Chapter 2

The resilience of Life

Survival · Retention of what works · Integration · Energy efficiency · Adaptive capacity · Frugality · Extreme adaptive capacity · Dormancy and other hibernatory states · Exploration & curiosity · Sense of self-other : Cooperation, Community, Family and Friends · Control of the external environment · Fragmentation and dis-association · Hybridisation · Ingenuity · Metamorphosis · Fire and water · Communication and persistence · Inhibition · Intelligence · Complexity, chaos & emergence · Beauty

In the sand-drift, on the veldt-side, in the fern-scrub we lay,
That our sons might follow after by the bones on the way.
Follow after-follow after! We have watered the root,
And the bud has come to blossom that ripens for fruit!
Follow after - we are waiting, by the trails that we lost,
For the sounds of many footsteps, for the tread of a host.
Follow after-follow after - for the harvest is sown:
By the bones about the wayside ye shall come to your own!

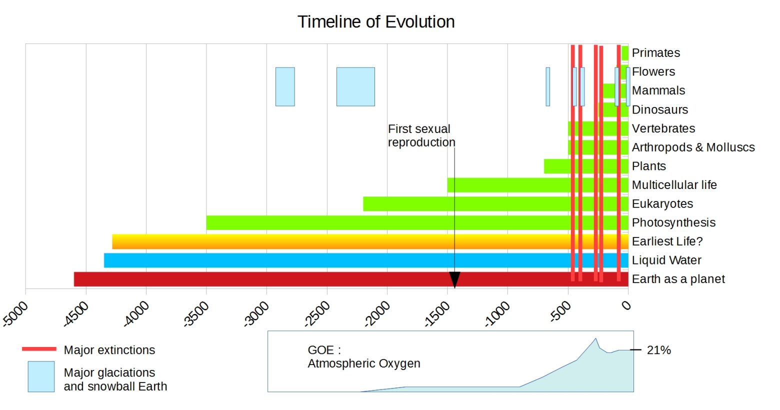
— *From The Song of the Dead, Rudyard Kipling*

"The same stream of life that runs through my veins night and day runs through the world and dances in rhythmic measures. It is the same life that shoots in joy through the dust of the earth in numberless blades of grass and breaks into tumultuous waves of leaves and flowers. It is the same life that is rocked in the ocean-cradle of birth and of death, in ebb and in flow. I feel my limbs are made glorious by the touch of this world of life. And my pride is from the life-throb of ages dancing in my blood this moment."

– Rabindranath Tagore

We have seen that Life did not enter easily into the world. A newborn baby exiting the birth canal has probably gone through one of the greatest tests it will ever be presented with in its life. In a similar but far more extreme way, new Life on Earth went through almost four billion years of repeated testing to destruction before it arrived at this present stage of development. As multicelled differentiated organisms, we hold that inheritance in every nook and cranny of our bodies and in every adaptive shift of our physiology. Two billion years of that evolutionary journey was taken up in perfecting the single cell. But more importantly in laying down the foundations for undifferentiated multicellularity. A few examples include … which proteins do what (including which chirality works best), how to convert energy and information with maximum efficiency between chemical, mechanical and electrical / electromagnetic media, how to recycle rare trace elements, mechanisms that allow fruitful symbiotic relationships and that allow agglomerations of undifferentiated cells to work cooperatively in a colony. Since then, the theme of the story has changed only slightly, the focus being about how many ways that little indestructible package can recombine, diversify, specialise, aggregate, and manifest in ever more strange and beautiful ways whilst still retaining its resilience. I find it quite amazing that a nematode can withstand forces[1, 2] equivalent to 400,000 g's. This makes this small worm no more than half a millimetre long capable of surviving being ejected out into space by a meteor larger than the Chicxulub impact.

So what does it take to colonise a newly born planet? I have listed in this Chapter a set of attributes that have collectively ensured our survival. Each of these must be viewed in the light of all of the other points on the list! It is also worth bearing in mind that specific examples given should not be thought of as constraining these principles to a particular level of organic complexity – or alternately, of (necessarily) implying that humans have inherited *all* of that capacity… Unfortunately we are not so good as nematodes at withstanding being ejected forcefully into space! However, the same general principles apply universally to single cells, primitive and complex multicellular organisms, to humans, to super-organisms such as ant or bee colonies, and even in many cases to societies. Wherever a higher organism has "invented" a



more efficient or effective way of doing something, that inevitably follows on from a foundational development at a more primitive and probably unicellular level, in a simpler and more autonomous manner with simpler mechanisms.

Retention of what works

Nature tends to invent something once, and then plays variations on that theme.

– Alexander Schier[3]

Cells tend to work on a combination of "if it ain't broke, don't fix it" and a junk room where all the unused furniture, hand tools and old vacuum cleaners are stored just in case they might be useful at some unspecified time in the future for some unspecified purpose. Provided that the overhead of keeping them is not too great (DNA replication uses precious materials and energy, and so Life being frugal has regular spring cleaning sessions) - whatever has been of use tends to be kept – for one of those "just in case" moments. We see this in so-called *Junk DNA* – all those parts of the genome that we don't understand and that seem surplus[4]. If something kept us alive in the past, it may have use in the future. So as new specialised adaptations are added that "replace" something more primitive, this is not done by literally creating something new, but by adapting what is already there. This process of adaptation tends to retain something of the previous ("redundant") more primitive, but also more robust functionality.

Using a modern analogy, one could say that those old metabolic pathways that survived extinction events are *proven technology*, and are not just to be discarded in favour of the latest gizmo. If the new adaptation is pushed beyond its adaptive capacity, a fallback response is still available – that takes our physiology, our nervous system and our conscious experience back to a previous way of being at an earlier stage of evolution. To continue with that analogy, if we developed new technology the same way our cells evolve, then all light fittings would have wiring that passed through gas pipes that are still full (the gas also being used for some other purpose such as heating), and should the electricity supply prove inadequate, the gas lights can still be turned on. Some new developments are so reliable, efficient, tried and tested (e.g. the symbiotic relationship with mitochondria in Eukaryotic cells) that they might (?) completely displace previous mechanisms. But, for very good reason, most of evolution is conservative, and not so revolutionary. Looking in detail at the level of complex multicellular organisms – such as humans – several adaptive layers of fallback metabolic states are available, that are not "normal", but they are adapt-ive and may save our lives.

In experimenting for a few billion years, Life has found that – although there is an almost infinite number of different organic molecules, there are only a few that suit Life's purpose in the most efficient and adaptable ways possible. For instance, the mechanism that allows sponges (a very ancient life form) to move by inflation and deflation of fluid cavities is exactly the same inflammatory/relaxation pathway that controls human arteries[5]. Given the importance of molecules that manipulate hydrophilic / hydrophobic boundaries (such as the lipids that form cell walls), plus basic building blocks such as collagen, elastin, actin, there must be mechanisms for generating these as efficiently as possible, and from as few and easily accessible basic building blocks as possible – or more usually the intermediate building blocks are have important functionality of their own. In fact, the Krebs cycle is exactly that. This chemical reaction that uses electrical energy to produce ATP can also work in reverse. In this mode there are a handful of molecules (and the Krebs cycle itself) common to every known form of life[6]. This fundamental tension between energy production (Krebs Cycle) vs production of proteins (reverse Krebs Cycle) is continuous through to higher orders of organisation, and visible in mammals as the energy-using Sympathetic/adrenal function in tension with the vegetative Vagal function.

Symmetry and segmentation are particularly universal attributes that we share with almost all complex life - whose genetic blueprints (along with many other associated physiological processes such as an immune system and tissue repair) have been around for at least 550 million years[7]. Thinking particularly of signalling molecules – peptides, neurotransmitters, hormones ... the molecule must be easily made from common building blocks with minimal energy expenditure. It should be stable when in use. The building blocks themselves or even the entire molecule itself should be useful for multiple and "other" purposes. It should be easily re-metabhttps://phys.org/news/2024-01-ancient-inflammatory-mechanism-sponges.htmlolised back into something useful, or easily eliminated. Its effect on the organism at all stages must be beneficial (i.e. it cannot be toxic in any situation, unless it is meant to be for e.g. immune purposes). Clearly some metabolites have to be toxic – carbon dioxide and urea being the main ones. But even those are not hugely toxic unless they are allowed to accumulate. And both are proactively used and can be fed back in at low concentrations with some beneficial effects. So one way to bring a person back to consciousness after concussion is to place their nose in a hole in the ground, because CO2 levels in the hole are always slightly elevated, and CO2 is an important part of blood composition – that regulates the destructive (oxidative) burn that arises from excess oxygen saturation – because oxygen is extremely toxic to life. It is the most basic and apparently primitive processes that underpin everything, because the requirement of single cells to metabolise largely determines the metabolic processes of larger, more complex and differentiated life forms such as humans.

A question rarely asked is – why does life of all kinds use exactly the same molecules as building blocks, *and why use those specific molecules and not others*? One recent finding[8] is that the spiral shape of proteins creates a pathway for electron transport that will carry electrons with one spin direction more easily than electrons with the opposite spin, so maybe there are biological functions for spin polarisation (chirality).

> *"The photosynthetic machinery produces high energy electrons that should quickly react with other atoms within the complex. However, because of the unique [spiral] molecular structure and quantum properties of biomolecules within the living system, the high energy electrons are transferred with 100% efficiency within the photosynthetic core. This is the opposite result of what was expected from physicists, who generally regards the cell as a disorganized, chaotic environment that should be wholly inhospitable to maintaining quantum states. However, because of the unique structure of biomolecules ... the cellular machinery is observed to be able to transmit high energy electrons*

with 100% efficiency---a level of efficiency usually only seen in superconductors."

Let's repeat that figure … 100% efficiency. It would even seem that very specific molecules are required so that they have the properties necessary for life to be sufficiently resilient. This could be why almost all known single celled organisms use almost exactly the same – and almost as many - neurotransmitters as a human brain. The above paper suggests that proteins have been selected as a useful class of biological building blocks precisely because they are chiral. As another example, research carried out into the functioning of the nervous system[9,10] has shown that the electrical action potential in nerves is transmitted within a mechanical pulse that shifts lipid structures from quasi-crystalline to liquid and back again as the charge passes down the nerve[11] producing an effect rather like a cricket ball passing down the neck of an ostrich. The lipid molecules have very specific mechanical properties that allow this to take place, and only have those properties in the range of temperatures in which life metabolises. It is likely that this effect is related to the way that water enters a semi-crystalline and strongly ionised state in the presence of a hydrophilic surface[12].

Having experimented for a maybe a few hundred million years, Life found that certain very specific structures and molecules gave it the ability to function in ways that are most stable, reliable, integrable on multiple levels, and energy-efficient. And those "decisions" will have been very much determined by the way those specific organic molecules interact with water, and the way that they allow electrical charge to move through them when in a hydrated state. For example, microtubules are critical parts of even early cells, both internally as cytoskeleton (and other functions) and externally as means of locomotion (flagellae/cilia). And we know that development of the human embryo, from basic mitiosis/cell division[13] through to the organisation of the growing brain is wholly dependent on these apparently simple organelles[14,15,16]. Microtubules are also potential locations of consciousness in living tissue, since the tubes are exactly the ideal width for quantum states to remain stable. Dana Zohar[17], and later Stuart Hameroff and Roger Penrose[18] have identified them as being theoretically capable of sustaining Bose-Einstein condensates throughout a single organism (such as a human being), and therefore form one possible basis for consciousness as a coherent quantum field. The microtubules' multiple functionality – internal Bose-Einstein consdensate, external fluid pump[19], rigidity as cytoskeleton, spiral whipping motion when moved as a flagellum that makes it ideal as a means of locomotion (etc?) - is a wonderful example of biological efficiency and frugality. There are so many reasons why using one structure for multiple purposes (instead of three or four individual dedicated structures) is far more efficient. The capacity to manufacture them is simpler, the raw materials fewer, and the energy to make and maintain them is less, etc. The integration of biological function across organelles, cells and systems becomes far easier (and more energy efficient). A more (unnecessarily) complex structure would be harder to maintain in health.

As tool-makers and tool-users, we are very familiar with mechanical devices, and often unwittingly use these linear devices as an analogical way of understanding the world. Simply put, the machine is a very poor analogy for a living cell, and the slightest temptation to view the living cell as a machine should be vigorously rejected. The example of microtubules above should give several good reasons why this is so. A better analogy of a cell organelle is perhaps how someone in the stone-age might have viewed a piece of flint as it nestled in the Earth beside a dandelion and a celandine ….

> *Grandmother said to me: "Remember, child, that plants have been here since Mother Earth became Mother. And we are her daughters. We came later … They contain the sacred memory of our roots."*
>
> *~Author unknown*

It is worth remembering that the evolutionary sequence of development, took us from protists/extremophiles to Prokaryotes, to photosynthesising plants, to fungi, to Eukaryotes, to animals. So, although life tends to evolve particularly useful attributes (such as eyes) in several different ways, our cells may therefore retain at least some of the capacity of our precursors – fungi, plants and undifferentiated single and multi-celled organisms like sponges and coral. One interesting question is – how much of the capacity of these precursors do we (as human beings – or more to the point, our cells) still retain? For instance, plant cells are pluripotential, and possess an extraordinary range of senses. A plant can detect[20] light, gravity, moisture, trace nutrients and salts, toxins, airborne chemicals, physical contact, and vibrations (such as sound). And they can identify whether another plant is of the same species – so many plants exhibit social behaviour based on kin-selection (see later). Do our cells (that evolved from the organisms that plants evolved from) also preserve and contain some of that pluropotentiality, and how might they be using it? Certainly, plants have conserved their own primitive responses. The metabolic answer to an aggressive pathogen *Phytophthora palmivora* is the same in tobacco and liverwort, even though their evolutionary line diverged 400 million years ago[21]. How old *are* these immune responses? To quote the authors of this research:

> *"Fossil evidence shows that plants have engaged in close-interactions with microbial life forms throughout their evolutionary history. Our research has uncovered a common set of pathogen-responsive genes shared in early-divergent land plants and more evolutionarily young flowering plants, which are all likely to have been critical for the expansion of plants onto land. Further comparative studies focusing on other distantly related land plants and their aquatic algal predecessors should reveal even more information about the evolution and role of these vital gene families."*

Integration

"In nature we never see anything isolated, but everything in connection with something else which is before it, beside it, under it and over it."
— Johann Wolfgang von Goethe

I find myself regularly telling people in my clinic that their body is not a Landrover – when they talk about their jaw or their spine as if it is totally unrelated to any other part of the body. The mechanical analogical model of the body[22] is so universal in Western cultures that it has become subconscious and is applied to everything. It is also the end result of a reductionist philosophy that says we can dissect and study the parts using "science", and then what we reconstruct from the parts must be equivalent to the whole. There are so many ways in which the body is an integrated whole, it would take several books to do justice to this topic. On a cellular level, it is impossible to distinguish between processes to the extent that cause and effect can be indefinable. The cell wall and inter-molecular forces (not least those between water molecules[23] create physical forces of contraction and repulsion[24], to which are added active physical movements of actin and microtubules – creating changes in mechanical tension across cell membranes, and driving vital movement of fluid during gestation and later in life[25]. As mechanical forces on membranes affect the molecular spacing, they also change membrane permeability to ions (i.e. to electrons, and cations, mainly Na, K, Ca and Mg[26]). A change in the diffusive motion of electrical charge and ions changes the pH, which affects membrane hydrophilic/phobic relationship to water. All of these changes (electrical charge / membrane potential, pH, ionic composition) affect the mechanical properties of the membrane. Notice we have now come a full circle. So far I have only described relatively static, local and non-quantum processes. But the cell is also heavily dependent on quantum effects, is interconnected internally and out beyond the membrane wall at a quantum level via microtubules and actin fibres; and there are dynamic process which also interact in a similar way to those already described. The mechanical components (microtubules and actin fibres) also coordinate and orchestrate all cellular activity via the centrosome, and link every cell mechanically via the connective tissue matrix to macro-structures of the body (such as the skeleton)[27,28]. And there are less direct means of communication. Cells generate biophotons and other electromagnetic spectrum activity, and also appear to be able to detect and respond to these over considerable distances.

"All things are connected like the blood that unites us. We do not weave the web of life, we are merely a strand in it. Whatever we do to the web, we do to ourselves."
— Chief Seattle

This level of integration is carried through larger and larger scales up to an organic level as large as a blue whale, or the 5000 year old baobab trees of the Makgadikgadi Pans, or the single supercolony of ants that lives along the entire Mediterranean coast of southern France. It is true that some processes do not communicate particularly quickly over these larger distances except in specialist communication cells (such as myelinated neurons). But they still do communicate. And that communication extends out beyond the cell, into the organism, and then through into the group, family, society, ecosystem, and entire planetary biosphere via subtle shifts in electrical charge, electromagnetic activity, mechanical vibration (such as sound), and smells/signalling molecules and molecular charge cascades propagating through structured cellular water[29]. The world is more connected both through a Bee's waggledance, or a transatlantic telecommunications cable laid on the sea floor (which is an extension of the human communication system)[30]. In so far as life is concerned, it's all information, whether it's electrical pulsations, mechanical shifts in the cell wall or the position of organelles, or ionic changes related to chemistry and pH (etc). And Life exists in a three-fold harmonised interaction between matter, energy and information[31]. This information is transcendent, in that Life – as an information-based process - recognises information in ways that are well beyond the mathematical fudges inherent in "Artificial Intelligence". The universal principle of "equivalence" (isomorphism) is unsolvable in a general mathematical form – being in the category of hardest and most intractable computational problems[32]. Yet we apply it every second of our daily lives as we recognise similarities in our environment. Simply put, intelligence and consciousness as applied to sensory awareness and processes of *recognition* - of the kind used by even the simplest of living organisms - are not mathematical or any form of calculation.

Cells regularly translate (transduce) between different kinds of energy – to the extent that one could almost say that cells are so adaptable *because* they are able to convert information between electrical / electronic, chemical / ionic and mechanical / motion / force. There are fundamental questions as to how much communication – and particularly coherent communication – actually exists in the natural world. Schroedinger assumed that Quantum entanglement is restricted to small, simple systems (e.g. pairs of subatomic particles). Which is why he chose a cat as an example in his famous thought experiment. But it appears that this was an incorrect assumption :

> *The ability of an object to show quantum behaviour, such as interference, superposition and entanglement-induced correlations, has nothing to do with how big* [or small] *it is. Instead it depends on how entangled it is with its environment*[33].

If Schroedinger's cat was entangled before it entered the box, then its quantum state will collapse in response to events outside the box, even if they were to happen on the other side of the universe and carry no obvious causal relationship. The questions remain unanswered, partly because whatever level of entanglement exists obviously affects all observations in ways that are difficult to control in complex systems (such as what goes on in the experimenters mind!). Each change – be it through instrumentation or captivity or stress, or feeding regime, or a million other factors – including the experimenter's intention, attitude and gender – potentially carries weight that affects the experimental outcome on a typical white laboratory mouse. The likelihood is that entanglement is as universal in a biosphere as are mycelia in the soil of a forest.

Integration is particularly difficult to quantify – it creates qualitative changes that can only be observed in its wholeness, and cannot be observed in a dissected specimen.

And wholeness for an animal whose existence depends on both an internal environment-ecosystem and an external environment-ecosystem cannot be observed in its integrated wholeness if that animal is removed from one of those ecosystems. One relatively simple example of integration relates to the sense of touch. We have so far identified a handful of different Low Threshold Mechanoreceptors (LTMRs) that are sensitive to specific kinds of non-painful stimuli[34] (i.e. contact that does not damage tissue). Some of these are located around hair follicles, being responsive to light touch. On non-hairy (glabrous) skin there are also :

- Meissner's corpuscles (skin movement, rapidly adapting low frequency vibration and fine touch)
- Ruffini endings (slow adapting skin stretch, which also feeds into micro-proprioception)
- Pacinian corpuscles (high frequency vibration and rapidly-adapting strong pressure)
- Merkel cell-neurite complexes/discs (textural discrimination, slow adaptation, light touch)

The point is that everyday experience of the subtleties and capabilities of touch is far more than can be accounted for by these (Chapter 3) – it is far more than the sum of the parts. It may well be that we have not yet identified all of the sensory system. But the vast range of touch-sense capacity that we have is an *integrative* one (see chapter on Senses). Stimuli from these specialised nerve endings are interpreted holistically, continuously with other senses (such as the proprioceptive senses that provide "where" to complement the "what", that along with auditory information are processed in the visual cortex). All this occurs with a nuance and precision that cannot be attributed to the kind of simple linear systems that are to be found in the man-made objects we are familiar with, or with arrays of supposedly equivalent man-made sensors.

> *A recognised fact, which goes back to the earliest times, is that every living organism is not the sun of a multitude of unitary processes, but it, by virtue of interrelationships and of higher and lower levels of control, an unbroken unity... For man also, in health and sickness, is not just the sum of his organs, but is indeed a human organism[35].*
>
> *Hess W. (1949) The central control of the activity of internal organs - a lecture given on receipt of the Nobel Prize.*

So a reductive analysis of reduced parts may be useful in some ways, but the mechanoreceptors in your fingers cannot be compared to sensors in a man-made device (which *do* work in a disconnected fashion). Reductionist descriptions of life bear little relationship to the way that the organism works as an integrated whole. The current fashion for thinking that the brain does everything (or that specific parts of it have a specific and unique function) is the result of a culture that does not think of intrinsic wholes, but thinks of parts that are (re-)assembled (see Chapter 6). Consider that this holistic principle of "the *sum is greater than the parts*" applies not just to the sense of touch (which we can *experientially* investigate), but to every biological process and structure – mechanical, chemical, neurological, systemic, homeostatic, responsive, local/cellular… *everything* is fully integrated. And were his not so, we would be a very inefficient organism, and would have fallen out of the tree of life like a stoned koala bear[36]. It should not be surprising that activities reminiscent of abnormal mental states such as schizophrenia and psychosis are visible in the activity of isolated stem cells (i.e. of the immune system)[37]. Raising the interesting chicken-and-egg question as to whether mental states trigger shifts in the behaviour of immune cells (and the entire immune system) or whether it is some kind of aberrant immune system activity that induces a loss of mental homeostasis – or whether both are responding to something else. Or maybe some multi-directional systemic combination of factors is at play that may be observed and identified when one isolates social behaviour or stem cell behaviour? Or (more likely) all of the above.

