Science, Imagination, and Poetry

Tom McLeish FRS
Chair of Natural Philosophy in the Department of Physics
University of York, UK

In memoriam: Professor Tom McLeish FRS (May 1, 1962 - February 27, 2023).

For at least a century, both public media and high school education have downplayed, or even silenced, the role of imagination and creativity in the scientific process. Yet as all scientists know, and as many have described powerfully in spoken or written form, the imagination is essential to the immense task of re-creating a shared model of nature from the cosmos, through biological complexity, to subatomic structures. It has become urgent to recover a cultural perspective on science that celebrates its creative imagination as much as its knowledge-production. The education and formation of the next generation of scientists will be severely compromised if this faculty is not nurtured.

The loss of an association of imagination with science can be historically located in a slow divergence of disciplines over the 18th and 19th centuries, and is connected with the fragmentation of humanities and sciences into the 20th century's 'Two Cultures' narrative. A deep connecting sinew that became severed in this process, is the practice of poesis, or poetic thinking. All creativity calls on the power of the imagination within the constraints of form. In science the creation is the imaginative image of the universe, and the constraint the observed universe itself. In poetry, the creation is the content, the constraint the poetic form. Science, from this perspective, becomes the metaphorical writing of a giant poem.

The presence of strongly theological resonances of such an approach to creative imagination is no co-incidence: a 'trinity' of interdisciplinary conversation between science, poetry and theology is a recurrent and mutually-reinforcing one.

The article will conclude with some practical avenues for poetic expression of scientific thinking both in the public forum and in science practice itself, and a suggestion of contemplative practices learned from other disciplines in the past, but applicable to the scientific challenges of today.

Introduction: The Modern Public Atrophy of Scientific Imagination

"I could not see any place in science for my creativity or imagination," was the explanation, of an exceptionally bright school leaver to me, of why, as permitted in the UK, she had abandoned all study of science from the age of 16. Repeats of such conversations show that any discussion of the role that creative imagination plays in science has been essentially absent from science education, as well as from public discussion of science, for a considerable time. The urgency to redress the misunderstanding, if science is to engage the bright minds of the future, or even to be understood and engaged in fruitful public discourse, motivated an extensive historical and topical study on the author's part.

The historical and psychological association between the imagination and mental processes linked to emotion, as distinct from the illusion of purely rational and cognitive tasks, has added to the divergent momentum of imagination and reason as pathways to knowledge. A BBC television documentary in the Horizon series screened in 2016 featured a scientist involved the search for extra-terrestrial intelligence who affirmed straight to camera, 'there is no emotion in science'. In spite of quieter voices insisting that a search for beauty, and its emotional response, remains an essential guide to science, such covering-over of the role of the unconscious, affective, and integrative

is assisted by reluctance to address the imaginative ingredients of science, or the twin roles of passive and active engagement of cognition and perception.

The first intimations of a theme suggesting the conceptual divorce of imagination and science, or in particular, the progressive denial that imagination as well as reason and perception, acts as a route to knowledge, seem to lie in the early modern period. Yet their final crescendo and climax seems to have occurred in the 19th century. The Victorian Scottish writer George MacDonald is himself now not as widely read as he might be, although the acknowledged inventor of 'fantasy literature,' and lauded as such and for his personal inspiration of their own works by C.S. Lewis and J.R.R. Tolkien (MacDonald's literary production, including fictional works such as *Lilith*, opened possibilities for the literary creation of worlds that enabled others to call them up into the forms of Narnia and Middle Earth, that have not yet seen an equal). MacDonald also wrote in philosophical/theological mode, though less well known than his artistic writing. Long misunderstood as holding a low view of science, it has more recently become clear that it was the 19th century unimaginative, mechanical, and instrumental framing of science that constituted the object of his criticism. It is worth quoting an exchange from his 1867 essay, *The Imagination, its Function and its Culture* in full. It starts with an imagined dialogue with a disciple of Thomas Sprat:

> *But the facts of Nature are to be discovered only by observation and experiment!*
>
> *True. But how does the man of science come to think of his experiments? Does observation reach to the non-present, the possible, the yet unconceived? Even if it showed you the experiments which ought to be made, will observation reveal to you the experiments which might be made? And who can tell of which kind is the one that carries in its bosom the secret of the*

