Writing Science: Part One

The problem from one side can be stated thus: is language so inherently metaphorical, so incorrigibly figurative, that it cannot be ultimately aligned to a scientific description of reality? And has modern science, in particular quantum physics, become so mathematical in its conception and expression that any linguistic statement of quantum realities can never hope to be more than a loose approximation to the truths discovered in the last century? We have seen how, when Thomas Sprat wrote his *History of the Royal Society,* he believed metaphor could be expunged from writing altogether. He believed metaphor to be an unnecessary surface decoration, an embellishment with no function but the distraction of insufficiently focused minds. Since then we have come to see language differently, and now realise that metaphor is inherent in language. We cannot avoid it; we can only stay alert to the potency of its manoeuvres, and attempt to use it to our profit, rather than being imprisoned within it.

Just how quickly the metaphoric agency can become invisible is evident in a notion like natural selection. Darwin himself was aware of the danger inherent in this term, in that it seems to imply an agency, an intelligence even, where what is being described is in fact a vast accumulation of natural processes, whose result can be described metaphorically as though it were a selecting agent, like a pigeon fancier who prefers a certain size and shape of bird, a particular length of beak, etc.; this is one of the analogies Darwin actually uses, in order to explain the matter to himself. Add together all these processes throughout evolution and you end up with the survival of those mutations of species best suited to thrive in their specific environments. How easily though, in saying 'natural selection', we think instead of an intelligent agency inseparable from Nature itself, making choices, and dispensing with those who have not met the requisite standards. What is 'Nature' here anyway, but a personification, an anthropomorphism, in other words a different type of metaphor? It is effectively the same personification as that used by Alexander Pope:

> Nature, and Nature's laws, lay hid in Night;
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> God said, Let Newton be! and all was light.

Nature here seems to be perilously close to Andromeda, the female prisoner about to be rescued by the Perseus of science. Richard Dawkins, the devil's chaplain to the devil's chaplain, constantly speaks of the 'pitilessness' of nature. The term is meaningless, though, except by metaphoric extension. We can only speak of pitilessness where pity is possible. I can say that Creon behaved in a pitiless manner by refusing to let Antigone bury her brother, but I can hardly say that the lion behaves in a pitiless manner in eating the gazelle. The lion is merely being itself. This is what lions do; there is no ethical choice to be made, because human ethics are inapplicable to lions. It is inherent in the leonine state that a gazelle is a moving object to be halted, torn apart and consumed. Similarly, Dawkins in ascribing pitilessness to that set of laws and probabilities we call for convenience Nature is blind to his own inherent metaphor. Blindness here is a metaphor too; there's no escape from them.

Blindness to metaphor: this is everywhere the problem. The biggest metaphors we live inside tend to become invisible, and we take them for reality. Perhaps this is what Plato was getting at with his allegory of the cave-dwellers taking the shadows on the wall for reality. We mentioned how Wittgenstein, in a brilliant piece of analysis in *The*

Brown Book, shows how Augustine's difficulties about the meaning of time in *The Confessions* all stem from his sense of time as a river. Because this metaphor is built so deeply into Augustine's psyche, he does not believe it is a metaphor at all; merely an accurate description of reality, an expression of knowledge. So he thinks of time as flowing; he thinks of the present as existing at one point on the map, with the past upstream of it, and the future downstream. Out of this topographic notion of time as geographic location with a current flowing through its terrain arise all his conundrums. In other words, the linguistic expression and its concomitant metaphor create a set of consequences, imagistic and logical, which are implicit in the usage. We must analyse the usage to discover those implications which otherwise seem merely 'natural'. Unless we can come to understand the metaphors we are inhabiting, we are entrapped by them. This is the burden of Wittgenstein's later philosophy.

So, given this inherently metaphoric nature of language, can it ever convey scientific truth? Many scientists have said, 'No'; only mathematics can properly convey reality with the requisite precision. But the great Danish physicist Niels Bohr said over and over again: 'We are suspended in language.' He was addressing his fellow scientists, alerting them to the danger that science needed to translate itself out of equations and into a language comprehensible to non-specialists, if science were not to become hermetically sealed inside its own preoccupations. Insofar as it is possible, the achievements and considerations of science should be expressed in a language intelligible to all. It was Bohr who invented the term 'complementarity' to describe the nature of modern physics – its discovery of wave-particle duality, for example – and the complementary half of Bohr's statement could be this: 'We are all of us sustained by science.' If the scientists are suspended in language, the non-scientists are implicated in a world of scientific discovery and development. To be entirely ignorant of this world, our world, is to be … well, ignorant. Writers cannot afford such ignorance. An ignorant writer is, *de facto*, a bad one. Swift could never have written *Gulliver's Travels* without his fascination with the *Transactions of the Royal Society*; Pope understood the distinction between effulgence and refulgence because of his interest in Newton. He could not get very far with the *Principia* though – very few people in the world could. And just to make the point even more sharply, Newton never permitted an English version of the book to be published in his lifetime. The first one came out three years after his death. He had, he said, not wanted to be troubled by 'smatterers'.

