Towards an Animistic Science of the Earth
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Introduction

At first sight, science and animism appear to be irreconcilable. Whereas over the last four centuries science has held sway with the view that nature is nothing more than a vast lifeless mechanism that can be understood and controlled by means of experiment and detached analytical reasoning, ‘animists’, in their various guises (including shamans, poets, priests and philosophers and psychologists), have for millennia professed an intuitive knowing of nature as a great soul, mind or psyche; as alive, redolent with purpose and meaning; as saturated with mysterious creativity.

Clearly, modern science and technology have brought us many benefits and are without doubt among humanity’s greatest intellectual achievements, but they have also unwittingly contributed to the massive global crisis we are now facing. In essence, science has made us clever, but it has not made us wise. If we are to have any chance of surviving the looming catastrophe that science and technology have inadvertently helped to create we will need more wisdom, not more analytical capacity, of which there is a plentiful supply. And so, along with a growing number of fellow scientists, philosophers and activists, I believe that we now urgently need to develop a new approach in science that integrates analysis with wisdom, fact with value and nature with culture (ref to Brian). We think that this can be done by replacing our demonstrably unwise (and until recently, unconscious) assumption that the world is a inert machine with the arguably wiser and more accurate metaphor that the world is a vast animate (and hence ‘sentient’) being. Thus, strange and trite as it may seem, the survival of civilisation itself could in part depend on a fusion of science with animism. Furthermore, given the very real dangers that seem set to befall us as a result of our impact on the earth’s climate, there is perhaps no better way to begin this work than with an animistic reformulation of our scientific understanding of the very earth itself.

The first question we need to explore is what an animistic approach to nature actually entails. (something about Graham Harvey’s definition of animism – how it had a bad press and how it can be revived) We could of course refer here to the many indigenous cultures of the world, some, if not all of whom were inspired by animistic cosmologies and ways of living, but it seems most appropriate for us to bring to light the animistic sensibilities and insights that lie within Western culture itself, since this is where modern science and technology originated.

A Brief History of Animism in the West

We can begin perhaps with Thales of Miletus, the eminent pre-Socratic Ionian philosopher of the 6th century BCE who is widely recognised as one of the progenitors of modern science. He, along with several other Ionian philosophers of the time, taught that we could understand nature by focussing on the physical forces that underlie the workings of the natural world rather than on the actions of the
capricious supernatural Gods who were widely believed at the time to be the prime movers behind all things. Of interest to us in our quest for an animistic science was Thales' assertion that all matter is alive, or ‘full of Gods’. He seems to have reached this conclusion by observing that the attractive powers of rubbed amber and magnets were akin to the equivalent powers within biological entities. The emphasis on matter as being sentient was never completely lost in the West, despite the gradual schism between mind and matter that gradually took root during subsequent centuries.

A major revival of this idea took place during the Renaissance, when Marsilio Ficino (1433-1499) and other hermeticists (such as Pico della Mirandola (1463-1494)) explored the view that the material world is saturated with the enlivening influences of the anima mundi (the world soul), which in turn derives its power from a transcendent divine intellect. For these thinkers and magi, true knowledge required an understanding of how the Ideas in the divine intellect manifested in matter and in the world at large (Wertheim 1995, p88). A prominent hermeticist was Giordano Bruno (1548-1600), who thought of the planets as huge animals each with its own soul, and who regarded solar systems (like our own) as the fundamental units in a universe as vast and limitless as the divine intellect itself.

