Climate Change and Cultural Transformation

Part 4 THE GOOD, THE TRUE AND THE SUBLIME

Chapter 15 **Science and Consciousness II**

What is now proved was once only imagin'd.

Blake, "The Proverbs of Hell"

In the previous chapter I suggested ways in which science could begin to be self-critical and to recognise how, historically, it has come to pursue its progress independently of other value systems, in particular the human, ethical and aesthetic/ artistic domains. In short, how, in doing so, ideologically and practically, it has contributed to the split of "the two cultures", as epitomised in the hostile debate between C.P. Snow and F. R. Leavis in Britain in the 1960s. In his culturally critical view Leavis accused Snow of a crass belief in technocracy and economic progress while Snow in turn accused Leavis of being a Luddite. The debate was personally offensive but the issues remain even more relevant today. [1]

In this chapter I want to suggest ways in which science and scientists are being viewed differently, both by people from outside the traditional scientific culture and by practising scientists themselves. As I mentioned in the previous chapter the human sciences are beginning to take a social and anthropological interest in the activities and thinking of scientists and there is also a growing awareness of common ground between science and the arts. At the same time the scientists themselves are looking at nature differently, becoming more aware of themselves in relation to their work, and seeing again how science is a dialogue with nature, not just an objective examination.

Bruno Latour, the philosophical anthropologist, applied his ethnographical skills to the scientist themselves in their place of work, the laboratory. By observing them as the anthropologist might a tribe in their setting, he and his colleague demonstrated that what scientists thought they were doing and the manner in which they were doing it - and the what and how of what they were actually doing - were, to the

anthropologists, quite different. *Laboratory Life* is the book where Latour and Steve Woolgar, provided the first social and anthropological analysis of science. [2] Latour went on later to question whether science had ever truly been modern, whether it had ever, in truth, replaced religion. [3]

All those years ago at school, having to choose either science or humanities at 16 felt like a form of psychic surgery. I, personally, chose humanities, but felt estranged from scientific subjects, a feeling which stayed with me for many years. The gap just widened until I re-discovered science through the imaginative writings of people like Richard Dawkins and Steven J. Gould. Whether scientific thinking had become more creative compared with the teaching - as I experienced it - in my school, or whether I was more open to the "magic" of science, I am not sure, but, though I was still angry at the scientific "illiteracy" I felt the split educational system had left me with for too many years, it felt liberating.

Some challenge the whole idea of the two cultures. David Locke, for instance, in his *Science as Writing,* denies there is a great gulf between science and the humanities. He sees science and literature as companion endeavours, working together to describe, in their respective ways, the world of human experience. Locke is a professor of literature who has also been a scientist but argues that scientific language can be highly imaginative, expressive and self-conscious. He even explores how literary criticism can be applied to the reading of scientific texts. [4]

Kathryn A. Neeley's biography of the nineteenth century scientist, Mary Somerville, writes in her prologue of Somerville's "transforming vision", which connects science, gender and illumination. Quoting from a contemporary review of Somerville's *On the Connexion of the Physical Sciences* (1843) by William Whewell, she pointed to the "Peculiar Illumination" of the female mind and suggested: "In Somerville's case, the capacities of the poet and the mathematician came together with those of the skilful writer who could not only help her readers see more but also see it much more clearly.....This quality of mind compares the perceptive power of science with that of poetry to go far beyond ordinary experience and to present a view that is at once precisely delineated, easy to comprehend and pleasurable to contemplate". [5]

In the dialogue between poetry and science, Newley suggested Somerville showed how they came together in “the scientific sublime”. Somerville took the poetic traditions of Milton, 18th century poets and the Romantics and “transformed them for scientific prose”, presenting science as both “exact calculation” and “elevated meditation”. In short, Summerville exemplified “how the illumination of science could be transformed into enlightenment for humankind; how human imagination empowered through science could cross magnitudes of space and time; and how language could be used to help imagination construct what could not be directly observed”. [6]

One thinks also of the life of Alexander Von Humboldt, just before Summerville’s time. He gave the world a cosmic, ecological vision that included the spirit of science and poetry but was also born out of the practical exploration of the Earth. Humboldt was a giant figure in his time, as famous as Napoleon. His vision inspired Goethe and the Romantic poets while Darwin said he could not have written *On the Origin of the Species* without the work and example of Humboldt before him. Humboldt travelled to South and Central America before Darwin made his journey on the Beagle. He was a scientist and naturalist who did meticulous research work on all his travels.