> *law you seek? We yield you your facts. The laws we claim for the prophetic imagination. "He hath set the world in man's heart," not in his understanding. And the heart must open the door to the understanding. It is the far-seeing imagination which beholds what might be a form of things, and says to the intellect: "Try whether that may not be the form of these things;"... Nay, the poetic relations themselves in the phenomenon may suggest to the imagination the law that rules its scientific life. Yea, more than this: we dare to claim for the true, childlike, humble imagination, such an inward oneness with the laws of the universe that it possesses in itself an insight into the very nature of things.*

MacDonald continues, 'to inquire into what God has made is the main function of the imagination … The man has but to light the lamp within the form, his imagination is the light, it is not the form.' In MacDonald we encounter once more, but illuminated now by theological insight, poetry becoming not only a great metaphor for, but also a generator of science. Both shape the power, or 'light', of imagination by the creative constraints of 'form'. In poetry the form is literary, in science simply the form provided by the world as we observe it. Both draw together the double dynamic, the inward and the outward flow, of imagination.

The Secret Truth of Scientific Practice

This public and educational narrative that emphasizes method, fact and formula over exploration, imagination and contemplation, in the experience of science contrasts markedly with the honest witness of working scientists themselves, muted though these voices are in the public arena.

The Japanese physicist, Leo Esaki, shared the 1973 Nobel Prize for the discovery of 'electron tunnelling,' and the elucidation of its quantum mechanical properties. This phenomenon exemplifies one of the counterintuitive ways in which matter behaves when governed by quantum, rather than classical, behavior: it permits particles to reach

places and states that classical physics would forbid. On the pathway to these places, particles have to 'tunnel' through regions where, under Newtonian mechanics, they would possess a meaningless 'negative energy.' Yet in quantum mechanics, negative energy does assume a meaning—and translates into a physical leaking through the classical barrier, and a finite probability for occupying classically-forbidden territory. Today, many vital electronic components rely on this effect for their function. Esaki wrote more candidly than most scientists about the role of emotions in driving science, in an essay on twentieth-century culture:

> *. . . science too has dual characteristics. It has a logical, objective, cool, and rational or rigorous face — the aspect of the finished product that appears in manuals and is presented to the public in conventions and conferences. . . The other face is fantastic, subjective, individualistic, intuitive, and lively, and reflects the process by which the new is created. It is a process based on perception and inspiration, obviously supported by an acute mind. Scientists can use their imagination to grope forward, in a desperate struggle of trial and error, seeking out the secrets of the universe. If by chance they find a solution and their efforts are rewarded, then they can be truly happy: that rarely happens. This is the creative process which is the essence of science.*

'Fantastic', 'subjective', 'lively', 'desperate', 'truly happy'—these words signify experiences that flow in the field of affect —and here they are playing out in a scientist's reflection on the progress of twentieth-century science itself. Nor are they emerging as emotional by-products of scientific discovery, but in this account clearly run the warp to the methodological weft of the very process of discovery. In the process of researching *The Poetry and Music of Science*, I heard innumerable accounts of this nature from mathematicians, chemists, physicists, biologists when asked, not for a précis of their results but for a narrative account of how they achieved new scientific insight. All their stories resounded with a similar admixture of emotion and wonder,

of the hidden, apophatic side to mental ideation, of intuition and imagination.

The dreamlike and uncontrolled nature of scientific ideation gave French molecular biophysicist Francois Jacob the metaphor of ‘day science’ and ‘night science’ to describe the logical and imaginative sides of science respectively:

> *Night science wanders blind. It hesitates, stumbles, recoils, sweats, wakes with a start. Doubting everything, it is forever trying to find itself, question itself, pull itself back together. Night science is a sort of workshop of the possible where what will become the building material of science is worked out.*

That ‘workshop of the possible’ within the night-time hours of a creative cycle draws on an earlier, and celebrated work, on mathematical creativity by French mathematician Henri Poincaré. He gives an extended personal account of the familiar pattern of hard conscious struggle and apparently fruitless labor, before leaving the problem, only to for later unforced experiences to illuminate a beautiful new approach towards a solution. He goes further than others who have told similar stories of the ‘aha moment’ — charging himself to think seriously about how the non-conscious mind achieves such a miracle:

> *What is the cause then, among the thousand products of our unconscious activity, some are called to pass the threshold, while others remain below? Is it a simple chance which confers this privilege? Evidently not; among all the stimuli of our senses, for example, only the most intense fix our attention, unless it has been drawn to them by other causes. More generally the privileged unconscious phenomena, those susceptible of becoming conscious, are those which, directly or indirectly, affect most profoundly our emotional sensibility.*

