vegetation of the hollow in which they sat, the motionless and the uninhabited solitude, intruded the chink of guineas, the rattle of dice, the exclamations of the reckless players.

They change the game and play for lower, letting God 'mix it around' in Julian Barnes's terms. Throughout this scene a half-assurance has been preferred to the reader: that Venn must win. The story patterns of Wildeve's tales promise that fulfilment. That's how such stories end. The whole is determined. The reedleman does win. He does so by virtue of his virtue; the cards connive, under the ordering hand of the walker. The reedleman is impassive, Wildeve agitated; these moral attitudes appear to control success and failure. Christian loses because he is weak and Wildeve because he is unstable. A moral drama is enacted, a popular story. Gambling is under the sway of some larger law that orders the chances.

But the chapter, and the book 'The Fascination' ends with a vertiginous loosening of hazard again. Venn meets in the darkness first Clym and Eustacia, and then Thomasin. To Thomasin he gives all the money he has won, not aware that half of it was meant for Clym: now the narrative becomes predictive: 'it was an error which afterwards helped to cause more misfortune than trouble in money value could have borne'. Venn's intercession, or meddling, is 'a new force' that 'disrupts the current', not channels it for good. The next book is ominously entitled 'The Closed Door'.

The reader is balked of control, forced to survey the reassuring expectations with which we habitually people the future. The re-telling of fictions seems to assure our trust—or at least their efficacy. Hardy displays the absurdity of that belief, while his own novel sardonically performs another narrative prediction: bad luck is good for story. 'So the subject recurred: if he (Clym) were making a fortune and a name, so much the better for him; if he were making a tragical figure in the world, so much the better for a narrative' (186).

Hardy here leverages his narrative to the new forces that disturb the current of the 1870s, those of uncertainty and entropy, the cosmic lottery. But he pins it also into that other antique yearning gratified by play: the longing for disaster, the full but fictive experience of obliteration. That desire is contained and gratified, for the moment, by gaining, or the bounds of a book.

When I first imagined this essay I set it in the late 1920s and 1930s, the period when the elegant expositions of Eddington and Jeans, and the fame of Einstein, were communicating to non-scientists how modern physics crazed categories and diminished boundaries. As Eddington wrote: 'In the scientific world the conception of substance is wholly lacking ... For this reason the scientific world often shakes us by its appearance of unreality. It offers nothing to satisfy our demand for the concrete. How should it, when we cannot formulate that demand?' (127).

By the late 1920s waves in motion are all the universe consists in—and they are probably fictitious, 'odes fictives', as de Broglie called them, or as Jeans suggests in The Mysterious Universe: 'the ethers and their undulations, the waves which form in the universe, are in all probability fictitious ... they exist in our minds' (79). He is thus led, long before Baudrillard, to equalize representations and enactments: 'The motion of electrons and atoms does not resemble those of the parts of a locomotive so much as those of the dancers in a cotillion. And if the "true essence of substances" is for ever unknowable, it does not matter whether the cotillion is danced at a ball in real life, or on a cinematograph screen, or in a story of Boccaccio' (136). 'The universe', he asserts, 'is best pictured ... as consisting of pure thought.'

How does literary realism engage with a scientific system that denies substance, dissolves difference, and in the early 1930s insists that the universe is best understood as mind? The problem is that in such a formation all realism's work has, paradoxically, been done for its: the difficult forging of likeness between symbol and substance is prematurely accomplished; indeed, there is an 'always already' complete fusion between represented and
goes on to observe the interplay between sociology and physics in this invocation of statistical explanation: Maxwell had been led to his model and his analysis after reading an account of Quesnel’s research into social phenomena. In a sense he modelled his random distribution of molecular motion on social interactions. Maxwell himself may have held, at least for a time, that his models were more than models (Olby: 70).

In the period that concerns me in this essay the margins between models, thought experiments, social occurrences, and mechanical events were a central topic for dispute. How to represent the relations between the all-inclusive laws of thermodynamics and their incommensurate, diverse, and transient manifestations? ‘She arrived in tears and a sedan chair’—the rhetorical figure of zeugma is, I think, useful here. The acceptance of multiple, incommensurable outcomes driven by a single verb opened the way alike to modernist literature and thought and to wave–particle theory.

Nineteenth-century scientists from Helmholtz to Thomson, Clausius to Clerk Maxwell, were pursuing a single explanation of cosmic processes that would include light, heat, and sound and that would construct them all as motion, passing irreversibly beyond the reach of the senses and dissipating irregularly through the ether (that crucial explanatory substance that ebbed quietly out of the universe early in the twentieth century, going the way of eighteenth-century phlogiston, the material principle of combustibility) (Cantor and Hodge passim, esp. 199–40).