He also seemed to know leaders in all walks of life. It is a mystery why he has been so forgotten, but Andrea Wulf’s impressive recent account of him could not be more timely. In her view ecologists, environmentalists, and nature writers rely on his vision. He gave us our concept of nature itself. For instance, “when Humboldt described the Earth as ‘a natural whole animated and moved by inward forces’ he predated Lovelock’s ideas by more than 150 years. Humboldt called his book describing this new concept, *Cosmos,* having initially considered (but then discarded) ‘Gaïa’ as a title”. [7]

The scientific imagination: what moves the world?

Behind all scientific investigation, natural and human, there must lie, consciously or unconsciously, the impulse to determine how life emerged from matter, and consciousness from life, leading to the evolutionary question of what comes next.

Perhaps an understanding of “what comes next” depends on our two cultures working together in a new integrative way.

In *What is Life?* Erwin Schroedinger reflected, from a physicist’s perspective, on life’s fundamental mystery - how it is that atoms come to form molecules or cells, the mystery of how life emerges from apparently inanimate matter. He hypothesised that the most essential part of the living cell - the chromosome fibre - “may suitably be called *an aperiodic* (irregular) *crystal”.* The “humble physicist” knows about *periodic crystals,* those very interesting and complicated objects which constitute “one of the most fascinating and complex material structures by which inanimate nature puzzles his wits. Yet, compared with the aperiodic crystal, they are rather plain and dull”. Shroedinger compares the two:

> The difference in structures is of the same kind as that between an ordinary wallpaper, in which the same pattern is repeated again and again in regular periodicity, and a masterpiece of embroidery, say a Raphael tapestry, which shows no dull repetition, but an elaborate, coherent, meaningful design traced by the great master. [8]

This hypothesising led to what has arguably been the most exciting breakthrough of modern biological science - the discovery of DNA by Crick and Watson. Yet, though DNA describes the fascinating mechanism by which life replicates itself, it still isn’t able to say what life is, the subject Shroedinger set out to reflect on. The science of Shroedinger’s quantum mechanics is not at all easy to follow for a non-physicist or non-scientist but in the end he refers to the Indian metaphysics of the Vedanta tradition which he found in Aldous Huxley’s *The Perennial Philosophy.* At the same time, in a discussion of determinism and free will, he notes the prevalence of “quantum indeterminancy” over classical physics or traditional biology. He doesn’t quote the *Kena Upanishad* - from the heart of Vedanta - but it asks the same elusive question: “Who Moves the World?”:

> Who makes my mind think?
>
> Who fills my body with vitality?
>
> Who causes my tongue to speak? Who is that
>
> Invisible one who sees through my eyes

> And hears through my ears? [9]

The answer to these questions is what Vedanta calls the Self, not the ordinary, finite, knowable self but in answer to that other question that pervades the Upanishads:

> 'What is that by knowing which all things are known?'

In other words, the invisible, ineffable, infinite Self which Vedanta holds is at the heart of the mystery of Life, to be identified with all things.

Order from chaos

The same question that Schroedinger asked was repeated by the biologist Lynn Margulis and her son Dorion Sagan - his father was the famous cosmologist, Carl Sagan - in their book with the same title as Schroediger's. The essence of life is in the asking, not in any absolute answer, for there is none. Answers are only ever provisional, descriptive ones. To that end Margulis dedicated her life to investigating microscopic life rather than the traditional focus of physiological organisms. [10] She focussed on the role of bacteria in evolution, while her son, a student of the humanities as well as science, ventured a speculative answer to the question:

> So, what is life? It's a material process sifting and surfing over matter like a strange slow wave. It is a controlled, artistic chaos , a set of chemical reactions so staggeringly complex that more than eighty million years ago it produced the mammalian brain that now, in human form, composes love letters and uses silicon computers to calculate the temperature of matter at the beginning of the universe. [11]

He adds by way of speculating on the present: "Life, moreover appears to be on the verge of perceiving for the first time its strange but true place in an inexorably evolving cosmos".

The picture of "controlled, artistic chaos" was analysed in a landmark work by the Belgian physical chemist, Ilya Prigogine and philosopher, Isabelle Stengers. *Order Out of Chaos* was subtitled *Man's New Dialogue with Nature.* Prigogine and Stengers argued that our vision of nature is undergoing a radical change away from

the rational, logical and mathematical certainties of classical science toward the multiple, the temporal, and the complex uncertainties of late twentieth century chaos theory:

> In the past few decades, something very dramatic has been happening in science, something as unexpected as the birth of geometry or the grand vision of the cosmos as expressed in Newton's work. We are becoming more and more conscious of the fact that on all levels, from elementary particles to cosmology, randomness and irreversibility play an ever-increasing role. *Science is rediscovering time.* It is this conceptual revolution that this book sets out to describe. [12]

Classical science had, of course, been challenged at the beginning of the last century by the two revolutions of Relativity theory and Quantum mechanics but, Prigogine suggested, they were incomplete revolutions insofar as Einstein failed to find a unified theory of Relativity and, as Feynman, like others, famously remarked, anyone who thinks they have understood quantum theory clearly hasn't. Nor did either theory relate the ascetic and esoteric practice of physics to other fields of scientific or human thinking in the way that chaos theory promises to do.

