principles. As first-law optimism pervades the poem's cosmology, "one far-off divine event" (the flip side of "Spring no more") suggests a moment in which currently interconvertible elements—heat, electricity, work, light, and life—merge as one divine, undifferentiated element. (A very optimistic take on heat death!) Tennyson, then, closes the system, as he closes the poem—both vast enough to encompass what once seemed lost. At the same time, he expresses a hope, at once religious and scientific, for universal applicability. For the monotheistic mission of "One God, one law, one element" suggests a scientific aspiration as well: the desire, attached to the discovery of energy transformation, that we will discover a single law that governs all natural processes, a grand unified theory for the nineteenth century—a hope that nineteenth-century physics will hold close to the heart.

NOTES

[1] Susan Gliserman has been extremely important in revitalizing interest in the cultural exchange between Victorian science and *In Memoriam*. Tess Coslett revisits this aspect of Tennyson's thought, remarking on "the way his approach corresponds to that of the scientific writers" and finding in "the vast length of the poem, as opposed to earlier elegies," the gradualism that shapes Lyell's geology (43, 47). Isobel Armstrong, who observes similarly that "*In Memoriam* [. . .] uses the myth of geology structurally as well as absorbing its language," complicates the geological narrative as she reads "the double poem" created out of the tension between two opposing geological worldviews (102, 110). Howard Fulweiler places Tennyson's distinctive theory of evolution in serious scientific conversation with Darwin's and Lyell's. James Eli Adams adds gender to the mix, exploring how "Tennyson's personification of nature [. . .] suggests that evolutionary speculation also rendered newly problematic a deeply traditional and comforting archetype of womanhood" (7). And Jacob Korg, moving away from geology and biology, argues that Tennyson "was more receptive to astronomy than any other poet of his time" (143).

[2] Though it is beyond the scope of this paper to trace the influence of Kantian thought on Tennyson or physics, one aspect of their shared concerns is particularly relevant here: the emphasis on a unified theory of nature. One of the ways this Kantian idea passes into English science is through Coleridge to his friend the prominent chemist Humphry Davy (Brush 20). Similarly, Laplace's *Treatise on Celestial Mechanics* not only elaborates the nebular hypothesis so resonant in *In Memoriam* but also insists that heat, light, and electricity as well as mechanical phenomena can and should be explained by a single, unifying mechanism (Harman 15–19).

[3] My colleague in physics Russel P. Kauffman helped me immeasurably to articulate this distinction between physical and popular usage.

[4] Thus, in works such as G. H. Lewes's essay "Animal Heat" through E. B. Rosa's "The Human Body as Engine" we see repeated attempts to explain not only the body but also human psychological, sexual, and social behavior through the principles of thermodynamics. Anson Rabinbach's chapter "The Political Economy of Labor Power" directly addresses the social implications of energy conservation (69–83), and his theme of fatigue suggests the second law throughout. Cynthia Russett's chapter "The Machinery of the Body" considers the deployment of thermodynamic principles, especially in the medical regulation of gender (104–29).

[5] According to Kuhn, such resistance is characteristic of the periods that precede scientific revolution (*Structure*). The particular resistance to concepts of loss produces the distinctive elegiac character of prethermodynamic discourse.

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