However, by the end of the sixteenth and during the early seventeenth centuries the Church had instigated its murderous activities against the magi and hermeticists, of which about one million women - the so-called ‘witches’ – perished at the hands of the clerics and their agents. This was the time when the new mathematical science was in the ascendency, lead by the infamous Marin Mersenne (1588-1648) a Minim Monk, the sworn enemy of the heretical hermeticism, of the anima mundi and hence of animistic thinking in general. Mersenne favoured a purely mechanistic conception of nature compatible with the Catholic Church’s ideas about the relationship between God and his creation (Dear 1988, pp3-4). One of Mersenne’s allies was the priest Pierre Gassendi (1592-1655) who described the universe as a collection of inert atoms obeying mathematical laws imposed from above by a transcendent God. In the words of Margaret Wertheim (1995, p 94), it was through Mersenne and Gassendi that “the animating spirits and souls of the world were drained away like the blood from a slaughtered calf. The self-activating universe of the magi was killed off, and in its place stood an inert machine.” But it wasn’t easy for the early mechanists to establish their dominance – they needed a champion who would conclusively demonstrate the supremacy of the mathematical way of knowing. According to Wertheim (19...) to a large extent it was Rene Descartes (1596-1650) who fulfilled this role, but he went further in declaring that there was a fundamental division between the human mind (the ‘res cogitans’) and the rest of nature, which was, of course, a vast dead machine (the ‘res extensa’). Thus, according to Wertheim (1995) and others (i.e. Merchant 19.. Yates..) Descartes established the principle that only a detached mathematical intellect could gain reliable knowledge of nature.

This history evokes strong reactions. As I awoke this morning, pondering these thoughts, an image appeared. It seemed to me that for the hermitics everything in the cosmos a tiny point of flickering, living candle light in the vastness of the universe. Then, with Mersenne, Gassendi, Descartes and what later became modern science, all those little flames were stolen from their sources and gathered
up into one single, giant flame, the flame of our detached scientific intellect, which towered above the world like a lighthouse, leaving the universe dark and dead once all the little lights had been extinguished. Henceforth only science, with its massive stolen flame, tucked away in its lighthouse consciousness, would shine its light as a powerfully focussed beam on one dead phenomenon at a time. But this flame is now so hot, so intense that it risks burning the earth and itself to cinders. Our task now is to abandon the lighthouse and to use its flame to re-ignite all the little candles that have spent 400 years waiting patiently in the darkness for their flames to return.

This move clearly requires us to shift our view of the world. Father Thomas Berry (ref) sums up the world-view shift that is now needed with wonderfully succinctness when he says that “the universe is not a collection of objects, it is a communion of subjects”. In other words, we need to abandon the billiard ball view of the universe as a set of isolated, inert objects that interact in only the most superficial of ways, and move instead to a view in which every entity is an experiencing subject, full of creative agency, which is deeply changed through its interactions with every other entity around it. Berry points out that every so-called ‘object’ is in fact a subject with its own experience, no matter how rudimentary. In other words, it feels like something to be an electron, an atom, a molecule, an organism, an ecosystem, a planet, a universe

Goethe

An animistic science would therefore take account of this inward, ‘soulful’ nature of things. Perhaps the most important exponent of such an approach in science was Johann Wolfgang von Goethe (1749-1832), who developed an intuitive method for connecting with the inwardness of natural phenomena which in fact can be traced back several centuries before him to Ficino and Paracelsus, and before them to the hermetic tradition. In this method, careful attention is paid to the phenomenon being studied through a process of active looking without attempting to reduce the experience to quantities, explanations or theories. If this works as it should, one has the intuitive perception of the thing as an active, soulful presence within oneself, and not as an object outside one’s own being. This sense of deep relatedness to the phenomenon transforms consciousness into a means for holistic perception through which we are able to apprehend the intrinsic qualities of things as well as their inherent wholeness (refs). Goethian science leads us to the conclusion that ‘mind’ or ‘soul’ is not, as Descartes thought, located within the human skull and nowhere else – we realise instead (through our intuitive faculty) that these qualities are distributed throughout the universe, which is therefore, as the ancients have said, a great mind or soul in its own right.