Prigogine and Stengers point out that there are two basic questions which our science has no answer for. The first is the relation between order and disorder. While the famous second law of thermodynamics, the law of the increase of entropy, describes the world as evolving from order to disorder, biology or social evolution shows how the complex seems somehow to emerge from the simple. As the authors comment: "How is this possible? How can structure arise from disorder? Great progress has been realised in this question. We now know that nonequilibrium, the flow of matter and energy, may be a source of order". [13]

The second question concerns the absence of an evolutionary principle in classical or quantum physics. The latter describes the world as reversible, as static. In its view there is no evolution, neither to order or disorder. In other words it is a mechanistic world with no time dimension. There is a clear contradiction between the static view of dynamics and the evolutionary paradigm of thermodynamics. Prigogine and Stengers concede that order and disorder are complicated notions: "the units

involved in the static descriptions of dynamics are not the same as those that have to be introduced to achieve the evolutionary paradigm as expressed by the growth of entropy. This transition leads to a new concept of matter, matter as 'active', as matter leads to irreversible processes and irreversible processes organise matter". [14]

The introduction of an evolutionary paradigm and the reality of time and irreversible processes into scientific thinking and practice has fundamental implications for all disciplines. Firstly it promises to open up the closed, mechanistic world of classical physics to the life sciences and to the possibility of looking for a way of integrating them. It was increasingly felt that nature, described in Newtonian laws, was shown to be robotic, automaton and mechanical. Man was felt to be separate from nature and matter itself to be passive and acted upon, even dead. The thought that all forms of matter might be alive, spontaneous and unpredictable was startling and exciting.

Secondly, the "discovery" and experience of time in the twentieth century was felt across the whole of culture, in all forms of modernist art, philosophy and psychology, in the humanities as well as in science. Was there not some way of relating "the two cultures" so that art and science, rather than being in opposition, were part of one continuum? The title of the original French edition of Prigogine and Stengers' book was *La Nouvelle Alliance.* This was not just a bridge between the two traditions of science - the classical sciences that looked for rational, repetitive laws and the evolutionary sciences that embraced irreversible, "irrational" processes - nor just between the two cultures but involved the very relationship of man to nature. Did the order within seeming chaos bring the human race back into relationship with the nature he had felt so separate from?

Alexander Koyre, the Russian-French philosopher of science, defined the scientific method of experimentation not merely as the observation of facts as they occur, nor just the search for empirical connection between phenomena, but also in terms of a relationship between the scientific mind and the object of observation - the natural world. In its method classical science rightly adheres to the testing and disproving of its hypotheses in the search for truth but it has neglected, as I have already suggested, to ask how its practitioners come to form their hypotheses in the first place. Koyre implied there was a systematic interaction between theoretical

concepts and observation, nature, as it were, responding to experimental interrogation by way of the human imagination. In this sense the relationship between man and nature can be redefined and re-identified and science conceived as also very much an art. [15]

The art is how to ask the right question and then wait for the answer to present itself, for often it is then possible to see how the puzzle fits together. As Prigogine and Stengers put it:

> Science is like a two partner game in which we have to guess the behaviour of a reality unrelated to our beliefs, our ambitions or our hopes. Nature cannot be forced to say anything we want it to. Scientific investigation is not a monologue. It is precisely the risk involved that makes this game exciting. [16]

They conclude that, although science is a risky game, it seems "to have discovered questions to which nature provides consistent answers". This is what makes for a "scientific revolution". For them the "Neolithic revolution" was a primary example even though it happened over thousands of years, while the scientific revolution of the seventeenth century by contrast started only three hundred years ago but is now undergoing a further revolution.

The new revolution at the end of the twentieth century and gaining momentum in the twenty-first is about seeing the relationship between the opposites that have exercised the mind in particular of modern Western culture. It was the Sinologist, Joseph Needham's view, with his understanding of Chinese philosophy and science and the Taoist view of the interdependency of apparent contraries, that Western thought has always oscillated between the scientific view of a mechanistic universe and a theology that requires an external God to create and govern it. In fact these visions are symbiotic. A mechanical universe needs an external God to make sense of it. Out of this fundamental split come our irresolvable philosophical polarisations and dilemmas, such as necessity and chance, freedom and determinism, art and science, man over against nature.