Ideas of flux were of course in no way new; all things fleet away; we never step into the same river twice; alles geht vorbei. Such Heraclitean tropes were familiar, and were themselves resources, and assurances, for working scientists of the time. What was unfamiliar was the universalizing of wave theory (as thermodynamics continued to be called) to account for all phenomena. Unfamiliarity, too, were the twin emphases in the laws of thermodynamics on the constancy of energy within a system and the tendency to increasing disorganization (entropy always tends to increase to a maximum).

There is no need for agreement between legendary and scientific accounts for the release of new imaginative energies. It helps, though, if the phenomena under description are already familiar both in canonical literature and in daily life. This is the case both in thermodynamics and in chaos theory, where observed but hitherto excluded phenomena move into the centre of meaning. Even phenomena like the sun and the waves and tides are, after all, reflected differently at different times in the same place.

Educated people in Victorian Britain read Heraclitus, Lucretius, and Ovid in their youth, and often continued to read them in adulthood. All these writers emphasized the wavelike flow of energies. Moreover, people in nineteenth-century Britain were far more conscious of the manifest waves of the sea than we are. They experienced their action. They, or their kin and acquaintance, were obliged to take sea voyages, often long ones. Emigration, imperialism, and trade depended on proscribed sea journeys. Even crossing the Channel to Europe in unstimulated boats gave—and can still give—an unforgettable physical experience of wave activity. Fishing was a major industry with a high death-toll, the matter of Victorian ballads such as Kingsley’s ‘Men must work and women must weep’. The fashion for sea bathing was, in the mid-nineteenth century, still sufficiently new to add a frisson to being buffeted or chill British shores. (Lying on the beach was not then an acceptable alternative.) So there was a manifest social complex of referents which could overlap, incompletely but persuasively, with fresh scientific theory. Waves were not only the visible waves of the sea, now, but any kind of periodic disturbance in a medium or in space. The physicist John Tyndall, travelling to the Alps, describes in a continuous implied argument seakickness, heat as a mode of motion, the intellect as a function of temperature, a thunderstorm, the sound of agitated water, the ‘sonorous vibrations’ of air bubbles, reflected light, and human sleepers in a carriage ‘each burning the slow fire which we call life’ (Hours of Exercising: 59–65).

In 1858 Herbert Spencer, the economest and philosopher, wrote to Tyndall, shaken by Tyndall’s exposition to him of the second law of thermodynamics: ‘That which was new to me in your position … was that equilibration was death. Regarding, as I have done, equilibration as the ultimate and highest state of society, I had assumed it to be not only the ultimate but also the highest state of the universe. And your assertion that when
equilibrium was reached life must cease, staggered it (Duncan: 104). The assumption that a congruity must exist between ideal representations of society and the universe is not peculiar to the Victorians. Such congruity is sought persistently, even at high cost, as now chaos theory has been eagerly seized upon by non-scientists as reinstating the erratic with meaning and thus surcharging social description with significance—a significance that need no longer depend upon equilibrium.

When familiar ideas and phenomena become the focus of scientific theory and research they acquire, for the moment, a new dignity. Half understood and rapidly received, they move across other fields of enquiry, and they cluster, unstably transformed, amidst the needs and anxieties of a community. I have argued elsewhere that that process involved the new significations of solar physics in Victorian society; the coming death of the sun was no longer a matter of legendary history only, though those precedent legends (Balder dead, the fall of the lycans, Max Müller's solar interpretations of Aryan myth) inform the scientific enquiry, and its reception. Helmholtz, Thomson, Clerk Maxwell made that heat death of the universe seem imminent not by moving it forward temporally, but by changing the level of assent demanded. No longer an as-if story, nor a foundational one, the new physics counted up the number of years likely to intervene before the death of the sun. Their sums varied (anything from 15 to 20 million years) but their totals did not: the earth will become too cold for life.

Stephen Brush, in his invaluable two-volume study The Kind of Motion We Call Heat: A History of the Kinetic Theory of Gases in the Nineteenth Century, observes the inductive problem of thermodynamics: 'It is difficult to conceive of a time when people did not know that heat flows from hot bodies to cold bodies. Our problem is to understand how this apparently trivial example of irreversibility was translated into an illustration of a general law of nature, the Principle of Dissipation of Energy, and as such was seen to be in conflict with Newtonian mechanics.' (553). One might turn that argument around and say that for most people, once observed, it was not easy to know where the application of the principle stopped. It could be made into a description of mind; it could become grounds for spiritualism; it could provide a vocabulary for degenerationism; it could disarm all boundaries and disturb all organizations. Happily, it began to play all these parts in early modernism. As Pater puts it in Plato and Platonism:

These opinions too, coming and going, these conjectures as to what underlay the sensible world, were themselves but fluid elements on the changing surface of existence.

