NATURE'S FRAGILE HARMONIES

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FIRST WORDS

WE TEND TO HAVE A ROSE-TINTED IDEA ABOUT HARMONY IN NATURE as if somehow it involves a state of static perfection devoid of conflict, friction and strife. But this view of harmony may not hold up under close scrutiny, for harmony in nature seems to appear when opposite tendencies and forces – creation and destruction, positive and negative, predator and prey, implosion and explosion – reach a transient state of equilibrium in which, for a while at least, some kind of fragile dynamic balance is achieved. If this view is correct, we would expect to find harmony emerging from the interaction of opposites at every level of existence, from sub-atomic particles to galaxies to galaxy clusters and beyond. Here I'll explore the notion that harmony, forever fragile, emerges from a delicate reconciliation between opposites in a progression that begins with so-called sub-atomic 'particles' and ends with Gaia, the global ecosystem, leaving you, the reader, to ponder whether the principle might apply at larger, more cosmic scales.

My definition of harmony, therefore, is that it arises from in all physical, chemical, biological and geological processes as an interplay of opposites. The dynamics of harmonious systems manifest as complex behaviours which can be described mathematically as either stable, periodic or chaotic in the technical sense in which many ordered patterns are folded into one another, often giving a superficial impression of randomness.

FIELDS AND ATOMS

If I have understood what my physics colleagues have told me, there is, in fact, no such thing as solid matter, and therefore no solid sub-atomic particles.[1] They tell me that what appears to us as solid matter is in fact constituted by strange field-like entities whose influence is felt everywhere in the universe. We call these entities electrons, protons, neutrons and so on when they collapse out of their field-like state (the quantum vacuum, which contains impermanent fields and particles that come in and out of existence and interact with each other) whereupon we make simplistic assumptions about a particle-like nature which they don't in fact have.[2] If we extrapolate from this and consider the field state to be a kind of non-existence and if the 'solid' state to represent existence, then here, even at this deepest level of things, we can see two opposites interacting in fragile harmony to give us the density and substance of the familiar world around us. When I am able to look at the world in this way, I feel a softening, a rounding of edges. I feel it all flowing as a vast field of being with its own strange mystery and purpose. I experience a delicious, living, fragile harmony, a glow, a golden feeling – in those brief moments when I'm able to hold and grow these opposites – existence and non-existence, being and non-being within myself, inwardly.

As we return from the mysterious world of the quantum vacuum and re-enter the domain of atoms and molecules, we need to see how fragile harmonies might arise out of the interaction of opposites in this new, seemingly much more solid realm. The obvious thought is that the opposites at this level of reality must be the positive and negative electrical charges that somehow haunt all atoms, no matter what their size and configuration. The positive charge emanates from protons in the atomic nucleus, whilst the negative charge inheres in the electrons that orbit around the nucleus in well-defined orbits or shells as suggested by the Rutherford-Bohr model of the atom, which although far too simplistic, is good enough for our purposes and for understanding much of chemistry.[3] According to this model, the inner shell of all atoms holds a maximum of two electrons, whilst the next shell out holds a maximum of eight of these negatively charged particles.

We humans tend to search for harmony in endlessly complex ways, but most atoms, if we consider them to be much simpler beings, find it by filling their outer electron shells though sharing electrons with their neighbours, creating chemically bonded communities of atoms known to us as molecules. Forging these chemical bonds involves a two-step process.[4] First, the positive charges in the nucleus of one atom and the negative charges in the electrons around another atom attract the atoms into a close and intimate proximity. The second step takes place as soon as the atoms have been brought close by this archetypal attraction between the opposites of positive and negative. Now their outer electron shells overlap so much that electrons can at last be shared, allowing each atom to complete its outer shell, and hence feel complete in itself.

The atomic nucleus is itself held together in fragile harmony by another deeply significant interaction between opposites. Consider this conundrum. Given the well-known principle that opposite charges attract and like charges repel, how is that that several positively charged protons co-exist harmoniously within the nuclei of atoms heavier than primordial hydrogen? Shouldn't they fly apart, fleeing from each other's protonic influences as fast as possible? Indeed, they should, were it not for another powerfully opposing force, known to scientists as the strong nuclear force, which counteracts these repulsive energies, binding protons (and neutrons) together in atomic nuclei. [5] One can get a sense of the power of these opposing forces by considering what happens when scientists contrive ways of destroying the fragile harmony at the heart of the nucleus by unbinding the strong force, producing atom bombs and nuclear power stations. The strong force, once released, can be vastly destructive, or, if carefully controlled, can engender huge amounts of electric power, depending on our motivation and intent. Either way, destroying the fragile atomic harmony at the very heart of matter has serious consequences for the life of our planet.