Do we have to side with the one or the other of these binaries? Do we have to choose between an inhuman, alienating science or an anti-scientific metaphysical

view of nature? Perhaps it's a choice we no longer have to make. Science is evolving and as Prigogine and Stengers suggest we now have a unique opportunity to reconsider its position in culture generally. Modern science may have originated in the specific context of the European seventeenth century but they took the view that towards the end of the twentieth century, when their book was published, "a more universal message is carried by science, a message that concerns the interaction of man and nature as well as of man to man". [17]

How is science beginning to free itself from the assumptions of classical science with its conviction that at some level the world is simple and governed by mechanical, time-reversible fundamental laws? This may seem a simplification but it might be compared to the reduction of a building to a pile of bricks. Rather than focus solely on the bricks we can alternatively look at the whole building and see it as a product of a culture, a society, an aesthetic.

This raises the issue of design. Classical science assumed consciously or unconsciously that the design came from without, as the creation of God or the eternal metaphysical forms of idealistic philosophy. From this perspective time is an illusion but in the twentieth century it was discovered that, rather, time and irreversibility play an essential role. Nature seems in some way to organise and create itself. It is auto-poetic. Reversibility and determinism apply only to limiting, simple cases, while irreversibility and randomness are the rules.

While classical and modern science have made major and extraordinary discoveries in the investigation of sub-atomic and cosmological phenomena, it has not thought to speculate on their essential origin or evolution. Assuming that change and evolution are not an illusion and there is no longer a God to direct it, then, as Prigogine and Stengers suggest, "we must give to its very 'bricks' - that is, to its microscopic activity - a description that accounts for its activity". [18]

This is just what the remarkable Lynn Margulis did. Anyone who has leafed through her and Dorion Sagan, her son's book *What is Life?* will be astounded at the invention and creative artistry of microbiotic life, apparent from the illustrations alone before coming to the descriptions, analysis and theory about the complexity and symbiogenesis of bacterial forms. At the centre of Margulis' work was the desire to

show how the simple prokaryotic cell mysteriously evolved into the more complex eukaryotic. This extended the spirit of Shroedinger's thinking about physics into biology.

Moreover she was able to think systemically how her microscopic work applied also to other systems on a different scale. Her collaboration with James Lovelock showed how ecological and integrative issues were central to her life and she eventually transferred to the department of Geosciences at Amherst, University of Massachusetts, where she was the Distinguished Professor.

Interestingly Margulis' "symbiogenetic" spirit influenced a young Canadian sociologist of science who enterprisingly went to study with her at Amherst and wrote up the experience in *The Origins of Sociable Life.* In her original book Myra Hird showed how the evolution and "microontology" of microbial life could inform sociological thinking about such topics as self, sex and the environment, thereby also providing an example of how the gap between science and the humanities might be creatively bridged. [19]

Evolution, Darwin, and Ervin Laszlo

In his introduction to *On the Origin of Species* Darwin described how when on the Beagle he considered the *o*rigin of species "the mystery of mysteries". On returning home in 1837 it occurred to him "something might be made out on this question by patiently accumulating and reflecting on all sorts of facts which could possibly have bearing on it." After five years he allowed himself to speculate on the subject and drew up "some short notes". He waited some twenty years before publication - eventually prompted by Wallace's letter -"to show that I have not been hasty in coming to a decision". Hence the "abstract" as he referred to *On the Origin.* [20]

Darwin considered his "Abstract" to be "imperfect" and "some errors to have crept in" but when he reflected on "the mutual affinities of organic beings, on their embryological relations, their geographical distribution, geological succession, and other such facts" he thought any naturalist could conceivably come to the conclusion that "each species had not been independently created, but had descended, like varieties, from other species". However this still left Darwin with his mystery: "how the innumerable species inhabiting this world have been modified, so as to acquire

that perfection of structure and coadaptation which most justly excites our admiration". Naturalists refer to external conditions but it would be preposterous to attribute to mere external conditions "the structure, for instance of the woodpecker, with its feet, tail, beak, and tongue so admirably adapted to catch insects under the bark of trees". And he gives other examples of the interconnections of all species.

Darwin's provisional answer, given that no internal condition had been discovered, was what he called "natural selection". Neo-Darwinists consider that the notion of natural selection solves the mystery. But does it? Darwin, to many people's consternation, may have rightly called into question the whole idea of supernatural selection. Natural selection may question traditional theology but it still, however ingeniously, explains only the how of selection, not what it is. "What is Life?" remained unanswered. And was still so, after Mendel offered his research into the internal workings of inheritance and Crick and Watson's discovered DNA.

