Literature & Science: Paradigm Shifts Implicit in the Works of Goethe

Literature and science have a closer relationship than may at first meet the eye. In this paper, the catalytic function of literature in effecting important new ways of seeing and conceptualising the world of the scientist is predicated. As background to this argument, some of the major paradigm shifts that have brought us from a classical Newtonian, mechanistic world to a modern quantum perspective are discussed. Early quantum scientists themselves refer to literary ideas impacting upon their vision of reality; with this in mind, important philosophical ideas that are played out in Goethe's works and which helped to galvanise a paradigm shift in science are discussed. My personal vision is a reinstatement of the importance of the arts to science and to human understanding.

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Literature and philosophy form two important catalytic sources of new ideas stimulating the creative unconscious of the scientist's mind, providing a springboard for the ultimate new leaps which have advanced us from a mechanistic Newtonian understanding of life to a dynamic quantum framework. One example of this can be seen in the works of the great German writer, Johann Wolfgang von Goethe. The argument for the crucial role of literature and philosophy in scientific conceptualisation is based on three logical steps: one, that a pre-existing conceptual framework influences the way a scientist interprets what is seen in an experiment or an observation; two, that important paradigm shifts are necessary to make new interpretations of data, and to facilitate the major scientific advancements we have made; and three, that these shifts in paradigm or framework do not materialise out of nowhere, but come from the surrounding discourse of the scientist's era. Goethe's late eighteenth and early nineteenth-century writings, in which he dramatises and plays through important philosophical ideas and visions, contributed to a change in the philosophical and thus scientific understanding of reality influencing the development of twentieth-century quantum mechanics.

For the first two steps in my argument, I will adduce historical detail from some of the major scientific conceptual changes leading to the development of quantum physics that took place between the 1800s and the mid-1920s.[1] This will both demonstrate the need for shifts in world view to enable new understanding and will also serve as an introduction to the quantum ideas later shown to be presciently articulated by Goethe. My attention will then turn to some selections from Goethe's literature that indicate alternative conceptualisations from the hegemonic Newtonian ones and which I thus regard as promoting the paradigm shifts indispensable for new scientific thought. It is my contention that Goethe explored in his literature important philosophical ideas integral to later scientific development.

Vision becomes important at this point in two ways. Firstly, there is the vision of the scientist which, on the positive side, might inspire the design and interpretation of the research, or, on the negative, might restrict an interpretation of results by locking a scientist into unprofitable, rigid lines of thought. These need to be changed if the scientist is to understand what is, in fact, being 'seen'. Secondly, there is my own vision of a greater general recognition of the place of the humanities in the advancement of scientific work. By providing new understandings of the world that form the basis of the framework scientists will use to interpret their work, the humanities are instrumental in inducing change. Scientific advances do not occur in a vacuum, but feed off ideas circulating in the community thanks to the influence of the arts.

My understanding of the term 'conceptual framework' in this discussion is taken from similes used by the scientists themselves. In the German language, Wolfgang Pauli speaks of 'Vorstellung' (how we imagine something)[2] and Einstein of 'philosophische Einstellung' in the sense of attitude or view.[3] Other useful terms employed by Einstein are 'philosophische Vorurteile' (philosophical prejudices),[4] 'begriffliche Konstruktion' (intellectual construct)[5] and 'Betrachtungsweise' (way of observing or viewing)[6]—although, perhaps his descriptor 'hobby-horse[s]' is his most honest offering.[7] Werner Heisenberg, writing in English, refers to 'concept of reality',[8] and 'way of thinking';[9] Paul Dirac to 'picture of the world' and 'fundamental ideas';[10] Max Born to 'philosophical attitude',[11] 'philosophical principles' and 'philosophical convictions';[12] and Stephen Hawking to 'philosophical standpoint'.[13] Niels Bohr's favourite locution is the one which I will employ most frequently—'conceptual framework'.[14] However, the range of usages I have quoted indicates the ways in which I intend the term.[15]

I.