Surface we say; but was there really anything beneath it ... Was not the very essence of thought itself also such perpetual motion? ... The principle of disintegration [is] inherent in the primary elements alike of matter and of the soul ... the principle of lapse, of waste, was, in fact, in one self. (14-15)

Such lapping could also produce resistance, a flow to be staunched, as T. E. Hulme later attempted to do.

At the end of his essay on Helmholtz, Clerk Maxwell invites the reader to join him in observing Helmholtz observing the waves of the sea.

Now that we are no longer under the sway of that irresistible power which has been bearing us along through the depths of mathematics, anatomy, and music, we may venture to observe from a safe distance the whole figure of the intellectual giant as he sits on some lofty cliff watching the waves, great and small, as each pursues its independent course on the surface of the sea below. (Scientific Papers II, 558)

The scene is heroic and dizzying: Helmholtz is a 'giant', Maxwell and the reader are at 'a safe distance', released momentarily from 'that irresistible power which has been bearing us along' in an imaginative likeness to the action of thermodynamics; the waves are each 'independent'.

Maxwell continues by quoting Helmholtz, taking us into the pleasures and difficulties of vision, in the double sense peculiarly apt for Helmholtz, who for so long worked on optics, on acoustics, on energy.

'I must own,' he [Helmholtz] says, 'that whenever I attentively observe this spectacle, it awakens in me a peculiar kind of intellectual pleasure, because here is laid open before the bodily eye what, in the case of the waves of the invisible atmospheric ocean, can be rendered intelligible only to the eye of the understanding, and by the help of a long series of complicated propositions.' (Ibid. 598)

Instead of series and complexity, Helmholtz here delights in instantaneity. The visible waves touch for as well as represent
the ‘invisible atmospheric ocean’. They give it the effortless ‘reality’ of the manifest. The intensity of the scene is imbued also with Maxwell’s own scientific nostalgia, for manifestation, for models, for sufficient equivalence, for an escape from the impass of theories which mean that ‘we are once more on a pathless sea, starless, windless and poless’ (letter to Tait, 11 Nov. 1874, Add. 7655f/32b/32).

Many later-nineteenth-century scientists, and in particular Maxwell, were scrupulously aware of the problems of representation, problems not only intrinsic to language but specific to the theoretical work in which they were engaged. In The Meaning of Truth (1904) William James argued that ‘up to about 1850 almost everyone believed that sciences expressed truths that were exact copies of a definite code of non-human realities’.

But the enormously rapid multiplication of theories in these latter days has well-nigh upset the notion of any one of them being a more literally objective kind of thing than another. There are so many geometries, so many logics, so many physical and chemical hypotheses, so many classifications, each one of them good for so much yet not good for everything, that the notion that even the truest formula may be a human device not a literal transcript has dawned upon us. We bear scientific laws now treated as so much conceptual shorthand, true so far as they are useful but no further. Our mind has become tolerant of symbol instead of reproduction, of approximation instead of exactness, of plausibility instead of rigor. ‘Energetics,’ measuring the bare face of sensible phenomena so as to describe in a single formula all their changes of level, is the last word of this scientific humanism. (40–1)

We do not need entirely to agree with James’s view of science before 1850 to find some reinforcement of what he is arguing in the work of late-nineteenth-century scientists, especially those concerned with ‘energetics’. Not only in the social theorizing-out from evolutionary ideas, but in the fields of physics and mathematics, we find a heightened awareness of the instability of language, certainly, and also—more strikingly—of the insufficiency of symbol and of algebra.

In the number of the Westminster Review in which Walter Pater’s important early essay ‘Coleridge’s Writings’ was first published (NS 2, 1 Jan. 1866) George Grote reviewed John Stuart Mill on The Philosophy of William Hamilton. This is not the same William Hamilton whose initiating work on quaternion vectors Maxwell was studying at that same time (a useful remainder of the principle that things do not fit neatly but remain recalcitrant). But all those writers, philosophers, and mathematicians alike, are concerned with the issue of the relativity of knowledge. Pater in his essay argues that ‘modern thought is distinguished from ancient by its cultivation of the “relative” spirit in place of the “absolute”’. Hamilton, says Grote, advances the doctrine of the Relativity of Knowledge and yet elsewhere (in his dissertation on Reid) argues that ‘our knowledge is only partly, not wholly, relative; that the secondary qualities of matter, indeed, are known to us only relatively, but that the primary qualities are known to us as they are in themselves, or as they exist objectively, and that they may be even evolved by demonstration a priori’ (12).

The argument concerning the relativity of knowledge is absolutely necessary to the emergence of modernism. And it is particularly in the cognitive confusion between method and findings that connections between late-nineteenth-century physics and mathematics and proto-modernist texts can, I believe, be uncovered.