Darwin's work had shown us how prodigious and infinitely interconnected nature is but he researched only the "descent" dimension of evolution, development from the past, not the pull of the future, evolution as ascent. This was perhaps why people were so outraged at the time. Looking at the contemporary cartoons in Punch, which are shown in my illustrated edition of the *Origin,* you can see why. We needed to be reminded that we were an animal, and that was an essential part of our nature, but we were also human. We have minds, capable of abstract thought beyond the capacity of other animal species. How does this come to be so?

Ervin Laslo, in his 1979 summary of the General Theory of Evolution, suggested there is an identifiable logic to evolution and that this logic is apparent at different levels and across different fields, which he calls "The realms of Evolution". Matter evolves, as does biological life, and human society. He also included a chapter on "The Nature and Continued Evolution of Mind", before concluding with an appendix on "The Evolution of Science". Does the General Theory apply to science - "and thus to itself?" he asks. It's an intriguing question. Would the general theory of evolution describe its own genesis? [21]

The answer is not obvious. While the general theory of evolution refers to dynamic matter-energy systems in the empirical world we must not forget, or overlook, that

scientific theories themselves are also conceptual systems in the heads of scientists. What is so interesting about science is not just the objective descriptions and theorising about nature but the fact of science itself as a form of human consciousness. The process in the mind of the scientist is as amazing as the world he, or she, is describing. And as Laszlo reminds us: "scientific theories arise through the interaction and intercommunication of scientists with each other and with 'nature'…. they emerge in the context of the interaction of some highly specific matter-energy systems with each other and with their environment". [22]

Which brings us to the question of the human mind - as a primary "matter-energy system"- and, whether in its scientific or cultural activities and thinking, it is itself evolving. In other words, is human nature evolving? This is a subject which scientists do not speculate about, either leaving it to the philosophers and psychologists or assuming that it is outside the boundary of scientific thinking altogether. Unfortunately, since the humanities take their cue from science today they also neglect to ask the question. To get some ideas about this you have to go outside the mainstream.

The evolution of mind

Ken Wilber's extraordinary and comprehensive synthesis of thought in the tradition of perennial philosophy, *Sex, Ecology, Spirituality,* is subtitled *The Spirit of Evolution.* He showed an encyclopaedic vision for our time, which included individual, social, and ecological patterns of development from an inner - psychological and spiritual - as well as outer - scientific - dimension and situated it in an historical and future-orientated evolutionary perspective. [23]

In chapters 5 and 6 of Book One of *SES* he described the historical emergence of human nature from the age of hominids to the birth of *homo sapiens,* and particularly the last few thousand years up to the present day. Drawing on the work of the cultural historian, Jean Gebser, he mapped out the ages of social development from "archaic" to magic to mythic to rational - or the age of reason - cultures, and elucidated the evolution of the individual, cognitive mind that unfolds along with the social. Wilber identified the centuries in the first millennium BCE - from 800 to 200 BCE - when the seeds of imaginative reason emerged, called by Karl Jaspers "The

Axial Age". This time saw, for instance, the simultaneous emergence in the West of the Greek pre-Socratics and the prophets of Judaism, and in the East the wisdom of the Upanishads, the teaching of Gautama Buddha and the inspiration of the Chinese Daoists, Lao Tzu and Chang Tzu.

In Chapters 7 and 8 Wilber described the possibility of the "farther reaches of human nature", as it emerges from the seeds of the past and present and unfolds in future evolution. The present potential of the cultural mind is what Wilber called "vision-logic" or "network logic", a stage or level beyond, but including and emerging from, logical rationality. It has also been called "dialectical", "integrative", "creative synthetic" and so on. The next stage in the evolution of mind are "the transpersonal domains", which can be accessed by meditation, or a contemplative practice.

Meditation, or contemplation, Wilber contended, is an empirical mind-science which follows the steps of the method of our natural sciences, that is to say: firstly "injunction" - or experimentation; followed secondly by illumination - or apprehension; and, thirdly, with the testing of this in the community of people who practice the same science. Contemplation has been, and is, practised in all cultures and there are countless guides, or manuals, to instruct us of the many ways to do it, as well as accounts of the illumination that can be experienced with its practice. The distinction - and advantage - it has over modern Western natural science is that the "apparatus" is solely one's own mind. It is essentially the interior, introspective science and the only way to "prove" this science is to practise it oneself. As Wilber wrote:

> It is rather a description, often poetic, of a direct apprehension or a direct experience, and we are to test this direct experience, not by mulling it over philosophically, but by taking up the experimental method of contemplative awareness, developing the requisite cognitive tools, and then directly looking for ourselves. [24]