> *"Whatever affects one directly, affects all indirectly. I can never be what I ought to be until you are what you ought to be. This is the interrelated structure of reality."*
>
> *— Martin Luther King, Jr*

Another example of integration is the way that disturbances in the gut microbiome are now being implicated in almost every illness, from autoimmune problems through to autism and schizophrenia. A reductionist view then considers the gut to be central to everything. A more integrated and holistic viewpoint simply notes that when one part of the organism is out of balance, other parts are also out of balance, and no specific part of the organism can be considered to be primary. Issues of causality (where it all started) are harder to define. The upside of this observation is that many (if not all) illnesses and imbalances do not necessarily require that we identify the exact cause. Rather, all that is needed is that one part of the organism (e.g. the gut) is provided with some help and brought into a healthier state, and then the rest of the organism has a better chance of also rebalancing and reordering itself. The fact that the Autonomic Nervous System is comprised of both *efferent* (control fibers from the brain) and *afferent* (sensory fibers returning to the brain) has been known for many years. However, the way that viscera inform brain and brain informs viscera is a mutual arrangement far more than a top-down arrangement. Whilst modern medicine has veered towards specialisation, biological systems are so integrated that they cannot be separated into parts and the parts then re-assembled to gain a knowledge of the whole. Something will always be missing when a reductionist way of thinking is directed at a fully integrated living system.

Energy efficiency

Income twenty shillings, expenditure nineteen shillings and sixpence – result happiness.

Income twenty shillings, expenditure twenty shillings and sixpence – result misery.

Mr Micawber from David Copperfield (Charles Dickens)

One of the most basic ways any organism has to ensure its survival is to minimise its energy usage, to maximise what it can get from each unit of energy, and to optimise its energy storage and transport and availability. On an organelle level, some chemical-energy exchange processes are so efficient that they are possibly 100% efficient[38]! Quantum effects[39] are particularly useful in this regard because they are inherently energy efficient, and through quantum tunnelling make energy available when otherwise it would not be available. Photosynthesis, the direct or indirect powerhouse of much of the living world, is a process that relies on quantum tunnelling. We have found that it begins with only a single photon[40] of light(!) - a response efficiency of literally 100%. A recent study[41] has also discovered that plants absorb and convert sunlight with over 90% efficiency by adapting themselves so that the photons (literally) take the most efficient route possible to the absorption centres. This is the equivalent of a quantum computation for (e.g.) optimising the shortest road distance between two towns. And it is only possible in relatively large volumes of living matter if they are in a coherent (Bose-Einstein condensate/ laser) state for significant durations of time. So far humans have not created this kind of mechanism in a laboratory unless we cool the materials down to a temperature close to absolute zero to create cryo-superconductivity. If just one relatively obvious example has been identified, it rather begs the question how many more biological processes employ quantum states, and whether living tissues or certain structures within them are actually room temperature superconductors.

Necessity is known to be the mother of invention, and so every last scrap of energy in an organism is used to its utmost potential. Research into Heart-Rate Variability (HRV) has shown that the mental-emotional state of quietly grateful appreciation optimises the metabolic systems of the body, implying that this is the mental-emotional state that we were "designed" to be in. Probably explaining why dogs are so healthy compared to their owners. Exactly how it does that is an interesting question. Perhaps one answer can be found in spontaneous synchronisation – a phenomenon first observed in clocks by Christian Huygens in 1657. Similarly oscillating systems tend to fall into synchronisation because this optimises their energy usage. Many instances of spontaneous oscillator synchronisation have been found in living processes, including circadian rhythms, the heart, intestinal muscle peristalsis, insulin secretion, menstrual cycles, the brain, ambling elephants, and fireflies – to list just a few examples. This synchronisation is also to be found in the pressure-pulse motion of fluid within the elastic walls of the vascular system, which optimises its energy usage under specific conditions, requiring about 15% less energy[42] to move the same amount of blood. The specific conditions are a complex interplay of heart rate, elasticity of the heart and major vessels, and rhythmic (sympathetic) contraction of the vascular walls. It is likely that the pericardium, an organ closely tied to emotional state, particularly love and vulnerability, also plays a part in this[43].

Maintaining a balance of energy availability through a day or seasonal year[44] is no small thing. Many of the larger animals and apex species store energy as fat (whales, bears, seals, otters e.g.) and then rely on that to fuel them through the winter, and often through critical phases of the reproductive cycle. The balance is delicate. There comes a point with fat storage (in land animals) at which increased weight and reduced mobility itself becomes a survival threat. And when living off accumulated fat, energy expenditure has to balance out against energy storage until food becomes available once again. This principle runs deep – in that at every moment the body is attempting to optimise its energy expenditure locally and through its common systems *and* through its expectation of seasonal food availability; and will not remain in a high burn state any longer than it deems necessary.

Energy optimisation is found in relationship between cells and organs and whole-body systems, in homeostatic mechanisms and all aspects of physiology, and in structure. One example is the way that bones are constantly re-working themselves to optimise their strength-weight ratio to suit demand – so that we do not carry any more bone weight than we need. Or take the way that epithelial cells adopt a hexagonal / pentagonal ("scutoid") stacking geometry[45] that optimises energy expenditure during movement (in a manner reminiscent of the way that adjacent bubbles will always optimise stored tensile energy, to produce typical bubble geometries). Or another example is the way in which the brain's signalling is oscillatory[46] (as are all organic gestures[47]) – which allows for global shifts in mode to take place with minimal (or even zero) expenditure in energy. Yes – individual neurons require energy, but even these are intrinsically oscillatory, and so their energy demand is minimised, particularly under high excitation. So although the brain can take up 30% of the body's energy at any one time, this is still carried out with the utmost possible efficiency. Or take the way that many life forms use the Golden Ratio (Phi 1.618034), the most irrational number, to optimise their surface area. Using this ratio, leaves grow in a pattern that intercepts the maximum possible amount of sunlight. Like many of the "attributes" I am listing, these statements appear in retrospect to be so obvious as to be out of a children's encyclopedia. But the wider implications are rarely considered.

Similarly for every living organism, the days and seasonal years are divided into activity and rest; so energy is also conserved by periods of rest. This has been a feature of complex animals for at least a billion years, having evolved well before the advent of a central nervous system[48]. Rest is a time of recharge, and the particular nerves that becomes more active in times of rest – the Vagal or Parasympathetic nervous system that arises in the brainstem – are also called the "Vegetative" system. Rest-recharge is even inherent in normal motion, and whenever muscles relax every (ten times every second) they are recharged with fresh ATP ready for the next contraction[49].

> *We know now that nonequilibrium, the flow of matter and energy, may be a source of order ... we begin to have a glimpse of the road that leads from being to becoming.*
>
> *– Prigogine & Stengers[50]*

A small amount of consideration suggests that the more hard-wired local physiological interrelationships (if such things truly exist as direct analogues of man-made machines) must also be further optimised by a more regional or global intelligence. Any animal or cell that did not evolve to do so would have been first against the wall in a time of famine. So even in times of plenty, energy is not wasted. The distributed intelligence system in a modern car or robot in which local sensors control local processes, but are modulated by central processors – is (at least in the case of Robotics) directly copied from biology. And the human habit of (e.g.) manufacturing single use plastics, thus wasting energy and resources – is a very very poor survival choice for any species that wants to last any significant timespan, and is total anathema to any self-respecting amoeba. Human civilisation, particularly since the industrial revolution, has operated on a massive energy deficit largely supplied by carbon that had been stored in the earth for several hundred million years. Much of this has been used in ways that is non-cyclic – i.e. energy does not recycle between different uses or users – and it is only systems such as heat pumps or conjunctive use power schemes that even begin to attempt to use energy more efficiently. Economic patterns have similarly been disconnected from the ways that Life has found to survive. Money has increasingly flowed out of local economies into large global funds and into offshore tax havens – whereas the most efficient usage of money, like energy, requires that it is re-circulated and re-used locally as living organisms have learned to do. i.e. the organisms that have survived three and a half billion years of winnowing have have learned to do. Looked at from a biological perspective, human greed and particularly excess accumulation of wealth and money (energy) transaction systems that cream off a high tariff (such as bank loans and credit cards) are likely sooner or later (but a lot later) to kill us all off.

Adaptive capacity

> *In the midst of winter, I found there was, within me, an invincible summer. And that makes me happy. For it says that no matter how hard the world pushes against me, within me, there's something stronger – something better, pushing right back.*
>
> *– Albert Camus*

What must be understood from the start is that – there is hardly ever any fixed environment in which life might continue undisturbed. There is no single optimum state of balance which provides an easy and stable compromise to be reached that is universally applicable. Many compromises have to be catered for, and energy and resources transferred intelligently to meet whatever combination of challenges might be present at any one time. You can never guarantee that life will stress you in one way and still be kind to you in all other ways! So Life must be able to enjoy sustained periods of ease and plenty, and then be able to find the capacity to deal with many challenges all at once. This is quite visible in hunter-gatherer communities, who on average play, sing and socialise for 12 hours of their waking day – in a normal year – for the most part devoting only two or three hours to gathering food. Then, if they are faced with a drought that demands a journey of a thousand miles to find new hunting grounds, they have spare adaptive (time) capacity to do so. An organism that does not have adaptive capacity in its normal everyday existence is a dead organism as soon as the going gets tough.

So adaptive capacity (or more exactly, **spare adaptive capacity**) – our reserve capacity (or "slack") to deal with unusual situations – is a fundamental requirement for any life that is capable of being self-sustaining for long periods of time. It is possible to think of adaptive capacity as internal homoeostatic capacity – and indeed, for very primitive cells with no ability to move, this may generally be true. However, it goes much further. With movement, the external environment – either its choice (through moving towards more amenable environments) or its adaptation (as organisms quickly learned how to modify their local environment) becomes part of the homoeostatic process.

In truth, there is no absolute and optimum state of balance, because each moment a cell – or a human being – is in a different situation, requiring a different physiological balance. *Different stages of digestion, with differing concentrations of amino acids, sugars, major ions (e.g. Calcium) and trace elements entering the blood stream. Aggressive organisms that challenge the immune system from the air, the skin or from inside the body. Changes in physical activity requiring different blood and lymphatic circulation, different oxygen demand and different production patterns of ATP. Changes in mental activity requiring more or less blood to the brain, and causing different emotional states – which in turn are related to different physiological states. Old injuries and infections still causing some load on the body. Changes in light/dark, warmth/cold, human company or solitude, oxygen and carbon dioxide levels in the atmosphere, posture, gait, relaxation and alertness…* all of these (and more) demand certain physiological responses, and therefore, homoeostasis has a different meaning in each case, and in each combination of cases. Homoeostasis is not one absolute state, but rather, we can allow a certain amount of variation in our peripheral (or even core) temperature, in our blood cell count or Calcium saturation, and in every other physiological marker… yes, for each there is an ideal, but that ideal is always in the context of everything else.

Given a single stressor – be it a lack of food, changes in salinity or dissolved gas content of the local (fluid) environment, attack by other organisms, build-up of waste products locally (because they are not being adequately removed by natural processes), temperature stress, an argument with the neighbour, etc… we have evolved tried and tested responses. To take one example, "normally" the human heart beats somewhere between 50 and 70 times every minute (bpm), and when we get "stressed", it can potentially run at more over 200 bpm – typically (e.g.) in the case of Olympic downhill skiers or Judo contestants. So the ability of the heart to change its rhythm is one of many adaptations – and the ability of the heart to reach a very high rate (or not) is a measure of the adaptive capacity of that particular organ, and the health and vitality of the whole organism/body in supporting that (along with any other activity that comes with it). Adaptive capacity requires that all systems of the body are able to function normally over as wide a range as possible, and that the adaptation of one system is fully met by the co-adaptation of all other systems. It would be of no use to have all this blood circulation if it were not matched by increased oxygenation in the lungs or increased release of energy (or increased use of that to create ATP), or capacity of the muscles to absorb and use ATP and dispose of waste metabolic products… etc... The heart's beat is assisted by many other processes – the variation in blood viscosity, the opening or closing of the arteries by the sympathetic nervous system, the elastic pressure-volume storage of the major arteries and veins, the rate at which lymph re-enters the plasma, the beat-by-beat balance between fluid entering and leaving the heart (requiring appropriate elastic compliance of the major blood vessels)… to name just a few. Everything is optimised so that as little energy is used as possible, and so that there is always - except in the most extreme of circumstances - something kept in reserve.

Homeostasis is also an expression of adaptive capacity – particularly so when the whole body physiology reorganises contingently to maintain homeostatic balance in a specific environment. So for instance, although someone born in low lying terrain would rarely adapt as well as a native to altitudes in excess of 2000m, it is possible for most people to spend two weeks acclimatising in Cuzco, and then be able to move around easily at altitudes in excess of 4500 metres. Similarly, regular bathing in cold water changes blood flow, often with a very positive effect on immune function. My personal experience is that (having been badly affected by heat and sun in my early life) several years working in deserts, sometimes over 40˚C, has left me less likely to suffer sunburn and far more tolerant to heat – an acquired adaptation that has persisted now for several decades.

The body can also adapt to the strangest of diets and to varying levels of background stress. These adaptations require (amongst other things) significant shifts in the balance - and even the meaning – of neurotransmitters. The wide personal variation in what can be adapted to and what cannot is a strong indication that there is no such thing as an average person or a typical metabolism.

> *It is no measure of health to be well adjusted to a profoundly sick society.*
>
> *– Jiddu Krishnamurti*

Another aspect of adaptive capacity is **genetic resilience**, or morphological adaptability. This allows a single classification (e.g. an Order) of organism to dominate because it can adapt to many different ecological niches. Sauropods (dinosaurs) successful dominated Earth's ecosystems for 100 million years because they were so anatomically adaptable. Grasses are another example of this kind of resilience. The ability to morph successfully requires that the basic body plan and metabolic arrangement is very resilient, and that this is not too closely tied genetically or otherwise to external form. It appears that corals are not dying out with bleaching events, but as a species are reverting to a morphology and behaviour they last used some tens of millions of years ago. In a similar manner, metabolic adaptive capacity allows adaptation to a wide range of physiological demands without overstretching the stability of the core organiser. The commonplace belief that these many arrangements of inherently stable, adaptive and resilient organism can result *purely* from *accidental* errors in DNA duplication over just a few hundred generations begs many questions.

Homeostasis and the balance of energy

> *Happiness and freedom begin with a clear understanding of one principle: Some things are within our control, and some things are not. It is only after you have faced up to this fundamental rule and learned to distinguish between what you can and can't control that inner tranquility and outer effectiveness become possible.*
>
> *– Epictetus*

Having talked about adaptive capacity, it's important to bring that back to earth by pointing out that life adapts around a fairly stable normality. A few extremophiles and the family of water bears (*Tardigrada*) have adapted to a vast range of possible environments, but even they go into hibernation if conditions become too unsuitable. For most life there is a very narrow band of availability of energy and raw materials, outside of which there is no life possible. The total energy coming in must on average equal total energy expenditure. If there is spare, there may be some capacity to store it, but if that is carried around (rather than deposited in a grain silo or refrigerator), there is an increasing expenditure of energy carrying that excess mass of fat. So generally, there is a limit to how many calories or water can be taken in and digested at any one time, a limit to that internal storage, and that availability of energy from inside storage and outside availability places limits on the kinds of activity possible. And that in turn determines (amongst other things) the climatic range in which we can live[51]. One can sense that the whole thing is delicately balanced. Some inputs are relatively stable – and for oxygen-breathing animals (oxygen is one part of the energy supply), atmospheric oxygen normally has quite narrow limits, being at most 20.95% in dry[52] air, falling to less than 14% at about 4000 metres above sea level. However, there is a noticeable reduction in oxygen availability in cities, not because oxygen levels are particularly low, but because Carbon Monoxide, Carbon Dioxide and Nitrous Oxide levels are high – thus reducing absorption efficiency (and Nitrous Oxides and other pollutants also adding "oxidative" stress, making oxygen more inherently toxic). A study in Ukraine showed that three times as many urban children (compared to those living in rural areas) had measurable blood oxygen saturation deficiency[53].

In contrast, nutrition and water for animals and sunlight for plants is highly variable. It is instructive to watch a few of the "Naked and Afraid" TV episodes to see how quickly fat reserves can deplete, strength start to drop, and how eating protein can reverse that very quickly. So humans and all mammals (whose metabolism cannot be shifted so easily into non-seasonal dormancy as can that of reptiles) require a fairly regular input of food. If you think about ingestion, including necessary minerals, trace elements, water and proteins, it is tends to be episodic, so for land-based animals who cannot float a vast stomach in a suspensory sea, there is necessarily a limit to what can be taken in at any one time. Therefore a regular access to food and water is a survival issue – of relevance to our future discussion of the Autonomic Nervous System (Chapter 7). The homeostatic issues are complex. Excess sugar release into the blood stream is pathological (diabetes). All that calcium also has to be buffered by absorption onto bones followed by slow release, so that blood calcium levels remain stable. Too much oxygen circulating round would increase free radical oxidative load and cause cell damage. In contrast, plant-browsing animals have a less episodic calorie intake, browsing continuously for several hours every day, with ungulates having several stomachs to process the (literally) continuous throughput of vegetable matter. Plants themselves have a crafty way of regulating their energy input. By using the green of chlorophyll they reject the peak energy of mid-day sunlight[54] and therefore take in a more regulated blue/red light over a maximum number of hours in the day. So it is interesting to note that *stability (or reliable availability) of energy/food* is given a higher survival priority than total absorption efficiency. This can be made more sense of on a personal level if one considers that it is far better to have a regular supply of a small amount of food throughout the year – than to have a vast feast at Christmas and several months of no food at all.

In this light, it is not so surprising that agriculture (large crops could be stored and provide a reliable regular supply of food over winter months) was so attractive to our ancestors – even if the food quality and variety (providing vital trace-elements and phytochemicals) was less than that available to a hunter-gatherer. Foraging was initially as important as agriculture, and Bronze Age people used between 100 and 200 varieties of wild plant for medicine, food and wood/fiber. It was only later that the availability of foraged plants and meat reduced and we became dependent almost entirely on a very small (genetic) variety of agricultural crops. Hunting was originally aimed at the largest animals possible – such as mammoths – because this is a far more efficient way to obtain food. Killer whales had a similar strategy, and were in an ecological balance with their prey – the large whales – until humans became greedy for whale oil in the 19th century. It took hominids/humans about 1½ million years to gradually over-hunt a successively smaller size of prey until the average size of available game reduced to that of a small antelope. At which point we began to domesticate animals and grow crops, because that was easier than trying to hunt such small animals or search for increasingly rare foraged plants for food. Which in turn led to the invention of large urban areas.

But marginal farmers all over the world still forage to supplement their diet, and therefore tend to have a far healthier and varied diet than a supposedly well-fed typical urban family. It is only in the past 50 years or so that the variety of food we eat has plummeted even further as industrialised agriculture has selected a small number of crop types and continued to hybridise them for maximum volumetric production. But quantity is not the same as quality, and signs of malnutrition are now being seen in urban populations who eat high carbohydrate (associated with very poor quality fat) processed food diets. Bodies with low nutritional input give out constant hunger signals (leading to more eating), store fat (because biologically they are experiencing a famine), and tend to have high cortisol (leading to various stress syndromes and associated physical pathologies including cardiac and vascular diseases) because low availability of nutrition is a survival issue. In contrast, even in modern Europe it is possible to find the remnants an ancient tradition of foraging for herbs and mushrooms in rural areas of most countries. This was largely lost in my own country, the UK, but now seems to be returning.

Frugality

> *In the flippers of whales are the exact same bones that are in your hand. Under the skin we are all kin. We are organically related. We are family. This is the truth of the matter.*
>
> *– Carl Safina*[55]

Frugality is the left hand of energy optimisation and redundancy; and relates to the mechanisms and processes necessary to adapt to a very wide range of different potential stressors *whilst also conserving as much raw material as possible*. Frugality finds its human equivalent in a thousand years of near-empty larders – that have demanded superhuman efforts of inventiveness in the kitchen, and produced dozens of different ways to make something delicious out of just flour and water.

Frugality is everywhere. It occurs at an evolutionary level – for instance, in the way that basic building blocks (proteins, enzymes, etc.) are constructed in the body. There is no need to reinvent the wheel, although nature will do that if necessary for particularly important attributes – e.g. the convergent evolution of eyes from several different origins..

One example of frugality is that heme (part of the haemoglobin molecule that transports oxygen into the body of animals) comes about through a very small adaptation of chlorophyll, the molecule that is central to photosynthesis in plants[56]. Frugality is also apparent in the way many micronutrients are metabolised and recycled – rather than being excreted. For instance, copper is a vital trace element that ensures that iron is attached to haemoglobin (thus preventing anaemia), and which strengthens all connective tissue in the body – including blood vessels, and is vital for the formation of bones. Provided there is no particular reason why the copper is being lost from the body, 2 milligrams a day for a couple of weeks is enough to last about a year, as it is stored in the liver and continuously recycled.

Frugality also leads to Wolff's Law – the fact that bones will strengthen themselves only *exactly* in the places where they are insufficiently strong. Given just a small amount of loading in excess of a bone's capacity, micro-fractures generate high electrical charge potentials, inducing extra bony growth ("Wolff lines") that strengthen the bone in exactly the right way to make it stronger in the directions it is being loaded.

Frugality may sometimes be at odds with the "emergency" adaptation of **redundancy**. For instance, it is very inefficient to continue to make any chemical transformation if some other available organism does that as well. Some of the digestive bacteria that we host have been with us for many millions of years. So we no longer produce certain enzymes or immune responses because the bacteria can do that for us. Even tapeworms – probably endemic in evolving primates for several million years – actually assist the immune system of the intestines, and regulate inflammation. One of the biggest burdens carried by living organisms is DNA, and – symbiosis/parasitism being a common adaptive trait - it appears that the more parasitic an organism is, the less of its own DNA it needs to carry. Perhaps obvious for viruses, but less obvious for parasitic plants, who can discard astonishingly large swathes of genetic material[57]. More on the implications of this for defining an organism's identity in Chapter 3.1.

Frugality may even extend to something like cold fusion. There are numerous studies of elemental balance in living organisms that have thrown up inexplicable inconsistencies. In a 2012 article[58], Biberian reviewed all the evidence, and it appears that a wide range of "impossible" elemental transformations may occur frequently in living organisms. These include $Si^{28} + C^{12} \rightarrow Ca^{40}$ (Silica transforms to Calcium by absorbing a Carbon atom) and $Na^{23} + O^{16} \rightarrow K^{39}$ (Sodium transforms into Potassium by absorbing an Oxygen atom). Very careful long term observation of animals shows these conversions *have to* occur, but so far most science insists they are impossible.