Gregory Bateson

This idea of the extended mind can be found in the writings of several key contemporary thinkers. One of the most important was Gregory Bateson (1904-1980), whose work has been ably analysed and summarised by Charlton (2008), whose synthesis I draw on in what follows. Bateson proposed that mind only exists only within the relationships between the material parts of a system, which in turn must be of sufficient complexity for mind to emerge. Mind therefore certainly exists in biological systems, but not necessarily in the abiotic realm of rocks, air and water.
“News of difference”, constitutes the informational content of these relationships, which leads either to corrective (negative) feedback or to self-amplifying (positive) feedback within the system as a whole. This news of difference takes many forms, including changes in hormone levels, temperature, acidity, rainfall and so on, and it also manifests in communicative signals such as bird calls and insect warning colouration. For Bateson, mind is organised in nested patterns – the mind of an individual organism is found within the relationships that maintain it as a seemingly discrete entity, and the organism is itself part of the larger minds of the local population of its species, its ecological community and so on up to the planet as a living whole. Thus, every living being is part of an “eco-mental” system that includes its wider surroundings, such that if we create “insanity” in a lake by treating it badly, we will eventually feel this insanity when it feeds back into our own mental life and experience. Learning is thus a key characteristic of the process of mind. Charlton (2008 p48) points out that Bateson’s insights imply a widening of our concepts of awareness and perception, since awareness, which for Bateson is a characteristic of all mental systems, does not depend on consciousness or even self-consciousness as we experience them in our own human experience. Clearly, this view is in part justified on the grounds that almost all of our physiological functioning takes places without the involvement of our consciousness.

Charlton (200.) suggests that “Gregory Bateson’s understanding of the systems of the world as “minds” is a much needed insight, an ontological re-visioning of the living Earth that we should learn to value and accept”, and it is easy to see how one can fruitfully use Bateson’s notion of mind to postulate the existence of a global mind constituted by the complex relationships amongst the planet’s various components, including the human realm of being. This, as we shall see below, creates an excellent basis for an animistic science of the earth.

Biosemiotics

Another fruitful area of thought that lends itself well for incorporation into an animistic science of the earth is biosemiotics, which seeks to understand the biological world in terms of how living beings not only on the basis of their chemical and physical (or purely ‘mechanical’) properties, but also on how they interpret signs and meaning. The basic move here is to deny the validity of Descartes’ categorical assertion that only humans have minds – biosemioticians regard all biological beings as ‘minded’, just as all of living beings share the basic properties of cellular structure, biochemistry and physiology. Every living creature literally knows what is happening to it since it responds to signals received from both within itself and its environment using a style of knowing unique to each species that is not necessarily symbolic or logical or even conscious in the human sense, but which nevertheless involves a mind that interprets the signals that are being received. Biosemiotics therefore places the emphasis on mental acts of cognition and interpretation by minds that are ubiquitous in the biological realm. Hence there are as many minds - as many viewpoints on the world - as there are species. The biological world is a tangled mental web woven together into a coherent whole by means of a phenomenally diverse range of signals and signs that include physical, biochemical and behavioural stimuli.
Biosemiotics is a new and growing field within science that has much to offer. In the words of Donald Favareau (2010), a key player in the field; “...if biosemiotics has any one single most constructive message to give the mainstream scientific community, surely it is precisely this: a semiotic process is not a ghostly, mental, human thought process. Rather, it is, in the first instance, nothing more nor less mysterious than that natural interface by which an organism actively negotiates the present demands of its internal biological organization with the present demands of the organization of its external surround. And the fact that this is done incessantly – by all organisms, and by us – should not blind us to the significant fact that such moment-to-moment activity is always and perpetually an enacted accomplishment – and thus one that is going to have to be explained, if we are ever to understand the biological side of living organisms' material interactions.”

Bacteria as an example...

Gaia

Gaia theory is the brainchild of James Lovelock, who had a powerful revelation about the Earth whilst working for NASA in the quest to find life on Mars. By contrasting the atmospheric composition of the Earth with those of Mars and Venus, he suggested that life itself had not only generated the Earth’s atmosphere, but had also regulated it, keeping it at a composition favourable for life over billions of years.

Until recently conventional science told us that this could not be the case. Life could not have had such major impacts on the atmosphere, since living things were thought of as no more than second-class citizens on planet Earth. It was the non-living world of rocks, atmosphere and water which was thought to determine the global temperature and acidity, two key variables for life. Living beings had to adapt to these conditions or die- they had no major influence on the non-living world and therefore on the composition of the planetary surface.