From the *Principia* on, the situation gets worse. Modern science is formidable. The endless supply of volumes popularizing science shows the great hunger for some understanding of the achievements and discoveries of modern physics and cosmology. To write such science books one has to be a scientist. The problem is one of expertise. Much modern science does not yield up its secrets easily. To understand modern physics and cosmology with real depth you would need to be a sophisticated mathematician. But our age has seen the greatest proliferation of 'understanding science' books ever published. Why? Because the achievements of modern science (not just technology, but science as knowledge) are utterly astonishing. To be uninterested in them would be to be uninterested in life. This, after all, is where we can understand what we are made of, what forces shaped us, and how the words 'matter' and 'energy' are different ways of expressing the same matrix of existence.

Although there are earlier candidates for the title, Roger Bacon in the thirteenth century for example, most of our historic accounts date the birth of modern science to the time of Galileo. This was the moment when we shifted from the geocentric and Ptolemaic view of the world to a Copernican and heliocentric view of things. One can see how this took a lot of swallowing. We feel stationary enough, standing here on the earth. We do not appear to be hurtling about the heavens. And the Christian scriptures were read as confirming the fact. When Galileo was summoned to Rome in 1616, Cardinal Bellarmine drew his attention to what we would now call Psalm 19, where the sun is described as moving about the sky in its excitement before the Lord. So tradition and common sense informed the world that heliocentrism must be wrong. This was not the first time such ascription of error from *magisterium* to working science was to happen, nor was it to be the last. Galileo was looking through his telescope and arranging his planks so that balls could run down them (they went at the same speed, whatever their size, so Aristotle had been wrong about that). In other words, Galileo was treating all of the material world as subject to examination, scrutiny, measurement and investigation. There was no map marked, 'This is sacred: no enquiries here', as early maps had designated the unknown, and perhaps unknowable, parts of the world with the legend, 'Here be monsters'. When Galileo looked through his telescope and saw craters and protuberances on the face of the moon, he knew that the system known as Aristotelianism was now dead for ever, since it had declared the heavens to be a sphere of perfection and immutability. Those pockmarks on the lunar surface signified changes and collisions with other celestial bodies. They meant that the same laws applied up there as apply down here, something that would be demonstrated with seemingly incontrovertible force when Isaac Newton published *Principia Mathematica* in 1687. Interestingly, for the writer, Bellarmine sought to contradict Galileo's discoveries by pointing him towards another (substantial) piece of writing: the one we call the Bible.

This history of modern science makes for very exciting narratives. When a novelist as gifted as John Banville wrote two novels, *Doctor Copernicus* and *Kepler*,[1] he showed how well such material lends itself to contemporary writing. But you have to buckle down and do some serious reading. The mention of Newton reminds us of what we said earlier: modern science can be formidably difficult. Not many people could read *Principia* in his lifetime, and not many can read it now. And things begin to get even worse in the nineteenth century. Once James Clerk Maxwell starts formulating how electricity and magnetism form one united field of force, electromagnetism, science becomes increasingly dependent upon mathematical expression. The facts about heat, for example, those thermal realities which were so important for calculating the efficiency of steam engines, and the waste of energy that was too often involved, were presented as statistical realities rather than dynamic ones. This is to say that the reality of an observed phenomenon can only be measured and properly expressed by looking at it in terms of a large amount of data rather than observing a single trajectory, or one particular aspect of the phenomenon. This privileging of the statistical over the dynamic, of the mass of observable data over the itinerary of the one individual datum, becomes even more fundamental in quantum mechanics.