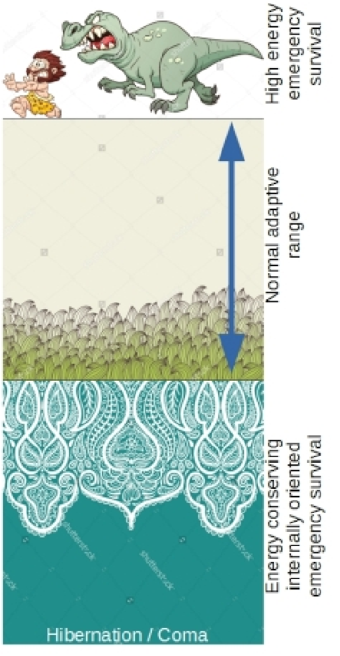
On the other hand, frugality is expressed in the entire physiological system in several ways. Possibly two of the most important are :

- Most *structures* are multifunctional, with many of those functions occurring as side effects for no significant additional expenditure of energy. A couple of examples … (1) the heart is important (obviously) for blood circulation[59]. *And* it produces an electrical discharge that appears to entrain brain activity in a manner strongly related to the emotional state, and has some similar effect (via electrical entrainment) on the entire physiology of the rest of the body. The Aorta (obviously) transports blood from the heart to the lesser arteries. But it *also* acts as an elastic pressure-volume storage vessel – such that that the pulse of the heart charges up the Aorta, which then continues to discharge blood under pressure for most of the pause before the next systolic heart contraction. (2) Bones (obviously) provide structural form to the body and anchor points for muscles. They also have several other functions, including production of immune cells, buffering of blood calcium levels, and production of adrenaline (bones are stressed during motion, motion requires energy, bone stress is a marker of energy usage – and so it is useful to link it onto the energy release cascade). Curiously, bones also have piezoluminescent properties when compressed – so (e.g.) when you run, your leg bones produce flashes of light. Considering the body's frugal use of every conceivable iota of energy, I am 99.9% sure these flashes are used somehow, but so far as I know, nobody has proposed how or what they might do. Most medical text books give a very system-oriented view of organs, as if they have one and only one purpose. This viewpoint may make for easy learning, but is contrary to biological principles of redundancy and frugality, and is gradually being turned on its head by new discoveries. For instance, it used to be thought that red and white blood cells are only produced in bone marrow. However, it has recently been discovered[60] that "c*ells in mouse lungs produce most blood platelets, and can replenish blood-making cells in bone marrow*". This is particularly interesting from the point of view of Traditional Chinese Medicine (TCM), which has considered the Lungs to be important for immune function – for hundreds of years.

- So-called immune functions are actually systemic responses that act across as many scenarios as possible. For a human being, there are common processes that deal with everything – emotional distress, burns, toxicity, anoxia, hypothermia, starvation, dehydration… There are also longer term "just in case" capacities… The fact is that if something only occurs maybe once or twice in a lifetime, it is highly inefficient to retain the capacity to respond to this in a dedicated system. Consider a company who once every 20 years (on average) have to face a major upheaval of their workforce as retirement dates converge with political changes in employment law, changes in company markets and cyclic changes in availability of suitable qualified or experienced people. One thing they don't do is employ a specially trained branch of the human resources department with their own room full of recruiters and telephones, waiting for the next 20-year staffing crisis! And yet Life has survived repeated extinction events some tens of millions of years apart, each of which must have pushed it to extremes of adaptive capacity. So somewhere in there, in amongst the normal physiology, is some biological switch that can be thrown that turns on some kind of adaptive superpower hidden amongst the normal well known cell organelles, hormones and metabolic functions. It is not literally something physically different, but rather, one or more ways in which everything can be reorganised to temporarily work in a different way.

Which brings us nicely to ...

Extreme adaptive capacity



> *Nature does not recognize good and evil. Nature recognises only balance and imbalance.*
>
> *– Walter Bishop*

It has been recognised for some time that the Autonomic Nervous System (ANS) found in humans and all mammals operates within a window of normality; and any activity inside that window is relatively sustainable and relatively adaptive. The window is defined by upper and lower bounds. At the upper end, we have the **Sympathetic** nervous system, which burns energy in order to sustain **movement** in response to the outside world. This takes place (described in the simplest terms possible) through release of glycogen and ATP, thyroxine and Adrenaline, along with regulation of the arterial system and heart rate to push them in sufficient quantity to wherever they are needed most. At the lower end, we have the **Vagal** nervous system which runs the "**vegetative**" processes of the body – housekeeping, homeostasis, immune and repair functions, digestion, energy and nutrient accumulation and storage, elimination… In fact, the width of the window (how extreme Sympathetic and Vagal responses can be before they flip into extreme survival mode) beyond that – more or less defines, the physiological, emotional and psychological resilience of an individual (Figure 1.5). This **window of normal adaptive range** (also called the "*Window of Tolerance*" in trauma physiology) is something we will return to again and again – just as all animals return to it again and again as their lives are disrupted and then return to normal!

All creatures – no matter how large or small, complex or simple – have a window of adaptive normality. If pushed beyond this, they do not just curl up and die – they attempt to survive by invoking reserves and levels of resourcefulness that are usually unavailable and invisible. This can only be done if each creature retains **spare adaptive capacity** of some form or other. Life is fundamentally unpredictable, and (has been stated previously) any animal that runs itself to the limit of its capacity during normal times will just not survive times that are abnormal. This is why even simple things are always energy-optimised… The few milli-joules of energy that was saved yesterday might make the difference between life and death tomorrow. Initially the development of adaptive capacity was forged by single cells in the fire of repeated earth-shaking meteor impacts. And later it was further developed by more complex multi-celled animals and their ecosystems, who also had to survive a few periods of winnowing brought about by further impacts.

As noted previously, these spare reserves are not hidden away in special boxes with "*break glass in case of emergency*" notices on them. The overhead in carrying them as just-in-case organs and cells would impose an an unnecessary load during normal times, and so reduce normal adaptive capacity (and so reduce the ability to survive). The most obvious exception to this rule is in sea creatures, who store a vast amount of fat, because the additional energy needed to move around is minimal. The hump on camels has a distinct upper size limit. Rather, spare reserves are usually embedded in functional parts of the physiology, which can switch to different adaptive states using the same processes and the same basic signalling chemicals in a reorganised manner.

It's difficult to find an analogy in the human-constructed world. Perhaps the closest is in the "Transformers" film franchise, where robots pack themselves up in the form of trucks and cars, but can also unpack themselves when necessary, and assimilate parts from other machines (equivalent to horizontal RNA transfer). The same more or less happens when deep survival emergency states are switched on. The Transformer is no longer a car – it's a robot. The mammal is actually no longer fully a mammal, because in order to survive, its physiology has shifted to something more akin to that of a crocodile. Same neural circuits (though maybe less of them), same signalling neurotransmitters and same metabolic pathways – just (re-)organised in a way that it used to be organised some distance back along the evolutionary path. Or (re-)organised in a way that provides very different adaptive capacities. So we use our adrenal glands all of the time – it's just that, presented with an emergency, their output ramps up to a level higher than it could normally attain. Many modern cars have a cruise speed regulator attached now, which can be set to (e.g.) keep us driving within the speed limit, or keep the engine revs low to ensure good fuel economy. High-burn emergency adaptive states take the upper limit off that adrenal engine. The danger is that all of the fuel is burnt up too quickly, or that something pops because the forces on it are too great, or that the immune system temporarily loses its resources to deal with a common cold. If it's an immediate life-or death situation, these usual safety limits cease to be such important considerations. This principle is seen regularly during pregnancy – where a physiological balance that might be considered abnormal for most of a woman's life is elegantly catered for by using the same homeostatic mechanisms. This does seem to require significant sexual differences in certain areas of metabolic control - something that has only received any significant research attention in the past decade.

Emergency adaptive states essentially re-call and activate previous evolutionary capacities. According to the fundamental pulsatile nature of life (see later), this adaptation can only turn in two directions… One is outwards, with an unsustainably high energy burn being directed at the outside world. Only available in higher animals, we call this "fight-flight", and it will be described in more detail in Chapter 7. The other possible direction is inwards, with the system turning in on itself, conserving energy and shutting off the lights. This "vegetative" response is one of the main ways in which single celled organisms have survived extremes – which in turn brings us to ...

Dormancy and other hibernatory states

In all things of nature there is something of the marvelous.

- Aristotle

Suitable conditions for life have always come and gone – sometimes in repeated and predictable ways such as the day-night cycle; sometimes with no warning. The intervening period may be just minutes or hours or even decades, and particularly so in the early days of evolution. The ability to wait passively is ancient, and probably defines any life that existed before motion was possible. We call the part of our (human) nervous system that "waits" the "Vegetative" nervous system. Plants know how to wait between seasons, and when chlorophyll-based plant life first tapped energy from sunlight three½ billion years ago, we must already have developed this ability... Sunlight is not available all the time – nights are 12 hours long in the tropics and there are seasonal changes closer to the poles. So a reliance on sunlight indicates that already cells were able to "vegetate" during the hours of night. For a relatively immobile single cell, the only logical response to fluctuations in availability of food (or conditions amenable to life) is to develop an ability to wait. It is therefore important to recognise that every cell has evolved with an ancestral capacity to enter some kind of suspended animation in which it turns inwards, energy use is cut to near-zero, and any conditions inimical to life are (so far as is possible) kept out. There are several different versions of this biological pause. For the most primitive of life forms (bacteria, but also the half-millimetre long water bears), self-dessication is a very common strategy.

Dormancy – the ability to suspend life until favourable circumstances arise – comes in many forms. Many organisms can predict the onset of winter by referring to the length of day or the angle of the sun or the progression of air temperature, and then just switch off for 6 months. A Lotus seed 1300 years old has been cultivated in China – so dormancy can allow for vast stretches of time. An organism we call a *rotifer* has recently been found to be capable of re-awakening[61] after 24,000 years "on ice" – not a particularly unusual feat for a single cell, but rotifers are complex animals (albeit only half a millimetre long) with a digestive tract, eyes and a brain and nervous system. They are all female, reproduce by cloning, and (when awake) can scavenge useful genetic material from other forms of life in their environment[62]. Many primitive cells and viruses are able to completely dry out and then exist (perhaps) indefinitely until they are hydrated again[63] – and bacteria may have have been revived from inside 25 million year amber[64], from ocean sediments 100 million years old[65], and even from rock salt crystals[66] that were formed 250 million years ago. Even vibrant ecosystems contain dormant plant seeds and bacteria that may have been hanging around for a hundred years or more. They are all patiently waiting for a difficult year or a bush fire, or a buffalo, or bulldozer to churn up the soil; or some other opportunity that interrupts the usual organisation of life, allows moisture back in and creates a space for roots to grow and light to penetrate.

Dormancy states are not conscious choices ("*I'm going to go to sleep for a while*"), but rather are the result of a biological switch being thrown. Something deeply metabolic (I prefer to call it "biological") takes over that has nothing to do with self-agency or conscious choice. A polar bear doesn't "decide" to hibernate like the cartoon Yogi Bear might prepare his bed, but rather feels a metabolic pull to turn inwards. This rises up into the creature's more active awareness such that it might modify its behaviour and build a cozy nest, or find a cave. And the switch might be delayed until this nest-making is complete. But the actual shift into dormancy (just as the switch into extreme adrenal fight-flight) is under the control of something very primitive and profoundly non-volitional. Just as (coming in the opposite direction) a caterpillar-eating bird's egg will not hatch until the outside temperature has reached a certain threshold that indicates caterpillars are on the way. The animal is tuned into its environment in a way such that we could say the environment is an extension of its life-cycle metabolic process, and it is in turn an extension of the environment.

There are some parallels with sleep – in that the transition from wakefulness to sleep is not under most people's control – but the parallels end there, because dormancy is far deeper and involves far more fundamental and irresistible metabolic changes. One could say with a reasonable accuracy that (as its name implies) dormancy is a deeper extension of sleep, or that sleep is dormancy-lite. And hibernation is thought to be entered into from a state of sleep.

Sleep is temporary, and for all animals is a time in which important maintenance work is carried out, including completion of digestion. The sleeping brain goes through a range of activities, some of which see it even more active than in normal waking. On the other hand, unused organs in hibernation are just switched off. If there is no food coming in, there is no need to digest, and so the digestive system is effectively turned off. There is no need to think or process information, and the brain (above the level critical for regulating metabolism) is also turned off. Just enough blood goes to all these sleeping organs to keep the cells alive and ticking over – but no more – so the heart also substantially reduces its rate of beat and stroke, settling down to maybe four or five beats per minute. All of this switching-off frees off huge reserves of energy – which may be used to maintain hibernation for long periods of time. This free energy may also be turned back and used for tissue repair. A 25-year study of black bears showed that they undergo extraordinary self-healing during hibernation. Despite the fact that even mild hypothermia tends to inhibit would healing in mammals, the bears exhibited almost no scarring even after extensive injury, and also overcome bacterial infections.

> *We identified a few animals each year with injuries resulting from gunshots or arrows from hunters; bite marks from other bears or predators. These wounds were considered to have been incurred some time before the bears denned, and were often infected or inflamed... in early winter. Yet typically, when we revisited bears in their dens a few months later, most wounds had completely resolved whether or not we [cleaned them], sutured the areas or administered antibiotics*[67]*.*

There are many forms of dormancy, and the metabolic shifts that occur during them are truly amazing and thought-provoking. The physiology of a sperm whale drops into a similar state of conservation during dives that can go more than half a mile down and last for over 90 minutes in search of giant squid. Its massive (125 kilogram) heart stilling itself from a normal thirty (as it swims on the surface) to sometimes less than five beats per minute.

With normal metabolism no longer being the case, in dormancy and hibernation there is not even a need to maintain core temperature at normal levels, and thermoregulation is one of the greatest energy burdens for many complex forms of life – particularly birds and mammals. “Predictive” dormancy is when an organism detects changes (decrease in duration of daylight, increase or decrease in temperature) that tell it a predict-able change is about to occur, such as night, or season change. In the tropics, predictive dormancy sets in as temperatures rise, whereas in higher latitudes it tends to set in when temperatures fall. Examples in higher animals tend to be for survival of winter, and include bears, dormice, and many small mammals such as chipmunks. But by far the greatest prevalence of predictive dormancy is found in the plant kingdom. There are is also “Consequential” dormancy, which is the strategy applied by most simple and single-celled organisms – a more immediate response to changing conditions.

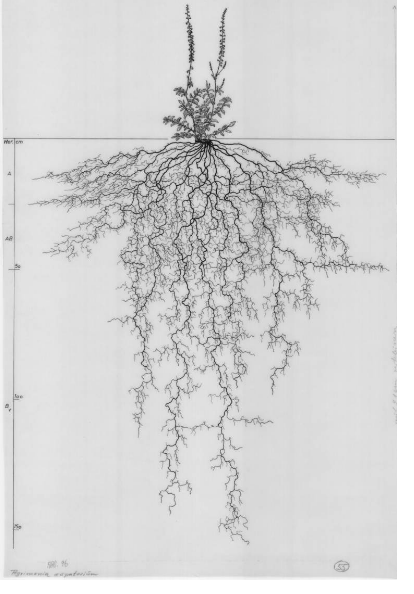
A few out of many possible animal examples :

- Some animals (such as hedgehogs) literally drop into the metabolic state of cold-blooded animals whist hibernating.
- Naked mole-rats thermoregulate above ambient temperatures of 28°C by sleeping underground for many hours, and have several adaptations to help them survive in sealed (snake-safe) and airless tunnels. Their haemoglobin is particularly efficient in attracting oxygen, and their metabolic rate is only 70% of that of a comparable rodent. They can survive CO_2 concentrations of up to 80% and oxygen as low as 5% for about five hours. Their heart beat drops from about 200 down to around 50 bpm, and they have developed a way to survive acidosis (resulting from anaerobic glycosis/sugar metabolism) without tissue-damage.
- The arctic ground squirrel drops its body temperature down to near-freezing for up to eight months, during which (roughly every three weeks whilst still asleep) it shivers for about 12 hours to heat its body.
- The hibernating woodchuck or groundhog (a ground squirrel) drops its heart rate from about 100 to less than 10 bpm, and might breathe once every five or six minutes.
- Bears drop their temperature by only about 7°C, and wake repeatedly, but still can hibernate (and not eat) for 7½ months, during which females will gestate and give birth to cubs.
- Fish, molluscs and amphibians (and insects like mosquitoes) living in environments that fluctuate between very arid and flooded – such as the Okovango delta – can bury themselves in mud and wait (*aestivation*) until the next rainy season. The physiological changes during this adaptation to extreme heat and dryness is very similar to the changes that take place during hibernation (which is usually in response to cold). For instance, the lungfish creates itself a mucous cocoon that traps and retains moisture, and some land snails seal the opening of their shells in a similar manner. One species of Madagascan lemur also aestivates for seven months to escape the heat – a mirror image of the brown bear's hibernatory period during winter!

Plants are even more capable. All deciduous trees go through a dormancy phase in winter during which they slow their metabolism, living on stored energy. It is easy to think of dormancy as being just surviving the winter (or summer) – but it's far more than that. The leaves decompose and create a rich soil in which bacteria thrive, which in turn assist the trees to extract nutrients from the ground. Which in turn feeds the associated soil bacteria and mycorrhizal fungi, which also act as a communication system between tree roots. The relationship between tree roots and their mycelia/mycorrhizal fungi is interestingly similar to the relationship between brain neurons and the immune glia and astrocytes that support them. Furthermore, the period of reduced water uptake by plants in winter months allows rainfall recharge to enter deep into the ground, which has a positive effect on the entire catchment hydrology, benefits all species – plants and animals – further downslope, and reduces seasonal flooding. The rich soil and stabilised hydrological cycle also supports a healthy population of other woodland plants, beetles and other insects, and an entire ecosystem up to large mammals and apex predators. Although there are a few life forms that tend to dominate, smother and make conditions difficult for other life, most organisms do the opposite – they encourage an environment that not only nourishes them, but also nourishes other organisms.

These ecosystems of shared benefits are extremely robust. One might think that such tenuous interdependencies are fragile. However, the greater biological diversity seems to be self-supportive, perhaps a clue to the steadily increasing resilience of life in its capacity to recover from extinction events over the past 500 million years. If one thinks of an ecosystem as if it is a single organism whose cells have differentiated (such as the kind of body that we walk round in as humans), this gives a far better understanding of the reality. In fact, it is a single organism (Gaia) that has differentiated! It's just that we have a particular cultural mindset that sees individual clumps of cells with the ability to move around on their own, and assume that they are separate from each other. In a vibrant and healthy ecosystem, that separation is something of an illusion. Humans are intrinsic to the Gaia-ecosystem, and it is (or should be) correspondingly intrinsic to human activity and long-term survival.

Exploration & curiosity



Agrimony roots
https://images.wur.nl/digital/collection/coll13/id/512/rec/27

> *Dwell on the beauty of life. Watch the stars and see yourself running with them.*
>
> *– Marcus Aurelius*

I cannot think of any one type of behaviour seen in organisms that have the ability to self-propel - that is more more important than the act of exploration. The very reason for possessing a capacity to move is so that we can find a better place or something in it that makes our survival more possible. The ability to move (or to grow in any direction, like the branches and roots of a plant) is relatively ineffective unless it is also matched by an ability to sense what it is that we wish to move towards (or away from), along with an ability to distinguish the meaning of what we sense. Movement may come second – i.e. we simply move *in response* to a stimulus. Remaining immobile waiting for something to pass by is a form of behaviour adopted (e.g.) by many spiders, and reptiles (such as crocodiles). It suits a particular form of metabolism in which a short burst of rapid movement works easily, but any prolonged expenditure of energy is not possible; and an immobile but awake / alert / watchful state can be sustained with a minimum of energy expenditure.

Some plants in nutrient-sparse environments have also adopted this waiting strategy, so carnivorous sundews in nutrient-poor wetlands will wait for flies, or the Welwitschia in the Namib desert will wait for fog to absorb precious moisture through its two leaves. But most plants cannot wait for water and nutrients to come towards them and will grow their roots in pursuit of it. And for anywhere outside the tropics even plants need to physically move to track the sun with their leaves. Every plant with any kind of significant root system needs to control where that root system extends so that whatever it takes up is wholesome. And every plant grows purposefully up out of the ground against the force of gravity and then towards the light. Overall, there are very few plants that are totally passive to their environment, and for all organisms movement is primary and sensory systems respond to an increased capacity for motion by increasing teir capacity for discrimination. i.e. the sensory egg arises after the chicken of motion.

Similarly, once primitive bacteria developed a simple means to self-propel by "crawling" (by using their internal cytoskeleton just as a large animal uses its bony skeleton) or began to swim in fluid using their flagellae; the world was their oyster (or perhaps oysters became their food). We say that "*with power comes responsibility*", and what naturally comes with movement – is the need to make decisions about which direction of movement might be best. Whilst it is true that some small marine organisms have a very random motion, most of even the smallest of them also have a preferred direction. A small organism cannot move very fast or very far, and in some ways a random choice of direction might be as good as any other. Once even a small capacity for preferred orientation of direction is available, then (and only then) it there advantage in developing the senses *and* the internal capacity to determine "meaning" to make more nuanced choices. However, as has already been mentioned, individual cells do appear to exercise intelligent choice, to have a memory, and to have some sense of identity, though certainly not the inflated one that we aspire to in Western culture. All of this *also* indicates the availability of sense organs that can detect significant variations in the external environment, and some way to assess the meaning of those changes such that one choice of movement is better than another.

In later chapters I will be discussing the reactive *sense – interpret (meaning) – response* cycle. But here we are dealing with something somewhat broader – the proactive use of movement when there is no obvious "best" direction in which to go. Exploration requires a willingness to go into the unknown on the off-chance that it is a better place to be. Which in turn requires an active something resembling curiosity – the willingness and propensity to explore, and recognising that the risks of the new are outweighed by their advantages. Somehow, many people have ended up so terrified of the world that they are unable to re-engage in curious exploration … meaning that their inner sense of meaning-making says the advantages of exploration and finding the new are outweighed by the risks. Which is so contrary to how the rest of the biological world operates that something has clearly gone very badly wrong in our culture. And which puts us in the position that pet dogs tend to be healthier both physically and psychologically than their owners.

It could be said that even crocodiles and spiders are curious in that whilst waiting they are not switched off … Rather, they have an active interest in any changes in their environment that might suggest food is nearby. This **active sensory engagement** whilst remaining motionless, or the active sensory engagement that occurs during exploration is a form of curiosity. Which rather begs the question – which comes first – the movement / exploration / awake-ness, or the curiosity itself? This curious sensory engagement ("interest") is not primarily intellectual, but rather has a somatic basis.

"Being interested" is an active relational state long before it becomes analytical or academic.