Mathematician that he is, Poincaré calculates that the sub-conscious mind that works on ostensibly unfruitful products of failed labor cannot do so by brute-force enumeration of possible steps forward. In this sense, he anticipates the completely different way that humans and machines play chess. The Deep Blue supercomputer does indeed work through an exponentially-growing future of potential chess-moves, as far as computational time will allow. Human masters, on the other hand, work through patterns, experience, recognition of strategies that draw on high-level descriptions akin to aesthetics. Poincaré even calls the hidden criteria of choice a 'shadow aesthetics.' Certainly, when strong, powerful and unexpected mathematical ideas, or pathways to solutions, appear in the conscious mind at those liminal moments of transfer, when the active conscious mind is quieted enough to listen to its sub-conscious twin, the emotional appeal can be overwhelming. Mathematician Andrew Wiles confessed to Simon Singh, the biographer of his long struggle to prove Fermat's Last Theorem, that the final insight that came in a period of desperate struggle to patch a faulty initial proof, was 'so beautiful.'

It is not hard to understand why a non-methodological, shadowy, imaginative force must be permanently present within the process of science. For even if the rigorous 'scientific method' of hypothesis testing and refutation that Karl Popper laid out with symbolic rigor in The Logic of Scientific Discovery is true, there is no such method for the formulation of the essential hypotheses in the first place. Popper recognized as much; the matter receives so little space in his work merely because, as he himself admits, he has nothing to say about it. As computational biologists Itai Yanai and Martin Lercher recently comment:

> *Reflect for a second on the hypothesis that you are testing. Did you pull it from the ether? How? There is no single answer to this question. In many cases, we may not even have a coherent answer, which may be why we prefer not to include it in most accounts of the scientific process.*

Yanai and Lercher have recently launched a podcast, *Night Science*, dedicated to promoting and discussing this essential and creative, though shadowy, side to science. Their main audience is that of scientists themselves, who, they are convinced, need to talk and share these examples from their working practice much more than at present. To suppress the narrative of scientific creativity is counter-productive at best, and psychologically damaging at worst. Naturally, the contribution of Night Science to public discourse can help to change the wider narrative too.

Literary scholar of science Irmtraud Huber has located the first parting of the ways of imagination and reason in science within the genre of poetry. From the early-modern period to the 19th century after all, as she writes, 'poetry is indisputably granted the highest rank in a cultural hierarchy in which science is a rising upstart, struggling for recognition, and particularly struggling for a place in an educational system privileging the study of classical texts.' We have also already heard MacDonald identifying the mental links between theory, experiment, and the world as 'poetic relations,' and recognising the task of 'night science' as requiring the same energies and sources as poetry to realise its visions. It therefore seems potentially fruitful to explore the story of interrelations between poetry and science as a specific pathway to recovering a vision for the scientific imagination.

The Historical Parting of Poesis and Theoria

The renunciation of imagination as a route to knowledge, complementary to that of reason, is perhaps the singular most characteristic shift from medieval and renaissance natural philosophy to early modern science. It is captured succinctly in Thomas Sprat's rejection of 'rhetoric, 'fancy' and 'fables' in his History of the Royal Society, and in John Locke's slightly later Essays Concerning Human Understanding, in which he identified 'the imagination' as the source of false and fantastical ideas, as opposed to experience – the reliable guide to the true. Yet Sprat and Locke clearly wrote into a culture

within which poetry and science were no strangers – rather they had enjoyed centuries of conversation.

The creative intellectual world of the 13th century Latin West was, as we have seen, invigorated by newly-translated science and philosophy from both Ancient Greece and early-medieval Islamic commentary on Aristotle and other ancient thinkers. 13th century English polymath Robert Grosseteste articulates, in his commentary on Aristotle's scientific method, a description of mental vision (Latin sollertia) 'descending below the apparent surface of materials. Yet the notion of 'imagination' (Latin imaginatio) at that time had a rather different meaning in medieval usage to that of today. Consider, for example, this summary of what we might term a 'theological epistemology' from the early Franciscan thinker St. Bonaventure's 1259 Itinerarium Mentis ad Deum (the Mind's Road to God):