The development of science often dictates the metaphors which predominate at a given cultural moment. If we traced the history of a number of words in English, we would see how the intellectual paradigms in which we

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[1] John Banville, *Doctor Copernicus: A Novel* (London: Secker & Warburg, 1976); John Banville, *Kepler: A Novel* (London: Secker & Warburg, 1981).

are situated at any one time change the very nature of our lexicon. For example:

Atmosphere

Gravity

Atom

Electron

Each of these words changes its potency and significance according to the state of scientific knowledge and agreement. The notion of atmosphere meaning a pressure of 14.7 lb on the square inch, available according to the *OED* from 1830, would not have been possible to earlier ages without the means of measuring it. Gravity simply meant weight or heaviness, a meaning retained in our Latinate *gravitas*, until Newton's great discoveries. He decided to name the universal attractive force *gravity*, and that meaning has remained with us ever since.

The notion of an *atom* (from the Greek word for indivisible) as the ultimate component of matter goes back to Greek antiquity, to Democritus and Leucippus, and only came to be fully accepted in the West in the seventeenth century. To call yourself an atomist in England in the 1590s could still have proved dangerous: it was to declare yourself part of the avant-garde in thought, possibly one of those who professed Copernicanism too. Those at the centre of power were not keen on such decenterings. Towards the end of the nineteenth century the word undergoes a transformation. It is discovered that the atom has a structure, that it is not indivisible. The meaning now starts to contradict its own etymology; this is common enough with words, and such a contradiction complicates the original metaphor beyond recognition. In the 1890s we discover that the atom can be divided further: there are electrons inside it. And why did we elect to call those elementary particles that? The Greek word *elektron* meant amber, which when rubbed will attract little bits of paper and wool to itself, thus exhibiting the force we call static electricity. William Gilbert wrote a treatise on the magnet in 1600 and began to use the word *electricam*, which finally ends up as our electricity. The negatively charged elementary particles which orbit the nucleus inside the atom are named after the amber which was first observed having 'electrical properties' two millennia before.

Looking at the four words we have given as examples, we can see the ceaseless interchange between scientific definition and metaphor, and how such interchange can confuse the relation between a scientific description of reality and a metaphoric use of language in non-scientific writing. If we read in a novel the line, 'The atmosphere between them had changed', we can be pretty certain that, whatever else is meant, the writer does not mean, 'The pressure on them both was no longer exactly 14.7 lb per square inch'. Similarly with gravity: a writer is far more likely to be using the older sense of *gravitas* in employing the English word in normal usage: 'He informed me, with some gravity, that there was something I should know.' A knowledgeable enough writer might write the following line: 'The force she exerted on his mind at this time was as unrelenting as the force of gravity on his body, and as unforgiving.' *Atom* is also likely to be used in the old sense of units of indivisibility: 'If we break this down into its individual atoms…' As for *electron*, it is unlikely to be used except for deliberate effect in non-scientific writing: 'Flies orbited about the rotting meat like electrons around a nucleus.' Far more likely is the use of the word electricity, and once again the usage will probably be metaphoric in a non-specific manner: 'The old electricity between them had died.' If we insist upon precise scientific definition here, the usage will become ridiculous: 'Harry was the anode, and Sue the cathode in this relationship…' Some metaphors have to be given a permitted space in which to function, and will simply resist too great an exactitude of interpretation.

Some years ago I was confronted with this problem in dramatic form. I was awarded an AHRB/Arts Council Fellowship to work with the particle physicist Goronwy Tudor Jones. We had elected to write a book together. The book was to be entitled *Extremities of Perception*, and started from images taken from the Hubble Telescope and bubble chambers in CERN. In other words, the largest things and the furthest things in the universe were to be contrasted with the very smallest things, elementary particles, and the way we imaged both realities was to be compared and contrasted. I began this project with an insouciance made possible only by complete ignorance. Little by little, it started to dawn on me what a mighty task we had taken on, though I suspect that Gron had always wondered about the viability of the book. It has never been published.[2] Sixty thousand words rest quietly in my files, awaiting a more accomplished revisiting, possibly in a different lifetime. What I finally offered as completion of the project was instead a novel, *Sylvie's Riddle*, and two books of poetry, *Alexander Pope at Twickenham* and *Gilgamesh*. This was a more than adequate completion of the Fellowship, but it might be worth looking in detail at one of the problems we encountered.