As humans, we know that (at least in our own, human awareness) curiosity usually comes first. I cannot personally watch a dog or cat (or mouse) or ant exploring a new place, or the shadows of leaves and patches of sunlight moving across a wall, or a film of an octopus[68], or any of Albrecht-Buehler's videos of single cells moving[69] – without having some feeling of recognition of a quality of curiosity and exploration. And curiosity requires a sense of *relative personal safety*. Again, observing any of the aforementioned life-forms in mortal danger – their behaviour is not at all curious, but rather, becomes focussed on evaluating the threat or fighting it or escaping it.

Sense of self-other

Cooperation, Community, Family and Friends

> *We cannot live only for ourselves. A thousand fibers connect us with our fellow men; and among those fibers, as sympathetic threads, our actions run as causes, and they come back to us as effects.*
>
> *– Herman Melville*

Kin-selection (and kin-discrimination) is a very common attribute at all levels of Life. One can think of it as being analogous to an extended version of the body's immune system; and as such it has similar requirements. There must be some sense of inner or self-identity, so that a distinction can be made between self and other. The way that kin-selection has usually been explained in higher animals – is that each family of dogs or fish (or whatever) – recognise the specific smell and fug of chemicals that surrounds their immediate companions; and there is then some unconscious bias in their nervous system that decides any animal with a different smell must be an unwelcome foreigner. This "automaton" argument breaks down at several levels, one of which being that the specific aroma surrounding each individual (large) animal is almost completely dependent on the specific ecological blend of microbiota that largely live in its gut. So a smell-based kin-selection is not *directly* related at all to the subtle variations in DNA that might separate different families and clans of the same species, but rather is an expression of the ecosystem they contain and live in – and so also reflects the food being eaten.

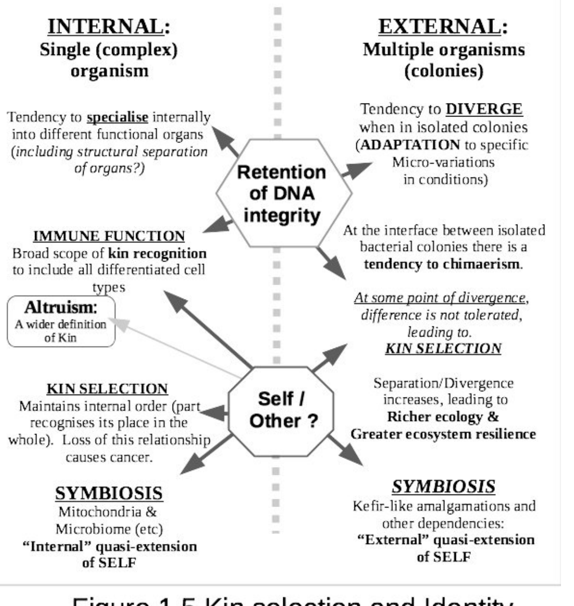


Figure 1.5 Kin selection and Identity

Whatever the mechanism of kin selection, the self-other distinction is virtually universal, and is even seen in prokaryotes (e.g. a common soil bacterium, *myxobacteria*)[70]. A recent study of E-Coli[71] found that when these bacteria are killed by antibiotics, the dying cells absorb the antibiotic so to remove it from the environment and help the other cells to live. I observed something similar when working in a hospital with patients receiving chemotherapy. Their arms would hide veins and retain some of the chemicals (resulting in chording – a painful tightening of connective tissue and muscle). All this was in a biologically-driven attempt to prevent the spread of toxins to the rest of the body, and with the arm offering itself in sacrifice to contain the poison. It might seem blindingly obvious that an arm could see itself as "kin" to the torso or the legs or to various internal organs. But this superficial dismissal ignores a lot of of difficult questions around the exact kind of relationship that does exist between different parts of an (apparently!) unitary body/complex organism.

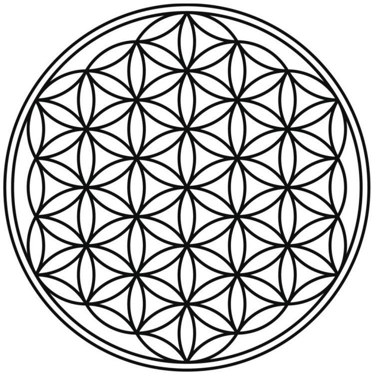
If the capacity to identify Kin and to preferentially protect or assist them at the level of single cells should indicate that this phenomenon is universal to life. Individual trees can distinguish the roots of other species of tree, and will avoid them (i.e. they don't create forest-wide communication networks through them), or might even actively prevent them from entering this particular patch of soil – keeping the water and nutrients to share amongst friends. Kin-selection goes further in that an individual organism will commit suicide if that benefits the survival of its species. Just as a few damaged or infected cells in your body will commit apoptosis (cell-suicide) to protect the whole organism. On the other hand, cancer is a state in which the damaged cells no longer recognise the fact that they are part of a greater whole and symbiotic organism - and so carry on growing, expressing their own self-interest as undifferentiated cells regardless. They have lost the ability to enter an apoptic cascade. Whilst this inability might be a very physico-chemical interruption/confusion (apoptosis is directly related to the inflammatory cycle, and chronic inflammation often precedes cancer), nobody has so far identified such an interruption and an unambigiously causal mechanism for cancer. So this begs questions about internal kin-selection, how identity is transmitted through a complex organism, and how individual cells receive it. One can immediately see the benefits of kin-selection when thinking of a single organism; and we explain it by saying that the immune system recognises what is us and healthy from what is foreign or damaged and mutated. It is not so easy to account for when considering superorganisms such as ants or bees, or termites. Or to symbionts – such as mitochondria, or the bacteria that live inside human the human dermis, or to the various species of fish that keep other fish (especially predators) clean and healthy.

Another form of kin selection is that certain individuals do not reproduce, but instead contribute in other ways to the community they are part of. Worker ants are one example – sterile females who look after the one fertile female Queen Bee. But there are many other cases of individuals (both male and female) assisting one female to rear her young. This more often than not is a close relative – worker ants are all sisters to the Queen. Or certain animals will act as guards (such as the meerkat up a tree). Their warning may save the lives of their companions, but potentially at the cost of their own; and this **altruistic** behaviour is a natural extension of kin-selection. In the body, it can be seen in (e.g. red blood) cells that have elected to lose even their nucleus and its chromosomes, so that they can better play their part in the entire body-ecosystem-colony. And indeed in any cell that loses its capacity to reproduce - so that a few eggs and sperm are able to be carried through life to (hopefully) the most ideal conjunction to ensure life continues.

As a behaviour trait, kin-selection is only one of many flavours of behaviour that go into cross-species cooperation and mutualism, merge with symbiosis (and even parasitism), and extend as far as empathy. There is no clear dividing line between any of these different ways that organisms interrelate. Although some specific forms of behaviour (like kin-selection) are singled out because they have very distinct and (apparently) easily defined attributes, in reality there is a continuous spectrum of different interrelationships. Many forms of symbiosis may be passive – the behaviour of one organism "accidentally" benefits others – but in the chain of Life, the likelihood is that an apparently passive symbiosis is actually mutual in many more ways than we currently understand. So whale-poo helps to fertilise the oceans and it is that fertility that creates large ecosystems that ultimately keep the whale alive. Elephants (and their large piles of elephant-poo) have a similar mutual relationship with the land they live on. Termites are another good example[72]. There are vast tracts of arid landscape that are peppered by fairy-ring structures, and these appear to be the work of countless generations of termite. Each termite colony digs in to find the water table and expands out until it meets a physical boundary (like a rock outcrop) or another termite colony. In addition to the expected tunnel excavation, termites alter the microstructure of the soil immediately around their nest, which in turn changes its moisture retention. The improved retention favours soil bacteria and the growth of plants, even trees; and these attract in turn other insects (beetles), lizards; and ultimately a complete chain of larger animals and predators are also drawn towards the slightly more fertile patch of desert. Notably, these termite-driven spots of fertility are also more resistant to drought; and species populations do not collapse in the way that happens when termites have not engineered the soil; and when rains return there is a faster recovery of the entire ecosystem. One could say that the termites only have the intention to grow grass so that they can harvest it to feed their underground fungal food factories. However, the complex ecosystem that forms round the termites contributes to soil fertility, which in the end helps the termites and their communal grass patch. One form of life becomes more resilient by benefiting other forms of life. If this mutualism and symbiosis is the general rule for apparently unrelated organisms, how much more might it be the general rule for differentiated cells in a single organism?

Termites also raise questions of identity, because each colony has its own specific identity. Parts of the Namibian desert landscape end up peppered with fairy rings because in contrast to the peace on the surface, termites are doing battle underground to protect their particular patch of earth against neighbouring termite colonies. Figure 1.5 (above) shows a very simplified list of the issues raised here. Identity seems to be somewhat malleable according to convenience. It is true that one can say we have honey badgers and honey guide birds, each being a very distinct and separate organism, one being a small relative of the parrot and the other being an extraordinarily tough cousin to weasels. In their symbiotic relationship, the bird finds a hive and leads the badger to it, and while the badger is feasting on honey, the bird feeds on the honeycombs. If they relied on each other to the extent that each would become extinct if the other became extinct, would they in reality be effectively one organism spread between two different physical forms? This would not be particularly different from the relationship between a eukaryote (e.g. a human) and the mitochondria it contains; or from a human and her gut microbiome. Or between a plant and its micorhyzae– without which plant roots would be unable to absorb nutrients. It's just that we have a perceptual filter that allows for symbiosis between animals of roughly equivalent size and complexity (like the honey badger and honeyguide), but which tends to ignore the little bacterial folk. When it comes to behaviour (overt or immunological) that expresses identity, symbiotic relationships at whatever scale blur the distinction between self and other. The cauliflower-shaped mass of organisms that is called Kefir is in fact a symbiotic colony of about 20 different species of bacteria and yeasts in a matrix of proteins, lipids, and sugars. Although Kefir looks like a single organism, it is really an ecosystem. Lichen is similar in may ways to kefir. But there is not a single universal basis for lichen – rather, lichen are a class of symbiotic colonies that consist of a species of fungus living cooperatively with a "photobiont" – one or more species of algae, yeast or cyanobacteria[73].

So the ability to come together is not dependent on species – but is instead dependent on each cells utility to its neighbour along with some kind of mutual recognition of that interrelationship. Although we may talk lightly about symbiosis, the depths to which it can go are quite startling. A recent study of plant communication[74] shows that the mycorrhizae around plant roots also provide a powerful signalling network, allowing plants to signal to each other when one is attacked by aphids. Almost as if the fungal strands act like a nervous system for the plants in that area.



The Flower of Life is a perennial image in many spiritual traditions that have a basis along the theme of "God in Nature". On one level, this image is a good representation of the biological web of life… Each circle intersects all its neighbouring circles, and the flowers arise because of these intersections. The flower is a result of the interplay and interdependence of each circle, to the extent that the circles that form it become almost invisible; and their combined effect – the petals of the flower – become the most powerful part of the image. Or, one can see the flowers/petals or the circles, but it is remarkably hard to keep both of these in view at once. This is also true of interconnected ecosystems and the internal workings of complex biological organisms. The forces that give rise to life become invisible, and it is their interplay that has the most visible expression, because we have certain internal perceptual filters that predispose us to see the one and not so much the other. As humans, the archetypal image of the *flower of life* is also of our proper relationship with the ecosystems in which we have evolved. Just as it is an accurate description of the (so-called internal and external) interdependencies - human or otherwise - that maintain our lives from moment to moment. So as a species we have not adapted on our own to the environment, but rather, the entire "internal" (microbiome/virome etc) and "external" ecosystem has evolved, and we have co-evolved as part of that collective evolutionary response to the environment. We are in effect a living emanation[75] and expression of a meta-organism[76]. And the environment itself is responsive to the life-forms that inhabit it ... to the extent that local climatic conditions are in part a product of regional vegetation, which is itself partly a product of the larger and smaller forms of life that live within it.

The place of humans in the world is therefore very different from the one we imagine in our anthropocentric conceit. At best we would be like strands of algae or dragonfly larvae that exist in a pond – we would not be there at all except for the pond, and the pond would not be there without our particular contribution to the interwoven-ness of its *flower of life*. The importance of humans adopting an unselfish, connected and compassionate individualised identity (and recognising the context of identity – embedded in its supportive, dependent and deeply interlaced ecology) is highlighted by Steiner :

> *But on the other hand, we must not forget that the "I" is at the same time that which gives to man his independence and his inner freedom, which in the truest sense of the word elevates him. His dignity is founded in this "I," it is the basis of the Divine in man. [...] Thus the "I" will be the pledge for the highest goal of man. But at the same time, if it does not discover love, if it hardens within itself, it is the tempter that plunges him into the abyss.*
>
> *For it is that which separates men from one another which brings them to the great War of All against All, not only to the war of nation against nation (for the conception of a nation will then no longer have the significance it possesses to-day) but to the war of each single person against every other person in every branch of life; to the war of class against class, of caste against caste and sex against sex.*
>
> *Thus in every field of life the "I" will become the apple of discord; hence we may say that it can lead on the one hand to the highest and on the other hand to the lowest. For this reason, it is a sharp two-edged sword.*
>
> *Rudolf Steiner – GA 104 – The Apocalypse of St. John: Lecture VIII – Nuremberg, 25th June 1908. Translated by M. Cotterell*

Control of the external environment

> *The more complex the network is, the more complex its pattern of interconnections, the more resilient it will be.*
>
> *– Fritjof Capra*

Whilst homeostasis (one of the definitions of organic life) is usually thought of as a control of the *internal* environment, in reality we are never truly separate from the so-called external world. So our internal housekeeping can be made more efficient by also controlling the external environment. Probably the most basic control of the external environment is the split between self and other (e.g. via the cell wall and its extensions of structured water and polysaccharides) that allows internal homeostatic processes to be contained within a limited domain. Skin, fur, cutaneous fat and feathers follow the same principle. And there are extensions of skin… Higher animals build nests and burrows. Termites excavate underground cities that may extend 70 metres down to the water table in the Kalahari desert, with an immaculately engineered structure above ground that uses the warmth of the sun and small shifts in wind direction to act as an extraordinarily efficient ventilation and air conditioning system.

The next most fundamental mechanism is the capacity to self-propel, so that the external environment may be controlled by getting away from inhospitable environments and searching for ones that are more nourishing. Movement is an almost miraculously adaptive ability, but it comes at the cost of substantial energy expenditure; and so moving is only a useful strategy for as long as there is enough energy to power it whilst still maintaining an adequate homeostatic balance. We move towards what we need/love, and away from what is causing problems. Mobility is the main characteristic that identifies animal from plant and mineral. But even plants have a degree of mobility. They track the arc of the sun across the sky with their leaves and flowers. Some of them can trap insects using fast movements triggered by nerve-like hairs that can count! Plants grow upwards and outwards towards the light; and underground their roots deliberately and intelligently (consciously) grow towards nutrition and water and away from concentrations of toxins. The roots of a 2000-year old sequoia might reach out over a mile from the visible tree trunk.

Humans are the supreme example of controlling our environment. We have populated almost every conceivable climatic and geographic zone on Earth by adapting the external environment to suit our needs. Clothes and buildings/shelter and tools are the most obvious means. But we also set up communication infrastructure – bringing water and food to our doorstep, allowing coordination of activity well beyond the ranges of our unassisted voice, transporting us to-and-fro by land, sea and air. We have devised central heating, double glazing, air conditioning, metal and kevlar armour, bulldozers, guns, cement, teaspoons, candles, soup bowls, communication satellites, buttons and electrical power lines – the list is endless… The ability of humans to adapt their external environment is the cause of the exponential population growth that has seen us become the dominant animals on the planet[77].

For most (if not all) other life forms, that capacity to control the environment is quite local and sustainable. Clown fish live by having adapted to be able to swim unharmed amongst poisonous anemone tentacles. Beavers create a dam and pond that protects their nest and supports their food. In fact, all other life's means of altering their external environment is inherently tied into sustainable ecosystems – to the point that those environmental changes are not just neutral in their effect – but positively contribute to the wellbeing of other animals. If they did not, the animals adopting them would themselves perish, because they are part of the ecosystem that they have negatively impacted. A lot of attention has been paid recently to apex predators and large animals (buffalo or elephants[78], and whales[79]), and all of them put in far more than they take out – via regulation (in the case of lions and wolves[80]), through to just the simple nutrient contribution that whale poo and whale carcasses make to the entire oceanic ecosystem.

Because (as humans) we make our own environment to such a degree; we have ceased to see the need to *participate* in ecosystems. Whilst almost all other animals have some net positive contribution to their ecosystem (indeed their ecosystem could not exist if this were not so), our net contribution is destructive, and the net effect is destruction. The living world is inherently one of relationship, that stems from each and every life form being the same life that has multiplied and enriched itself. I consider this hubristic rejection of participation to be possibly the greatest dissociation in a collective culture that is inherently dissociat-ive. It may even be that individual dissociativity is a direct result of this cultural and societal withdrawal from a symbiotic and deeply embedded relationship with nature, "*because we can*".

> *We are one, after all, you and I, together we suffer, together exist and forever will recreate one another.*
>
> *— Pierre Teilhard de Chardin*

Single cells, colonies of undifferentiated cells and colonies of symbiotic simple life forms (such as Kefir) can teach us a lot about what it is to be human, how we came to be human, and what how our biological body is organised – because they encompass most of the responses available to humans – who are possibly (in the way the central nervous system has become so specialised) one of the most sophisticated of multicellular organisms. Single cells also synthesise and use most of the neurotransmitters that we use. *Myxogastria* slime molds are particularly interesting. Consisting of Eukaryotic (membrane-enclosed) nuclear material floating freely in protoplasm *without* an external cell wall, they probably represent something of a transition between a-cellular and cellular life. There is something primaeval in the way that these undifferentiated cells create a single quasi-membrane to contain their common protoplasm; organise variations in the viscosity of the protoplasm so that it contains an active network of flow channels; and direct rhythmic fluid movement in these channels (cytoplasmic streaming). The streaming of cytoplasmic fluid brings in new food and removes waste products; and is powered by movements within the actin fibres – the "cytoskeleton" – and by local changes in osmotic potential (the shifting of water and charged particles to-and-fro across membrane-like compartments). There is a tendency to think of "green slime" as disorganised chaotic goo, but the reality is very different. Slime molds and biofilms composed of – nominally - undifferentiated cells exhibit startlinghly complex organisation and behaviour[81]. Slime molds are also well known for their ability to crawl (or more accurately, *ooze*) towards food. These shifts in internal fluid movements and in externally directed motion are coordinated *simultaneously across all* of the cells in the slime mold. For *Dictyostelium*, this synchronisation occurs over a uniform cycle of 200 seconds, in a way that suggests they are keying into a universal and external (i.e. environmental) "clock" rather than an internal one.

Fragmentation and dis-association
(or assembly-dis-assembly)

Look Down
Hands, arms fingers
moving freely
writhing
under my own control
is it my own?

Look Down
Legs, feet
one, and then the other
only pieces
of me.

I am fragmented
random pieces floating
in the air
connected
to what?

My reflection is deceiving
it tells me
that I am whole
that I am one
that I am.

But what is the mirror
to know what I am
to tell me that I am
whole?

Morgan Kelley (Wholeness)[82]

As has already been mentioned, a single cell always has the option to dissipate its RNA and DNA into the environment so that they might continue to exist as part of some other organism that assimilates them.

The behaviour of different types of cell is wonderfully varied. In particular, algae reproduce in astoundingly diverse ways and exhibit a very varied range of fragmentation for the purposes of reproduction. Some reproduce asexually, others use sexual reproduction, and many use both. In asexual reproduction an individual reproduces without combining its genetic material with that from another individual. The simplest form of asexual reproduction is binary fission, in which a unicellular organism simply divides into two new individuals. Some multicellular algae, including Sargassum, reproduce asexually through fragmentation, in which fragments of the parent develop into new individuals. In a similar process called budding, special buds detach from multicellular algae and develop into new individuals, commonly found in *Sphacelaria*. Many algae produce special cells called spores that are capable of growing into new individuals. If these spores move about using flagella, they are known as zoospores.

In sexual reproduction, genetic material from two individuals is combined. The simplest form of sexual reproduction in algae is conjugation, in which two similar organisms fuse, exchange genetic material, and then break apart. For example, in Spirogyra, which produces both asexually and sexually, two long, unbranched filaments join via conjugation tubes, through which genetic material is exchanged between cells. Most multicellular algae undergo a more complex form of sexual reproduction involving the union of special reproductive cells, called gametes, to form a single cell, known as a zygote[83].

Dissolution is not only about passing on DNA or reproduction. Apoptosis is the mechanism whereby cells deliberately kill themselves off. The fragments released during death are used throughout the living world to signal danger – a few examples include :

- Desert acacia trees can detect the aroma of nearby leaves being eaten – and this triggers an increase in the tanning content of leaves to make them undigestible. So when camels eat leaves they work their way upwind to make sure that the leaves are still edible.
- Cells undergoing Apoptosis in a multicellular organism issue signals to let the immune system know what is happening, so that it can clean up.
- Dead ants are picked up by their comrades and taken to an ant-mortuary. This appears to be a mechanism whereby any disease does not spread so easily through the colony. Interestingly, ants don't seem to detect a "dead" smell, but rather they sense a lack of vitality[84].

Apoptosis – cell suicide triggered from either outside or inside a cell – is also important in higher organisms for development, by corrosion of intermediate forms, and as a means to prevent inaccurate cell mitosis. Pupating insects dissolve their cells so that the resulting pulp is a feedstock for new cells to grow. Plants also use apoptosis – e.g. to localise damage due to viruses, and to prevent inbreeding. Autophagy is a process similar to (and which may induce) apoptosis – which is a means by which the organism effectively eats itself when there is a lack of the usual sources of nutrition. In humans it is one of the responses that can be triggered by Cortisol during the final stages of starvation.

It is easy to see the utility of this in a complex multicellular organism like a human being – where a cell might need to be disposed of because it has been physically damaged or has somehow ended up in the wrong place. It is also easy to see how a single cell in a complex multicellular organism might need to commit suicide if its DNA or some other organelles are severely compromised or it is infected by a virus – and so might interfere with the whole organism. But interestingly, evidence has been found that even unicellular organisms commit apoptosis[85], and apoptosis appears to have been a feature of unicellular organisms well before Eukaryotes came into existence[86] (about 2 billion years ago). If this is the case, then either those proto-single cell organism were actually taking part in a sophisticated society(!) or the act of death and dissemination is another way by which its life can continue. The trait may even have been inherited from ancient bacteria. It is strange that apoptosis may be regulated by changes to the mitochondrial cell wall[87]; so not only can cells die simply because the mitochondria have performed apoptosis, but also a mitochondrial cell may cause its eukaryotic cell to commit apoptosis through emission of *caspases*.