> *'Therefore, according to the six stages of ascension into God, there are six stages of the soul's powers by which we mount from the depths to the heights, from the external to the internal, from the temporal to the eternal–to wit, sense, imagination, reason, intellect, intelligence, and the apex of the mind, the illumination of conscience.*

To a modern reader, Bonaventure seems to be making a purely inner, 'spiritual', journey; but that would be a projection of a modern mindset. For the early Franciscans, a discovery of God would always also entail a discovery of the divine mind, in which lies an encounter with the world in all its multi-layered physical and material polychromy. Any mention of 'imagination' in the 16th and 17th centuries would be bound to echo its use in this high medieval 'ladder of understanding' that Isaac of Stella, in the 12th century, or Grosseteste and Bonaventure in the 13th, would invoke to explain the theological rationale for learning. For the medieval mind, the study of the material world within a prayerful and disciplined direction of both reason and affect together could redirect and resurrect the sequence of human appropriation of the world, spoiled and broken since the Fall. Medieval scholars saw a

ladder that starts with sensation, then via imagination and memory leads finally to a renewed and healed understanding. Their 'ladder' was the framework that enabled creative early-modern creation of the 'small worlds' that experimental method relied on.

The 17th century may have concluded with science and poetry parting ways, but it began with this inheritance from previous centuries, if not of poetry, then certainly of theologically-generated *poiesis*, or a 'scientific poetics.' Adding poetic force itself to this tradition was another, more classical, stream. For Latin verse had constituted the form for natural philosophy from late antiquity. Lucretius' discussion of classical atomic theory, *De Rerum Natura*, was itself a long poem in dactylic hexameter. The natural philosophy of Cicero and Seneca was replete with poetic quotation. Unsurprisingly, poetry itself was not far behind as an early model vehicle for scientific thought. If book VIII of Milton's Paradise Lost furnishes a sublime example, perhaps the expression of more every-day technology and science makes the point even more strongly. Thomas Moffet's *On Silkeworms and their Flies* (1599) gives a complete and lengthy account of silk technology in octavia rima.

Poetic form certainly served scientific communication. John Donne's *Second Anniversarie*, *The Progres of the Soule*, wrestles with questions of the embodied soul. Sir John Davies, *Nosce Teipsum* (1599), expresses a parallel tension in nature of order and decay. Elizabeth Tollet, who knew Newton well, wrote incisive poetic reflections on Hooke's *Micrographia* and Newton's *Optiks* (1727). Howeveer, as MacDonald later saw, poems also became places of conception for the scientific imagination. Such generative and imaginative power is well-illustrated by Margaret Cavendish's 'Atom Poetry.' More than forty poems, published by the Duchess of Newcastle (later, the first woman to attend a meeting of the Royal Society) in 1653, detailed in imaginative form the supposed properties of the microscopic 'atoms' that underlie the properties of the materials they constituted. The poems' images draw from contemporary natural philosophy, by which

atomic shape at the smallest scale is responsible for emergent harness, softness or fluidity. The poems themselves range in length, and employ varying forms of rhyming pentameter. A delightful example is found in the case of *Of Aiery Atoms*:

> *The Atomes long, which streaming Aire makes,*
>
> *hollow, from which Forme Aire softnesse takes.*
> *This makes that Aire, and water neer agree,*
> *Because in hollownesse alike they be.*
> *For Aiery Atomes made are like a Pipe,*
> *And watry Atomes, Round, and Cimball like.*
> *Although the one is Long, the other Round;*
> *Yet in the midst, a hollownesse is found.*
> *This makes us thinke, water turnes into Aire,*
> *And Aire often runs into water faire.*
> *And like two Twins, mistaken they are oft;*
> *Because their hollownesse makes them both soft.*

The poem employs its own couplet-form to link the spatial levels of atomic structure ('hollowness', 'roundness') and emergent fluid property ('softness', fluidity – 'streaming'). The poem invites reflection upon its own imaginative task – 'this makes us thinke …', which is to account for both the similarities and differences between water and air, as well as to understand how they appear to interconvert. Such observation that 'Aire often runs into water faire,' is, of course, the condensation of water vapour or steam rather than any sort of 'transmutation' of water and air in current scientific terms. Air (all gases and vapours) and water, share the properties of fluidity and, compared to solids, low density – it is this combination that Cavendish terms 'softnesse', and seeks for an explanation in atomic structure. She alights upon the idea of hollowness, providing lightness in a natural way, but expressed in different atomic shapes. We would describe her airy atoms as prolate, the watery as oblate. Implied but unstated is that the evaporation of water into vapour corresponds to an ingenious

atomic shape-shifting: the cymbal-shapes of water atoms must elongate along their axis of symmetry and retract in perpendicular dimensions to adopt the long cylindrical forms of airy atoms.