Perhaps the chemical element which most embodies harmony in the atomic/molecular world is carbon, which seeks four new electrons to join the four already present in its outer shell, making the eight needed for completion. How interesting that the number four appears over and over again in relation to wholeness and harmony in our human realm: the four directions, the four personality types, the four psychological functions, the four-fold nature of mandala images and so on as argued extensively by Jung.[6] Could it be the same in the chemical world? Is it mere coincidence that carbon's very embodiment of the number four makes it the most cooperative element in the periodic table, the one most able to forge immensely long chains of carbon atoms that create those deeply harmonious biomolecular cradles of life such as DNA, polysaccharides and fats?[7]

CELLS

What about the action of opposites amongst these biomolecules which teem within the cells of living organisms? The cell is inhabited by a hugely complex melee of large carbon-backboned molecules somewhat like carbon animals with fleshy muscles of nitrogen, oxygen, sulphur, hydrogen and other atoms, all attached to the carbon backbones by 'ligaments' – that sharing of electrons which constitutes the chemical bonding we considered earlier. [8] There is a constant interplay of creation and destruction as these biomolecules consume and remake each other in the continual dance of metabolism that is a key characteristic of life.[9]

These two opposites – creation and destruction – play out within a vastly complex network of relationships amongst the cell's huge variety of biomolecules. The network as a whole is deeply harmonious, regulating the levels of each biomolecule, all at once, simultaneously. This constant remaking by life from itself and out of itself requiring only inputs of energy and nutrients is what Chilean biologists Maturana and Varela came to call *autopoiesis* (self-making) proposing that if autopoiesis is the primary quality of life, then reproduction is merely a secondary phenomenon.[10] Reproduction involves making a full or partial copy of yourself which lives on into the next generation, and you need to remember who you are in order to do this. Some of this cellular memory is held in molecules of DNA, that massive, hugely beautiful spiralling biomolecule – that staggering demonstration of emergent creative harmony in which DNA is held together by oppositely shaped molecular bases at the core of its being that fit together like lock and key. So here, at the very core of life itself, we find something unexpected: life's fragile harmony gives rise to memory, To be alive, to be a coherent, self-making whole, the cell needs to enclose itself within an exquisitely selective semi-permeable boundary which it makes for itself out of its own autopoietic processes. This is the cell membrane. Can we discover how tensions between opposites give rise to harmony even here at this most fundamental of biological levels?

The cell membrane is composed of biomolecules known as phospholipids, which look rather like tiny molecule-sized tadpoles whose phosphorus-bearing heads adore water and whose lipid (fatty acid) tails find water utterly repulsive.[11] Here again we find attraction and repulsion, those by now familiar opposites, which in this case cause these tiny tadpoles to fall easily into a bi-layered arrangement. The tadpoles' heads stick out of the inner and outer surfaces of the bilayer, where there is plenty of water, whilst their lipid tails point inward where water is absent. In essence, the phospholipids settle into the harmonious arrangement that is the cell membrane because the tadpole heads feel themselves drawn towards water molecules that circulate both inside and outside the cell, whilst the water-hating lipids tails face inward to get themselves a far away as possible from the water molecules which they find so repulsive.

This fragile harmony between attraction and repulsion creates the flexible, semi-porous cell membrane which provides protection for the complex metabolic interactions that go on inside all cells. But the cell membrane does not simply rest in a mere molecular passivity, for it is studded with many kinds of selective molecular channels, making it the locus of an acute and highly active membranous intelligence: by intelligence here I mean the ability to sense molecules in the cellular surroundings and to then decide whether to absorb them or not.[12] This implies a rudimentary style of choice. These channels use their exquisite molecular sensitivity to decide what to allow into and out of the cell. Food in, wastes out. Calcium in, calcium out – and so on for thousands if not millions of further kinds of molecular, atomic and ionic beings. Here, in the very precincts of the cell membrane, we discover how a further fragile harmony between myriad opposites gives rise a style of intelligence within each individual cell, an intelligence very much concerned with the issue of *identity*, since a living cell needs to know the difference between 'me' and 'not me'. Each and every cell needs to consume what is not itself in order to produce more of itself. Destruction is needed to consume food and energy and creativity is required to use these inputs to make more cellular material. The fragile harmony which appears from the tension between these opposites, between creation and destruction at the level of cellular metabolism, gives rise to all the beautifully harmonious forms of living beings: exquisite flowers, iridescent beetles, luminous fungi, great whales, earthworms and bacteria.