Take, for example, Cayley’s mathematics. These caused extreme distress to more conservatively minded astronomers, such as the highly effective scientific writer Richard Proctor. In particular, Proctor attacked Cayley’s ‘Address at the opening of the 1883 meeting of the British Association’ (Universe of Space: 103). In his essay ‘Dream Space’ Proctor challenged what he saw as the unreal nature of the non-Euclidean geometry that Cayley pursued, in which Cayley considered four-dimensional space, worlds in which two and two make three, and inhabitants of ‘a perfectly smooth sphere’ who would with ‘a more extended experience and more accurate measurements’ be taught ‘that any two lines, if produced far enough each way, would meet in two points; they would in fact arrive at a spherical geometry, accurately representing the properties of the space in which they lived’ (168).

Proctor is appalled by these alternative worlds and by Cayley’s disturbance (by his inscribing of the word seems) of axioms such as that odd and even numbers succeed each other alternately ad infinitum. Cayley pointed out that ‘because a proposition is observed to hold good for a long series of generations, 1,000
numbers, 1,000 numbers, as the case may be, this is not only no proof, it is absolutely no evidence, that the proposition is a true proposition holding good for all numbers whatever; there are in the Theory of Numbers very remarkable instances of propositions observed to hold good for very long series of numbers which are nevertheless untrue' (quoted in Proctor: 306).

The mathematician W. K. Clifford similarly argued in his essay 'Aims of Scientific Thought' (1872) that the apparently reliable generalizing process of scientific induction is often only smile-making, and that prediction is an unsound grinding of past events upon the future. He questioned the view that Nature is reasonable, 'inasmuch as every effect has a cause' (i. 170). 'What,' he asks, 'do we mean by this?' The word represented by "Cause" has sixty-four meanings in Faro and forty-eight in Aristotle' (i. 170–71). We develop habits of mind that take for granted laws 'so familiar that you seem to see how the beginning must have followed from the end'. When sequences of outcome will not conform to the established simile, the majesty of mystery is invoked: 'The cause of that event is a mystery which must remain for ever unknown to me.' With some aspersion he observes, 'On equally just grounds the nervous system of my umbrella is a mystery which must for ever remain unknown to me. My umbrella has no nervous system' (172).

This emphasis among mathematicians on conditionality and relativity is a far cry from the position of a contemporary such as T. H. Huxley, who claims 'that there is not a curve of the waves, not a note in the howling chorus, not a rainbow glint on a bubble which is other than a necessary consequence of the ascertained laws of nature; and that with sufficient knowledge of the conditions competent physico-mathematical skill could account for, and indeed, predict, every one of these "chance" events' (Darwin: 553–5). Realism was put in question in this debate since it depends not only upon representations of interlocked events laterally, but upon the reader's acquiescence in the logic of sequence.

What most disquieted Proctor intellectually (and what most materially makes for my argument that scientific questioning and proto-modernism are closely interconnected) is that, as Proctor observes, Cayley's paper was enthusiastically taken up by The Times, the Globe, and the Spectator. The generalist journals and

the newspapers made new ideas rapidly available to people throughout the country. Demonstrations by travelling lecturers such as Proctor and Tyndall, with experiments set up on stage, made a dramatic impact on their audiences. Such lectures were arresting entertainment, expanding the scope of the senses and putting credence to the test. Yet such demonstrations also asserted the real presence of unforeseen phenomena 'out there': singing flames, invisible rays made visible, artificial blue skies. Materialism became a form of magic spectacle, and the spectacle implied both the relativity of knowledge and the actuality of phenomena beyond the customary reach of our unaided senses.

In the Conclusion to The Renaissance Pater presents physical life as perpetual motion, perpetually unobserved: 'the passage of the blood, the waste and repairing of the lenses of the eye, the modification of the tissues of the brain under every ray of light and sound—processes which science reduces to simpler and more elementary forces' (233). At the same time, Helmhotzian optics newly established the eye as an uncertain arbiter, an imperfect organ. Helmholtz, indeed, argued that 'the impressions of sense are the mere signs of external things' (quoted in Tyndall, Fragments of Science: i. 193).

Rosalind Krauss has recently emphasized in The Originality of the Avant-Garde and Other Modernist Myths that painters from the 1870s and Impressionism 'had to confront a particular fact: the physiological screen through which light passes to the human brain is not transparent, like a window pane; it is like a filter, involved in a set of specific distortions' (17). In the last edition of The Origin Darwin pinpoints Helmholtz's emphasis on the imperfection of the eye as according with the processes of natural selection which do not guarantee absolute perfection. The contradictions between these various recognitions were themselves startling representations of the relativity of knowledge.