At the time of Descartes, seeing was equated with knowing, and was the most prized of the senses: 'The conduct of our life depends entirely on our senses, and since sight is the noblest and most comprehensive of the senses, inventions which serve to increase its power are undoubtedly among the most useful there can be.'[16] Because of his sundering of subject and object, objectivity of the gaze was assumed, and, in that sense, subjectivity was not an issue; the 'I' of the subject observed the object of the scientific outside world. This objectivity of the outer then formed the foundation of Newton's mechanical interpretation of the world, unhampered by problems that might arise from incursive subjectivity. Objects moved independently of an observer in fully predictable patterns, governed by laws set in place by the creator of the universe and determinable by man. The particle constitution of matter, continuity, predictability and causality were integral features of the framework underpinning the Newtonian interpretation. However, with the development of Kantian philosophy, it became clear that all seeing is inherently limited,[17] and—as seeing and knowledge are interfused—that the prospects for knowledge, equally, are profoundly restricted. In the *Kritik* *der reinen Vernunft*,[18] Kant demonstrated an irrevocable divide between subject and object, the 'Ding-an-sich' (literally, the 'thing-in-itself'), by pointing out that we have no direct contact with the object. Realising the negative implications of this for science, he attempted in the *Kritik der Urteilskraft*[19] to erect a bridge over this hiatus between subject and object, but the attempt failed. The scientific stress on a supposedly independent object—first set in motion with the dualism of Plato, furthered by the extreme dualism of Descartes and climaxing in the idea of an independent but unreachable 'Ding-an-sich' in Kant—has continued to have lasting repercussions in Western thinking and scientific thought.[20] It was, as mentioned above, a large factor enabling the particular mechanistic concept of the world established by Newton, whose materialistic and static concepts reigned with enormous influence for two hundred years after they were established.[21] Right into the early nineteenth century, physicists still believed that the universe was a huge mechanical system running according to Newton's laws of motion. This vast cosmic machine was causal and determinate, with absolute certainties of prediction. This is the conceptual framework that scientists brought to the period under discussion here, a discussion which will begin with the first inroad into this way of thinking and the first challenge to a materialistic world view—Faraday's vision of fields of force rather than strictly solid matter. A field concept and a Newtonian matter concept of reality were mutually exclusive, as Einstein later pointed out: 'Matter which we perceive is merely nothing but a great concentration of energy in very small regions. ... There is no place in this new kind of physics for the field and matter for the field is the only reality.'[22]

II.

Contrary perhaps to our preconceptions, and in denial of what Descartes would have as true subjectless scientific rigour, scientists rarely come to their experiments without prior expectations. History repeatedly demonstrates that scientists bring a pre-existing conceptual framework to the experimental situation and interpret their results in terms of that framework and the expectations it engenders. For this reason Goethe spoke out, particularly in the second section of *Farbenlehre*,[23] against the use of experimental hypotheses that would influence perceived outcomes, campaigning instead for unbiased observation in the testing situation. This, of course, produces a less rigorous and thus less controlled experimental methodology, so his thoughts were not taken too seriously, but the point remains nonetheless, and with it the recognition that pure objectivity is

hard to obtain. In quantum mechanics, with acknowledgement of the influence of the experimenter and experimental apparatus on what is observed by Niels Bohr and his followers, there is greater recognition of subjectivity in science.

In fact, the discussion which follows could be interpreted as a cogent illustration of what Nietzsche argued in several of his works—that what we hold to as truth depends not on what reality may or may not be, but on what we wish to be the truth. This 'truth', says Nietzsche, is that which enables our own self-maintenance, or 'Wille zur Macht', as he terms it.[24] According to this argument, which follows directly from Kantian thinking, our belief statements thus have far more to do with that which makes us feel at one with our world—that which enhances our individual self-actualisation—than with any objective reality which might appear to be the basis of those beliefs.

If 'truth' is as subjective as this suggests, how do we ever achieve conceptual or factual advancements? This is obviously more difficult than the mere making of discoveries or acquiring a new piece of experimental knowledge—for example, Stephen Hawking points out that we had enough information about gravity in the late 1600s to have predicted an expanding universe, but that 'discovery' had to wait until Edwin Hubble's 1929 observations.[25]

The resistance to the theory of the expanding universe is an excellent demonstration of the lengths that scientists will go to in order to rescue an idea in the face of conflicting objective information—of the way that interpretation depends more on conceptual framework than the 'real' situation, whatever that may be. Newton's laws of gravity should have predicted a universe that would collapse in on itself unless it was expanding. Einstein struggled with this. So firm was his belief in a static universe—so strong was the hold, still, of Newtonian thinking—that he sought ways to overcome reality rather than yield to logic. Hawking documents his casuistry on this matter:

> *Even Einstein, when he formulated the general theory of relativity in 1915, was so sure that the universe had to be static that he modified his theory to make this possible, introducing a so-called cosmological constant into his equations.*[26]

New answers, then, involve not just new factual information, but a new vision—a change in orientation. This is a step for a few rare thinkers whose names are in the annals of scientific history. The history of scientific development reads very much as a history of changes in outlook rather than the story of new facts being uncovered. As Erwin Schrödinger is aware: 'The world … does not become manifest by its very existence, its becoming manifest is conditional on … certain events that happen in a brain.'[27] The above example of resistance is but one illustration.

III.

I wish now to concentrate on some of the conceptual shifts from Newtonian thinking that gradually paved the way for a quantum understanding of the universe. In the next section, I will detail how these new ways of seeing were foreshadowed in Goethe's work. As noted above, philosophical framework can operate as a positive inspiration, leading a scientist to search in directions that prove to be productive; or it can be negative, acting as a blindfold and preventing insight into what is otherwise there to be seen. As Allan Barton, Professor of Physics at Murdoch University, notes: 'Images, if relied on too strongly, can inhibit our understanding or appreciation by having a conditioning effect that prevents the acceptance of new ideas.'[28]

Michael Faraday was a man fuelled by his belief in the unity of the forces of nature. It was that belief in unity which first led him to extend Ørsted's nascent work and demonstrate unequivocally the strong relationship between the forces of electricity and magnetism, forces previously considered independent.[29] This belief in unity also motivated further innovative research that was instrumental in unseating the particle concept of matter.