Cavendish's sources here are the ancient Greek world's notion of atoms, ascribed to the fifth century BCE school of Leucippus and Democritus, transmitted largely through the later, but surviving, work of Lucretius *De Rerum Naturae* (On the Nature of Things), and references to his contemporary Epicurus, read throughout the Middle Ages and renaissance, though her elemental categories reflect a Platonic scheme from the Timaeus. These ancient philosophers had also envisaged materials composed of atoms possessing different shapes, and noticed the explanatory potential of such an atomic theory. The overarching challenge was to explain the phenomenon of change within constraints. More detailed aspects of material behaviour might also permit atomic explanation – the more 'sluggish' flow of oil when compared to water, for example, might arise from atoms that hook onto each other and cling. There is no evidence, however, suggesting that any of the ancients imagined hollow atoms. Margaret Cavendish is improvising on and extending the classical theme here, letting the poetry drive imaginative thought towards an account of 'softness.' It is worth remarking that, although this line of thought has little to do with our current theory of atoms, it does have a legacy at the higher length-scale pertinent to large molecules of complex shape, especially within the molecular-level theory of 'liquid crystals.' The other atom poems in the collection move the reader into stranger territory – inwards towards the brain, its thoughts and emotions, and the diseases of the body, and outwards to the hidden natures of the Sun and planets.

Through poetry Cavendish sees, and allows her readers to see, cosmical connections between the human and material world traced by the universal presence and motion of atoms. Albeit in painterly and metaphorical terms, she comments on her choice of form: 'some being done with Oily-colours of Poetry, others with Water-colours of Prose.' Her later works in natural philosophy continue to make use of both poetry and prose in a much more fluid way than does any writer today, but which brings to the surface the distinctive roles each form enjoys in

the articulation of creative thought. For Margaret Cavendish, poetry was the medium in which more speculative ideas could more freely develop.

In spite of such experience of scientific poetry constituting scientific *poiesis*, there are strong witnesses, by the early part of the 19th century, that the early modern partnership of science and poetry had been eroded. Goethe reminded his readers, in *An die Morphologie* (1827), that 'science arose from poetry,' yet had forgotten its provenance. Later 19th century literature added layers that went beyond amnesia to invective, such as the poetic accusations of Keats (Lamia) and Poe (Sonnet to Science) that science had disenchanted the world. A separation is likewise implied by a more positive prophecy, by William Wordsworth in the preface of Lyrical Ballads (2nd edition):

> *The remotest discoveries of the Chemist, the Botanist, or Mineralogist, will be as proper objects of the Poet's art as any upon which it can be employed, if the time should ever come when these things shall be familiar to us, and the relations under which they are contemplated by the followers of these respective sciences shall be manifestly and palpably material to us as enjoying and suffering beings.*

Wordsworth suggests that the separation of science and poetry lies in parallel divorces of science from feeling, and of scientific experience from common encounter. Some later writers were sufficiently attuned to this lost connection to pen reminders of it. British philosopher Owen Barfield wrote a century later:

> *When we start explaining the language of famous scientists as examples of 'poetic diction' ... [it is no] waste of time [if it helps anyone to be convinced] how essentially parochial is the fashionable distinction between Poetry and Science as modes of experience.*

Looking at scientific imagination through the lens of poetry, then, from medieval to late modern thinking shows that 'imagination' was, for

centuries, that mental place where sense-impressions were first received and curated – 'imaged'– not the canvas or tablet on which inner pictures or words were inscribed. It adopted a central role in early

experimental and observational science. But, as its meaning became subtly extended in the 17th century to allow this same mental locus to receive images and impressions from within as well as originally, from without through the senses, so through the elevation of rational thought over the forms of creative writing that The Royal Society and other professional scientific bodies outlawed, science slowly forgot its essential debt to the creative imagination, and its common cradle with poetry.