Human beings are adept at living in multiple and conflicted epistemologies, or we could not survive. In postmodernism we have even attempted to domesticate that awareness of conflicted multiplicity, as Don DeLillo demonstrates in his novel White Noise. In the late nineteenth century, play, vestige, and denial were all provoked in readers by the disequilibrium and illimitability that the new physics was attempting to grip in symbols.
Clerk Maxwell indeed hoped that the 'intelligent public' would be weaned from determinism by being led in pursuit of the arcana of science to the study of the singularities and instabilities, rather than the continuities and stabilities of things (Campbell and Garnett: 444).

Among scientific workers themselves the referentiality of language became a dilemma to be argued through. Nor was mathematics naïvely seen as an escape from the problems of language. The correspondence between Faraday and others concerning the term 'force' makes that clear.

'Relationalism' of representation need not at all, of course, infringe upon a belief in the actuality of phenomena under description. Indeed, an awareness of slippages within representation—the scraping at terms and disavowal of any exact reference—may be a form of hyper-realism: an assertion that there is an 'out there' so powerfully sui generis that it cannot be captured by already existing terms. The race in science between neologism and agreed nomenclature shows that tendency in action.

In the late 1840s, Tyndall thanks Maxwell for offprints in dynamics, the perception of colours, and for his monograph 'The Lines of Force.' His tone seems a trifle tart: 'I never doubted the possibility of giving Faraday's notions a mathematical form, and you would probably be one of the last to deny the possibility of a totally different imagery by which the phenomena might be represented' (7 Nov. 1847, Add 7655/R/13).

Clerk Maxwell's correspondence with Tait in particular (now in the Cambridge University Library, to whom I am grateful for permission to quote the material in this essay) is a fruitful source of three debates concerning representation and phenomena. Maxwell's struggle to establish exact terms is undertaken with a serious merriment that is alert to the multivocality of language and tries to yoke that to his purposes. He is both lighthearted and exacting in his attempts to control what he calls 'plurality'. In the following passage he seeks the apt and stringent word. He toys with sexual reference and escapes it. He controls the pace implied by the chosen term.

The discussion is about the vocabulary of vector quantities. (Vector quantities are measures of motion in which both magnitude and direction must be stated: displacement and velocity are examples of vector quantities.)

Maxwell was charmed by the over-abundance of nomenclature and recognized the difficulty of naming any word to one limited notion, particularly when a field is new. How to say little enough is the problem. But he is also well aware that mathematical symbols are no simple alternative to the communicative problems of language. Language, after all, is composed of grammar and syntax quite as fundamentally as of semantics, and Maxwell felt the lack of a secure grammar in the current mathematical field of quaternions derived from W. R. Hamilton's work. He complained of the want of a 'Grammar of Quaternions' and the 'proper position of . . . Contents, Notation, Syntax, Prosody, NIabla' (4 and 9 Oct. 1872, lb/40, 50).

By the end of that sentence he has moved across the spectrum into his own punning habit of mind, between music and geometry. Tait, in Maxwell's repertory, is the 'Chief Musician upon Nabla' because 'Nabla was the name of an Assyrian harp of the shape $\nabla$ is a quaternion operator . . . invented by Sir W. R. Hamilton, whose use and properties were first fully discussed by Professor Tait' (Campbell and Garnett: 634, n. 1).

Maxwell was an extraordinarily skillful poeticist. In his poem addressed 'To the Chief Musician Upon Nabla: A Tyndallic Ode', he uses quaternion rhymes in a performance, half celebration, half mockery, of John Tyndall's scientific demonstrations. The opening stanza of this long ode runs:

I come from fields of fractured ice,
Whose wounds are cured by squeezing,
Melting they cool, but in a trice,
Get warm again by freezing.
Here, in the frosty air, the sprays
With fern-like hoar-frost bristle,
There, liquid stars their watery rays
Shoot through the solid crystal.
I come from empyrean firm—
From microscopic space,
Where molecules with fierce desire,
Shiver in hot embraces.
The atoms clash, the spectra flash,
Projected on the screen,
The double D, magnesium b,
And Thallium’s living green.

Precisely equivalent passages to the scenes described in these and the ensuing stanzas of this poem can be found in Tyndall’s 1865 Rede Lecture on radiation (Fragments of Science: i. 28–73), in his Heat as a Mode of Motion, and in his paper ‘On the Blue Colour of the Sky, and the Polarisation of Skylight’ (Fragments: i. 59–30).

A week later, in his correspondence with Tait, Maxwell returns to the problem of representational orders: ‘the interaction of many is necessary for the full development of a new notation . . . Algebra is very far from O.K. after now some centuries . . . We put down everything, payments, debts, receipts, cash, credit, in a row or column and trust to good sense in totting up’ (9 Oct. 1871, Add 7655/IV/50). In 1873 he proposed a spoof question for the Cambridge Natural Sciences Tripos: ‘General Exercise: Interpret every 400 [i.e., Quaternion] expression in literal geometrical terms.’