Faraday's new concept of fields was ultimately a triple challenge to a Newtonian conceptual framework. Firstly, his studies were the first indication that forces operated inside what were thought of as solid particles. Secondly, fields were intangible, not material. And thirdly, his theory involved a dynamism at odds with Newtonian static constructs. There was room for a new framework for those prepared to change their thinking and leave the aegis of the stable, predictable Newtonian world.

The next conceptual challenge came with Max Planck's very reluctant discovery of discontinuity. Planck was embarrassed at, and disbelieving of, his findings, for continuity was another belief central to the existing philosophical system.[30] The challenge that his findings posed to his own beliefs was so strong that he was not able to realise their wider import. A full interpretation had to wait another five years for Einstein,

who, in what Werner Heisenberg describes as a 'stroke of wizardry', proposed the idea of light quanta and developed a whole new understanding. He could only do this, notes Heisenberg, by stepping boldly outside conventional thought patterns.[31] Einstein hadn't, in fact, *found* anything. What he had done was to think differently, to adopt a new conceptual framework.

Einstein was also the one responsible for the next major step in debunking a classical framework with his theory of general relativity, published, together with his groundbreaking contribution on light quanta, in the *Annalen der Physik* in 1905. As Max Born noted, the other physicists were immediately aware 'that a genius of the first order had emerged'.[32] Under the classical paradigm, time and space were both absolute and independent, an idea also supported in Kant's envisaging them as a priori concepts. The leap here by Einstein is monumental; but again, its significance lies in his ability to transcend existing thought patterns rather than any new factual piece of experimental information observed.

However, there is another side to Einstein. The Born–Einstein letters that contain the above comment by Born also document Einstein's surprising resistance to the next step of quantum, and the debilitating effect of clinging to old beliefs. In these letters, Einstein rebuffed the wider implications of quantum mechanics, not by utilising mathematical or scientific reasoning, but with statements such as: 'I believe';[33] 'I find the idea quite intolerable';[34] 'an inner voice tells me';[35] and 'My whole instinct rebels against it irresistibly'.[36] Born is frustrated by objections couched in this way, complaining: 'he rejected it for no definite reason. … It was based on a basic difference of philosophical attitude'.[37] Perhaps this is why he wrote in a different context: 'I am convinced that theoretical physics is actual philosophy.'[38] It certainly provides good grounds for Heisenberg to write: 'All scientific work is, of course, based consciously or subconsciously on some philosophical attitude … The letters … movingly demonstrate the degree to which the work of the scientist … is fundamentally determined by philosophical and human attitudes.'[39]

Today the same issue still exists, as demonstrated in the Penrose–Hawking debates. The main emphasis of the debate is not, as might be expected, mathematics, but is rather on the philosophical standpoint behind the mathematics. From that standpoint, each then uses maths to advance his argument—either a positivist one, in the case of Hawking, or a Platonist one, in the case of Penrose (so worded by Hawking).[40]

IV.

Thomas Kuhn, in *The Structure of Scientific Revolutions* of 1962, and again in his revised edition of 1970,[41] also noted the importance of conceptual framework within his wider thesis that changes in paradigm in science are dramatic rather than incremental—'revolutionary', in fact. Kuhn, using different source material from that used in this argument, endorses what had been noted by quantum physicists before him: that this revolution is not about a gain in knowledge as such, but a change of stance and of world view. In fact, Claude Bernard, French medical researcher, had noted a hundred years before Kuhn that science proceeds by 'revolution' and not by 'addition pure and simple'.[42] Kant, in his preface to the second, 1787 edition of the *Kritik der reinen Vernunft* also views the advances in science as occurring via a process of revolution.[43]

Kuhn notes the presence of paradigm shifts, in particular their revolutionary nature, and their influence in reforming conceptualisations and influencing interpretation of data. He does not, however, address the issue of how such revolutions take place. Mathematicians Henri Poincaré and Jacques Hadamard and neurologist Oliver Sacks have concentrated on the issue of change. All concur that it is the result of 'long unconscious prior work'[44]—a phase of preparation and assemblage of the ingredients of later change. All then emphasise the suddenness of the final inspiration, which Sacks attributes to the creative right hemisphere of the brain.

Many of the world's leading scientists, especially the Nobel Prize winners under consideration in this paper, have been ready to acknowledge the influence on their thought of various philosophical ideas that have reached them either from philosophical writings, or through literature which has played out, and worked through, the philosophical problems in the context of narrative fiction. This is part of the long, unconscious prior work referred to by Sacks, Poincaré and Hadamard. Sometimes that absorption of ideas can be unconscious, as Einstein notes in his tribute to Ernst Mach: 'Ich glaube ... daß die jenigen, welche sich für Gegner Machs halten, kaum Wissen, wieviel von Machscher Betrachtungsweise sie sozusagen mit der Muttermilch eingesogen haben' ('I believe that those who think themselves opponents of Mach are hardly aware of how much of Mach's way of seeing things they have imbibed, as it were, with their mother's milk').[45] Einstein acknowledges in the same paper his personal debt to the philosophical writings of both David Hume and Ernst Mach in forming his own

conceptual framework—specifically in their helping him to stop thinking in the absolutes required by a Newtonian paradigm. In a similar vein, Gillian Beer in *Darwin's Plots* discusses the influence of the metaphors issuing from Darwin's *Origin of Species* that influenced the discourse of subsequent eras, with or without a direct reading of Darwin.[46]