For single celled organisms, there are no easy answers as to "why" they should have developed a capacity to commit suicide (or be told to by their mitochondria) – unless we suppose that even archaea and bacteria both recognise the sameness of their brothers and sisters and some members of a "colony" deliberately commit suicide in a kin-selective act if (e.g.)

- there are excess metabolites or
- there is insufficient nutrition for all the cells, or
- they become infected by a hostile organism.

There are plenty of examples of higher organisms taking out their predators when they die – such as the hagfish producing a large mucous exudate that covers its attacker and suffocates it[88]. For the hagfish, the cost of a producing a small amount of collagen is quite small, and so it can use this defence repeatedly. Other creatures have higher-cost defences, such as the cane toad now infesting Australia (which just poisons anything that eats it) or the carpet ant[89]. But for a single celled organism to apply these tactics, it must – on a biological level – already "think" that it is part of a larger entity, and that action therefore serves a "greater good". Ultimately these questions lead us back to the issue of cell consciousness and something along the lines of Rupert Sheldrake's morphic resonance[90].

Nature never rushes, yet everything is accomplished
– Lao Tzu

Hybridisation

Whilst self-identity and kin-selection maintain stability, on their own they would be far too static, unresponsive and unadaptive as a species; a potential problem that is answered by genetic promiscuity and hybridisation. The idea of a LUCA – a last common universal ancestor - turns out to be indefinable because of the way that genetic sequences and even organelles were so mobile between different early cellular life forms. And this malleability of identity has been found to be the driving force of evolution up to this day, with species being only apparently fixed forms within a constantly shifting backdrop of time, space, environment and interaction with other species. The classification system of species devised by Linnaeus is therefore something of an optical illusion, a simplification that helps us to communicate about particular kinds of beastie, but which really gives the wrong impression. Hybrids are forming all of the time, as are sub-species. So, for instance, humans locked into a narrow range of territory through custom, geography or external pressure will develop a distinctive genetic sub-pattern, which has certain advantages in that situation.

Before cities existed, human migration probably followed animal migration – up to thousands of miles in a year. The annual celebration at Stonehenge (not the pop festival – the original one in the Bronze Age!) saw up to 20% of the UK population herding animals from as far as northern Scotland towards an extraordinary gathering. Then gradually, agricultural society made life smaller and smaller. Up to the beginning of the industrial revolution, the average distance between birth places of married couples in England was less than 10 miles. Then, as travel became more easy that distance increased, and the net effect was exactly the same as a hybridisation breeding programme that might bring together different types of tomato. Many of the children of these more genetically diverse parents were taller, and more intelligent.

Modern genetic profiling tells us that species do not have clear boundaries created by their DNA, but rather, their DNA is maintained within a certain range through isolation custom, preference, and mutuality with other species in the same ecosystem. Many life forms can procreate across species boundaries – such as beluga whales and narwhales – but tend not to do so because of aesthetic preference. As a human "species" we arose from the mixing of many primate strands – including Homo Habilis, Neanderthals and Denisovans, all of which contributed to the modern human "Homo Sapiens". Likewise, small genetically isolated pools are constantly splitting off into sub-species, who then re-mix. This process is quite obvious in plants, but the constant tendency towards hybridisation has only recently been recognised in animals. Furthermore, there is a continuous transfer of genetic material to and between individuals through viruses, sometimes even cross-species. The total impression is not so much of a "Tree of Life" (though the general shape of it does have that tree-like quality) – but rather a chaotic system in which order appears to exist if one takes a snapshot in time, just like a river may have swirls, eddies, wavelets, ripples that can be captured with a camera, but are transient. Even the river's course is transient as its banks erode and the river bed shifts.

Thus, species survival does not follow social rules or any human moral code. There is no racial prejudice, but almost the opposite; whilst at the same time there is no evolutionary mercy for hybrids that are not fitter for their environment. Peering into this evolutionary abyss is terrifying because if it were only down to survival, its morality is far different from the one that we have come to live by in human society. Whilst Nature is not really "red in tooth and claw", and can be extraordinarily compassionate, that compassion occurs within a framework of order, in which life and death are the final arbiters. In this biological existence, death is a necessary servant of life, whose services are required to ensure Life flourishes ever more resiliently and abundantly. Thus, the issues of kin selection (conservation of form) and hybridisation (separation and exuberant multiplicity of form) do not only open up a Gaia-centric view of the human world that encompasses all the life that shares our ecosystem; but also points to a major flaw in the organisation of some parts of Western society: in that death is seen as bad for the individual (and we go to great lengths to prolong it for a few months), bad for the collective, and is not integrated into our way of being in the world. From a biological and an evolutionary perspective, no truly moral form of society can exist unless it embraces death as much as it embraces life. Therefore, as will be further expanded when we finally arrive at the topic of Dissociation, an existential fear that is not at peace with death is fundamentally incapable of embracing life, or of being truly embodied.

Ingenuity

Earth is an ecosystem inarguably dominated by plants . . . much more advanced, adaptable, and intelligent beings than we're inclined to think.
– Stefano Mancuso and Alessandra Viola

There can be no doubt at all that life expresses the utmost ingenuity in its processes, its interrelationships; and its ways of exploiting niches. The griffon vulture is so-named because when hunched over a carcass and viewed from the front its wings and body appear to be like the face of a lion-like beast (the tiny head of the vulture being its black nose-tip). One has to ask – how on Earth did that arise? Many orchids pattern themselves and have reproductive apparatus according to the specific markings and feeding styles of very specific insects. To the extent that some are camouflaged as particular species of female bee so that the male will mate energetically with the orchid and so be covered by its pollen. How does this happen purely by means of "random mutation"? Insect wings and caparaces are coloured in the most spectacular and exuberant ways by manipulating micron-scale features on their bodies. Using similar variations in microtexture, plants make their leaves waterproof, and creatures up to the size of a gecko can have such adaptive gripping capacity that they can even "walk" on vertical sheets of glass. Cuttlefish can present and vary colours almost with the adaptability of a megapixel computer screen – by modulating coloured pigment, reflection and spectral absorption in three distinct layers of skin cell. We don't really know either the true capacity or function of these colour changes. The philosopher Peter Godfrey-Smith reports[91] once seeing a cuttlefish presenting a kaleidoscopic display to another passing cuttlefish on one side of its body (a wink and a nod - or a whole conversation?), whilst its other side remained safely camouflaged.

Perhaps the most graphic examples of complex ingenuity can be found in the exploits of parasites. So for example – one species of *cordyceps* fungus infects ants, and travels to their central nervous system. From there, it changes the behaviour of the ant – so that the ant climbs as high as it can; at which point the fungal growth explodes and consumes the insects body, flowering out of its head and sending spores on the wind to find the next hapless host. Or take the *Ribeiroia* parasite, a form of flatworm (trematode). It hangs around inside water snails until frog tadpoles emerge from their eggs. At this point, the *Ribeiroia* leave their snail hosts and infect the genital area of the tadpoles. Somehow they alter local DNA expression in the pelvic area so that the frogs produce two sets of legs; incapacitating the frogs, and making them easy prey. The frogs are caught and eaten by waterbirds, and the parasite then progresses on to the bird's digestive system. There it mates with another trematode, in the ideal environment for it to produce eggs. Then, as the bird flies round from one pond to another the eggs are released, and the newly hatched worms find themselves a snail…

All this ingenuity in more complex creatures is matched by ingenuity within cells, as it is matched by ingenuity within physiological processes and within ecosystems. Ingenuity is very much tied into diversity and the complexity of interactions that brings. Research on the brain has recently found that DNA is "randomly" shuffled[92] when the central nervous system is growing, which creates an apparently chaotic bed of neurons, all with slightly different functions. This is amplified during a persons life, as short sections of DNA are cut and pasted onto brain cells by transposons[93]. Mathematical modelling of this shows – much to everybody's surprise(!) – that the greater the complex (apparent) disorder at a cellular level, the greater the systemic functional order that arises, and the greater the number of interconnections. From apparent chaos comes an emergent capacity for resonance and organisation. This principle of order arising from diversity is likely to be the case for *all* ecologies. There are about a million different species of bacteria in 30 grams of *healthy* forest topsoil, and so a question I'm asking myself more and more is *"is soil conscious?"…* or at the very least – *what does all that complexity do?* Who knows wah problems we potentially create by applying pesticides to soil, and antibiotics to animals and humans. Blanked pesticides are an attempt to forcefully control by wildly blasting away with a shotgun to kill off what we don't want (instead of finding how to work with and enhance the living ecological system) has consequences.

There is a popular argument in evolutionary biology against the idea that nature is driven "naturally" towards complexity, and it cites many examples of individual species that have remained unchanged for hundreds of millions of years (such as the coelacanth or shark or molluscs), or even species such as parasites that tend to become more simple. The argument, however is tautological, based on looking at individual species. It carries an inherent and unstated (and therefore invisible) assumption that each species *can be separated* for its environment and co-dependencies, and *can be understood* in relatively simple terms. If one looks at the entire web of life – the way that organisms organ-ise themselves in a self-sustaining ecology, then Life as a *whole* can be seen to be steadily increasing its complexity and degree of interrelationship. After all – Life as a whole is a set of differentiate-able self-organising autopoietic structures that is constantly finding new ways to organise itself to optimise its overall ability to harvest energy from its environment. What we call a "different species" is equivalent to a muscle cell sitting next to a neural cell – but at a greater distance and on a bigger scale and with less direct sharing of blood and other metabolic streams - with necessarily different means of communication. But it's still the same life, and so symbiosis within planetary Gaia is more like the normal relationship that exists between cells in a single identifiable organism. With each new species comes an opportunity for a new kind of symbiosis, a new relationship or even kind of relationship (such as predator-prey) that will re-weave the web of life with just that tiny bit more colour.

Consequently, the fact that some organisms can continue to fit into whatever milieu they live in for tens of millions of years is not to be <u>un</u>expected. The question maybe that needs asking is – *what do these organisms contribute that makes them so desirable in a flourishing ecosystem?* Because of they did not contribute, the ecosystems they lived in might not do so well at all – which in turn would not be so good for those particular critters. We are only just starting to recognise the damage that occurs when a small number of apex predators and large animals (such as whales) are removed from ecosystems that have attained stability over millions of years (and the synergy to which those animals and their adaptive behaviour have evolved into). For species that have a more closely coupled symbiosis (as opposed to just happening to live in the same loosely defined ecosystem), as mutual symbiosis[94] occurs, each participating life form achieves more genetic and physiological plasticity and elasticity, because its symbiont has taken some of the strain[95]. And in reality – symbiosis is simply the unity of Life re-organising itself.

Perhaps the greatest ingenuity of all is the way in which organisms adapt. It has been thought for about 150 years that the adaptations made by Nature are random. This was one of the principles proposed by Darwin, in contrast to the Lamarkian idea of "***inheritance of acquired characteristics***", which is not random. The science of genetics seemed to confirm randomness, and the zenith of the theory of randomness came with Richard Dawkins' publication[96] of "The Blind Watchmaker". Science continues to move on. Now[97] there is recognition of - at the very least - a proportion of Lamarkian inherited changes[98], first *epi*genetically (i.e. as the way that genes are allowed to express themselves – or not), and then to the genetic code itself - which are adaptive to conditions in the lifetime of the parent. In fact, the maths of evolution via purely random variations just doesn't add up, and neither does it explain the inheritance advantages of sexual reproduction. However, Sexual reproduction is the main method of inheritance adopted by complex life forms, so it must convey some advantage. What appears to be happening is that the DNA is pre-selected for traits that suit current environmental pressures; and these pre-selections are conserved during the more random shuffling process that occurs during fertilisation. All of this may even be driven from a microbiological level as much as (or even more than) a macro-level[99]; because if the host organism survives, then the inhabitants of its microbiomic ecology also do well! Horizontal Gene Transfer (HGT) is one "explanation" for rapid non-Darwinian evolution. In one recent case study[100], an insect was observed to receive improved immune function through interactions leading to HGT from a symbiotic parasite. If we kill off the parasites and bacteria and viruses because we think them "bad", what does this do to the chain of life?

It would be odd to exclude tool making and other aspects of human (and animal) behavioural ingenuity as part of this short exploration of biological ingenuity. After all, we are part of the biological world, and human activity is just an extension of that. Indeed, some scientists have stated that there is nothing new invented by humans that has not already been invented and honed to perfection (a far more efficient perfection than we can achieve) by the processes of evolution. The use of fire as a tool is usually thought of as being a very human invention, but birds of prey in Australia have been observed deliberately spreading a bush fire by carrying burning twigs – so that they can flush out small rodents[101]. One wonders to what extent early hominids might have seen that kind of behaviour and copied it… Australian aborigines have used fire for several tens of thousands of years. Maybe they brought this skill from their travels through Asia, or maybe they copied the hawks. Or maybe the hawks copied the humans… Controlled use of fire is a means to manage large areas of bush, to maintain biodiversity so that they have a more plentiful source of food – and to ensure that their physical survival is not threatened by the kind of out-of-control wildfires that can spring up from bush that has not been so managed.

One particular area of human ingenuity is food processing. Humans are quite unusual in the vast range of climatic environments and ecosystems we can live in. One reason for that capacity is the almost unique-to-humans system of thermal regulation by sweating through the skin – which also requires substantial adaptations of water-electrolyte and therefore adrenal physiology. But we also have intelligence, and another way that we have adapted to different environments is to process (plant) food to remove the toxins that the plants fill themselves with to make them inedible and dangerous to eat. Every animal (including humans) has developed ways to neutralise plant toxins in its digestive tract, or to include them usefully in its physiology as a form of medicine, or has learned to avoid them. But humans also cook and dry and soak and ferment and preserve. Many traditional ways of cooking are concerned with preservation of food so that it is available throughout the year. But traditional cooking and preservation methods are also about removing or neutralising toxins. So, for example, acorns are made edible by crushing and soaking them in a stream for a week or so to remove the astringent tannins. Tomatoes have been a staple part of Italian diet for thousands of years, and the most usual *traditional* way to eat tomato in Italy is as paste with the skin and seeds removed. It turns out that the skin and seeds contain solanine, a deadly and somewhat cumulative toxin. Similarly, we sprout, bake, soak, boil and pickle in vinegar (and many other things besides) foods, or pick them only at certain times of year – to remove toxins[102]. Or we grow and preserve food in certain ways to prevent toxin-producing fungi from entering them. Standard cooking methods remove much of any heavy metal content of foods. For instance, washing rice before boiling is a simple act that just happens to remove much of any Arsenic that may be present[103].

And ingenuity is built into the very fabric of evolution, as viruses, bacteria and fungi constantly remind us as they adapt, evolve, and change[104]. The fact is that Life is adaptive, and most life forms (certainly all higher life forms) feed on each other and compete to find the best possible niche in the most suitable ecosystem. Being here, surviving as a complex organism a few billion years on from the beginnings of life means that our immune systems are also ingenious in adapting to the adaptations that constantly surround us. Human intellectual ingenuity is incapable of fitting into and integrating the ingenuity of Life, unless we work to its rules. So far, modern technology has tended to be antipathetic to Life's rules, and even to life itself. It's not that we are incapable of organising ourselves to inhabit a natural world on its terms, but that we have so far decided in a fit of egocentric pique and bloody-mindedness to attempt to re-make the world in our own image.

Metamorphosis

> *As Gregor Samsa awoke one morning from uneasy dreams, he found himself transformed in his bed into a gigantic insect…*
>
> *"I cannot make you understand; I cannot make anyone understand what is happening inside me, I cannot even explain it to myself"*
>
> *– Franz Kafka (Metamorphosis)*

The usual way of thinking is that metamorphosis is constrained to insects, such as caterpillars and butterflies, or dragonfly larvae and adult dragonflies. But it goes much further than that. Sea anemones (cnidarians[105]) – the spiky little balls that shuffle round the sea bed in environments from tropical coral reefs through to deep abyssal plains – arose from our common ancestral line before there was a division between insects (symmetrical animals with an exoskeleton) and vertebrates (symmetrical animals with an internal skeleton) – the substantial differences between the two being brought about by means of a simple topological flip in the early embryonic stages. As a common ancestor of vertebrates and insects, cnidarians undergo (at least) a two-stage life. They begin as soft transparent larvae. Transported by ocean currents and living in the sunlit waters near the ocean's surface, they start to grow a second organism inside themselves. At some point as the larva nears the end of its life and the internal sea urchin growing within it takes up more and more space, its final act is to swim to the ocean floor. As they grow, the sea urchin spines gradually rip the larva apart fro the inside and eventually penetrate the outside skin of the original larva. Eventually the sea urchin emerges, leaving behind a tattered sac that once was a living creature in its own right, that in a sense gave birth to it. This kind of scene is perhaps more reminiscent of an Alien movie than how we normally envision life. Metamorphosis is a branch of the tree of Life's processes that is mutually shared between the trees of ingenuity and kin-selection. It is an almost ubiquitous process in the maturation and growth of complex life.

You might think that all this is irrelevant to human beings. Surely the greatest transformation that we undergo is the shift from being a baby inside its mother to one that made the transition to the outside world? The heart, liver and kidneys reorganise themselves, the sensory system changes, the lungs expel their internal fluid and within a few minutes are taking in oxygen. But in fact, possibly the greatest metamorphosis is the transition from unfertilised egg to actively growing zygote, blastocyst and blastula. Then something even more extraordinary happens. The blastula (a hollow sphere of cells) is the human being at this stage, and just like the larva of the sea urchin, swims towards solid ground – in this case, looking for a suitable nesting site in the wall of the womb. The blastula then embeds itself in to the wall of the womb (the sea floor), whilst at the same time just one cell on its inner surface starts to divide and grow into a human being. So exactly like the sea urchin we have a larval stage – the blastula-placenta - which is eventually discarded in a process of metamorphosis. In a very real sense this metamorphic process of sea urchin and human alike is *also* a re-telling of the story of the acorn which is likewise fertilised by pollen (sperm) blowing in the wind (floating in the sea), exists as a living entity in its own right, falls to the Earth, and then the final plant grows from the seed *germ*, eventually discarding the bulk of original acorn as its roots and leaves emerge and split the acorn in twain. The lungs, vascular system and nervous systems of higher animals are internally-growing fractally organised space-filling versions of the externally-growing roots and branches of a plant. Sea urchins are are organised inside-out relative to mammals, having their endoderm (mammalian digestive system) on the outside and their ectoderm (mammalian nervous system and skin) on the inside. This inside-outside flip was one of the major significant stages in our evolution.

To summarise the above, the metamorphosis of a plant from unfertilised seed through to fertilised seed through to plant is almost exactly the same as that of a sea urchin or a human – except that the sea urchin has turned its branched growth inwards instead of outwards, and the human has flipped its endoderm to the inside instead of the outside. In all three cases – plant, sea urchin, human – the final form grows from a "germ" inside the vessel of a proto-form that initially has a life of its own, but which is then discarded as its germ outgrows its container.

The act of metamorphosis occurs when Life becomes more complex – or as we put it, when a new life (child) is born. Since Life is continuous, a flame that is constantly being passed on, there is a serious problem with age-ing, the fact that when a human egg is pollinated it is already the age of its mother plus 6 months. If nothing were done about this, everyone born would already be biologically the age of their mother at birth – not a particularly great thing, considering that most cells and organisms do age and become less viable over time. So the metamorphosis of regeneration and birth must also *necessarily* be accompanied by some means by which the biological clock of the egg is set to zero. At one time it was thought that germline cells were ageless and effectively immortal, but this was proven to be incorrect some time ago. It has, however, recently been shown that the human egg resets[106] its biological clock to zero! Isn't that beautiful, and mysterious?

Fire and water

It is a well known fact that water is essential to life, and that most life is mainly composed of water. Perhaps less well known are the strange properties of water that are manipulated by living creatures in the everyday processes of living. In fact, it is the specific and unusual (one might say strange) properties of water that make life as we know it possible at all. Almost all of the molecules that comprise the internal surfaces of living organisms are hydrophilic (i.e. they attract water). Research by Gerald Pollack[107] showed that when water bounded by a hydrophilic surface is provided with energised photons (e.g. normal daylight), it organises itself into a very ordered, quasi-crystalline structure similar to ice – a "fourth phase of water". This structured water is also known as "Exclusion Zone" or "EZ" water because the tight crystalline structure pushes all atoms and molecules to the side, creating a bed of pure and highly viscous material with interesting electrical properties. So whilst it is true that all living organisms contain saline water as a representation of the salty seas in which life first evolved, that salinity is not the same as the salinity in a glass of sea water. Organelles and membranes are so close together and hydrophilic surfaces so prevalent, that all fluid in a living organism is pure and ionised, with oppositely charged "dissolved" ions being forced and retained by the crystalline structure onto the hydrophilic surfaces. It is only when those surfaces are penetrated or otherwise disrupted that the salts and other charged molecules are released into the fluid. From this respect, one has to think of all living organisms as obeying the "Observer principle" – it is virtually impossible to investigate living processes (especially when this is done invasively) without the means of investigation changing what is being observed.

The formation of layers of EZ water is a process of charge separation (OH^- separates from H^+), which creates strong pH gradients along with significant electrical potentials. Pollack believes that almost all (if not all) water in living organisms is structured. All the movements and chemical reactions and other processes occurring inside cells and larger multicellular bodies are then taking place within the milieu of this structured, semi-crystalline, electrically charged environment; and so the simple models we have produced of physiology based on the non-structured properties of water are probably fictional half-truths.

One has to ask where the photons come from for this re-structuring of water. Whilst it is true that the tissues of the body are translucent and light can pass directly through them, this is less so for the deepest structures, and for the largest bones; or for heavily skinned animals such as elephant or bison; or indeed for subterranean and deep abyssal creatures that never see the light of day. Nature is ingenious, as always, in providing for photons. Bones, the least light-permeable structures in the body are both piezoelectric and piezoluminescent semiconductors, and so generate internal sparks of electricity and light when they are loaded. And research by the biophysicist Fritz-Albert Popp[108] has indicated that living organisms generate a plentiful supply of its own light internally – biophotons. Indeed, it seems that the degree of health ("life force" or organic reslience) is directly related to the intensity and quality (frequency spectrum) of biophoton production. There is a tendency to think in a causal manner about physical processes, but at the level of biophotons (which must necessarily reflect quantum-level activity) this direction of causality starts to blur. Is life more resilient because photons are produced (because this enables structuring of water)? Or are more photons produced because life (i.e. something that might be thought of as a life-force) is more strong? Or both?