As Emerson put it, "What we are, that only can we see."' Thus, Wilber argued for "the validity claims of mysticism" and promoted "the reconstruction of the contemplative path". [25]

Science may be about interrogating - or communicating with - nature, as if nature was an entity separate from us - objective, material, over there - but science is a

human activity necessarily entangled with the world it is examining. We may be discovering how extraordinary the microscopic and cosmological worlds are but what is equally extraordinary is the fact of the human mind making the discovery. In short we may be learning, at the same time, as much about ourselves as the universe we are exploring. In that sense science is an unacknowledged contemplative practice. We ourselves - individually and socially - are an essential exemplar of the nature we are observing.

Might this not return science, as an epistemological discipline, to the centre of a new natural philosophy? When we are asking, along with Shroedinger and Lynn Margulis, “What is Life?”, we are also implicitly asking “Who - or what - are we?” Questions we make about nature may equally be questions of ourselves. Prigogine’s book is subtitled “Man’s new dialogue with nature”. The dialogue with nature is also humanity’s dialogue with itself. So in realising how intelligent nature is, how communicative, how it evolves, we are discovering this about ourselves.

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To illustrate the different way in which today’s scientist and science writers approach their work, I would like to take two examples, examining similar themes on different scales: one, the more microscopic, focussing on materials science from a physicist’s point of view; the other a more ecological and global view of the climate crisis; but both examples showing a human and imaginative perspective. Interestingly, the books I refer to won the Royal Society Winton prize in successive years - 2014 and 2015.

Materials science

Mark Miodownik, Professor of Materials and Society at UCL, described in his extraordinary book, *Stuff Matters,* how, as a teenager, he was attacked in the London Underground by a man wielding - as a weapon - a razor blade wrapped in tape. This event triggered for Miodownik an obsessional, life-long interest in the nature of physical materials. The tiny piece of steel had cut through five layers of his clothes and penetrated his skin with ease. When he saw the razor in the police station after the attack, Miodownik described how he was mesmerised: “as the police quizzed me about the weapon, the table between us wobbled and the razor blade on it wobbled

too. In doing so, it glinted in the fluorescent lights, and I saw clearly that it's steel edge was still perfect, unaffected by its afternoon's work". [26]

He continued to be mesmerised by the material quality of steel as it made its presence manifest in a variety of forms to him throughout that day, culminating with the soup spoon he put in his mouth over dinner that evening. He remembers asking his dad "What is this stuff?", as he waved the spoon at him, before putting it back in his mouth and noting the steel itself didn't taste of anything. The experience of the day provoked a million questions: "How is it that this one material does so much for us, and yet we hardly talk about it?.....Why does a razor blade cut while a paper clip bends? Why are metals shiny? Why, for that matter, is glass transparent? Why does everyone seem to hate concrete but love diamond? And why is it that chocolate tastes so good? Why does any material look and behave the way it does?" (P 3)

In *Stuff Matters* Miodownik described the nature of ten examples of materials and how they are made up, giving each a descriptive, non-scientific word, suggesting how they are perceived by him personally. He did this to suggest that what we think are qualities intrinsic to the material - and the "matter" we think constitutes them - are in fact "a reflection of who we are, a multi-scale expression of our human needs and desires". [27] Moreover, in order to create materials in our own image we have had to do something quite remarkable: "we have had to master the complexity of their inner structure". [28]

Materials science offers "a unifying concept". Although a material may appear uniform and monolithic, this is an illusion: "materials are, in fact, composed of many different entities that combine to form the whole, and these different entities reveal themselves at different scales" (p 237). Like a Russian doll, any material is composed of many nested structures, invisible to the human eye but forming a "hierarchical architecture", each structure smaller and fitting exactly into the one before. This gives materials their complex identities - "and, in a very literal sense, it also gives us our identities too".

Miodownik explained this further by a simple but profound hand-drawn diagram illustrating the hierarchical structure of materials in terms of scale, from the smallest,

the atomic scale, through the increasingly larger - or less small - “nano”, “micro” and “macro”, until we reach the just visible “miniature”, before the “human” scale. Atoms are ten billion times smaller than us, while “nano” means a billionth, and so on, eventually up to our human scale.