In contrast, the key insight of Gaia theory is wonderfully holistic and non-hierarchical - it suggests that it is the Gaian system as a whole that does the regulating, that the sum of all the complex feedbacks between life, atmosphere, rocks and water give rise to Gaia, the evolving, self-regulating planetary entity that has maintained habitable conditions on the surface of our planet over vast stretches of geological time. Gaia is in some sense alive......

This is a radical departure from the mainstream view which put the non-biological processes in control of the Earth. Gaia theory suggests that life and the non-living environment are tightly coupled, like partners in a good marriage. This means that what happens to one partner happens to the other, and implies that all the rocks on the Earth’s surface, the atmosphere and the waters have all been deeply altered by life, and vice versa. The self-regulation arising from this tight coupling is an emergent property that could not have been predicted from knowledge of biology, geology, physics or chemistry as separate disciplines. Gaia evolves as an entirety and, like a beehive or a termite colony, is a superorganism, which for Lovelock is ‘an ensemble of living and non-living components which acts as a single self-regulating system’. Thus the atmosphere is a much the product of life as is a cat's fur or the bark of a tree.
By thinking of the earth as a great living being, Gaia theory opens the door to an animistic interpretation of nature. Etc.

Jung

Before we can begin to explore how we can weave the various strands alluded to so far – the ‘magical’ thinking of Ficino and the hermiticists, the phenomenological science of Goethe, Bateson’s concept of mind, the insights of biosemiotics and Gaia theory into a coherent animistic science of the Earth, there is one more step that needs to be taken: a brief exploration of the ways of knowing that we humans are capable of. Here we bring in the work of C.G. Jung (1875-1961), the great Swiss psychologist who revolutionised our understanding of the psyche, which he considered to be a property of our species and of nature itself. Based on his empirical work with his many patients, Jung realised that we have four fundamental ways of knowing the world, which are, in brief, thinking, feeling, sensing and intuition. These occur as dyadic opposites, so that a person whose dominant function is thinking will be undeveloped in their feeling (and vice versa) – likewise for intuition and sensing. Thinking and feeling are evaluative, whereas intuition and sensing are not. Thinking evaluates through reason, logic and analysis, feeling through a ‘gut’ feeling of what is right (or wrong) in any given situation. Hence feeling in this context is more about ethics than emotion, but an ethics born not from reasoning but from a deeper, more embodied reading of the world. We receive information about the sensual qualities of our surroundings via our senses, whereas intuition is an inner knowing, a “spontaneous perception of wholeness” (H. Bortfot, pers. comm.) that is presented to us often fully formed perhaps from the unconscious, or from the wider psyche of the cosmos. We have so far in this chapter mostly dwelt in the domain of the thinking, intellectual mind, but in what follows I hope to show how we need to use all four ways of knowing in an integrated way if we are to develop a truly animistic science of the earth.

Bringing the threads together

It is now time to bring the various threads that we have explored above into a coherent outline of what an animistic science of the earth might be. I will use Jung’s four ways of knowing as a template for this task, since it seems to be that the sort of science we are looking for needs to involve the entirety of our psyches, and not just the thinking function which has dominated science as we know it.

Adam Croft

Shledrake

So how can we bring together this long tradition of animistic thinking with our modern scientific understanding of the earth? It seems to me that the key idea here is *personification* (Hillman....). Animists perceive all things as persons, and it is not difficult to see how we can do this in science without losing intellectual rigour. ]]
One can do this by considering the earth at a variety of different scales. Perhaps the most fundamental is that of the chemical elements. Here, we speak of CHNOPS – the six major chemical elements that are of vital importance for life on our planet. Read any chemistry book and you would be forgiven to gaining the impression that these, and indeed all chemical elements belong to a dry, dusty world of purely functional, utilitarian considerations. In these accounts the elements are described in dry, soulless language, as if seen by some remote, detached all knowing observer who feels a peculiar revulsion for the dead corpse of nature that it is exploring. There is for me no love in these descriptions, only a kind of Victorian prudishness – an almost fearful arms-length denial of the sheer sensual delight of being truly in one’s bodily immersion the world. Of course, the information about the elements that one gleans from these standard scientific texts is deeply interesting and even exciting, but it needs hard work to get beyond their thick, dense blubber of objectified language into a living sense of the chemical elements as vibrant persons with whom I have a deep connection and to whom we owe our lives.