Maxwell is careful to preserve a distinction between our knowledge of the world and the possible nature of the world, as did Schrödinger and Einstein later. Thus, in his Britanica article ‘Diffusion’, Maxwell argues that the idea of entropy depends on our knowledge of the system and is not itself an observable property of the system: ‘New, confusion, like the correlutive term order, is not a property of material things in themselves, but only in relation to the mind which perceives them’ (quoted in Brunei: 597–8).

Maxwell repeatedly uses the tacity and distanced form of denomination that Helmholzt also recommended to the scientist: ‘the motion called heat.’ This power of distancing himself from terms allows a limber play of attention across even those concepts most necessary to his projects. He jokes about the ether, which yet (as his contemporary R. T. Glazebrook wrote concerning Maxwell) seemed to be for scientists at the time the remaining secret to be unlocked. ‘In light waves periodic changes in the ether are taking place . . . The laws of these vibrations, when they are completely known, will give us the secret of the ether’ (DNB: xx. 120).

Maxwell combines the extreme of scepticism with the extreme of faith, remaining always devout while testing out the obduracies of the invisible material world. Indeed, for his theological comfort he needs that distinction between what he calls in another letter ‘the ignorance and finitude of human science’ and the enduring energies and dissipations of the universe. In the space between them his God can remain stable, even while Maxwell himself experiences through his study of Clausius, as he remarks wryly, ‘that state of disgregation in which one becomes conscious of the increase of the general sum of Entropy’ (12 Feb. 1872, IV/43).

Maxwell struggles, with great self-discipline and scepticism, against a temptation in epistemology, where, for example, evolutionism employs the branching model to represent the procedures by which theory is formed as well as the theory that is formed, thus confirming its own theorization. This tendency, I have already suggested, proved fruitful in modernist writing where it could be reconceived as mimetic form. Maxwell avoided merging his mode of explanation with the topic studied, but he was highly conscious of the changing functions of metaphor as they extend across scientific fields, shifting from technical description toward generalization that allows productive switching to take place between two fields.

By means of the finitude of mathematical symbols and theorems Maxwell sought to wrest his own representation away from any likeness to the entropic processes he described. But he was also acute about the instability even of mathematical symbols. To Tait he wrote that he ‘should make a supplementary book on Quaternions explaining the true principles of dots and brackets and defining the limits of the way of symbols’ (14 June 1875, IV/50).

He concludes this postcard by writing out a ‘Sylvestrian sonnet’, ‘Tasso to Eleonora’, without remark. The poem is thereby made to bear upon the theoretical problem they are surveying in their study of thermodynamics. The octave runs:

Calm, pure, and mirroring the blue above
To whom commingling my love’s streams flow.
Making that one which many seemed but now,
WAVE THEORY

Thou art the sun and ocean of my love.
What though my soul rebellious pulses prove:
These are the gales that o'er the surface play,
The fleeting colours painted on the spray;
They cannot in its depths the oceans move.

The writing-out of the poem in the context of this correspondence produces an implicit analysis that he need not spell out. Here, current topics in science are serenely re-imagined in the traditional tropes of love sonnets: the blue of the sky (which Tyndall had recently shown to be the result of the polarization of sunlight by particles in the upper atmosphere), the expanding of a single explanatory system to encompass light, heat, sound; the conserving of energy through the whole system; the fleeting colours of the spectrum in the turning wave; and the recognition that the particles of water do not move forward but simply up and down, the disturbances being at right angles to the direction of propagation. All these subjects are to be found in the work of Helmholtz and Maxwell, and are set forth with ravishing clarity in Tyndall's essays gathered in *Fragments of Science*. The tropes of Renaissance poetry are the current topics of science, Maxwell indicates. Recontextualizing the sonnet draws attention to the complexities of limiting 'the sway of symbols'. Language is fertile with fresh reference.

Maxwell has an unusual spatial capacity in his thought that allows him to hold geometry, poetry, logic, statistics, and joke alongside each other without seeking resolution or hierarchy among them, in a manner that actualizes Bakhtin's idea of the polyphonic. This ranging is achieved without muddle. Even his puns are models of precision.

Maxwell warns against popular expository rhetorics, which he calls 'the sensationalist' and 'the hierophantic':

The sensationalist says 'I am now going to grapple with the Forces of the Universe and if I succeed in this extremely delicate experiment you will see for yourselves exactly how the world is kept going.' The Hierophant says 'I do not expect to make you or the like of you understand a word of what I say, but you may see for yourselves in what a mass of absurdity the subject is involved.' (13 Dec. 1869)

Up to now in this argument I have concentrated on the writings of Clerk Maxwell, partly because he is so clear and adept a thinker about communicative questions and also because his work has continued to be of profound importance in the development of physical theory. But Clerk Maxwell's influence took time to be felt and acknowledged in cultural circles beyond science.