The thinker I wish to focus on in this discussion of literary influences is Johann Wolfgang von Goethe. Tracing lines of thought from quantum back to Goethe is not difficult—the physicists themselves draw the connections, which helps endorse my point that literature has moulded their thought patterns.[47] In *What is Life?*, a book interpreting biological phenomena in terms of quantum mechanics (a series of lectures given in Dublin in 1943), Erwin Schrödinger begins each chapter (lecture) with a quotation from either Goethe or Spinoza, the great pantheist.[48] Max Born begins *The Restless Universe* with Schiller and ends with Goethe,[49] while *My Life and Views* contains a discussion of a section of Goethe's *Maxims and Reflections*. The most comprehensive quotation of Goethe, however, comes from Werner Heisenberg, who, like Born, quotes from *Faust I*. I will give both the English version that Heisenberg uses and the more satisfying German original for those who can read it:

Waste not your time, so fast it flies;	*Gebraucht der Zeit, sie geht so schnell von hinnen*
Method will teach you time to win;	*Doch Ordnung lehrt Euch Zeit gewinnen.*
Hence, my young friend, I would advise,	*Mein teurer Freund, ich rat Euch drum*
With college logic to begin.	*Zuerst Collegian Logicum.*
Then will your mind be so well brac'd,	*Da wird der Geist Euch wohl dressiert,*
In Spanish boots so tightly lac'd,	*In spanische Stiefeln eingeschnürt*
That on 'twill circumspectly creep,	*Daß er bedächtiger so fortan*
Thought's beaten track securely keep	*Hinschleiche die Gedankenbahn ... .*
Then many a day they'll teach you how	*Dann lehret man Euch manchen Tag,*
The mind's spontaneous acts, till now	*Daß, was Ihr sonst auf einem Schlag*
As eating and as drinking free,	*Getrieben, wie Essen und Trinken frei*
Require a process:—one, two, three!	*Eins! Zwei! Drei! Dazu nötig sei.*

In truth the subtle web of thought
Is like the weaver's fabric wrought,
One treadle moves a thousand lines,
Swift dart the shuttles to and fro,
Unseen the threads unnumber'd flow.[50]

Zwar ist's mit der Gedankenfabrik
Wie mit einem Weber-Meisterstück,
Wo ein tritt tausand Fäden regt.
Die Schifflein herüber hinüber schließen,
Die Fäden ungesehen fließen.[51]

One sees here the Goethe of the late 1700s[52] breaking out from Newtonian confines, preparing the way for others to follow. Mephistopheles, the devil, advises the student in this scene to learn college logic to keep the mind travelling on neat, linear and rigid classical tracks, the converse of the kind of thinking needed in the matrix mathematics of quantum. The mind, in the conceptual paradigm discussed here, will be as tightly laced as Spanish boots, restricted in its interpretative powers and its ability to understand the world. The student will be taught to do what was previously done without thinking—the formerly unconscious will be brought into the restrictive, uncreative domain of conscious thought and control, and given the numbers of inflexibility and rigidity. And so Mephistopheles speaks to the student with heavy irony. He then draws the contrast with how thought should be when not submitted to this rigour—the sorts of images of later quantum. Linearity is replaced by interconnections (a 'subtle web of thought'), with the strands intertwining through the fabric. This is the kind of thinking required by the matrix mathematics of Max Born and Werner Heisenberg. They had to break through the barriers imposed by linear equations that could not describe the interconnections of quantum phenomena. In this advice Goethe is rebelling against the shackles of the Newtonian framework and reaching out for a conceptualisation which is less bound to 'beaten tracks' and to the rigidity of that kind of numbering. The flowing at the conclusion suggests the dynamism that imbued Goethe's work, and quantum theory to follow. Goethe is calling Newtonian thinking into question and positing a new way. Solidity gives way to dynamism and energy; linearity to matrix.

The same disdain for Newtonian thinking can be seen in Faust's own disillusionment as he surveys the pieces of scientific apparatus surrounding him in his study. From Bayard Taylor's translation:

Ye instruments, forsooth, but jeer at me,
Your wheels and cogs mere things of wonder;
When at your door, you were my keys to be,
Yet deftly wrought, your bits can move no words asunder.[53]

Faust can see in these instruments no purpose apart from the mockery of the subject's attempts to use them to reach the object. They stultify the scientist's attempt to examine the vitality of nature through a contrived experimental situation. The wheels and cogs of such mechanistic devices may be objects of wonder, but they do not serve the intended purpose of probing reality. The hope of science to penetrate nature with instruments or to provide a clue to understanding some guiding principle of reality—expressed in 'you were my keys to be'—is a jejune hope; it 'moves no words asunder'. Goethe in *Faust* corrodes the confidence of his age in a Newtonian world view predicated on a belief in objective examination via scientific method. Over a hundred years later, Niels Bohr was to assert the same as he stressed the fact that objective observation is a myth. In quantum physics, interaction between observer and observed 'forms an integral part of the phenomena'.[54]