The personalities of the elements.

In order to deeply understand the life of our planet we need to explore the cycles of the chemical elements, for without their coming to life in organisms there would be no Gaia to speak of. So what exactly are the chemical elements? Democritus was right - the material world is indeed made of atoms, but, atoms are not dead, mechanical entities; they are participatory beings with characters akin to our own. If we think of matter in this way, we can draw two important conclusions. Firstly, it no longer seems to be such a stretch to imagine that the many little ‘freedoms' in matter can produce the high level of freedom that is so much a part of human consciousness. In the words of philosopher J. McDaniel "our own subjective experiences are highly developed forms of what there was in the beginning in sub-microscopic matter", and " 'matter' and 'mind' are simply names for different types of actual occasions of experience". In the words of philosopher Christian De Quincey, “matter tingles with experience” and “matter feels to its deepest roots". Secondly, we can no longer treat matter with disrespect, because it is, after all, sentient in some sense by virtue of having a creative agency and capacity for experience that demands our ethical consideration. We realise the profound wisdom in the etymological root of the word ‘matter', which comes form the Latin for 'mother' (mater), and 'matrix', or womb.

If this approach is correct, then, in contrast to the mainstream view, we can conceive of matter as being inherently creative. Matter falls into certain patterns of relationship improvisationally, much as an artist explores new domains of being and interaction. For animists, matter and psyche are indissoluble, for the psyche of the world resides nowhere else but in matter itself. Thus the great archetypes of Gaia and anima mundi that figure so importantly in the human soul could well be prefigured in some mysterious way not in some abstract realm far from this world, but in the very molecules and atoms that constitute our palpable, sensing bodies. Perhaps psyche becomes visible when the relationships amongst a community of interacting agents are powerful and complex enough to call it forth from within the very matrix of materiality. If this is true – if psyche is indeed revealed in the very
thick of relationship - then Gaia may well be a domain in which the presence of living beings so quickens and intensifies the planet-wide interactions amongst atoms, rocks, atmosphere and water that the Earth literally awakens and begins to experience herself as alive and sentient.

Thus, an animistic science of the earth teaches us that chemistry need no longer be thought of in merely mechanical ways, as if 'chemicals' are nothing more than dead, static cogs. Chemical properties are sublimely fluid - they are the ways in which different aspects of the inner natures of the elements reveal themselves in different contexts and circumstances, just as our own behaviour is dependent to some extent on the social setting in which we find ourselves.

There are many different kinds of atoms each with different chemical personalities. These are called the elements, because they were once thought to be the building blocks of everything around us, including our own bodies, and of course, the Earth. In the last century it was discovered that atoms are in fact not fundamental after all, but are themselves divisible into three 'particles' - the electron, the proton and the neutron. The physicist Neils Bohr was responsible for providing us with a now outdated but nevertheless useful model of how these particles are arranged within atoms and how they interact with each other. Atoms, he said, are like miniature solar systems. In the centre, in the place of the sun, is the nucleus, which is composed of positively charged protons and charge-less neutrons. Around the nucleus are the negatively charged electrons orbiting around it as planets do around the sun. Protons and neutrons are heavy, and constitute most of the mass of an atom, whilst electrons are almost without mass at all, but all atoms are 99.99% empty space. All the particles wink in and out of existence according to some quantum physicists, entering what cosmologist Brian Swimme calls the 'All Nourishing Abyss' – the quantum vacuum or zero point energy field, when they briefly pass out of existence.