The electrical charge implications of biologically bound water are profound, and cells appear to direct all their inner processes through separation and manipulation of electrical charge. ATP is the most obvious example, with each adenosine triphosphate molecule being specifically chosen because it is able to transport twelve electrons (four electrons on three phosphate ions). Becker[109] showed that electrical charge is critical for the regeneration of limbs in salamanders – which in turn suggests that it is equally critical in the development of limbs in the growing foetus. And the semi-crystalline water structure (along with the semiconducting properties of hydrated collagen) essentially forms an ideal substrate for electronic activity. It has also recently been discovered that gut bacteria (just like soil bacteria[110]) produce electrical charge[111]. In this context, the action potentials of nerves no longer look quite so special. Rather, nerves are special because their bodies link across large distances; and so electrical charge is distributed over a greater distance.

When thinking of cellular electricity it's easy to miss the obvious because we do not easily place ourselves to experience the world at that scale. Cells exclude protons and accumulate electrons so there is a protein ratio of about 1:1000 from inside to outside across a cell wall. This amounts to about 100-150mV – a tiny amount at human scale. But at the scale of a cell it is equivalent to a few million volts/m – the same charge density that drives lightning bolts[112].

Communication and persistence

When one thinks about communication in an organism, most people will immediately think of nerves – neurons. Nerves (and particularly the central nervous system) must be important because they have such a high metabolic overhead – up to 30% of total body energy use in a human. And (on the basis of energy conservation and frugality), and organism must have very good reasons to have such a high proportion of cells that use up so much energy. But nerves are not the only means of communication.

The usual wisdom is that molecular communication at a small scale is dominated by diffusion, but this assumption is one of many that has to be reviewed in the light of EZ/structured water and the very powerful and densely crowded surface-charge-gradient effects found in and around cells. Inside cells, the cytoskeletal framework of microtubules and actin fibres create mechanical forces that transmit information, and provide a 3-dimensional communication network which extends out beyond the cell wall and connects directly to the gross fascial and skeletal network of complex animals[113]. In particular, large packets of molecules are ferried along the electrically active surface of microtubules, as can be seen in the cell animation video produced by XVIVO[114].

Although this animation is useful in showing the different kinds of process that occur at cellular level, it is also somewhat deceptive. Cells are actually crammed full of organelles, and not open in the way portrayed in the simulation. And it does not answer the question of how anything moves at all in this very tightly packed space, let alone “knows” where its intended target might be. The question simply does not arise in normal water that is not crowded with obstructions – which is the familiar state of affairs according to our macro-scale experience – where spare molecules can hang around waiting to be detected. The XVIVO simulation also ignores the (invisible) changes in electrical charge density and polarity, the near-UV light pulses of biophotons and the near-Infra-Red activity found in cells that also form part of any local intra and inter-cellular communication system. Neither does the simulation really answer the question as to how even closely proximal signalling molecules and their absorption sites finally come together, given that the signalling molecule’s motion is supposedly random and “unintelligent”. Vibration is probably one answer to this question. Each molecule has a particular set of vibrational resonant frequencies that may be attracted to (and/or attract) the hist receptor sites… but in turn, that possibility opens up a whole additional layer of communication at a cellular level.

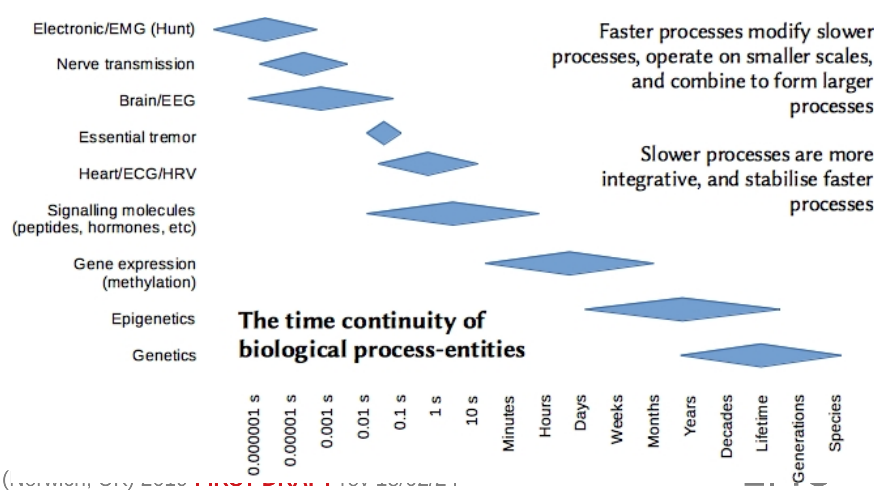
There are many chemicals used for signalling in a human body – hormones, cytokines, neurotransmitters, peptides, and even extremely simple molecules such as Nitrous Oxides (NOx). Although it is useful to classify them for general consideration of their effect, the definition of each classification starts to become more and more complex as more detail revealed, and all that can truly be said is that these very general groups represent waymarkers in a more or less continuous spectrum of signalling chemicals. For example, initially it was thought that hormones are only produced in endocrine glands, and neurotransmitters in the brain/nervous system. However, even single cells produce and use a remarkable range of neurotransmitters – almost as many as are used in the entire human body. And about 70% of serotonin[115] in the human body is produced and stored locally by gut bacteria. It is also a fact that the presence of feedback loops in the body mean that almost any chemical used in metabolism has a signalling function in addition to its physiological function. So, for instance, NOx is released by the central nervous system as a shotgun immune response, and so its presence signals the presence of invasive pathogens. But it also regulates mood, acts as a painkiller and regulates blood flow and pressure by vasodilation, in addition to a dozen or so other effects on various metabolic pathways and biochemical reactions. When it comes to living organisms, there is inevitably a blurred distinction between communication, process and function, since every metabolite (e.g. glucose, cholesterol, sodium) carries an inherent contextual meaning for the organism; and communication is all about conveying meaning. The neurotransmitters (etc.) that are used for signalling also often have functional use at their target – being necessary components of the process they trigger, or of secondary processes. And in that sense they are *participatory* carriers of information, rather than passive bits of information more typical of morse code or data streaming from a modem.

Once an organism grows beyond a certain physical size, it needs more efficient communication – to obtain food and dispose of waste, and for signalling to and from nearby organisms. The first level up is to create a dedicated fluid transport system, bringing about some distinction (again, somewhat blurred) between local chemical signalling in and between adjacent cells vs systemic signalling fluid circulation. Information transfer and residence times are significant – and with systemic flow also comes advection-dispersion and other mechanisms whereby the signal may persist for some time. **Persistence** is another facet of biological communication which blurs the distinction between process/state and information. Information is by definition something new, and after a while the lack of change equates to zero information, and what was once information now becomes the norm, against which all new information is measured. This has great utility for or a living organism; because persistence is necessary to provide continuity and stability. So although nerves provide the capacity for fast communication, their message is transient and ephemeral. Time is only recognised because we have a memory and a sense of the flow of time – a sense of change, because of persistence. In the central nervous system, and indeed throughout the body, this is provided by chemical signalling that persists well beyond the millisecond shimmer of nerve impulses. Even nitric oxides persist for a couple of seconds before they decay; and any molecule in the blood or lymph or cerebrospinal fluid persists for several tens of seconds up to tens of minutes before it is transported elsewhere or decays, and is broken down in the liver. Mental, emotional and physiological continuity is stabilised by these persistent systemic molecules against a background of much fasterAge of onset is also important in trauma work, and I'm wondering if it starts in infancy? neural and cellular activity. Every living thing is therefore swimming inside its own chemical soup of signals, and one could say that the net activity and behaviour at any one time is more or less controlled by the particular flavour and ingredients in that soup. As the old ingredients are eaten, new ones are added to the pot, and so the flavour (and meaning) of the soup continuously changes. If persistence were too long or fixed, then there would be no capacity to adapt, and if it were too short or unstable, then there would be no ability to take meaningful responses, because of the noise of constant change.

Once a *mobile and self-propelling* organism (animal) reaches a certain size, it has to employ nerves cells, because this is the only way to transfer electrical signalling across significant distances. The benefits of motion are high, because nerve cells are used in greater numbers as organisms become more complex, despite the high metabolic overhead in keeping these cells alive and energised. And with scale comes the problem of coordination and integration, and so it also becomes necessary to have an internal clock or clocks – very much like that in a computer central processor (CPU), that coordinates metabolic activity across the entire organism. The human heart is just one example; its powerful electrical signal not only penetrating every cell, and even affecting the space several feet away from the physical body.

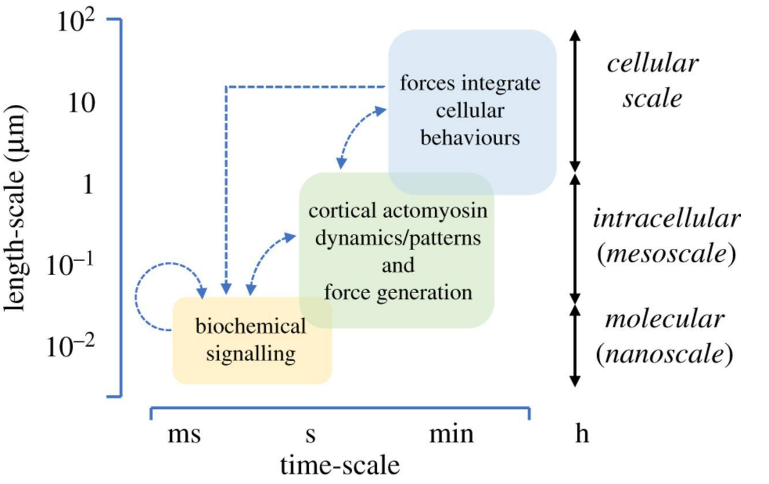
Given the vast complexity of a large organism (about 37 trillion human cells, and about the same number of bacterial cells in an adult human body) each part has to know that it is part of a whole, and has to coordinate its activity with the whole. The different time persistences create a set of interacting identities that operate on different timescales, and those entities have somehow to recognise their commonality. If there is a loss of such coordination – the cell no longer recognises its host – then one result is cancer. Research into cell activity has shown that biomechanical motion (via microtubules and actin fibers) is closely bound to biochemical activity – which makes sense purely because organelles must move in order to function, so time (frequency) is also related to physical size. The figure below shows the relationship between biomechanical and biochemical activity in a cell[116].

Valerie Hunt discovered another whole-body communication system[117] when investigating Electromyogams (EMGs) – the signals that arise in body tissue, comparable to the ECG (Electrocardiogram) signals from the heart and the EEG (Electroencephalogram) signals from the brain. The signal above about 2000 Hz is usually filtered out during measurement, because it is considered to be random noise. Dr Hunt analysed the higher frequency signals – up to about 250,000 Hz – and found that they have distinct structure, and contain information about the health and mental-emotional states of individuals. It would be easy to think that this is "only" the noise produced by cellular activity in the body; except that several different electronic systems have been produced – by both the Russian and American space programs, and by various independent researchers – that analyse the EM biofield and then reinforce certain frequencies to cause physiological changes. At its simplest level, the body appears to be strongly dependent on Schumann frequencies – the resonant cavity waves starting at 7.81 Hz, that bounce around the Earth's ionosphere. So part of the EM communication system is directly tunes into the Earth's electrical environment and the effects of the solar wind. And, of



course, the EM activity in all other life forms – including plants and bacteria.

In summary, communication in a large animal such as a human being is complex and multi-layered. It tends to be dominated on a physical level by neurological and chemical signalling – the latter simply because the chemical soup is persistent over medium to long time frames. But there are also mechanical (q.v. Ingber / biotensegrity) and vibrational, electrical (neural and ionic), electronic (Oschmann[118]), and electromagnetic (biophotons, and q.v. Hunt) layers of communication with a continuous field of activity from sub-cellular up to to systemic scales. Physical body position (gesture) and movement convey inwardly directed as well as externally directed meaning. The entire communication network is inherently tied into physiology; and at that level, information, meaning and action are one and the same thing. Whilst chemistry dominates and provides stability and continuity, organisms would not be adaptive if they were only stable and continuous – so there is an inbuilt chaotic instability and complexity of structure and signalling, with multiple links between different signalling processes. A small change in one alters the context of everything else. This kind of feedback system is chaotic and unstable to the extent that it can be perturbed (its balance altered) by very small inputs. Whilst the electronic and electromagnetic signalling layers are semi-redundant, they provide information that allows fine tuning, or even large perturbations (a butterfly's wing-beat in Peking starts a hurricane in the Atlantic) to take place. So far as the organism is concerned, everything is information, and communication of that information takes place on multiple levels, on multiple timeframes, and extends far beyond the confines of the skin. The molecular persistence of biochemistry – adrenalin, oxytocin, dopamine, etc – is further extended in time through days and years by changes in methylation state (gene expression); and through a lifetime and generations by epigenetics and genetic inheritance.



> *... bacteria and other microbes communicate chemically through various means, such as peptides, auto-inducers, signal molecules, and bioluminescence. At every scale, an invisible and complex fabric of signals and meanings arranges itself through communication, building sacred relationships —weaving the rhythmic, pulsing music of creation[119].*

The sheer exuberance of communication systems in life is displayed in the world of bacteria. What should be remembered is that we are made of single cells, and evolved from single cells. And whilst complex life forms have found ways to differentiate and gain even greater complexity, the means by which they do so started off in the complex and pluripotential world of unicellular life. It was the evolution of inter-cellular communication in individual cells and undifferentiated bacterial colonies that forms the basis for communication inside the human body. Complex differentiated animals simply do not evolve new cellular mechanisms. Their evolution at that level is complete, partly because the stages required to generate a new cellular mechanism that can be elegantly integrated into and be compatible with (and not create unfortunate side effects within) the rest of the cellular functionality and organic wholeness are too complex, too specific. So evolution at a differentiated level is about using the tools that are already present. Looking at the many inventive means by which bacteria communicate – that condition can hardly be considered to be a restriction.

Inhibition

The inhibitory form of control that dominates physiology is somewhat counter-intuitive. We tend to think of switching things ON so that they work – and not switching them off. But inhibition is not only typical of many control functions of the human body – it is the dominant form of control in all of Life! Several important aspects of inhibition will be revisited in detail later – the inhibition of muscles to create smooth motion, the inhibition of the adrenal system by means of the Vagal brake… So for now I will just give a brief description. As has been mentioned above, it is not biologically efficient to have any system on standby, simply doing nothing useful except waiting. There are several logical conclusions that one may draw from this. Firstly, any system that is only used occasionally must either

- have other important jobs to do in the meantime, specifically jobs that it would not be required to do in exactly that way when it is working fully in its main role; *and/or*
- it must be fully multitasking – being capable of equally performing two or more mutually exclusive physiological roles equally well, as occasion sees fit; *and/or*
- it must be switched on all of the time (and so constantly available), but its action is inhibited.

Secondly, it is worth asking how exactly this capacity originally became part of the organic system of control. The answer cannot be that it was taken in "just in case" without having a particular task – rather it must have been an important function that was subsequently suppressed or inhibited , and that inhibition created a greater overall adaptive (and responsive) capacity. It could logically also have been replaced/superseded, but as we have also seen above, biology tends not to work in that way – it retains and adapts what it has for very good reason, and does not go out to make something new from scratch.

All of these arguments result in a *requirement* for inhibition as a commonly used biological mechanism of control. So the high energy capacity of the mammalian adrenal system spends most of its time on tick-over, easily adapting to small shifts in energy demand. This comes about because the Vagal system inhibits the sympathetic nervous system – in a process called the "Vagal Brake". This makes excellent sense, because when there is no high demand for energy output, the high Vagal tone also encourages vegetative activity. When there is demand for high energy output, the Vagal tone decreases, and so as the brake comes off, energy is directed away from vegetative processes and towards muscles. The beauty of this inhibitory system is that in normal life there is always energy kept in reserve, because working energy is allocated between external and internal priorities (instead of just giving up energy to every demand). So if your electricity supplier charged you 10x the price if your electricity demand exceeded 3kW, you would make sure that the kettle had finished boiling before the electric toaster was switched on. It might even be possible to install a local information network that communicated between all the various electrical devices and restricted total power consumption below a certain limit. Such systems have recently been introduced in regional smart power grids in Denmark. In installing this energy limiting system, you would simply be making a rather coarse copy of something found in every animal.

Intelligence

Here we come to the nub of the matter – that fact that all the ingenuity described above that is displayed by living organisms is difficult to explain without some kind of organising intelligence. Exactly what intelligence might be – is not so easy to define. However, the subject matter of this book revolves around the presence of consciousness in living tissue, and by definition one cannot have active intelligence without a foundation of consciousness. Intelligence creates changes that cannot be explained by the usual assumptions of random interactions in a mechanistic and stochastic unconscious nature. For instance, it seems that human eggs choose[120] the particular sperm that is allowed inside to complete fertilisation – based on its genetic characteristics. The "behaviour" of the female's reproductive system has been found to defy normal mendelian statistics in several species …

> *"Some females, including many species of reptiles, fish, birds and amphibians, that copulate with more than one male (which biologists estimate are a vast majority of species) can store sperm for months, even years, altering the storage environment to stack the odds to favour one male over another. Many female birds, including domestic chickens, can eject sperm after mating, which lets them bias fertilization in favour of the best male."*

And the intelligent action continues past the point of fertilisation. Ignoring some very troublesome and difficult definitions (of consciousness and intelligence) for the moment, let's take a look at Mitosis. In the wondrous intricacy of cell division, it is the microtubules that choreograph the dance of DNA, by pumping water along their outer surfaces[121] to orient the DNA strands and move them into the correct position ready for the mechanical phase of cell division. So, given that a group of organelles that are "just" long stacks of polymerised proteins act in unison to physically move DNA into the correct position, what is the bottom line mechanism that coordinates and controls a cell as it divides? Ignoring the duplication of all other organelles, often initiated and performed by the organelles themselves (e.g. the centriole self-duplicates), DNA replication is not trivial. What we know so far is that

- The DNA is split/unzipped by the helicase enzyme – a rotating "motor protein" that moves directionally along the DNA backbone. This creates a forward and backward pointing strand, each of which has to be replicated differently.
- The leading strand first must be marked by a "primer". From this point, DNA polymerase "walks" along it, adding complementary pairs. i.e. it detects which base is at each point, and then takes raw material from – somewhere – and adds it appropriately.
- The Lagging strand is the wrong way round, and so short groups (Ozaki fragments) have to be constructed and then moved to the correct location and joined together.
- The primers are then removed and suitable DNA is infilled at their binding locations
- The DNA is "proof-read" (!) There is typically about 1 error per 10^8 base pairs, and repair enzymes reduce this to about 1 error per 10^{10} base pairs. i.e. there are about three errors in a human genome every time it is copied.
- Finally it is sealed back into two continuous strands by DNA ligase in a four-step process that repairs broken strands.

At either end of this process, the DNA must be unpacked and then re-packed. A chromosome is only one or two microns long but the DNA in it is about 10cm long, giving a physical packing ratio of about 50,000:1 – which is accomplished by repeated twisting, as one might find on a thick multistrand rope[122]. Any protein synthesis requires that exactly the correct part of the chromosome is located, unpacked and exposed, followed by the replication process above, and then re-packed exactly how it was found (so it can be found again). The more detail is discovered by science, the harder it is to conceive how all this came together – of even how it comes together in everyday cell dynamics – without some kind of conscious intelligence operating on all scales. The presence of behaviour of organelles "as if" they are making intelligent decisions and moving "as if" they know what they are doing has been noted by Albrecht-Buehler in his work on cell intelligence. And scaling up from a single cell to a whole human body, it is similarly hard to explain (without numerous "Gods of the Gaps") how a trillion cells coordinate unless there is some degree of intelligence (and consciousness) in the cells themselves : i.e. they "know" (whatever that means) that they are part of a greater unit – a cell or a whole organism; and the "know" (whatever that means) their role in that organism. Indeed, one of the most prevalent diseases of the 21st century – cancer – is a situation in which the cancerous cells have "forgotten" that they are part of a greater whole, and so are not adopting the form that they should and are reproducing as if they are on their own.

> *Nobody in his right mind would believe that the contractile protein molecules in a person's throat speak English. Clearly, the molecules follow orders issued ultimately by the person's brain. This is not a matter of the size of the organism. The contractile proteins in the muscle cells of a small nematode are not gliding or swimming, either. They, too, receive orders from the nervous system of the worm. In short, the interactions between the molecules of any organism*

generally do not create the functions of the organism, but it is the other way around: The functions of the organism initiate and control the interactions between its molecules. The necessity for such control is obvious. Using the example of contractile proteins, the molecules can only polymerize, depolymerize or slide along each other, but they would not know when and with what force and when to stop. A signal-integrating mechanism is required.

Why should the situation be different for single cells? After all, protozoa are in effect small but quite universal organisms and the above conclusion should apply to them as much as to a fly, a frog or the author of this website. Yet, the vast majority of today's biologists devote their efforts to prove the opposite, namely that specific molecular interactions create the cellular functions such as cell division, directed locomotion, differentiation, design of the extracellular matrix, adhesion to materials and other cells and so forth.

My research for the past 30 years or so was devoted to examine whether cells have such signal integration and control centre(s). The results suggest that mammalian cells, indeed, possess intelligence. The experimental basis for this conclusion is presented in the following web pages.4

The most significant experimental results are:

1. The motile machinery of cells contains subdomains ('microplasts') that can be isolated from the cell and then are capable of autonomous movements. Yet, inside the cell they do not exercise their ability. The situation is comparable to a person's muscles that are capable of contraction outside a person's body, but do not contract at will once they are part of the person, suggesting that they are subject to a control center.

2. The cell as a whole is capable of immensely complex migration patterns for which their genome cannot contain a detailed program as they are responses to unforseeable encounters (Cell movement is not random).

3. Cells can 'see', i.e. they can map the directions of near-infrared light sources in their environment and direct their movements toward them. No such 'vision' is possible without a very sophisticated signal processing system ('cell brain') that is linked to the movement control of the cell. (The larger their light scattering, the larger the distance from which aggregating cells came together.)