In *Across the Frontiers*, Heisenberg also suggests that the mysterious signs that Faust seeks in the book of Nostradamus (another false attempt to gain knowledge) represent the symbols of mathematics. The literary character Faust articulates the stance of Goethe in his role of scientist, strongly resisting the Newtonian description of the complexity and wholeness of nature in terms of numbers, as he does, directly, in *Farbenlehre*. This expresses another aspect of Goethe's pervading holism, which resisted both reductive mechanism and an abstraction that removed science from direct experience. This holistic attitude permeates the way nature is understood in the continuation of *Faust*, as argued by Kate Rigby.[55] In *Faust II*, the sea is portrayed as both life-giving and life-destroying. Faust's blindness in failing to comprehend the disparate forces of nature—his failure to acknowledge the whole—results in tragedy.

This appreciation of life as a unity and the holistic emphasis apropos of nature is evident even in Goethe's first novel written at the age of twenty-two, *Die Leiden des Jungen Werther*, first published in 1774. The eponymous hero of this work is not, like Faust, a disillusioned scientist, but rather an artist feeling the manacles of a society committed to rationality forged from Cartesian dualism and Newtonian mechanism. Werther's private world is unified, dynamic and fluid. He sees the finite in the infinite, and the infinite in the finite—the almighty in a blade of grass, the teeming insect life as an expression of the all-powerful being.[56]

A concept of the unity of existence imbues each of his encounters with nature, whether he is discussing the miniscule, such as here, or the mighty power of a river in flood.[57]

It was just such a belief that kindled Michael Faraday's experimental zeal, and led to his spotting unity in the separated areas of magnetism and electricity. On 5 November 1845, he dispatched a paper entitled 'On the Magnetisation of Light and the Illumination of Magnetic Lines of Force', in which he commented: 'I have long held an opinion … that the various forms under which the forces of matter are made manifest have one common origin; or, in other words, are so directly related and mutually dependent, that they are convertible, as it were, one into another'[58]—the kind of idea aired in *Werther* and *Faust*. This belief inspired his further, albeit unsuccessful, attempts to find a single force to describe the whole of nature. On 19 July 1850, he lamented: 'Here are my trials for the present. The results are negative; they do not shake my strong feeling of an existence of a relation between gravity and electricity, though they give no proof that such a relation exists.'[59] Physicists of similar persuasion have still not abandoned Faraday's hope (see the closing sections of Hawking's *The Theory of Everything*).

Not only does Werther see the interfusion of finite and infinite in nature, he is more able than the blind Faust to embrace nature in its totality. In the same year that *Werther* was published, Goethe wrote a criticism of a simpering attitude to beauty which only wanted to accept the 'pretty' and 'tame' aspects of nature: 'Sind die wütenden Stürme, Wasserfluten, Feuerregen, unterirdische Glut und Tod in allen Elementen nicht ebenso wahre Zeugen ihres ewigen Lebens als die herrlich aufgehende Sonne?' ('Aren't wild storms, floods, raining balls of fire, subterranean glow and death just as much genuine signs of eternal life as the magnificent setting sun?').[60] Werther expresses this same acceptance of the wild and harsh as well as the pretty, for example, in his letter of the 26 May, where, having inveighed against those who would try to constrain nature with rules, he invokes the image of timid landholders on the banks of a mighty river, building dams and ditches to keep out the danger of a flood rather than respecting the power of the potential forces—a forerunner to the ideas at the end of *Faust II*. Werther in his imagery accepts the legitimacy of the destructive power and excess of flood along with the beauty of a flowing stream. His understanding of nature is all-inclusive. One is reminded here of the Theory of Complementarity, with its logic-defying paradoxes, formulated in the late

1920s by Niels Bohr to express his understanding of the duality of light. Bohr maintained that light could be both wave and particle, depending on the observation situation. Like Goethe's holism, Bohr's theory is indebted to Spinoza's pantheism.[61] Both had a vision of a whole; both understood that observation of one sector of reality did not exclude the other aspects.

Werther's general thought patterns also reflect a holism that does not brook the kind of either–or thinking engendered by Newtonian logic, which prescinds the complement of what is being observed. Werther argues against this kind of logic in a debate within the novel with an arch-rationalist, Albert, who views the world in conventional black-and-white terms. In frustration with Albert's reasoning, he enunciates what is, in fact, Goethe's stance against Newton: 'In der Welt ist es sehr selten mit dem Entweder–Oder getan' ('The world rarely operates in terms of either–or').[62] When physicist Wolfgang Pauli talks of 'sterile(r) Rationalismus' (sterile rationalism),[63] or when Erwin Schrödinger makes the comment, 'I should not like to have to pass judgement as to who has come nearer to the deepest truth, Fechner (a pantheistic extremist) or the bankrupts of rationalism',[64] they are repeating Werther's distaste, and echoing both his holistic and his non-linear outlook. The interpenetration which complicates attempts at linearity and either–or deduction later finds expression at a quantum level in the matrix mathematics of Born and Heisenberg.