And yet, most cells don't live in isolation – many live in some sort of community, some very loosely connected, some more strongly communal. Here again our question must be: does harmonious communication *between* cells emerge, somehow, from a harmonious reconciliation of opposites, allowing them to live successful communal lives? Whenever the urge for identity (that powerful desire to be 'me') becomes collective, language (communication) is required, since individual cells clearly need to converse with each other in order to be communal.

Communication amongst cells probably began as soon as the very first cells (archaea and bacteria) appeared on our planet some 3,800 million years ago.[13] We humans mostly use speech to communicate by vibrating molecules of air with our vocal chords. Bacteria don't bother with sound, which would probably be impractical at their scale of existence. Instead, a key aspect of their language involves a system of chemical signalling known as *quorum sensing* in which each bacterium decides whether or not to commit energy to a specific response, such as producing a toxin, based on chemical signals it receives from its neighbours.[14] In essence, each bacterium sends chemical signals to other bacteria of its own species whilst also absorbing and interpreting chemical signals from its fellows. At low bacterial densities each bacterium receives a small number of signals and does not waste energy in responding. But once the bacterial density increases to a critical level, each bacterium receives a much higher number of signals. Individual bacteria interpret this situation as meaning that there are now enough of its fellows present nearby to make investing energy in a response worthwhile, giving rise to suitably adaptive action from the population as a whole.

A classic example involves the emission of light by the bacterium *Vibrio fischeri* which lives in the open sea and in the Hawaiian bobtail squid's specialised light organs which provide the bacteria with shelter and nutrition.[15] At dawn the squid eject around 90% of their *Vibrio* bacteria from their light organs back into the sea. The squid then hide in the sand all day, slowly feeding nutrients to the few remaining bacteria in their light organs. These *Vibrio* bacteria in the squid's light organ use quorum sensing to signal to each other all the while, but during the day there is no response since their density, although increasing, is still below a critical threshold. But by nightfall the bacterial population has grown so much that each bacterium now receives the critical number of signals from its fellows, which it interprets as meaning, as we might say (this is a human's way of saying exactly how the bacteria are interpreting the meaning of the chemical signals): 'there are now enough of us to make it worthwhile for *me* to produce light'. And sure enough the bobtail squid's light organs become bright with luminescence as each bacterium activates genes for light production, helping the squid to avoid predators by eliminating its shadow on the shallow sea floor on moonlit nights when it is active. At dawn, the squid ejects the bacteria to save energy, and the cycle begins again. Here is a case where language, in the guise of quorum sensing, is used to coordinate behaviours that benefit the members of the bacterial community in the light organ, since in exchange for light the squid gives the bacteria high-quality food and shelter.

But quorum sensing can also be used to opposite effect – to destroy members of competing bacterial species. Most bacteria can detect chemical signals specific to competitors.[16] When these alien signals reach a critical density, the entire population of the bacteria under threat can take a collective decision to emit toxins – often antibiotics – that harm or kill their competitors. One well-studied example takes place right inside our mouths, within the complex bacterial community we know as dental plaque. Most bacteria live in biofilms – thin films of bacteria sticking together embedded in slimy substances attached to surfaces such as our teeth, fallen leaves, hot springs and even ice cold glaciers.[17] Many hundreds of bacterial species live in our dental plaque, each species with around 10^10 individual bacteria, a thousand times greater than the entire global human population. Bacteria in biofilms coordinate behaviours through signalling pathways such as quorum sensing, creating communicative networks that far exceed the complexity of all our human networks, making what have justly called been called 'bacterial cities'. There are many cooperative interactions between different bacterial species in a biofilm, but there are also competitive interactions, mediated by quorum sensing, which help to promote the diversity of bacterial species within the biofilm. The result is that the bacterial community as a whole is less likely to be taken over by one species. Thus bacterial chemical language – quorum sensing – promotes both intraspecies cooperation and interspecies competition, an interplay between opposites which gives rise to species diversity and thus to a shifting, highly adaptive dynamic harmony within the bacterial community as a whole.