Abstract Science, Poetry, Theology – a Trinity of Creativity

No one grasps this evolved double meaning of imagination as clearly as the poetic counter-voice, at the turn of the 18th to 19th centuries, of Wordsworth's colleague, Samuel Taylor Coleridge. Although it was Coleridge who once insisted (perhaps in the spirit of the times voiced by Keats and Poe) that the opposite of 'poetry' was not 'prose', but 'science', by this he meant the dreary assembly of fact and mechanism that science had become under the aegis of its national institutions and their insistence of flattening prose-reporting of empirical data. A closer look, however, at Coleridge's long collaboration in both poetry and chemistry with Humphrey Davy at the Royal Institution, or his collaboration with William Wordsworth on the *Lyrical Ballads* with its strong invocation of science as a potential source of poetic song, indicates that he believed that poetry and science could rediscover their commonality through a partnership of theoria and imagination. At Davy's invitation, Coleridge lectured on Poetry and the Imagination at the Royal Institution in 1808, in spite of the scientist's clearly mixed view of the poet's genius which, though possessing 'exalted genius, enlarged views, sensitive heart and enlarged mind', still wanted, in the scientist's opinion, 'order, precision and regularity.'

Far less well-known than his early poetry, Coleridge's later writings spring from poetically-inspired theological and philosophical

reflection. His own experience of the creative imagination was fed by both the science he loved (he read Newton's *Opticks* in its entirety), and by a powerful, even shocking, personal revelation through the contemplation of Moses' encounter with God at the burning bush. He writes in his *Biographia Litteraria* of 1817:

> *The Primary Imagination I hold to be the living power and primary agent of all creation as a repetition in the finite mind of the eternal act of creation in the infinite I AM.*

As poet and Coleridge scholar Malcolm Guite comments, 'it is as though the creative word that speaks the cosmos into being echoes back to God from minds made in his image.' Coleridge is not only restoring the imagination to a place in which it rediscovers an essential role in humans' knowledge of the natural world, but is also addressing a related, deep problem of modern philosophy – the divorce, as codified by Kant, between those very human subjects and the objects that they seek to know. Coleridge answers by the theological insight that humans, created in the image of God ('*in imago Dei'*) are ourselves both created and observed objects and living, creating and participating subjects. Our very perception of the world is as objects within the world, but made in the image of its original creating subject. Humans are the place and image where the categories of subject and object overlap; and part of the structure of that image is the creative ability itself.

As Coleridge and MacDonald hint, as the early modern examples of science-poetry illustrate, and as Wordsworth foretold, there is a closer connection between science and poetry than the merely metaphorical. The North-East of England's most visionary 20th century philosopher, Mary Midgley, chose *Science and Poetry* as the title of a book which, although it does not discuss much poetry, nevertheless sees the nexus of poetry and science as a necessary road to bridging the science and arts, imagination and reason. Midgley's ambitious book also suggests another requirement: the recovery of human freedom from

determinism, and minds from reductionism. In particular, Science and Poetry explores the 'dependence of detailed thought on entirely non-detailed visions.' It is the imaginative conception of this apparition of

the world in the form of theory, and its generation of the desire to discover it in its fullness and entirety, that Midgley terms 'poetry' for the sake of her thesis. She continues:

> *What makes theories persuasive in the first place is some other quality in their vision, something in them which answers to a wider need. There is always an imaginative appeal involved as well as an intellectual thirst for understanding.*

Science and Poetry also tackles, as did Coleridge, the related dualism of subject and object, proposing that there is a right, but also a wrong way, of attempting to unite them. The mistaken route is to make something called 'consciousness' an isolatable, objective puzzle. In this endless self-referential and circular labyrinth, the subject becomes its own solipsistic object:

To suppose that we have a problem about the existence of other minds is to be in trouble already because it is to have started in the wrong place – Descartes's wrong place. If we once sit down in that place we shall never get rid of the problem (Bertrand Russell, who was wedded to this starting point, never did get rid of it). This approach conceives of minds – or consciousness – unrealistically as self-contained, isolated both from each other and from the world around them. It is terminally solipsistic.

Midgley's vision bursts through Descartes's isolationism that insists on suppressing the essentially relational task of all art and science. The task is a healing of a set of broken relationships of humans to each other and to the natural world itself. Imagination's source, as Coleridge perceived, is external, but, as MacDonald clarified, shines through us to illuminate the world for us, and for each other's consciousness, by reflection.