Werther is also non-divisive, and non-excluding, in his attitude to society. He befriends children, the poor, aristocrats, murderers and madmen. His attitude to madness exemplifies his encompassing inclusion. In order to contextualise this, one should note that it is being enacted in a period in which, as Michel Foucault documents, the 'mad' were still sequestered from society, as argued particularly in *Madness and Civilisation* and *Mental Illness and Psychology*. There are several scenes in the book where Werther has dealings with characters who are deemed 'outsiders' by rational society because they fail to conform to the standard modes of action dictated by this conceptualisation of 'us–them' thinking which excludes the other in a diremptive act. Rather than exclude, Werther places himself in the shoes of these characters in an inclusion that can be seen as an aspect of holism. Thus Werther takes the side of a character who, due to his extreme passion, actually commits murder, because he sees life from that man's perspective and understands the driving force and frustrated passion behind his act. When he confronts a psychotic in the forest—a man totally divorced from reality and living in a wonderful world of his own imagining—Werther neither labels him mad nor excludes him, but rather views life from his angle, and ponders whether it would not be preferable to be unburdened by the cares of reality as this man is.[65]

The above examination of the possibility of life from an apparently antithetical position, and the refusal to exclude or deny the complementary other, endorses not only interpenetration and holism but also a perspectivity which does not belong to the absolutism of Newtonian thinking. Goethe is here gestating ideas that will eventually take scientific shape in Einstein's Theory of Relativity, where classical absolutism is abandoned at the scientific level. These ideas also pave the way for Heisenberg's *Unschärferelation* (Uncertainty Principle) that allows for the indeterminate factor in quantum, caused by the unpredictable movements of the quanta of action. This was also emphasised in Erwin Schrödinger's probability equation, and Max Born's interpretation of Schrödinger's mathematics in terms of probability waves. Born, in response to the fact that physicists such as himself, Schröder and Heisenberg accepted the uncertainties and discontinuities of quantum both statistically and philosophically, wrote towards the end of his life: 'I am convinced that ideas such as absolute certainty, absolute precision, final truth, and so on are phantoms which should be excluded from science ... For the belief that there is only one truth and that oneself is in possession of it, seems to me the deepest root of all that is evil in the world.'[66] This is an extension of Werther's refusal to only acknowledge one way of being human.

CONCLUSION

The above discussion of *Faust* and *Werther* has illustrated the fact that speculative and imaginative philosophical ideas introduced into the discourse through literature can later find expression in scientific ideas. Science draws upon the arts, not just in the ways traditionally envisaged—for ethical considerations or to widen general horizons, although both of these are of supreme importance—but also as a battery of ideas which will ultimately provide sparks to ignite scientific exploration. When, as Niels Bohr says, 'every man's world picture is and always remains a construct of his mind',[67] literature and philosophy form part of that construct.

Certainly in Goethe's case, science and art cannot be said to be unrelated fields of enquiry with an existence independent of each other, and Jürgen Habermas' claim that the cleft between the two is unavoidable (*unvermeidlich*) is untenable.[68] Goethe's literary work expresses ideas that challenge and alter the prevailing scientific mindset and help foster scientific advancement—his work influenced the questions scientists asked and the way they interpreted their data, and impeached the authority of preceding luminaries. The famous French physiologist, Claude Bernard, writing in the mid-1800s about the need to make medicine experimental and rigorously scientific, nevertheless also understood the importance of artistic inspiration to the scientist. 'Two things are necessary—science and art, reason and emotion', he wrote.[69] The presence of Goethe's ideas in later science exemplifies a cross-fertilisation of discourses.

ENDNOTES

[1] For those not particularly acquainted with physics, I will point out that for the most part I will be quoting quantum physicists, and ones who have received the Nobel prize for their innovative thought.

[2] Wolfgang Pauli, *Physik und Erkenntnistheorie*, Friedrich Vieweg und Sohn, Braunschweig, Wiesbaden, 1961, 5.

[3] Albert Einstein, *Autobiographisches*, in Paul Arthur Schilpp (ed.), *Albert Einstein: Philosopher-Scientist*, The Open Court, Illinois, 1970, 1–95, 48.

[4] Einstein, *Autobiographisches*, 48.

[5] Einstein, *Autobiographisches*, 50.

[6] Albert Einstein, 'Ernst Mach' in *Physikalische Zeitschrift*, vol.17, 1916, 101–4, 102.

[7] Max Born, *The Born–Einstein Letters*, MacMillan, London, 1971, 180.

[8] Werner Heisenberg, *Physics and Philosophy*, Allen and Unwin, London, 1963 (c.1958), 33.

[9] Heisenberg, *Physics*, 38.

[10] Paul Dirac, 'An account of how physical theory has developed in the past and how, in the light of this development, it can perhaps be expected to develop in the future', *Scientific American*, 208, 1963, 45–53, 47 and 50.