In addition there is the supporting theoretical consideration that the hitherto completely unexplained complex structure of centrioles is predicted in every detail if one asks what structure a cellular 'eye' should have. (The structure of a pair of centrioles suggests their function as cellular eyes.)[123]

Complexity, chaos & emergence

Emergence is a strange property that depends on random variation. If randomness is insufficiently large, the resulting structures and relationships and processes are rigid – which works for inert matter such as snowflakes; but this degree of rigidity to (e.g.) hexagonal form in a physiological system would make life unresponsive to its environment. And if the randomness is too large, then the result is an unstable system that is completely disordered, approaching the classic bell-curve statistical probability distribution of Brownian motion. A good example of use of emergent chaos in a natural system is a line of ants, where typically there are about 90-95% of ants following a trail, and the rest are exploring "randomly", and do not follow the trail. If there are no outlier ants, then if that trail were disrupted by an elephant stepping on it, or the food supply at the end became exhausted, the colony would die because it would not have the flexibility to adapt to the need for a new trail. And if too many ants act randomly, then there would be no consistent line of supply to reliable sources of food. Physiological systems are inherently unstable and chaotic whilst at the same time being internally structured by strong inter-relational linkages due to anatomy, neurology, biochemistry and electromagnetic activity. This instability allows them to respond to the smallest of perturbations; but except in extreme situations that response is a relatively delicate shift of priority and gesture. Patterns such as turbulence are another example of self-organising chaos, which still have a recognisable ordered form despite the apparent randomness they contain.

So, given just the right degree of randomness, complex emergent structures form and self-organise on their own. Life has learned to manipulate this random variation to its advantage; and a typical multicellular organism will make all its cells slightly different, creating emergent patterns of form and function. This is particularly true for the cells of the central nervous system. The slight variations in function of each cell cause an emergent self-organisation, that is one of the fundamental features of neural architecture. Neural networks – computer analogues of natural neural arrangements - have been investigated for several decades. The function of these networks – how quickly they work, what kind of processing they are optimised for, what tasks they are capable of – has been found to be directly affected by their internal structure, i.e. the geometry and topology of their interconnections.

There are several types of emergence from complexity, but they are all self-referential in one way or another, and so most tend to be fractal (self-similar at a range of scales).

Crystalline structures such as snowflakes are immediately recognisable; even though every single snowflake is unique, since its precise form arises from a host of random variations superimposed on a basic hexagonal crystalline framework. They, like all crystalline forms, are space-filling in both inwards and outwards directions.

Projective geometry is a system of mathematics that describes how moving points in space relate to each other and to infinity; and the set of forms that it creates dominate the natural world. The family of shapes that arises from this relational geometry spans the divide between living and non-living; consisting of egg and seed shapes (with implicit two-phase spirals on their external surface, typified by the pine cone and sunflower seed head) – which also mathematically invert to become vortexes (waterspouts, hurricanes and spiral galaxies).

Another expression of emergence is the dominance of Fractal (or self-similar) organisation in the natural world. Fractals are not scale-dependent, and exhibit the same patterns across a wide range of scales. Examples include river networks, the vascular system (of an animal), clouds, landscapes, trees … Landscapes are emergent, and specific large scale landscape morphologies reflect the crystalline or bedded form, strength and susceptibility to erosion of the parent rock. Trees are externally space-filling, in that they seek sunlight, so their network is always facing outwards. The leaves and growth are therefore on the outside of the canopy, and the tree grows bigger and bigger. Animal bodies have a finite size, so their branched fractal networks (veins, arteries, nerves) are internally space-filling. Fractal networks might appear to have a random distribution at any specific scale, but that distribution is completely dependent on the scale on which they are measured. As we look at smaller and smaller scales, the length of branching (or length of coastline – because coastlines are also Fractal/self-similar at multiple scales) becomes closer and closer to infinity[124]. Since the real world has physical limits to how small its structure can be, there is an upper limit (e.g. the Aorta) and a bottom limit (e.g. a blood capillary), in contrast to mathematical fractals, which can be magnified indefinitely.

There is no doubt that Life is shot through with complexity, fractal self-referential patterns arising from chaotic processes, and emergence. In a sense, emergence from chaos/complexity deliberately generated by slight variations in cellular function is one of the “computers” that has allowed organisms to optimise their energy usage and many other survival-critical functions described previously in this chapter. Perhaps one of the most remarkable things about life is that it creates local pockets of reversed Entropy[125]. Prigogine and Stengers described how this happens in the bigger thermodynamic picture. We exist in a vast stream of energy radiating from the sun. Just as small eddies form in a river, that give local structure to an otherwise featureless movement of water, Life takes a small fraction of the energy flowing round it and uses that to form structure. The non-living universe decays and energy is dissipated out to infinity, and gradually becomes less and less concentrated. So if I heat up some toast and coffee in the morning and wait half an hour before sitting at the table the heat has gone, and my breakfast is cold. Where has that heat (energy) gone to? It has slightly warmed up the room that I am in. This is a one-way transfer of and loss of energy to a chaotic and structureless background. The description of this process used in physics is to say that Entropy (unstructured chaos) has increased. Life reverses Entropy by creating form and structure and by ordering energy, using it and recycling it time and again through metabolic and ecological pathways. Structure is information, and another way to describe Entropy is that it is a measure of an absence of information. Once energy has been taken into the stream of life by photosynthesis and conversion into carbon compounds, it tends to stay inside the cycle of life. Anthropogenic global warming has come about as a result of us taking energy from outside the self-regulating, self-sustaining cycle of energy that usually exists in the biosphere.

Beauty

Our task must be to free ourselves by widening our circle of compassion to embrace all living creatures and the whole of nature in its beauty.

~Albert Einstein

One could even say that Life exists to give meaning to the universe, because otherwise, Entropy would make it increasingly meaning-less. Anyone who looks closely at living creatures and plants cannot but help that at some time they will be struck by the beauty of Nature. Whether it is the shimmer of light reflected from a fish turning in shallow water, or the deep blue-black iridescence of a raven's feathers, or the glorious meeting of hundreds of millions of monarch butterflies, or the explosion of flowers and grasses of an abundance of different colours on the great grasslands in spring, or the primaeval grandeur of the Mkgadigadi Baobabs … there is literally no end to the extraordinary beauty that Life on this Earth displays. It is true that – as living creatures ourselves, maybe it is inevitable that we will be attuned to beauty in similar living creatures; that the golden section of phi (1.618…) found universally in living systems might also be the mathematical basis of proportion for the greatest (human) masterpieces of art and music, as well as the proportions of the human body.

But on the other hand, given that pollinating insects do not perceive many colours outside the ultraviolet spectrum, why do flowers display such voluptuousness of colour? If nature constantly optimises itself, why should it not have fallen on a single shape or colour of leaf and bark and branching so that every tree would look almost identical in an indistinguishable sea of the same green? Why should a rainbow of mesmerising iridescence that requires fine texture at less than a micron be present on so many insect caparaces and butterfly wings and bird feathers? It is hard to dismiss the suspicion that somehow beauty is a fundamental part of the way in which Life wishes to express itself – that it is a necessity of Life's longing for itself. That Life knows its own beauty and strives to be ever more beautiful. The native American indians used to paint their horses, partly because the horses loved to be painted – because a horse has a sense of its own beauty. This appreciation of beauty and aesthetic can be found particularly in the world of birds - in the dances of cranes, the courtship rituals of grebes and blue footed boobies, the installation art of bower birds and the dazzling variety of coloured feathers that birds adorn themselves with. If Life is emergent, what makes it select beauty? It is quite possible that we tend to perceive causality quite the wrong way round. Female Ring Doves make a nest-coo when the male performs his courtship display in front of her, and this ritual triggers the growth of follicles in the ovary. It was thought that the male's display triggers this release of eggs. However, it turns out that the trigger for the hormonal changes that produce eggs is the nest-coo of the female. The conclusion is that female doves are not cooing only at the males - they are also cooing at their own ovaries to trigger the release of eggs.

Beauty is found in the many patterns of nature – the spots of a leopard or stripes of a tiger, the branched structures of trees, veins and river systems, the almost regular spots and squares on the skin of a whale shark. These are part of the ancient Chinese principle of Li[126] – epitomised by the pattern of grain in wood. Seeing light passing through leaves – that particular dappled, part-structured, part-random interplay of incandescent greens and half-shadows – if it is allowed to filter deeply enough into the conscious mind, travels further, deep into the midbrain, the hindbrain, the very cells and tissues of the body, and reminds them of a stillness they have become unfamiliar with. Many patterns in nature that touch something inside us with their beauty appear to arise from the reaction-diffusion mechanism[127] discovered by the mathematician Alan Turing[128], though exactly how Nature uses that (in principle) very simple arrangement in practice has not been so easy to fathom. What has been found is that this method of creation of pattern and texture is common to hair, feathers and shark skin. These mechanisms are deeply conserved in evolution, and maybe on some profound level we recognise and respond to their primaeval simplicity.

> *Biological diversity, across the board, is based on a fairly restricted set of principles that seem to work and are reused over and over again in evolution.*
>
> *Gareth Fraser*

Perhaps one answer to the question of beauty is to be found in the way that we perceive it – for a recognition of the beauty in an animal or a landscape *requires* that we take up more of a felt, experiential sense of connection to it. One of the many extraordinary moments in Anna Breytenbach's "*Animal Communicator*" documentary[129] is when she connects to the Kudu she is tracking … "*I'm standing under a tree, watching the sunset...*"

So ask yourself - why should a Kudu stand and watch the sun setting?

Polarity

> *Fear, separation, hate and anger come from the wrong view that you and the earth are two separate entities, the Earth is only the environment. You are in the centre and you want to do something for the Earth in order for you to survive. That is a dualistic way of seeing. So to breathe in and be aware of your body and look deeply into it and realise you are the Earth and your consciousness is also the consciousness of the earth. Not to cut the tree not to pollute the water, that is not enough.*
>
> *– Thich Nhat Hanh*

Underlying ALL of the above is the apparently simple principle of Polarity. Polarities have recently had a bad press and converted into things that oppose each other, are paradoxical, are in conflict, are mutually exclusive or inimical– just to name a few of the modern ways to view opposites. This comes about in the same way of thinking that emphasises the survival of the fittest – an identification with one pole, which becomes "good", and then the opposite therefore necessarily becomes "bad", so it is

There are moments
I hang on too tight,
trying to control what is.

And the clouds smile at me…
knowing
that it's only a matter of time
before I return to the clarity of wide open space.

There are times I forget that the
back and forth
is where the growth is.

That life is too beautiful
to just land in one space and stay there.

That movement and change
equal growth and wisdom.

That all states of being
and the exploration of them
are evenly valuable.

Spiralling in tight thought loops…
makes me appreciate the vastness
of open awareness.

Fighting with what is…
makes me appreciate the softness
of surrender.

Struggling with worldly conflicts…
makes me appreciate my harmonious
relationships
more fully.

The clouds teach me that everything,
everything that is, was, and will be,
has its place somewhere.

They teach me to trust life.
All things eventually find their place.
All things eventually flow into where they belong.

This too will move,
change,
and dissolve.

The clouds teach me not to be too sure,
because even this knowing will change.
All things will change.

They remind me
that love and patience
outlast anger and irritation.

And they show me in my open moments
that all things in existence are here
because they are meant to be…

including me.

~*Christine Wushke*[130]

Notes : Chapter 2

1 Tiago Alves Jorge de Souza & Tiago Campos Pereira (2018) Caenorhabditis elegans Tolerates Hyperaccelerations up to 400,000 x g. Astrobiology. 18(7) Jul http://doi.org/10.1089/ast.2017.1802

2 A "g" is the acceleration due to gravity. A mere 5 g's is enough to make most people lose consciousness, and pilots and astronauts train to stay conscious in a few seconds exposure to 10 g's .

3 https://www.schierlab.fas.harvard.edu/

4 About half of what used to be called "Junk DNA" is now recognised to have an important role in gene expression. Non-junk DNA is an instruction template to make proteins, and also regulates the timing of embryological shifts that ensure growth occurs in the proper order. Once there is a basic organism (e.g. a mammal with a warm-blooded circulation, a brain, four limbs etc.), it seems to be small variations in morphology that make a difference. For instance, a dogs excellent sense of smell is dependent on a particularly well- folded nasal turbinate – the complex and delicate part of the ethmoid bone that sits in the upper reaches of the nasal tract. More complex folding of the turbinate increases the available surface area. Humans have more or less the same potential capacity to smell as a dog, but we simply have less surface area available to detect airborne molecules.

5 Fabian Ruperti, Isabelle Becher, Anniek Stokkermans, Jacob M. Musser, Mikhail M. Savitski, Detlev Arendt et. al. (2024) Molecular profiling of sponge deflation reveals an ancient relaxant-inflammatory response. Current Biology 34(2) pp361-375.e9 (Open Access) DOI:https://doi.org/10.1016/j.cub.2023.12.021

6 Nick Lane (Dec 4, 2023) The electrical origins of life. Talk at NCCR Molecular Systems Engineering https://www.youtube.com/watch?v=FLaTU-t1CQM&t=341s

7 Cameron Duke (23rd March 2021) Genes of 500 million-year-old sea monsters live inside us: They looked nothing like us, but their genes live inside us still. Live Science. https://www.livescience.com/ediacarian-creatures-share-genes-with-humans.html

8 Olivier Alirol (2019) Nature's effective way of conducting electrons. Resonance Science Foundation. https://resonance.is/natures-effective-way-of-conducting-electrons/

9 Ahmed El Hady & Benjamin B. Machta (2015) Mechanical surface waves accompany action potential propagation. Nature Communications. 30 Mar 6:6697 pp1-7 DOI: 10.1038/ncomms7697

10 Thomas Heimburg & Andrew D. Jackson (2005) On soliton propagation in biomembranes and nerves. PNAS 102(28) 12 Jul, pp9790-9795 www.pnas.org/cgi/doi/10.1073/pnas.0503823102

11 This may provide an elegant explanation as to why myelinated nerves transmit signals more quickly; since the myelin sheath will alter the mechanical properties of the nerve. Since myelin is wrapped round the nerve in the form of a coil spring, maybe it provides lateral stiffness so that the mechanical impulse (of lipids undergoing a phase change as they are polarised by the action potential) travels faster. Thus allowing the charge to also travel more quickly.

12 Gerald Pollack (2013) Fourth Phase of Water: Beyond Solid, Liquid & Vapor. Publ. Ebner & Sons. ISBN-13: 978-0962689543

13 Yuuta Imoto, Yamato Yoshida, Fumi Yagisawa, Haruko Kuroiwa & Tsuneyoshi Kuroiwa (2011) The cell cycle, including the mitotic cycle and organelle division cycles, as revealed by cytological observations. J Electron Microsc (Tokyo) (2011) 60 (suppl 1): S117-S136. doi: 10.1093/jmicro/dfr034

Notes : Chapter 2

14 Jonathan B. Freund, Jacky G. Goetz, Kent L. Hill & Julien Vermot (2012) Review : Fluid flows and forces in development: functions, features and biophysical principles. Development 139, 1229-1245 (2012) doi: 10.1242/dev.073593

15 Zaman Mirzadeh, Young-Goo Han, Mario Soriano-Navarro, Jose Manuel García-Verdugo, and Arturo Alvarez-Buylla (2010) Cilia Organize Ependymal Planar Polarity. The Journal of Neuroscience, 17 February 30(7): 2600-2610; doi: 10.1523/JNEUROSCI.3744-09.2010

16 Blaise Yvert, Claire Mazzocco, Sébastien Joucla, Adeline Langla, & Pierre Meyrand (2011) Artificial CSF Motion Ensures Rhythmic Activity in the Developing CNS Ex Vivo: A Mechanical Source of Rhythmogenesis? The Journal of Neuroscience, 15 June 2011, 31(24): 8832-8840; doi: 10.1523/NEUROSCI.1354-11.2011

17 Dana Zohar (1990) The Quantum Self. Publ Flamingo / Bloomsbury ISBN 0747502714

18 http://www.quantumconsciousness.org/

19 Gerald Pollack (2001) Cells, Gels & the Engines of Life: A New Unifying Approach to Cell Function. 320pp Publ. Ebner and Sons ISBN-13: 978-0962689529

20 Stefano Mancuso & Alessandra Viola (2015) Brilliant Green : The surprising history and science of plant intelligence. Publ. Island Press. ISBN-13: 978-1-61091-603-5

21 University of Cambridge (July 11, 2019) Ancient defense strategy continues to protect plants from pathogens. Punblished online. https://phys.org/news/2019-07-ancient-defense-strategy-pathogens.html and see original article Philip Carella, Anna Gogleva, David John Hoey, Anthony John Bridgen, Sara Christina Stolze, Hirofumi Nakagami, and Sebastian Schornack. 'Conserved Biochemical Defenses Underpin Host Responses to Oomycete Infection in an Early-Divergent Land Plant Lineage.' Current Biology (2019). DOI: 10.1016/j.cub.2019.05.078

22 There is a lot of confusion arising from the idea of "*Deus ex Machina*". Alan Turing encapsulated the issue very nicely in his test for intelligence. He never said that machines would ever be intelligent – he simply said that there would come a point at which someone would be able to make a machine that – were a human to interact with it for a certain length of time, they would be unable to tell if it were a machine or a human. That nuance is often lost. A machine is programmed to mimic. The idea of consciousness arising from a critical mass of computing power is a natural extension of the modern distortion of Descartes' "*Cogito, ergo sum*" and the idea that the mind is ultimate. Modern neurology research indicates that the entire purpose of the brain and most of its early plasticity is centred on physical movement, via the feedback loop of "Sense – Interpret/Meaning – Response/movement" (Chapter 3). Also see Chapter 8 (Consciousness).

23 Gerald Pollack (2013) Fourth Phase of Water: Beyond Solid, Liquid & Vapor. Publ. Ebner and Sons. 357pp ISBN-13: 978-0962689543. I cannot recommend this book enough – it is the future of both physical and biological science, and has been written with such simple clarity that even a non-scientist can understand many of the concepts. Pollack has made the book freely available online – see http://www.mdpi.com/2073-4441/5/2/638/pdf

24 Usually any mechanical component bears BOTH compressive and tensile forces. Tensegrity is a remarkable system of construction in which the compressive and tensile forces are isolated into single elements. It was devised by architect and sculptor Ken Snelson when he was apprenticed to the great 20th century engineer and futurist Buckminster Fuller. At time of writing there

are no general books on Tensegrity in print. There are, however, quite a few books on BioTensegrity (tensegrity structures in living organisms), *including* Graham Melvin Scarr (2014) Biotensegrity: The Structural Basis of Life. Publ. Handspring, paperback, 160pp ISBN-13: 978-1909141216. The original research into Tensegrity structures in cells was carried out by Donald Ingber – who showed that apparently mechanical stiff structures such as actin fibres and microtubules took part in a tensegrity structure that acts as a communication system connecting and orchestrating *all* of the functions of the cell. The research was summarised in Swanson RL. Biotensegrity: A Unifying Theory of Biological Architecture With Applications to Osteopathic Practice, Education, and Research—A Review and Analysis. J Am Osteopath Assoc 2013;113(1):34–52. http://jaoa.org/article.aspx?articleid=2094459

25 Francis Collins (2016) Scoliosis Traced to Problems in Spinal Fluid Flow. NIH Director's Blog Posted on July 7th. https://directorsblog.nih.gov/2016/07/07/scoliosis-traced-to-problems-in-spinal-fluid-flow/ – also see Grimes DT, Boswell CW, Morante NF, Henkelman RM, Burdine RD & Ciruna B (2016) Zebrafish models of idiopathic scoliosis link cerebrospinal fluid flow defects to spine curvature. Science Jun 10;352(6291):1341-1344 https://doi.org/10.1126/science.aaf6419

26 Na, K, Ca and Mg is chemical shorthand for Sodium (Na, or *Natrium* in Latin), Potassium (K or *Kalium* in Latin or *Al kali* in Arabic), Calcium (Ca) and Magnesium (Mg). These are the four major ions of the body, and are the main electrolytes in blood plasma.

27 Swanson RL. Biotensegrity: A Unifying Theory of Biological Architecture With Applications to Osteopathic Practice, Education, and Research—A Review and Analysis. J Am Osteopath Assoc 2013;113(1):34–52. http://jaoa.org/article.aspx?articleid=2094459

28 Donald Ingber has published many papers on cell architecture and the relationships between the mechanical force sin a cell and its reproduction, metabolism and the extracellular matrix. One of his original papers : Donald E. Ingber (1988) The Architecture of Life : A universal set of building rules seems to guide the design of organic structures—from simple carbon compounds to complex cells and tissues. Scientific American, Jan pp48-57. And a more recent summary : Ingber DE, Wang N, Stamenovic D. Tensegrity, cellular biophysics, and the mechanics of living systems. Reports On Progress in Physics. Physical Society (Great Britain). 77: 046603. PMID 24695087 DOI: 10.1088/0034-4885/77/4/046603. A full list of publications can be found at https://academictree.org/cellbio/publications.php?pid=57087&searchstring=&showfilter=all

29 Pollack (2013) op. cit.

30 Perhaps the factor that differentiates much of human electronic communication from that found in Nature is that most natural communication is imbued with meaning and interrelationship.

31 Krakauer, D., Bertschinger, N., Olbrich, E. et al. (2020) The information theory of individuality. Theory Biosci. 139, 209–223. https://doi.org/10.1007/s12064-020-00313-7

32 Steve Nadis (August 5, 2021) Mathematicians Solve Decades-Old Classification Problem. Quanta Magazine ¦ Set Theory. https://www.quantamagazine.org/mathematicians-solve-decades-old-classification-problem-20210805/

33 Philip Ball (2018) Real-Life Schrödinger's Cats Probe the Boundary of the Quantum World : Recent experiments have put relatively large objects into quantum states, illuminating the processes by which the ordinary world emerges out of the quantum one. Quanta Magazine June 25. https://www.quantamagazine.org/real-life-schrodingers-cats-probe-the-boundary-of-the-quantum-world-20180625/

Notes : Chapter 2

34 Roudaut, Y., Lonigro, A., Coste, B., Hao, J., Delmas, P., & Crest, M. (2012). Touch sense: Functional organization and molecular determinants of mechanosensitive receptors. Channels, 6(4), 234–245. http://doi.org/10.4161/chan.22213

35 Available from: http://www.nobelprize.org/nobel_prizes/medicine/laureates/1949/hess-lecture.html

36 The Australian aphorism "out of his tree" refers to koala bears – who eat eucalyptus leaves. The leaves contain so many aromatics that the koala can become intoxicated – and then might just lose grip of the tree and fall to the ground, stoned.

37 LIBD (January 10, 2022) Neurons Derived From Stem Cells Predict Psychosis and Cognitive Deficits in Individuals With Schizophrenia. Neuroscience News https://neurosciencenews.com/psychosis-stem-cells-schizophrenia-19891/

38 Mae Wan Ho (1998) The Rainbow and the Worm : the physics of organisms ISBN-10:981024813X

39 Jim Al-Khalili (2014) Life on the Edge: The Coming of Age of Quantum Biology. Publ. Bantam Press, Paperback, 368 pp ISBN-13: 978-0593069325 This book is a great read for the most part, but is also somewhat annoying. He writes as if quantum biology is new, and actually it's not. What is new is that fact that it has been accepted by mainstream biological and medical science, in parts, but also with a lot of lip service. The ramifications of quantum biology extend through to possible ways of describing consciousness and questions about how that conscious intelligence interfaces with DNA and evolution. But Al Khalili keeps to a very conservative position and dismisses the broader implications out of hand as pseudoscience. The final impression is not "Isn't life amazing?", but rather, "Isn't science amazing?" Having said all that, his description of quantum tunnelling is beautifully concise.