Endosymbiosis

But perhaps the most astonishing domain of life where we see a fragile harmony emerging from the reconciliation of opposites is in the cells that make up the bodies of all multicellular beings: the fungi, plants, animals and also the unicellular bodies of some protoctista such as amoeba and paramecium, and in their multicellular cousins, such as seaweeds. These kinds of cells are known as eukaryotes (literally, good nut or kernel), since they carry a 'good nut' within them: the cell nucleus which contains large amounts of DNA surrounded by its own semi-permeable membrane, very similar to the cell membrane we encountered earlier.[18] By contrast, the bacteria and archaea are known as *prokaryotes* – meaning 'those before the nucleus' or literally 'before the nut' or 'kernel' – since their DNA is not located in a nucleus but is found as a freely moving loop within the main body of the cell.

Eukaryote cells have many organelles within them – fine structures that carry out a large variety of metabolic tasks. Amongst these are the mitochondria, the energy producers of the cell, and in photosynthesising eukaryotes, those green solar energy capturers known as chloroplasts. The mitochondria and chloroplasts swim freely within the cell. The mitochondria look like little sausages, the chloroplasts like small minty green lozenges.

The stunning thing is that there is virtually incontrovertible evidence that the ancestors of both these organelles were once, thousands of millions of years ago, free-living bacteria that were engulfed by a larger cell, perhaps a predator, which prepared to digest them. This clearly would have spelt destruction for the engulfed one, but instead of digestion, a creative act of communication took place in which the ingested one and the one ingesting worked out a way of living together. One partner was predatory, the other resisted predation (opposites again) out of which an exchange of services emerged. In the case of the mitochondrion, the service offered by its ancestor to its ingestor was the use of oxygen to release energy from molecules of food, and in the case of the chloroplast the service offered by its ancestor was sugar-creating, water-splitting, oxygen-producing photosynthesis. In exchange, the ingestor offered protection to the ingested within a safe intracellular environment. In both instances this symbiosis from within, or 'endosymbiosis' resulted in a completely new, more complex type of cell with its own new style of fragile dynamic metabolic harmony never before seen on the planet.

One can imagine oneself as the ancestral mitochondrion, a free-living oxygen-respiring bacterium, engulfed by a larger cell. It is not at all clear which cell was predator and which prey. Perhaps the soon-to-be mitochondrion was the predator, or perhaps it was the larger cell. We don't know for sure. But what is clear is that one or the other was intent on abating its ravenous predatory hunger. Here, at the very birth of the endosymbiotic encounter, we once again sense the presence of interacting opposites: destruction and creation. The predator must have been doing its best to digest its victim, whilst the prey must have attempted to resist, during which communication between the two helped them discover a new, mutually beneficial endosymbiotic possibility for both together as a new unity. One of the opposites was the urge to dissolve and absorb the other, to annihilate and dismember it for one's own benefit, the other an impulse to resist being digested. Together this opened a space for communication and collaboration, creating a new, totally unexpected emergent kind of cell, greater and perhaps more aware and intelligent than either bacterial partner in isolation. The details of how this happened are almost too complex to contemplate, but the advantages were so great that soon unicellular eukaryotes swarmed all over the global ocean around 1,700 hundred million years ago.

Life Goes Multicellular

For the following billion years or so, life was mostly unicellular and was lived almost entirely in the oceans. But the first large, multicellular eukaryotic organisms appear as fossils in rocks from around six hundred million years ago. Known as *Ediacarans*, these were mostly soft, frond-like jellies, rooted to the floor of shallow regions of the world's oceans.[19] With no mouth and no anus, they must somehow have absorbed small particles of food from the surrounding seawater.

But what caused the evolution of these multicellular eukaryotic beings? Could opposing forces have been involved even here? The period just before the appearance of the Ediacarans was punctuated by a series of aptly named 'snowball Earths' – cold periods so extreme that the entire planet was covered in ice many kilometres thick, with the possible exception of the tropics where slush, not ice, might have predominated. These extreme conditions may have forced unicellular eukaryotes to evolve the animal style of multicellularity. But why?