[11] Max Born, *The Born–Einstein Letters*, MacMillan, London, 1971, 91.

[12] Born, *Letters*, 72.

[13] Stephen Hawking & Roger Penrose, *The Nature of Space and Time*, Princeton University Press, Princeton, 1996, vi.

[14] Niels Bohr, *Atomic Physics and Human Knowledge*, John Wiley and Sons, New York, 1958, 20, 67, 84.

[15] Karl Popper, confluent with his statement that we do not need to agree on what we mean by a term before we discuss it, does not define what he means by framework, but his usage suggests something akin to ideology. The understanding of framework in this paper, and as discussed by the scientists themselves, can have this strong, almost religious adherence in mind, but can equally refer to something much broader and looser. Karl Popper, *The Myth of the Framework*, Routledge, London, New York, 1994.

[16] René Descartes, *Selected Philosophical Writings*, John Cottingham, Robert Stoothoff & Dugald Murdoch (trans.), Cambridge University Press, Cambridge, 1988, 57.

[17] Tim Mehigan, '"From hence they resolve all Beings to Eyes": Zur Blickproblematik in Goethes *Wahlverwandtschaften*', G Brandstetter (ed.), *Erzählen und Wissen: Paradigmen und Aporien ihrer Inszenierung in Goethes 'Wahlverwandtschaften'*, Rombach Verlag, Freiburg, 2003, 169–185, 169.

[18] Immanuel Kant, *Kritik der reinen Vernunft*, in *Immanuel Kants Werke, Band III*, Ernst Cassirer (ed.), Bruno Cassirer, Berlin, 1922–3 (1781/7).

[19] Immanuel Kant, *Kritik der Urteilskraft*, in *Immanuel Kants Werke, Band V*, Ernst Cassirer (ed.), Bruno Cassirer, Berlin, 1922–3 (1790).

[20] An example of the impact of this Kantian divide into the era of quantum thinking can be seen in Max Planck's argument: '(Wir) werden genötigt, hinter der Sinnenwelt noch eine zweite, die reale Welt, anzunehmen, welche ein selbständiges, vor Menschen unabhängiges Dasein führt, eine Welt, die wir allerdings niemals direkt, sondern stets nur durch das Medium der Sinnenwelt hindurch wahrnehmen können' ('We're compelled to assume that there is a second, real world which lies behind the world of the senses, a world which has a self-contained, independent existence. It is, moreover, a world which we can never reach directly; rather, it can only be perceived through the medium of the senses'); Max Planck's *Das Weltbild der neuen Physik*, Johann Ambrosius Barth, Leipzig, 1929, 10. These sentiments are directly Kantian as argued in the *Kritik der reinen Vernunft*.

Aage Peterson also very specifically refers to the Kantian subject–object question in his discussion of Niels Bohr, and Schrödinger addresses the issue in *Science and Humanism*; Peterson, Aage, 'The Philosophy of Niels Bohr', Anthony French & PJ Kennedy (eds), *Niels Bohr*, Cambridge, Mass.: Harvard Uni Press, 1985; Erwin Schrödinger, *Science and Humanism*, Cambridge University Press, Cambridge, 1951.

[21] Heisenberg is only one of many who see Newton's mechanistic concepts as being directly related to Cartesian philosophy; Heisenberg, 72–3.

[22] Quoted in Luis De Broglie, *New Perspectives in Physics*, Basic Books, New York, 1962, 187–8.

[23] Johann Goethe, *Farbenlehre* in *Die Schriften zur Naturwissenschaft, Vol 9*, Hermann Böhlaus Nachfolger, Weimar, 1954.

[24] This is argued very pointedly in *Über Wahrheit und Lüge. Der Antichrist*, and *Wille zur Macht* also reiterate the ideas.

[25] Stephen Hawking, *A Brief History of Time*, Bantam Books, Toronto, 1988, 39. Stephen Hawking, *The Theory of Everything*, New Millennium Press, Beverly Hills, CA, 2002, 24.

[26] Hawking, *Time*, 40.

[27] Erwin Schrödinger, *Mind and Matter*, Cambridge University Press, London, 1958, 1.

[28] Allan Barton, *States of Matter, States of Mind*, Institute of Physics Publishing, Bristol, Philadelphia, 1997, 24.

[29] Ørsted's paper of 1820 had merely demonstrated that a compass needle in the presence of an electric current would be deflected. Faraday's work was far more comprehensive, and hence he receives the accolades.

[30] Schrödinger words it even more strongly: 'Max Planck was seriously frightened by the idea of a discontinuous exchange of energy which he had introduced in order to explain the distribution of energy in black-body-radiation. He made strong efforts to weaken the hypothesis, and, if possible, to get away from it, but in vain'; Schrödinger, *Science*, 54.

[31] Werner Heisenberg, *Across the Frontiers*, Harper and Row, London, 1974, 5.

[32] Born, *Letters*, 1.

[33] Born, *Letters*, 28, 158.

[34] Born, *Letters*, 82.

[35] Born, *Letters*, 91.