What is especially interesting about Miodownik’s diagram is that he has two - handdrawn - columns, one for the “animate”, one for the “inanimate world”. In fact all his work explored the blurring of boundaries between the two “worlds”. While the apparent differences between the animate and the inanimate are evident through five of the scales - for example, cell and crystal, dna and nanotube - we, as animate beings, share the atomic level with matter. The common ground between the animate and inanimate - the “material” and the “human” - is the atom. As Miodownik conceives it, he maps out the world of materials, not on a single scale, but by offering “a map that shows terrain on a variety of scales: the inner space of materials”. [29]

Nanotechnology is particularly interesting today and, as Miodownik pointed out, we now have tools and microscopes for directly manipulating structures at this scale. What is almost “spooky ..... but in line with the existing laws of physics ..... is that many of the structures at this scale self assemble. This means that the materials are able to organise themselves”. [30] There is a seeming alchemy within “matter” itself. It is not the passive, inert substance modern orthodox science has believed it to be. And that apparent alchemy also applies, not just to the materials themselves, but also to our relationship with them.

A new geological epoch

Gaïa Vince published her *Adventures in the Anthropocene* in 2014 and won the Royal Society Winton prize with it in 2015. She writes on a “geological timescale” and, as she explains in her introductory chapter, we have entered the age of the Anthropocene because of the changes we have made to the Earth, not just in terms of geology and the lithosphere but also in respect of the atmosphere and the hydrosphere. We have now made this “a human planet” and have moved from the Holocene to the Anthropocene, a term first used by the Dutch chemist, Paul Crutzen, in 2002.

As Vince declares:

> We live in epoch-making times. Literally. The changes humans have made in recent decades have been on such a scale that they have altered our world beyond anything it has experienced in its 4.5 billion year history. Our planet is crossing a geological boundary and we humans are the change-makers. [31]

Geologists speculate how future generations will see evidence in the fossil record of our own industrial and material civilisation - “our human fingerprint”. Just as we see evidence of dinosaurs in the rocks of the Jurassic or the explosion of life in the Cambrian era, “our influence will show up as a mass of species going extinct, changes in the chemistry of the oceans, the loss of forests and the growth of deserts, the damming of rivers, the retreat of glaciers and the sinking of islands”. 4

In her career as a science journalist for *Nature* it was Vince’s business to take a special interest in reports on how the biosphere was changing. Study after study, describing these changes, all pointed to “a common theme: the impact of humans”. As a result our world was becoming a different planet. There was no doubt about the environmental crises we were responsible for. But at the same time as we became aware of the damage we were doing to our planet Vince was also reading about the triumphs of science: “the genius of humans, our inventions and discoveries, about how scientists were finding new ways to improve plants, stave off disease, transport electricity and make entirely new materials. We are an incredible force of nature”. [32]

Vince is aware of the interest of non-scientists - artists, poets, sociologists, ecologists, politicians and lawyers - in the Anthropocene and the different perspective of many of these and has written her book in the light and shadow of the cultural transformations that are taking place across the planet. Interestingly, she began all her chapters with inspired and imaginative pieces, whether about the atmosphere, mountains, rivers, oceans, deserts or forests. These preludes to her more academic and descriptive writing form a poetic tribute to the sublimity of the planet we inhabit. It is all the more poignant, as is the genius Miodownik brings to his work on materials, given the damage we are also doing to the Earth and to ourselves. If we are to survive beyond this century we need a radical mind change.

We need to think very differently about our planet and ourselves. For instance Vince opened her introductory chapter with how we might begin to view ourselves in a cosmic context:

> Four and a half billion years ago out of the dirty halo of cosmic dust left over from the creation of our sun, a spinning clump of minerals coalesced. Earth was born, the third rock from the sun. Soon after, a big rock crashed into our planet, shaving a huge chunk off, forming the moon and knocking our world on a tilted axis. The tilt gave us seasons and currents and the moon brought ocean tides. These helped provide the conditions for life, which first emerged some 4 billion years ago. Over the next 3.5 billion years , the planet swung in and out of extreme glaciations. When the last of these ended, there was an explosion of complex multicellular life forms. [33]

The question is whether we continue to treat the planet and it's resources selfishly, for ourselves only, or whether we are capable of learning and exercising a sense of responsibility and stewardship for all of life; whether we can come to understand that our future well-being depends on recognising our interdependence with all other species. As a scientific journalist she retains a degree of optimism, despite the challenges.

Vince decided that, rather than sit behind a desk reading about the Anthropocene in London, she would travel to the places in the world where it's impact was being felt and see how people were adapting, as far as they were able. She found considerable suffering but also great ingenuity. For instance, in Ladakh there was Chewang Norphel, a retired railway engineer - "the glacier man" - who had devised an artificial glacier for his local community; and Salomon Parco and friends in Peru, who, aggrieved at the black rock revealed by the the melting of their local glacier, were, quixotically, painting their mountain white, as they thought this would reflect the heat of the sun. People were devising schemes to adapt to an anthropocean world we in the modern West were responsible for.