Despite their immense difference in mass, an electron’s negative charge exactly cancels out the positive charge on a proton. Bohr pointed out one further astonishing fact – that the number protons and electrons in pure elemental atoms are always equal, so that the overall charge in such atoms is zero. Science seems to gloss over an extraordinary fact - that 'positive' and 'negative' exist at all. What a mystery it is that like charges repel and unlike attract. That these two polarities must always try to be close to one another, to 'cancel' each other out, or to 'complement' each other - we know not which - gives us all of biology and chemistry, and quite a lot of physics. The French say that 'le contraire se touche', Attraction and repulsion have something to do with the intelligence, with the 'soul' of the universe itself – they are the manifestation at the level of matter/ energy of the participatory nature of electrons and protons, perhaps no different in principle to the attractions and repulsions that we humans feel towards each other. Thus, atoms, like humans, are constantly trying to find fulfilment, and atoms find theirs by arranging things so that they have the right number of electrons orbiting their nucleus.

Bohr suggested that an atom’s electrons are arranged in a set of concentric orbits. The innermost orbit can hold a maximum of two electrons, the next one out, eight, the one beyond that another eight, the next eighteen, then 32, and so on for the outer orbits which needn't concern us here. Electrons in orbits closer to the nucleus have less energy than those further out. The whole of chemistry, and the whole of life depends on the simple fact that every atom is utterly compelled to do whatever it
can to end up with a full outer orbit. Atoms aren't satisfied until they achieve this, and of course atoms can't do this alone, they have to interact with each other to share or exchange outer electrons, and in so doing they create the bewildering variety of molecules, or communities of atoms, that we see in the worlds of chemistry, physics and biology. Each molecule in an emergent domain with properties not reducible to those of its constituent atoms. Water is a good example. Two parts hydrogen and one part oxygen, its melting point, fluid dynamics, expansion on freezing and so on cannot be fully predicted from a knowledge of oxygen and hydrogen separately.

Gaia's Elements

The most important elements for life and Gaia are just six - carbon, hydrogen, nitrogen, oxygen phosphorus and sulphur, remembered in the trade by the acronym CHNOPS. Let's look at how Bohr's model helps us to understand the personalities of these six chemical beings. Carbon has a full inner orbit with two electrons, but the next and outermost orbit is incomplete with only four. Thus, to find completion, carbon needs another four electrons, and finds them by sharing those in the outer orbits of other atoms, especially other carbons, forming what chemists call covalent bonds. When this happens, both atoms at last achieve a satisfactory resting state. The fact that carbon has a need for four electrons makes it a highly cooperative and intensely social chemical being. It is the solid, reliable Swede of the chemical world, loving nothing better than to share each electron with a fellow carbon atom, which means that it can link up with four neighbouring carbons to make large chains, rings and chains of rings in which multitudes of carbon atoms and associated oxygen, nitrogen, phosphorus and other atoms find collective fulfilment in the huge, often complexly convoluted molecules of life such as sugars, proteins and DNA. These linkages amongst carbon atoms are the basis of life as we know it; without them Gaia could not exist, and our planet would be as devoid of living beings as is our nearest neighbour, the Moon.

The essence of carbon is centrality. It occupies a pivotal place in the community of elements by virtue of its half-filled outer electron shell (figure 16), and it also occupies a central place in the workings of Gaia: atmospheric carbon dioxide and methane help to set the global temperature; dissolved carbon compounds regulate the acidity of the oceans; and, as we shall see, the burial of organic carbon helps to regulate the oxygen content of the air. The key point about global temperature is this: any gas molecule in the air that contains two or more atoms delays the escape to space of heat given off by the Earth after it has been warmed by the light of the sun. Carbon is present in at least two such greenhouse gasses: carbon dioxide (CO2) and methane (CH4). Water vapour (H2O) is another potent greenhouse gas. The addition of these and other greenhouse gasses to the air raises global temperature; their removal decreases it.