The intense cold of a snowball Earth would have been an immense challenge. Small populations of genetically similar single-celled eukaryotes would have found themselves isolated from the extremes of cold in small refuges such as hot springs on land and small meltwater ponds on the ice. Single-celled eukaryotes in these refuges would have been forced to resist the powerful obliterating force of the cold by becoming multicellular, an altruistic condition which would have helped them to most efficiently share metabolic processes and local resources. Because the populations were small and genetically similar, destructive 'cheat' cells were less likely to prevail. One can barely imagine the complexity of the chemical communication that must have gone on amongst those single-celled beings that made it possible for them to join together in the mutually beneficial, highly cooperative arrangement of multicellularity. Successful populations would have survived to pass on the trait of multicellularity to future generations, whilst those that failed to develop the multicellular mode of life were wiped out. If this scenario is correct we see once again how the interplay between the opposing forces of stress and resistance gave rise to a new emergent fragile harmony in the biological world – to a new adventure in being and awareness which we call multicellularity.

By about 545 million years ago, multicellular animals with hard shells had appeared in the shallow oceans.[20] There were even small animals in the oceans sporting what would much later become the vertebrate backbone. By 480 million years ago the first moss-like plants colonised the edges of the continents, and by 400 million years ago these had developed into plants with vascular systems, roots and woody stems. By 460 million years ago some of the invertebrates in the oceans evolved into the first land animals. These were the first spiders, mites, springtails and millipedes. In all these domains, and in all those that were to follow after, all the way to our modern world, ecological relationships involving tensions between myriad opposites held the web of life together.

FUNGI

For an ecological community to be healthy there has to be efficient energy capture, efficient communication and exchange of information, and efficient recycling. Perhaps the fungal kingdom most easily displays some of the opposing forces required for this healthy functioning. Fungi are decidedly strange – they are multicellular eukaryotes which have made themselves into tubes by dissolving the boundaries between their cells so that their nuclei, mitochondria and other cellular constituents flow freely along the tubes, which can extend over long distances and fuse when they meet, forming a complex tubular network known as a *mycelium*.[21]

Mycorrhizal fungi engage symbiotically with plant roots. These fungi are essential for the health of almost all land-based ecological communities. The fungus feeds its plants with otherwise inaccessible soil nutrients and water in exchange for sugars forged high up in the plant's leaves by photosynthesis. This is the fundamental source of energy for much of the living world. Mycorrhizal fungi transfer sugars from plants in the light to plants that struggle to find enough light in the shade, often to plants of a different species. They also transfer signalling molecules from plant to plant. A plant being eaten by herbivores synthesises warning chemicals which it passes to neighbouring plants via the mycorrhizal fungal tubes linked into its roots, allowing neighbours to mount their own chemical defences. Thus the fungi provide biotic communities with efficient means of communication and information transfer.

Other fungi are predators. Their tubes flow into a plant's tissues, sometimes waiting until the plant weakens before killing and digesting it, sometimes killing it immediately. Yet others decompose dead bodies – these are the recyclers of the ecological community. In these interactions we see how the fungal kingdom contributes to the emergence of health and harmony in ecological communities through the interplay of the opposing forces of life-giving communion and death-dealing predation. By helping plants to enhance their energy capture via photosynthesis, by enhancing communication between species and by promoting decomposition and hence recycling, the entire fungal kingdom hugely contributes to the efficient functioning of terrestrial ecosystems.

THE EDGE OF CHAOS

Perhaps two of the most pervasive opposites which we have not yet visited are order and mathematical chaos (in which many kinds of order are layered into each other, sometimes giving a superficial appearance of randomness), and nowhere are these more dramatically manifested than in the lives of social insects such as ants. Most ants live in complex colonies in which no single individual holds the blueprint for how the colony as a whole should behave, and yet the colony exhibits a range of supremely well-adapted behaviours in relation to prevailing conditions both within and beyond the colony such as tending the brood and foraging for food. These behaviours emerge purely from the interactions between individual ants during which they stimulate each other through touch and via chemical signals known as pheromones. It turns out that the density of ants in the colony is of critical importance in evoking the coherent behaviours which have enabled the ants to thrive for almost 100 million years. When there are too few interacting ants, the colony displays chaotic or unpredictable rhythms of activity which are too incoherent to favour survival. A situation with too many ants, on the other hand, leads to strongly ordered rhythmical activity patterns which are also of little use in surviving since they are too rigid to allow adaptation to prevailing conditions. And yet, coherent, harmonious well-adapted behaviours do emerge, but only within a narrow range of densities where rhythmical patterns of activity appear which are a fruitful mixture of order and chaos.[22] This zone, known to science as the 'edge of chaos' gives the colony maximum flexibility to adapt well to new challenges, whilst maintaining sufficient order for a coherent identity.[23]

It seems likely that the entirety of the living world, from populations of individual species to entire ecosystems and possibly the entire Earth, tune themselves to the edge of chaos through such finely adjusted interactions amongst their component beings. Order and chaos – for science these are perhaps the most fundamental opposites through which nature navigates herself into a state of creative yet fragile, dynamic harmony. If this view is right, the upshot is that to survive, life must tune itself to the edge of chaos – that delicate, sometimes deeply elusive, finely balanced domain between those archetypal opposites: order and chaos.