Malcolm Guite has written powerfully on the topic of 're-imagining imagination.' Although his *Faith, Hope and Poetry; Theology and the Poetic Imagination* does not signpost an immediate relevance to science in its title, its author, a poet, scholar and priest finds himself referring frequently to science as he writes on poetry, imagination and theology. Guite has no illusion over the magnitude nor importance of his task, to reaffirm of imagination as a route to knowledge in partnership with reason. For Guite, as it was for MacDonald and Coleridge before him, the insights of Christian theology and experience becomes essential to understand both the problem and the task. From Augustine to Bacon, reason is supposed less 'fallen,' less damaged or less prone to perversion than 'imagination,' yet 'these two ways of knowing are mutually enfolded and depend on one another.' The key idea, which also echoes Midgley' and Coleridge, is that:

> *If part of the Imago Dei is itself our creative imagination, then we should expect the action of the Word, indwelling and redeeming fallen humanity, to begin in, and work outward through, the human imagination. If this is so then we should be able to discern the presence of that Word in the works of art which are the fruit of our imagination.*

Furthermore, Guite knows that this must be true of science as well:

> *I want to support [Mary Midgley's] thesis that the poetic imagination is fully engaged in scientific endeavour and also that poetry is capable of refining and expressing the doubt, as well as the faith, that is part of the dynamic of both science and theology.*

Poetry, science and theology combine in the perspective, or the projection of gaze, onto and into the world. We look upon the world as an animated image, and with the same imagination of the gaze of love that is bestowed by its first Creator. Our poetry, finding form for expression, and our science, exploring in the imagination of theory the form of observational constraint, are related acts of 'waking into some measure of communicability, the shear inhuman otherness of matter,' a

teleology assigned to all art, in the words of literary scholar George Steiner, but which equally describe the human desire for reconciliation with a strange material world that is gradually met by the cultural energies we call 'science.'

There is another resonance found here, for Steiner's 'waking' in relation to both science and poetry. One of the great powers of science is its ability to distinguish between the merely familiar and the understood. To take up Keats' challenge: just because we are familiar with the rainbow in a sunlit rain-shower does not mean that we understand it. Nor even that we 'dissect' it in the poet's negative sense, so that is lies in so many dismembered, unwoven and wonder-less pieces at our feet. It is a glory of science that the delicate interlacing of light and water, geometry and atmospherics, retinal cells and the brain's processing of their signals, all combine to yield the perception of the bow. We know, and see, through the familiar into a richer appreciation of its underlying structure. Compare this effect of the theoretical gaze on nature with Coleridge's explanation of the aim of the *Lyrical Ballads*:

> *'... by awakening the mind's attention to the lethargy of custom, and directing it to the loneliness and the wonders of the world before us; an inexhaustible treasure, but for which, in consequence of the film of familiarity and selfish solicitude, we have eyes, yet see not, ears that hear not, and hearts that neither feel nor understand.*

The same blindness, or better the 'sleep,' of familiarity – 'custom' – to the world's inexhaustible wonders, is cleared and woken, for Coleridge, by the light of poetry in an uncannily similar way to the science's lifting of familiarity's veil.

The surprising mutual resonance of science, poetry and theology, in which discussion of any two seems to summon the third, helps us understand both how imagination has been obscured within science,

and why Goethe's 'common origin' of science and poetry has been forgotten. It also points to ways in which it might be restored, avenues that are briefly surveyed in the final section.

Re-Imagining Science

If such an essential element to scientific progress as the role of imagination has been forgotten, or at best marginalised, in the public and educational framing of science, then the consequences are severe. First, within the wider community, the formulaic, automatic, method-driven and fact-based aspects of science will grow in perception to represent its received whole, rendering the entire exercise repugnant. Second, scientists themselves will fail to fulfil their potential in scientific creativity, and will work in danger of the confusion and inner contradictions that arise from a felt experience in tension with an artificial modal narrative of how their work 'ought' to be.

For those not engaged professionally, an atrophied and mechanised view gives the impression that science calls on no creativity, that it would appeal only to an introverted and unemotional minority. Furthermore, such a methodological and highly rational route becomes fixed as the only pathway into science, a technocratic, largely unappealing, and typically gendered one. In the words of leading public science writer Andrea Wulf, 'Science is a beautiful palace with many doors, but we only show people one of those doors; most cannot enter that way.' Wulf found her own 'doorway' into science through writing an acclaimed biography of Alexander von Humboldt. In other words, used her own skill at investigative history and narrative writing to explore a life-history that opened up to her, and through her own cognitive and affective abilities the scientific concepts of what we would now term 'Earth systems science,' and to someone who had been assured in her youth that science was intellectually beyond her.