Hydrogen is the most abundant atom in the universe; 88% of all atoms are hydrogen, and indeed hydrogen is the primordial atom from which all others are derived through fusion in the intense heat and pressure within stars and supernovae explosions. It the simplest and lightest of all atoms- in its most basic form it has just one proton in its nucleus, which gives it its gravity-defying lightness, and one
electron in its single orbit. Hydrogen ions are the most chemically reactive ions in existence, and also the smallest. Hydrogen seeks fulfilment by finding another electron for its single orbit, which holds only two. This means that two hydrogen atoms happily bond to each other covalently to make H₂ - a hydrogen molecule - but hydrogen also bonds cheerfully with other elemental beings such as carbon, phosphorus or oxygen, and is a major constituent of living beings. Hydrogen is an airy, flippant creature which would love nothing better than to escape our planet altogether and return to its ancestral domain in outer space as hydrogen gas, for Gaia's gravitational field is not strong enough to keep it from floating off to outer space. If this were to happen, we would lose all our water and the planet would dry out completely. This may well be what happened on Venus, but life on our planet has various ways of re-capturing free hydrogen by combining it with oxygen before it can escape.

Oxygen is the third most abundant element in the universe, after hydrogen, and helium, but is the most abundant element in the Earth's crust. In very big stars, far bigger than our own sun, oxygen nuclei can fuse to give rise to silicon, phosphorus and sulphur, all of which have more protons than oxygen, and also an extra electron orbit to balance the extra positive charge. A full inner orbit but only six electrons in its outer shell makes oxygen passionately hungry for electrons, so hungry in fact that it can find fulfilment by bonding covalently with virtually every single known element. Only helium, neon, argon and krypton are immune from its fiery attentions, because these 'noble gases' enjoy complete outer orbits and are hence serenely aloof from the hurly-burly of the everyday soap opera of chemical life. Oxygen atoms love to bond covalently with each other, but in so doing a curious chemical anomaly becomes apparent - two electrons from each outer orbit refuse to join the melee, and remain unpaired. When oxygen is liquefied at very low temperatures, these free electrons make oxygen an excellent conductor of electricity. Oxygen is the passionate Italian of the chemical world - its urge to gather electrons is so powerful that it can literally burn up the complex molecules of life, releasing copious quantities of solar energy originally locked up by photosynthesis. Respiration, without which multicellular life, such as us, would be impossible, uses oxygen to burn up food molecules in a gradual, controlled way and stores the energy in special molecules such as phosphorus-rich ATP. As we saw earlier, abundant oxygen, together with combustible gasses such a methane in a planet's atmosphere, are a sure sign that life is present, for only life can release vast quantities of these gases into the air.

So passionate is oxygen in its quest for electrons that once inside the cell its reactions give rise to highly toxic free radicals that can interfere with DNA, causing ageing and even cancer. Free radicals are atoms that end up with a missing electron when the weak bonds that they have been involved in break up, especially after they have experienced the ardent attentions of oxygen. The free radicals then feel impelled to capture electrons from neighbouring molecules; thereby creating new free radicals that oftentimes set off a potentially highly damaging cascade effect. Cells have invented a host of enzymes to mop the rogue chemical beings, but a small number evade capture to carry out the demolitions of the genetic material that
will eventually kill most of us. So, like all the nutrients that are essential for life and even solar energy itself, oxygen is both a life giver and a dealer of death.

Many other elements are crucial for Gaia, and of those calcium, iron and silicon are of great importance. A calcium atom has four electron orbits, three of which are full, but its outer orbit has only two electrons, which makes it only too happy to engage in ionic bonds by giving these electrons away, leaving behind a calcium ion which carries a double positive charge. It is this that makes calcium so attractive to negatively charged ions. Calcium has been called the messenger of the cell because it is somewhat like those charismatic entrepreneurs of the human world who have a mercurial aptitude for networking. It is involved in virtually every cellular process ranging from cell division, to fertilization, to muscle contraction, and without this Hermes-like atom the astounding coordination of the cell's metabolism would be impossible. But too much calcium can kill, so cells must expend energy to keep it at a concentration low enough for optimum functioning.

References.


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