GAIA

Finally, we come to the planetary level, to Gaia herself. If our hypothesis is valid (that harmony appears through the interaction of opposites), we would expect to find interacting opposites here too that allow Gaia to self-regulate important aspects of her surface such as temperature, acidity and the distribution of key elements by means of harmonious dynamic emergent feedbacks between life, rock, atmosphere and water. It was James Lovelock, the originator of the Gaia hypothesis (which later developed into Gaia theory) who proposed that the first truly Gaian temperature regulation might have appeared some 2,800 million years ago when microbes in the purely bacterial biosphere of those times invented water-splitting photosynthesis which removes the greenhouse carbon dioxide from the very air itself.[24] The world then was mostly ocean, so there was no shortage of water, nor indeed of carbon dioxide which was abundant in the atmosphere. Water-splitting photosynthesis was a hugely successful strategy, and soon most of the planet's ocean surface was covered by this new kind of photosynthesising bacterium.

Eventually, these photosynthetic bacteria had removed so much carbon dioxide from the atmosphere that the planetary temperature began to plummet dangerously towards a snowball Earth.[25] The situation was saved by decomposer bacteria living in the sediments at the bottom of the oceans. These microbes liberated carbon dioxide and methane by digesting the dead bodies of the photosynthesisers which had sunk down to them from the ocean surface. These greenhouse gasses then travelled through the water column back into the atmosphere, thereby warming the planet, saving it from a snowball state. Here we see how dynamic harmony emerges from the interaction of two opposing yet complementary tendencies. The photosynthetic bacteria cooled the planet but preferred it warm, whereas the decomposing bacteria warmed the planet but liked it cool. Each bacterial type gave the other what it needed but could not provide for itself, giving rise to self-regulation in a way that seems to give us clues about how all opposites should be reconciled. Basing its analogy on horse riding, science knows this phenomenon as 'integral rein control', now thought to be common throughout nature.

There are countless more processes involving pairs of opposites that give rise to states of relative harmony at the Gaian level. Perhaps the most fundamental of these are plate tectonics, which are essential for regulating Gaia's temperature within limits suitable for life because of the way they cycle carbon dioxide in and out of the atmosphere over million-year time scales. Two of the opposites we discern here are the upwelling and downwelling of huge expanses of rock. Upwellings involve the rising up of great plumes of semi-molten rocks from deep within Earth's mantle to the surface, where they solidify into seafloor basalt at the mid-oceanic ridges before spreading away horizontally on either side of a ridge. This seafloor basalt is organised into seven major plates, each quite distinct, atop of which ride the lighter continents, made of granite. It was a shock for science to discover (it all began around the 1960s) that the plates move, pushed sideways by upwelling magma rocks at the mid-oceanic ridges.[26] Wherever plates meet, immense forces of collision produce earthquakes, volcanoes and vast mountain ranges such as the Andes and the Himalayas. At one kind of collision zone, known as a 'convergent margin', one plate is pushed deep down into the Earth's depths where it melts into the magma in the process of downwelling, or subduction. The downwelling slabs of seafloor basalt carry water which they have absorbed from the ocean into the depths. Here, high temperatures and pressures cook some of the basalt and water into molten granite, which rises to the surface, cooling into the solid granite of the continents.

The story continues on the continents. Here life in the form of bacteria, lichens, mosses and higher plants help to weather and dissolve these granitic continents, removing carbon dioxide from the atmosphere, locking up its carbon atoms in molecules of calcium bicarbonate that are washed by rivers into the ocean. Here, marine organisms convert the calcium bicarbonate into their exquisitely crafted shells and carapaces of calcium carbonate: chalk and limestone. When these beings die, these shells sink to the ocean floor, settling on top of the seafloor basalt. Subducting plates of seafloor basalt then carry these chalky shells into the depths, where they melt under intense temperatures and pressures, releasing carbon dioxide which bubbles out into the atmosphere through volcanoes. Here again are two opposites vital for life. The life-assisted weathering of granite cools the earth by removing carbon dioxide from the atmosphere, whereas the release of carbon dioxide via volcanoes from the melting of chalk deep under the surface warms our surface world.