Not only does such an etiolated science fail to appeal to those who might otherwise have enriched the scientific enterprise with a more fruitful diversity of background and aptitude, it distorts the wider public expectations of the, now closed-off and inscrutable, scientific

community. Science becomes an idol – a deliverer of ideals, but like all idols, dispensable when its demands become unpalatable. So, in a pandemic, science is embraced with the public rhetoric of 'following'

when it provides a vaccine, and even dressed up in inappropriate narratives of nationalistic warfare; but when epidemiological modelling suggests temporary restrictions to freedom in public life, the 'following' is quietly forgotten.

The need to re-imagine science as less exclusive, more human, engaging with desire, challenge, failure, storyline and narrative, is the realisation behind a cross-thematic project launched by the UK's scientific academy, the Royal Society, as 'Re-Imagining Science.' As the goal-statement has it, 'If Reimagining Science is successful, it will change how 'science' is written about, talked about and thought about. The hope is for people to enjoy and engage with science as with the arts or sport (and within sport more like football than polo).'

An equal need to reframe science is manifest, perhaps surprisingly, within the scientific community itself. When an early career researcher is given no indication that the essential generation of new ideas draws on human energies that go far beyond the prescriptive and methodological contents of their education, they are ill-equipped to realise their potential. When the pathway to re-imagining the universe, of which they are to play a small part, must pass through affective, sub-conscious territory, made fruitful, as far as we know, as much by music, appreciation of beauty, and sleep, as it is by experiment and calculation, then that pathway will not be taken if those human aspects are taught as possessing no overlap with the scientific task. To reinstate appreciation of imagination within the scientific community itself, is the task of the Night Science podcast referred to earlier, and by just a few of the more far-sighted graduate science programmes now available.

Finally, those within and without the professional scientific community are faced with the delightful prospect of together finding a new source of contemplation, aesthetic reflection and the human realisation of

poeisis in exploring Wulf's 'other doorways' into science. The rediscovery of poetry, in its private and public modes, is more promising today than a century ago, as a renewed partner and as natural

to science than many other human endeavours. There are strong signs that our spiritually-thirsty late-modern world is already rediscovering a partnership that the early modern world knew. An annual celebration of science and poetry, *Universe in Verse*, has been broadcast on Maria Popova's 'Brainpickings' (recently renamed 'The Marginalian') webpage from its Brooklyn venue since 2017.

More recently, 2020 saw the foundation, by Sam Illingworth at the University of Manchester, of the online journal *Consilience*, the first dedicated to science and poetry. Our time has also seen scientists who write marvelous poetry that accompanies and engages with their science. Astronomer Rebecca Elson's poems, for example, reveal and articulate the interior of her scientific thinking and feeling, and also reach out and entwine around other, distant, ideas, bringing them close as if through the optics of a giant telescope. Her posthumous anthology, *A Responsibility to Awe*, edited by her husband and close friends, contains complete poems, but also unfinished work from her notebooks that provides a rare insight into the workings of a mind that reaches out to the stars through verse, as well as through mathematics and the technology of telescopes.

A good poem results from the expansive energy of imagination meeting with the creative constraint of form – otherwise-untamed passion meets the shaping form of the sonnet. But what greater imaginative energy could be conceived than that required to re-imagine the universe? And what could constitute a tighter form than that universe as we observe it? From this regard science and poetry are metaphors for each other from their first stanzas to their last. The framing narrative of 'creativity within constraint' summarises more than the many parallels between poetry and the theoretical imperative within science, it indicates that, properly conceived, science itself constitutes the greatest of all poetic and theological acts.

Tom McLeish FRS was a physicist, academic interdisciplinary leader, and writer. He was Professor of Natural Philosophy (Emeritus) in the Department of Physics at the University of York, UK. He won awards in the UK, USA and EU for his interdisciplinary research in soft matter and biological physics, and also for his work across science and humanities on medieval science, and the theology, sociology, and philosophy of science. He was a licensed lay preacher in the Church of England and the Canon Scientist at St. Albans Cathedral. As well as over 200 specialist articles, he is also the author of *Faith and Wisdom in Science* (OUP 2014), *The Poetry and Music of Science* (OUP 2019), and *Soft Matter – A Very Short Introduction* (OUP 2020). He regularly appeared on BBC radio, including the morning prime-time religious reflection of current affairs, Thought for the Day.

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