Gron and I wrote a joint presentation called 'The Most Beautiful Experiment' (which appears below), in which we spoke about the double-slit experiment with electrons, often thought of as the most elegant experimental

[2] Though see Alan Wall and Goronwy Tudor Jones, 'Extremities of Perception', *Leonardo*, *39* (2006), 467-8.

demonstration ever conducted. What it demonstrates is wave-particle complementarity; in other words, how electrons can behave as both waves and particles. This duality, or complementarity, is the mystery enshrined at the heart of modern physics. All of the scientific knowledge here came from Gron, not from me. My job was to try to use whatever skills I had as a writer to convey as compellingly as possible some of the knowledge contained in my scientific collaborator's distinguished brain. Now, at a certain point, we wished to convey some sense of how atoms can only exist in certain quantum states. Using the hydrogen atom as an example, since it is the simplest of the atoms, with only one proton and one electron, I wrote the following sentence: 'Were it not for the quantum states, the negatively charged electron would collapse into the nucleus, and the atom would be abolished.' Gron could not accept this sentence, partly because he was not happy with the word 'collapse'. It carried an implication of a gravitational force, whereas the forces concerned were electrical. So here is the description we finally agreed upon:

> If electrons were really orbiting the nucleus as planets orbit the sun, then they would be losing energy constantly in the process – this is what Maxwell's electromagnetism tells us. But if they were constantly losing energy then the electrons would spiral into the nucleus and the atom wouldn't form. So how is it then that the electrons don't make it down as far as the nucleus? The answer to that question lies in wave-particle complementarity and the quantum states.

It is less immediately striking than the original sentence, but it is truer. And note that the atom here is not 'abolished'; instead, it 'wouldn't form'. This attempt at scrupulous exactitude has made the project simultaneously fascinating and difficult. Aligning one's usages of language with scientific acceptability is a painstaking and lengthy business, and probably represents one of the greatest challenges facing any writer who tries to write about science.

A thought struck us as we worked. The original double-slit experiment was conducted with light by Thomas Young in 1803 at the Royal Institute. In one sense it was an exercise in pattern recognition. Earlier, in the chapter on metaphor, we looked at how pattern recognition lies at the heart of metaphoric perception: we see similarity in dissimilarity and form a striking image out of it. This is precisely what Young did when he noticed that the interference he was observing when two sources of light met each other was parallel to the interference patterns one can see in water when two sources meet. And exactly the same ability for radical pattern recognition was to be employed by Young a decade later when he started decoding the Rosetta Stone. Patterns that could be detected in the Greek, which could be decoded, must be reproduced in the hieroglyphics, which at that point could not be understood. The same abilities were being employed in realizing that light propagated itself as a wave and identifying the significance of a cartouche on a hieroglyphic inscription.

Niels Bohr became famous for never making any statement without immediately qualifying it. It is hard to make unambiguous statements in language. Think of one of our normal statements: 'If things had turned out differently….' Things didn't, of course, it being in the nature of things not to. The little idiomatic phrase contains a metaphysical conundrum. We know that things always turn out the way they turn out, and that the notion that they 'might have turned out differently' is always by way of a lament that things, as ever, turned out precisely the way they did. There is, of course, a way of using the phrase to think about events: it is called alternative history. You start from a premise: for example, what if Hitler had won the war? But to do this in science requires us to rethink nature and reality in a way that seems almost whimsical. Such rethinking often takes the form of science fiction or SF. And the best SF tends to be written by people with some scientific knowledge. Their rethinks are invariably literate and informed.

The problem might be seen at its simplest by looking at the phrase, 'a quantum leap'. We say, 'The politician made a quantum leap there', meaning he made one of the biggest jumps he possibly could. Quantum leaps first came into atomic physics to describe how light is emitted when an electron 'makes a transition' (jumps) from a high energy level to a lower one within an atom – emitting a quantum of light. On the scale of phenomena known in the universe, this is tiny. One can see why some scientists are driven back to expressing their truths entirely in mathematics.

The Explanatory Analogy

There is probably one law we can state about scientific writing whose purpose is explanatory. Images from the known realm will be used in an attempt to elucidate the more difficult realm requiring exposition. This can be done by analogy, simile or metaphor. So in trying to explain the inner workings of the atom, to themselves as well as to others, Rutherford and Bohr modelled its workings, by analogy, on the planets orbiting the sun. The analogy broke down quite quickly, because the electron on this planetary model should be constantly shedding energy. But see how we take imagery from what we know well and apply it to what we are exploring. One old and famous example was the comparison of atoms with billiard balls in motion. Atoms are hard to break, like billiard balls, and so the well-known characteristics of the known object were employed to describe the nature of the more elusive one.

The best writing in science finds the most vivid analogies, the most striking similes, the most arresting metaphors. It is, in other words, engaged like poetry in pattern recognition. The biggest difference is that metaphor in science seeks to familiarize, whereas in literature it tends to defamiliarize.