[36] Born, *Letters*, 180–1.

[37] Born, *Letters*, 91.

[38] Max Born, *My Life and My Views*, Charles Scribner's Sons, New York, 1968, 48.

[39] Heisenberg in his introduction to *The Born–Einstein Letters*, x.

[40] Stephen Hawking and Roger Penrose, *The Nature of Space and Time*,

Princeton University Press, Princeton, 1996, 4 and 21. Planck worded it only slightly differently in 1929, arguing: 'da? die einzelnen Physiker, je nachdem sie mehr einer metaphysischen oder einer positivistischen Gedankenrichtung zuneigen, ihre Arbeit am physikalischen Weltbild mehr nach der einen oder nach der anderen Seite hin einstellen' ('individual physicists orient their work according to whether their personal preference is for metaphysical or positivist ideas'); Max Planck, *Das Weltbild der neuen Physik*, Johann Ambrosius Barth, Leipzig, 1929, 12.

[41] Thomas Kuhn, *The Structure of Scientific Revolutions*, Chicago University Press, Chicago, 1970 (1962).

[42] Claude Bernard, *The Cahier Rouge of Claude Bernard*, Hebbel Hoff (trans.), Schenkman, Cambridge, Mass., 1967, 87.

[43] Kant, *KrV*, 17.

[44] Henri Poincaré, 'Mathematical creation' in *The Foundations of Science*, The Science Press, New York, 1913, 389. Jacques Hadamard, *The Psychology of Invention in the Mathematical Field*, Dover Publications, New York, 1954, 14. Oliver Sacks, *Inaugural lecture for the Australian National University Centre for the Mind*, radio program, ABC Radio, Sydney, 6 September 1997.

[45] Albert Einstein, 'Ernst Mach' in *Physikalische Zeitschrift*, vol.17, 1916, 101–4, 102.

[46] Gillian Beer, *Darwin's Plots*, Cambridge University Press, Cambridge, 2000 (1983).

[47] Nineteenth-century pre-quantum scientists also quoted Goethe. Claude Bernard made repeated reference to him; see for example Claude Bernard, *An Introduction to the Study of Experimental Medicine*, Henry Green (trans.), Dover Publications, New York, 1957 (First 1867, *Introduction à l'étude de la medicine expérimentale*), 10, 31. Hermann Helmholtz quoted a section from *Faust* at the end of his essay, 'The Recent Progress of the Theory of Vision' (1868) in David Cahan (ed.), *Science and Culture: Popular and Philosophical Essays*, Chicago University Press, Chicago, 1995, 173–4.
This essay was referred to by Charles Darwin in *The Origin of Species*, and the same section from Faust was later used by Freud. Sigmund Freud, 'Über einen autobiographisch beschriebenen Fall von Paranoia', *Werke aus den Jahren 1909–1913, Gesammelte Werke, Band VIII*, Imago, London, 1947, 243–320, 307. ('An Autobiographical Case of Paranoia').

[48] Erwin Schrödinger, *What is Life?*, Cambridge University Press, Cambridge, 1944.

[49] Max Born, *The Restless Universe*, Blackie and Son, Glasgow, 1955.

[50] Heisenberg, 147–8.

[51] Johann Goethe, *Faust I*, 1790, 1908–1926.

[52] Goethe completed the manuscript for what we know as *Faust I* in April 1806, having initiated work on it in 1774. Work on the play had been executed in two periods of more concentrated attention: 1788–90 and 1796–1801. In 1790 *Faust. Ein Fragment* was published. In 1808, *Faust. Eine Tragödie* appeared.

[53] Goethe, *Faust I*, 668–671.

[54] Bohr, 72.

[55] Kate Rigby, 'Freeing the phenomena: Goethean science and the blindness of Faust', *ISLE*, vol.7, no.2, 2000, 25–41.

[56] Johann Goethe, *Die Leiden des jungen Werther*, Reclam, Stuttgart, 1986 (First, 1774), 7.

[57] Goethe, *Werther*, 16.

[58] Michael Faraday, *Experimental Researches in Electricity*, Dover Publications, New York, 1965 (Citations from Vol.III), 1–2.

[59] Faraday, 168.

[60] Johann Goethe, 'Die schönen Künste in ihrem Ursprung, ihrer wahren Natur und besten Anwendung, betrachtet von JG Sulzer' in Ernst Beutler (ed.), *Gedenkausgabe der Werke, Briefe und Gespräche*, Artemis, Zürich, 1949, 26–32, 28.

[61] Leon Rosenfeld, *Niels Bohr*, North Holland Publishing Co, Amsterdam, 1961, 13.

[62] Goethe, *Werther*, 50.

[63] Pauli, *Physik*, 'Pauli an Weisskopf, 8. Februar 1954'.

[64] Schrödinger, *Mind*, 3.

[65] Goethe, *Werther*, 107–9.

[66] Born, *Views*, 182–3.

[67] Bohr, 44.

[68] Jürgen Habermas, *Technik und Wissenschaft*, Suhrkamp, Frankfurt am Main, 1968, 107.

[69] Bernard, *Cahier*, 68.