When these opposites have harmonised and the removal of carbon dioxide has been balanced by its return through volcanoes by plate tectonics, the planetary temperature has remained relatively constant for many millions of years.[27] But occasionally such periods of fragile harmony have vanished when the delicate balance between these opposites has broken down. Perhaps the most important of such episodes towards global warming took place some 252 million years ago at the end of the Permian, when it seems that tectonic activity released huge amounts of carbon dioxide into the atmosphere, triggering severe climate change and a whole series of further catastrophic environmental events that lead to the extinction of 95% of all fossilisable life forms in the oceans. This is the famous end-Permian mass extinction[28] which was the most extreme of the five mass extinctions which have occurred during the last 540 million years, until, of course, the sixth, which we are initiating.

An example of the opposite tendency, towards global cooling, took place around 640 million years ago when it seems likely that the first lichens colonised the continents, weathering huge amounts of phosphorus from the rocks which was washed into the oceans via rivers. The phosphorus stimulated huge blooms of photosynthetic algae which removed immense quantities of carbon dioxide from the atmosphere, triggering the series of three or so snowball earth episodes which we earlier encountered. Each snowball ended when carbon dioxide emitted by volcanoes accumulated in sufficient quantities in the atmosphere to melt the ice.

FINAL THOUGHTS

I've given several examples from amongst a vast number that could have been chosen to illustrate the point that I have been trying to make throughout this chapter – that harmony in nature is always tentative, always deeply fragile due to delicate, finely balanced interactions between a whole series of contrasting opposites. At any moment nature's fragile harmony can break down when one or other of the opposites becomes dominant, leading to catastrophic effects that can ripple through a given domain of the natural world until a new fragile harmony is established, often when new sets of opposites interact. One could therefore say that nature's fragile harmonies are the result of strife or tension between opposing forces that reconcile their conflicting tendencies, creating transient states of what I call 'emergent harmonious coherence' at every level of existence, including, in the last resort, within our very own human consciousness within which these enlivening mysteries are contemplated, pondered and, hopefully, acted upon to create a better world for all, human and non-human in turn.

Indeed, when we ponder them from the standpoint of our ordinary conscious minds, the opposites seem irreconcilable. But if one can discover (or be blessed by) a different, more open, state of mind, then they somehow mingle to produce a new state of consciousness, an awareness of wholeness, born out of the tension between them. This experience gives the feeling of grace, of a healing insight that might not last very long, or that might one day be permanent. It all seems to be a matter of inner experience, not at all of intellect, which is of course needed to read or hear the words and to understand them in the first instance. Wholeness needs the opposites and the opposites need wholeness – they cannot exist without each other.

And with this we reach the realm of psyche, the most difficult of all. Here mythology helps us plumb the depth of our own natures and that of wider nature herself. According to the ancient Greek myth, Harmony was born alongside two boys, fear and terror, the result of a liaison between Aphrodite, goddess of love, and Ares, god of war.[29] Thus we are led to understand that Harmony was born from the most extreme opposites imaginable, a tension which therefore runs deeply through the whole of nature's fabric. It seems that, psychologically, consciousness, the awareness for oneself as oneself of what is actually going on around and within one, can only be born out of the tension of opposites. This notion is supported by an even deeper myth in which Aphrodite is born when the lovers Heaven (Ouranos – the sky and stars) and Gaia (Earth) are separated through a complex series of events involving the castration of Ouranos by Time (Chronos), and the throwing of his testicles into the ocean.[30] It was from this separation of opposites – of heaven and Earth – that fair Aphrodite was born in the foam of the sea. She represents a knowing, a consciousness, that loves and cares for all.

Since Gaia is Aphrodite's grandmother, one could say that Aphrodite represents for us a deep erotic love of the earth and all her beings: her rocks, swirling atmosphere, waters and life. Perhaps, if each of us, in our own individual way, can reconcile these opposites – Earth and Heaven – which for me at this moment, appear as earthiness and a sense of the eternal – then perhaps Harmony and her mother Aphrodite, she who reconciles the deepest opposites and thus reconciles them all, can come to comfort, guide and inform us in this time of deepest planetary ecological crisis.

NOTES

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