John Tyndall, in the physical sciences, was the writer who most spoke to his contemporaries, conveying to a general readership information about current scientific work and illuminating its penumbra of meaning. His effects can still be felt in the writing of Virginia Woolf, particularly *The Waves*, as I have argued elsewhere ('Victorians in Virginia Woolf'). He wrote in a style at once easy and incandescent. He was the person whom Pater read, Hopkins read, and in her youth Woolf read—indeed, he was the one writer you could scarcely have avoided scanning on scientific subjects if you read the generalist journals of the later nineteenth century.

Tyndall provoked controversy by his atheism, materialism, and insistence upon the imagination: itself an intriguing mix of preoccupations. He was from Ireland, not part of the social establishment, making his way from the ordnance survey of Ireland to the Preston Mechanics' Institute and thence as a mature student to Marburg University in Germany where he studied chemistry and mathematics. He was an atheist but 'redeemable', Hopkins hoped, and a materialist of a lofty, even transcendent, cast of mind (see Ch. 11 above). Much of the power in his writing came from his making visible to the imagination forces beyond the reach of sense. These paradoxical qualities meant that his work posed questions about cosmic order and extent. His work on radiation emphasized 'the incessant dissolution of limits' (*Fragments*: p. 2). His picturing of the outmost reaches of space was figured as sensation: 'It is the transported shiver of bodies countless millions of miles distant, which translates itself in human consciousness into the splendour of the firmament at night' (p. 4).

Heat and light are both modes of motion and

in the spaces of the universe both classes of undulations incessantly commingle. Here the waves issuing from uncounted centres cross, coincide, oppose, and pass through each other, without confusion or ultimate extinction. Every star is seen across the entanglement of wave-motions produced by all other stars. It is the ceaseless thrill caused by these distant orbs collectively in the ether, that constitutes what we call the 'temperature of space.' ([34])
Tyndall prefers words that are at once precise, sensational, and evaluative: here, 'thrill' technically signifies penetration and oscillation, and also communicates excitement. This talent for rousing sensation in the reader meant that, despite his specifying precise meanings for terms such as force, radiation, absorption, his work offered mental images that could be symbolically reapplied, even though his own position was firmly grounded in materialism. He sets as epigraph to his most famous essay, 'The Scientific Use of the Imagination' (1870), a passage from Emerson whose last four lines run:

The rushing metamorphosis
Dissolving all that entrance is,
Mists things that be to things that seem,
And solid nature to a dream.

The tendency of Tyndall's own rhetoric was not dissolution but making visible. His particular major contribution to research was on the 'obscure rays' of the sun and their powers, as well as on ice crystallization, and on the blue of the sky.

Tyndall's making visible, in his theoretical and experimental demonstrations, of the 'dark rays' of the sun was—for some beholders—not unlike the appearance of the aura in spiritualism. Azure and wave motion, the stirring topics of then current scientific enquiry, enter early modernism alongside spiritual emanations. If ether, why not aura? If dark rays, why not invisible presences? And if a 'medium' of transmission (the ether) is required for energy, why not for voices from beyond? Spiritualist seances and scientific demonstrations did not seem very different in their effects. Sign: science; seances: how were they to be distinguished? Photography, with its apparent authenticity of real presences, could be used to confirm spiritualism. The Victorian camera takes snapshots of emanations, by an optical and chemical process that seemed to parallel spiritualism's insistence on 'manifestation'.

The 'dark rays' of Tyndall's own experimental work manifested otherwise invisible presences and claimed for them a more than symbolic form. In an essay, 'Science and the Spirits' (Fragment: 444-52), Tyndall sets himself in competition with the medium at a seance. Both claim to bring hidden 'real' phenomena within the scope of the senses. In this unremarked essay

Tyndall gives a vivid account of a tussle between himself and the medium for control of interpretation. He and she are, equally, storytellers. Whose narratives more satisfyingly expound wave processes? Whose please the listeners more? Whose describe a 'real' world?

Our host here deprecated discussion, as it 'exhausted the medium.' The wonderful narratives were resumed, but I had narratives of my own quite as wonderful. These spirits, indeed, seemed clumsy creations, compared with those with which my own work had made me familiar. I therefore began to match the wonders related to me by other wonders. A lady present discoursed on spiritual atmospheres, which she could see as beautiful colours when she closed her eyes. I professed myself able to see similar colours, and, more than that, to be able to see the interior of my own eyes. The medium affirmed that she could see actual waves of light coming from the sun. I retorted that men of science could tell the exact number of waves emitted in a second, and also their exact length. The medium spoke of the performances of the spirits on musical instruments. I said that such a performance was gross, in comparison with a kind of music which had been discovered some time previously by a scientific man. Standing at a distance of twenty feet from a jet of gas, he could command the flame to emit a melodious note; it would obey and continue its song for hours... These were acknowledged to be as great marvels as any of those of spiritism. The spirits were then consulted, and I was pronounced to be a first-class medium. (I, 447)