It is clear from hearing about the impact of the Anthropocene on the "developing" world, we cannot in all conscience go on living in the way we in the affluent West do. Mark Miodownik showed how we can begin to think differently about our relationship

to the microscopic but prodigious world of materials. Gaïa Vince suggests how we might begin to consider the big ecological picture and awareness of our impact on the ecology of the Earth. Both Miodownik and Vince point to the crucial role humanity plays in its relationship to the rest of nature.

Their work leads me to ask questions of ourselves. Perhaps it is time we examined the human mind itself more closely. Perhaps our changing awareness of nature will lead to reviewing the place of human culture in nature. Perhaps the more we study nature - whether on a microscopic, human, or macroscopic scale - the more we will begin to think about ourselves and the part we play.

In chapter 16 I look at how our view of ourselves is changing, not so much as a separate and special species - with all the fears and anxieties this brings - but as an integral phenomenon to the Earth, a part of nature rather than apart from it. This implies more and more of us are beginning to awaken to our natural responsibility for the care of other species, as well as our own, but also to a new sense of what it means to be alive. We might even begin to appreciate how we, ourselves, are a sublime expression of an evolving planet.

Notes

[1] See F.R. Leavis *Two Cultures? The Significance of C.P. Snow,* with Introduction by *Stefan Collini,* Cambridge University Press, 2013.

[2] Bruno Latour and Steve Woolgar, *Laboratory Life; The Construction of Scientific Facts,* Introduction by Jonas Salk, with a new postscript by the authors. New Jersey: Princeton University Press, 1986,1979.

[3] Bruno Latour, *We Have Never Been Modern,* translated by Catherine Porter, Harvard University Press, 1993, originally published in French, 1991.

[4] David Locke, *Science as Writing,* New Haven, Yale UP, 1992.

[5] Kathryn A. Neeley, *Mary Summerville: Science, Illumination, and the Female Mind,* Cambridge University Press, 2001, p 3.

[6] Ibid. pp 9-10.

[7] Andrea Wulf, *The Invention of Nature; The Adventures of Alexander Von Humboldt, the Lost Hero of Science,* London: John Murray, 2015, p 7.

[8] Erwin Shroedinger, *What is Life?: The Physical Aspect of the Living Cell,* Cambridge University Press, 1977, 1944, p 5 .

[9] *The Upanishads,* Introduced and Translated by Eknath Easwaran, Afterword by Michael N. Nagler, Tomales, California: Nilgiri Press, 2007, 1987, p 213.

[10] Margulis also worked with James Lovelock on the Gaia hypothesis, thus embodying the ecological notion that there is a correspondence and continuum between microscopic and macroscopic life.

[11] Lynn Margulis and Dorion Sagan, *What is Life? ,* foreword by Niles Eldredge, London: Weidenfeld and Nicolson, 1995, p 33

[12] Ilya Prigogine and Isabelle Stengers, *Order Out of Chaos: Man's New Dialogue with Nature,* foreword by Alvin Toffler, London: Flamingo Fontana, 1988, 1984, p xxviii

[13] Ibid. p xxix.

[14] Ibid. p xxix

[15] Alexandre Koyre, *From the Closed World to the Infinite Universe,* Forgotten Books, 2008, 1957.

[16] Prigogine & Stengers, 1988, p 5.

[17] Ibid. p 7.

[18] Ibid p 7.

[19] Myra J. Hird, *The Origins of Sociable Life: Evolution After Science Studies,* ,Palgrave Macmillan, 2009.

[20] Charles Darwin, *On the Origin of Species: the Illustrated Edition,* general editor, David Quammen, New York: Sterling Signature, 2011, 1859 of course. My quotes are taken from this edition, particularly Darwin's own introductory chapter.

[21] Erwin Laszlo, *Evolution: the General Theory,* Cresskill, New Jersey: Hampton Press Inc., 1996.

[22] Ibid. p 141

[23] Ken Wilber, *Sex, Ecology, Spirituality: the Future of Evolution,* Boston: Shambhala, 2000, 1995.

[24] Ibid. p 276

[25] Ibid. pp 281-284

[26] Mark Miodownik, *Stuff Matters: the Strange Stories of the Marvellous Materials That Shape Our Man-World,* London: Penguin, 2014, 2013, p 2.

[27] Ibid. p 248

[28] ibid. p 237

[29] Ibid. p 239

[30] Ibid. p 241

[31] Gaia Vince, *Adventures in the Anthropocene: a Journey to the Heart of the Planet We Made,* London: Vintage, 2016, 2014, p 4.

[32] Ibid. p 6.

[33] Ibid. p 1.