(This 'siren song' is alluded to in the Maxwell poem I quoted earlier.) Tyndall triumphs, or believes himself so to do, but the exchange also takes us back to his early letter to Maxwell, arguing for variety of representations. Tyndall's materialism makes room for variety of interpretation and representation, but within the pale of scientific debate. Single truth and hyper-realism prevail. That scene of debate between scientist and medium, both conjurers of demonstrations, both claiming a higher validity for their performance, suggests also a context (which I shall not here develop further) for Yeats's early poetry.

The idea of the universe as waves, of the parallels between light, heat, and sound, and the single process expressed through them, enters late-nineteenth-century writing with a fresh urgency. Flux, the vortex, the ocean, the aura, the 'sea of forces flowing and rushing together', as Nietzsche called it, so important in modernism, are all elements of a repertoire shifting across fields.
In this I have concentrated on issues of representation among British scientific writers of the later nineteenth century concerned with wave theory, rather than on the famous philosophical examples of Nietzsche and Bergson in the formation of early modernism. One of the oddities of modernist chronology is the frequency of time-warp, delays of reception which have sustained the insistence on novelty so important to modernist ideology. Let me conclude by glancing at this oddity since it has its bearing on questions of representation and realism. In French writing of the later nineteenth century science and symbolism are not at odds: witness Mallarme’s ‘L’azar’, and the great and hideous invocation of the ocean in Lautréamont’s ‘Maldoror’. Lautréamont idealizes mathematical signs in his sado-masochistic ecstasies which, in a series of cantos, flow associatively through reformation and deformation of the human body and psyche: ‘Ainsi, les etres humains, ces vagues vivantes, mesurent l’un après l’autre, d’une manière monotone, mais sans laisser de bruit échoués [. . .]’. Les bras rageant aveuglement dans les eaux iridescentes de l’ethère’ (4.6). Lautréamont, like Gerard Hopkins (and, so far as non-scientific circles go, like Clerk Maxwell too), is a curious example of the time-crumpling nature of modernist reception. (When Woolf came to write The Waves she was responding both to Einstein and to Tyndall simultaneously.) Lautréamont died in the 1870s yet his heyday was in the period of Surrealism in the 1920s. Similarly Hopkins appears as the first poet in the Faber Book of Modern Verse, set away from the period in which he himself lived among the surrounding languages of poets like Swinburne, writers like Maxwell and Tyndall.

The force of scientific ideas in literary works is to provoke resistance as often as it is to persuade acquiescence or extension. In his essay ‘Bergson’s Theory of Art’ in Speculations, T. E. Hulme describes the activity of the mind through a forced extension of the waves metaphor:

It is as if the surface of our mind was a sea in a continual state of motion, that there were no waves on it, their existence was so transient, and they interfered so much with each other, that one was unable to perceive them. The artist by making a fixed model of one of these transient waves enables you to isolate it out and to perceive it in yourself. [359–2]

The important modernist principle here is that of falsification: to model or to fix a wave is to interfere fundamentally with its representation. The violent seizure of the provoked image is one important strain in modernism; as in the vortex, the interpenetrating cones. Holme sees science, and indeed all thought, as the art of reduction in the service of power: ‘to reduce the complex and inevitably disconnected world of grit and cinders to a few ideal counters, which we can move about and so form an ungritlike picture of reality—one flattering to our sense of power over the world. . . . In the end this is true too of mathematics’ (‘Cinders’, Speculations: 224). That emphasis on arrest and power is one important element in modernism. It is set in energetic opposition to entropy and to the vanishing of substance. Yet the metaphor of cinders also recalls the degradation of energy through the entropic process and calls on that as the ‘real’ against the stylization of art. A different expression of modernist creativity, which does draw on wave theory without quarrel, is that of oceanic communality. It is voiced alike be Woolf in The Waves and by Schrödinger. Schrödinger, like Woolf, like Jung indeed, wrote of ‘conscious awareness as something emerging in individuals like tips of waves from a deep and common ocean’ (quoted in MacKinnon: 221).

The questioning of substance in twentieth-century physics, and the formulation of wave-particle theory, gave realism a new lease of life (if in a manner somewhat analogous to the move in theology from literalism to the hermeneutics of myth). It is harder to deny an ‘out there’ that is undifferentiated, or irresolute, or composed of ‘ondes factices’ than it is to challenge substantive phenomena. Realism spurs paradox: it seeks referential (and reverential) equivalence, the one-to-one locking of word and thing. But it has come to depend on paradox and on the logic of zeugma.

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