40 Meghan Bartels (June 19, 2023) Quantum Light Experiment Proves Photosynthesis Starts with a Single Photon | Scientists have used quantum technology to track individual particles of light as they begin the process of photosynthesis. Scientific American | Plants https://www.scientificamerican.com/article/quantum-light-experiment-proves-photosynthesis-starts-with-a-single-photon/

41 Richard Hildner, Daan Brinks, Jana B. Nieder, Richard J. Cogdell & Niek F. van Hulst (2013) Quantum Coherent Energy Transfer over Varying Pathways in Single Light-Harvesting Complexes. Science 21 Jun Vol. 340, Issue 6139, pp. 1448-1451 DOI: 10.1126/science.1235820 and summary at https://www.bbc.co.uk/news/science-environment-22996054

42 S. Lim & E. Jung (2010) A three-dimensional model of a closed valveless pump system immersed in a viscous fluid SIAM J. Appl. Math. 70(6):1999-2022 DOI: 10.1137/08073620X and http://homepages.uc.edu/~limsg/vp3d.html

43 Lindsay D. Waldrop & Laura A. Miller (2015) The role of the pericardium in the valveless, tubular heart of the tunicate Ciona savignyi. Journal of Experimental Biology 218: 2753-2763; doi: 10.1242/jeb.116863

44 The Breath of the seasons. Images from NASA... https://www.youtube.com/watch?v=r2yLSLmnsY4

45 Pedro Gómez-Gálvez, Pablo Vicente-Munuera, Antonio Tagua, Cristina Forja, Ana M. Castro, Marta Letrán, Andrea Valencia-Expósito, Clara Grima, Marina Bermúdez-Gallardo, Óscar Serrano-Pérez-Higueras, Florencia Cavodeassi, Sol Sotillos, María D. Martín-Bermudo, Alberto Márquez, Javier Buceta & Luis M. Escudero (2018) Scutoids are a geometrical solution to three-dimensional packing of epithelia. Nature Communicationsvolume 9, Article number: 2960. doi.org/10.1038/s41467-018-05376-1 https://www.nature.com/articles/s41467-018-05376-1.pdf

46 György Buzsáki (2006) Rhythms of the Brain. Publ. OUP 464pp ISBN-13: 978-0195301069

Notes : Chapter 2

47 Stanley Keleman (1987) Embodying Experience: Forming a Personal Life. 88pp Center Press ISBN-13: 978-0934320122

48 The hydra sleeps every four hours, probably to facilitate cell repair : Veronique Greenwood (May 18, 2021) Sleep Evolved Before Brains. Hydras Are Living Proof: Studies of sleep are usually neurological. But some of nature's simplest animals suggest that sleep evolved for metabolic reasons, long before brains even existed. Quanta Magazine ¦ Sleep https://www.quantamagazine.org/sleep-evolved-before-brains-hydras-are-living-proof-20210518/

49 So a truly de-energised muscle is not a floppy one … it is one that is in spasm and full of rigor. **See** Gerald Pollack (2001) Cells, Gels & the Engines of Life: A New Unifying Approach to Cell Function. 320pp Publ. Ebner and Sons ISBN-13: 978-0962689529

50 Energy Ilya Prigogine & Isabelle Stengers (1989) Order out of Chaos. Publ Bantam Doubleday Bell. ISBN-13: 978-0553343632

51 Pushing the metabolism out of its normal range appears to be beneficial in all kinds of ways. A lot has been said for regular exposure to cold (e.g. Wim Hof) and its beneficial effects on the immune system. My personal experience has been with high altitude and extreme heat. Up to my early 20's I had repeated problems with breathing and absorbing enough oxygen for extended exertion such as running. This may have been some low grade level of asthma, but if so was never diagnosed. In 1982 I went to Peru, and spent about four weeks well above 2500 metres, and up to about 3800 metres above sea level, near the Salkantay glacier. Despite the fact that oxygen is less available, once I had spent about one week acclimatising, I actually felt more alive and invigorated and able to breathe than I ever had done before, and this continued when I came home. So something about that oxygen stress (and maybe also the extreme cleanliness of the air) shifted my metabolism. In a similar way, I had always struggled with hot summers in England until I worked in Kalahari and Arabian deserts for a total of three years. Since then, even though it's now over 30 years ago, I can settle into a hot climate and my body seems to adapt very easily.

52 Since 100% moisture saturation of air at 30ºC is 4% moisture, even moist pure air has a minimum of 20.8% O_2

53 Olena Dmytrotsa, Yanko N, Shvayko S, Poruchynskiy A & Zhuravlov O (2018) Indices of Oxygen Saturation in Urban and Rural Children. Biomed J Sci & Tech Res May 11 pp3961-2 DOI: 10.26717/BJSTR.2018.04.001061

54 Rodrigo Pérez Ortega (July 30, 2020) Why Are Plants Green? To Reduce the Noise in Photosynthesis. Plants ignore the most energy-rich part of sunlight because stability matters more than efficiency, according to a new model of photosynthesis. Quanta Magazine https://www.quantamagazine.org/why-are-plants-green-to-reduce-the-noise-in-photosynthesis-20200730/

55 https://bioneers.org/carl-safina-animals-think-feel-ztvz1802/

56 Both the heme of haemoglobin and chlorophyll are constructed from four pyrrole rings (four carbon atoms and one nitrogen atom, connected with 3 single and 2 double bonds). With a few very small changes in the inner bonds of the rings (plus a different molecular structure hanging from two of the outer carbon atoms), the main difference is that at the very core of chlorophyll sits a Magnesium atom, whereas heme has an atom of Iron.

57 Christie Wilcox (April 21, 2021) DNA of Giant 'Corpse Flower' Parasite Surprises Biologists: The bizarre genome of the world's most mysterious flowering plants shows how far parasites will go in stealing, deleting and duplicating DNA. Quanta Magazine ¦ Genomics https://www.quantamagazine.org/dna-of-giant-corpse-flower-parasite-surprises-biologists-20210421/

58 Jean-Paul Biberian (2012) Biological Transmutations: Historical Perspective. Review Article, J. Condensed Matter Nucl. Sci. 7 pp11–25 http://www.ludkow.info/cf/406bio_alchemy.pdf

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59 Although the mainstream scientific wisdom is that “the heart pumps the blood like a pump”, hydrodynamic modelling by Russian researchers has shown that – purely in terms of standard hydraulics – the heart cannot possibly be solely responsible for circulating blood through the many miles of capillary bed. Furthermore, blood cells are larger (!) than the capillaries that they travel through. An alternate way of looking at this is to think of the heart as a pressure-volume regulator, something like a Ram Pump, with peristaltic contraction of the capillary bed providing the majority of circulatory force.

60 The lung is a site of platelet biogenesis and a reservoir for haematopoietic progenitors. Lefrançais E, Ortiz-Muñoz G, Caudrillier A, Mallavia B, Liu F, Sayah DM, Thornton EE, Headley MB, David T, Coughlin SR, Krummel MF, Leavitt AD, Passegué E, & Looney MR. Nature. 2017 Mar 22. doi: 10.1038/nature21706 **and** a summary can be seen at https://www.nih.gov/news-events/nih-research-matters/overlooked-role-lungs-blood-formation

61 https://phys.org/news/2021-06-arctic-rotifer-years-frozen-state.html

62 https://phys.org/news/2016-04-sexual-reproduction-rotifers-scavenge-genes.html

63 http://www.bbc.com/earth/story/20160602-some-lifeforms-may-have-been-alive-since-the-dinosaur-era

64 Cano RJ & Borucki M (1995) Revival and identification of bacterial spores in 25 to 40 million year old Dominican amber. Science 268, pp1060-1064

65 Morono, Y., Ito, M., Hoshino, T. et al. (2020) Aerobic microbial life persists in oxic marine sediment as old as 101.5 million years. Nat Commun 11, 3626. https://doi.org/10.1038/s41467-020-17330-1

66 Vreeland RH, Rosenzweig WD & Powers DW (2000) Isolation of a 250 million-year-old halotolerant bacterium from a primary salt crystal. Nature 407, pp 897-900 | doi:10.1038/35038060

67 Iaizzo P. A., Laske, T. G., Harlow, H. J., McClay, C. B. & Garshelis, D. L. (2012), Wound healing during hibernation by black bears (Ursus americanus) in the wild: elicitation of reduced scar formation. Integrative Zoology, 7(1), pp48-60. https://doi.org/10.1111/j.1749-4877.2011.00280.x

68 https://www.youtube.com/watch?v=oyBqZ-_5B_8

69 http://www.basic.northwestern.edu/g-buehler/FRAME.HTM

70 Wall, Daniel (2016) Kin recognition in bacteria. Annu Rev Microbiol September 08; 70, pp143–160. doi:10.1146/annurev-micro-102215-095325

71 Mehdi Snoussi, John Paul Talledo, Nathan-Alexander Del Rosario, Salimeh Mohammadi, Bae-Yeun Ha, Andrej Košmrlj, Sattar Taheri-Araghi (2018) Heterogeneous absorption of antimicrobial peptide LL37 in Escherichia coli cells enhances population survivability. eLife 2018;7:e38174 doi: 10.7554/eLife.38174 : summary also at https://www.princeton.edu/news/2019/02/05/dying-bacteria-absorb-antibiotic-allowing-others-survive-and-grow

72 Lisa Margonelli (2018) Underbug: An Obsessive Tale of Termites and Technology. Publ, OneWorld ISBN-13: 978-1786071903, summarised in Scientific American, August 2018, pp66-71

73 https://www.britishlichensociety.org.uk/learning/what-is-a-lichen

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74 Zdenka Babikova, Lucy Gilbert, Toby J. A. Bruce, Michael Birkett, John C. Caulfield, Christine Woodcock, John A. Pickett & David Johnson (2013) Underground signals carried through common mycelial networks warn neighbouring plants of aphid attack. Ecology Letters (2013) 16: 835–843 https://doi.org/10.1111/ele.12115

75 Rees T, Bosch T, Douglas AE (2018) How the microbiome challenges our concept of self. PLoS Biol 16(2): e2005358. https://doi.org/10.1371/journal.pbio.2005358

76 Thomas Bosch (Jan 31, 2019) Professor Thomas Bosch – The Metaorganism: The Microbiome and Its Host. Scientia (Biology) https://www.scientia.global/professor-thomas-bosch-the-metaorganism-the-microbiome-and-its-host/

77 This was first put into stark perspective for me some years ago when I carried out a water-balance survey on the Loch of Kinnordy nature reserve in Scotland, which was home to one of the biggest breeding colonies of black headed gulls in the UK – at its peak a few thousand birds. Compare this to the human population of just a small suburb of London. I think I had been aware of the numbers for many years, but this was the first time that I had been struck so deeply and profoundly by the harsh reality of this equation. We all love kingfishers and badgers and eagles dolphins – and if their total population is compared to that of humans, and they were all housed in human buildings, all of this precious wildlife that represents wildness would fit onto a medium sized conurbation – e.g. Warwick or Bracknell.

78 https://www.nikela.org/how-the-african-elephant-is-important-to-its-ecosystem/ or Ramakrishnan B., Ilakkia M., Karthick S., Veeramani A. (2018) The Role of Elephants in the Forest Ecosystem and Its Conservation Problems in Southern India. In: Sivaperuman C., Venkataraman K. (eds) Indian Hotspots. Publ. Springer ISBN-13: 978-981-10-6604-7 https://doi.org/10.1007/978-981-10-6605-4_16. Large animals dig holes that become permanent watering places or salt licks, each oftan having a rich surrounding ecology. They change distribution of vegetation (they are “gardeners”), and prevent the encroachment of bushy trees. Mature forest containing large animals always contains a broad range of habitats, including substantial areas of grassland. Near my home in Norfolk is the “Pingo Trail” – a series of shallow depressions and ponds and slightly larger bodies of water that are remnants of chunks of ice left behind by retreating glaciers. These were kept open and their ecology protected by large animals wading into them over a period of 10,000 years, but have increasingly silted up since cattle were enclosed by fences from medieval times on (and particularly in the past 50 years).

79 Whale poop is the main source of iron in the world's oceans, allowing oxygen-producing algae to bloom in vast tracts of sea that are otherwise almost completely devoid of nutrients. See : Wendy Zukerman (2010) Whale poop is vital to ocean’s carbon cycle. New Scientist 22 Apr https://www.newscientist.com/article/dn18807-whale-poop-is-vital-to-oceans-carbon-cycle/ or the original research at : Nicol, S. , Bowie, A. , Jarman, S. , Lannuzel, D. , Meiners, K. M. and Van Der Merwe, P. (2010), Southern Ocean iron fertilization by baleen whales and Antarctic krill. Fish and Fisheries, 11: 203-209. doi:10.1111/j.1467-2979.2010.00356.x

80 In the now famous case of reintroduction of a small pack of wolves to Yellowstone Park – the entire ecosystem changed. Moose and deer who had been devastating plant growth in valleys were driven back into upland pastures. The vegetation along watercourses changed, creating more openings for many other different species of plant, bird and animal to return and thrive. The end result was even a re-stabilisation of the banks of the river by the roots of small willows that had previously been suppressed by browsing. So a dozen wolves regulated and enriched the ecosystem of many hundred square miles of land. This would in turn create a more diverse food base for more wolves. It would be nice to think that there is an ideal wolf population – but in reality, there is a stable range of population at which on average the ecosystem is most diverse and rich, and the wolf population (and

that of other animals) is most sustainable through all annual variations in weather.

81 John Rennie & Lucy Reading-Ikkanda (November 13, 2017) Seeing the Beautiful Intelligence of Microbes. Bacterial biofilms and slime molds are more than crude patches of goo. Detailed time-lapse microscopy reveals how they sense and explore their surroundings, communicate with their neighbors and adaptively reshape themselves. Quanta Magazine https://www.quantamagazine.org/the-beautiful-intelligence-of-bacteria-and-other-microbes-20171113/

82 https://hellopoetry.com/morgan-kelley/

83 http://autocww.colorado.edu/~flc/E64ContentFiles/AlgaeAndFungi/Algae.html "Algae," Microsoft® Encarta® Online Encyclopedia 2000. http://encarta.msn.com © 1997-2000 Microsoft Corporation. All rights reserved.

84 Dong-Hwan C,, Millar JG & Rust MK (2009) Chemical signals associated with life inhibit necrophoresis in Argentine ants. PNAS, May 19, 106(20, pp8251–8255. Available online at http://www.pnas.org/content/106/20/8251.full.pdf

85 Ameisen JC, Idziorek T, Billaut-Mulot O, Loyens M, Tissier JP, Potentier A & Ouaissi A (1995) Apoptosis in a unicellular eukaryote (Trypanosoma cruzi): implications for the evolutionary origin and role of programmed cell death in the control of cell proliferation, differentiation and survival. Cell Death and Differentiation 2(4), pp285-300.

86 Zmasek CM & Adam Godzik A (2013) Evolution of the Animal Apoptosis Network. Cold Spring Harbor Perspectives in Biology 2013;5:a008649, 12pp available online at http://cshperspectives.cshlp.org/content/5/3/a008649.full.pdf

87 Tait SWG &Green DR (2013) Mitochondrial Regulation of Cell Death. Cold Spring Harbor Perspectives in Biology 2013;5:a008706, 15pp available online at http://cshperspectives.cshlp.org/content/5/9/a008706.full.pdf

88 https://www.youtube.com/watch?v=Bta18FdkVcA : a film of real attacks on hagfish by sharks and larger fish; and https://www.youtube.com/watch?v=pmaal7Hf0WA : a hagfish in an aquarium. The slime is mainly produced by collagen – that can bind with water to form a “gel”.

89 https://www.youtube.com/watch?v=WiALagjd4rs

90 Sheldrake, R (2009) Morphic Resonance: The Nature of Formative Causation. Publ. Park Street Press ISBN-13: 978-1594773174

91 Peter Godfrey-Smith (2017) Other Minds: The Octopus, The Sea, and the Deep Origins of Consciousness. Publ. Farrar, Straus & Giroux ISBN-13: 978-0374537197

92 Suzanne Rohrback, Craig April, Fiona Kaper, Richard R. Rivera, Christine S. Liu, Benjamin Siddoway & Jerold Chun (2018) Submegabase copy number variations arise during cerebral cortical neurogenesis as revealed by single-cell whole-genome sequencing. PNAS October 16, 115 (42) 10804-10809 https://doi.org/10.1073/pnas.1812702115

93 https://www.newyorker.com/tech/annals-of-technology/the-strangers-in-your-brain

94 Gilbert SF (2014) Symbiosis as the way of eukaryotic life: the dependent co-origination of the body. J Biosci. Apr;39(2) pp201-9 PMID:24736154 https://www.ias.ac.in/article/fulltext/jbsc/039/02/0201-0209

95 Provorov NA (2001) [Genetic-evolutionary basis of symbiosis doctrine].[Article in Russian] Zh Obshch Biol. Nov-Dec;62(6):472-95. Abstract available at https://www.ncbi.nlm.nih.gov/pubmed/11871266

Notes : Chapter 2

96 Richard Dawkins (2006) The Blind Watchmaker. Publ. Penguin Books ISBN-13: 978-0141026169

97 Paulien Hogeweg (2015) Non-random random mutations: a signature of evolution of evolution (EVOEVO). Proceedings of the European Conference on Artificial Life. https://www.mitpressjournals.org/doi/pdf/10.1162/978-0-262-33027-5-ch001

98 Adi Livnat (2013). Interaction-based evolution: how natural selection and nonrandom mutation work together. Biology direct, 8 (24). doi:10.1186/1745-6150-8-24

99 Ilana Zilber-Rosenberg & Eugene Rosenberg (2008) Role of microorganisms in the evolution of animals and plants: the hologenome theory of evolution. FEMS Microbiology Reviews, 32(5), 1 August pp723–735, https://doi.org/10.1111/j.1574-6976.2008.00123.x

100 Ilaria Di Lelio, Anna Illiano, Federica Astarita, Luca Gianfranceschi, David Horner, Paola Varricchio, Angela Amoresano, Pietro Pucci, Francesco Pennacchio & Silvia Caccia (2019) Evolution of an insect immune barrier through horizontal gene transfer mediated by a parasitic wasp. PLOS ¦ Genetics March 5, 2019 https://doi.org/10.1371/journal.pgen.1007998

101 George Nicholas (Feb 26, 2018) After Thousands of Years, Western Science Is Slowly Catching Up to Indigenous Knowledge : New research about how birds use fire to get a broader food supply comes as no surprise to Indigenous people. Yes! Magazine https://www.yesmagazine.org/people-power/after-thousands-of-years-western-science-is-slowly-catching-up-to-indigenous-knowledge-20180226

102 Jean-Louis Tu (date?) Natural toxic constituents in food, and effect (or absence of effect) of cooking. Beyond Vegetarianism. http://www.beyondveg.com/tu-j-l/raw-cooked/raw-cooked-1g.shtml

103 Hajeb, P. , Sloth, J. J., Shakibazadeh, S. , Mahyudin, N. A. and Afsah-Hejri, L. (2014), Toxic Elements in Food: Occurrence, Binding, and Reduction Approaches. Comprehensive Reviews in Food Science and Food Safety, 13: 457-472. doi:10.1111/1541-4337.12068

104 Centres for Disease Control and Prevention : General Information about Candida auris. https://www.cdc.gov/fungal/candida-auris/candida-auris-qanda.html

105 Mostly marine animals, the cnidarians include the corals, hydras, jellyfish, Portuguese men-of-war, sea anemones, sea pens, sea whips, and sea fans.

106 Erin Garcia de Jesús (June 25, 2021) Embryos appear to reverse their biological clock early in development: In mice, a 'rejuvenation event' wipes out genetic signs of aging days after fertilization. Science News https://www.sciencenews.org/article/embryos-biological-clock-development

107 Gerald Pollack (2013) Fourth Phase of Water: Beyond Solid, Liquid & Vapor. Publ. Ebner & Sons ISBN-13: 978-0962689543

108 Cohen, S. & Popp, F.A. (1997) Biophoton emission of the human body. Journal of Photochemistry and Photobiology B: Biology 40(2): pp187-189

109 Robert O. Becker & Gary Selden (1988) The Body Electric : Electromagnetism and the foundation of life. Publ. William Morrow ISBN-13: 978-0688069711

Notes : Chapter 2

110 Philip Ball (2007) Bacteria may be wiring up the soil : Microbes charge debate over nano networks. Nature 449, p388 doi:10.1038/449388a https://www.nature.com/news/2007/070926/full/449388a.html

111 Robert Sanders (2018) Gut bacteria's shocking secret: They produce electricity. Berlkeley News, Research, Science & environment 12 Sep http://news.berkeley.edu/2018/09/12/gut-bacterias-shocking-secret-they-produce-electricity/

112 Nick Lane (Dec 4, 2023) The electrical origins of life. Talk at NCCR Molecular Systems Engineering https://www.youtube.com/watch?v=FLaTU-t1CQM&t=341s

113 Christopher S. Chen & Donald E. Ingber (1999) Tensegrity and mechanoregulation: from skeleton to cytoskeleton. Osteoarthritis and Cartilage 7, pp81–94 https://www.oarsijournal.com/article/S1063-4584(98)90164-9/pdf

114 XVIVO (2013) The Inner Life of the Cell : A CGI animation https://www.xvivo.net/animation/the-inner-life-of-the-cell/

115 A chemical that regulates mood – hence the use of Selective Serotonin Re-uptake Inhibitors (SSRI's) as antidepressants

116 Figure 1. Spatio-temporal scales in dynamic feedback between signalling and cellular dynamics. Fast biochemical signalling at the molecular scale underlies all sub-cellular actomyosin dynamics and rearrangement. These mesoscale dynamics of cortical cytoskeleton give rise to forces and global tension that integrate several cellular scale behaviours. The dimensions of each module (box) qualitatively reflect their associated spatio-temporal scales. Interestingly, several regulatory interactions and feedbacks (arrows) exist within and between each module. From Suvrajit Saha, Tamas L. Nagy & Orion D. Weiner (2018) Joining forces: crosstalk between biochemical signalling and physical forces orchestrates cellular polarity and dynamics (Review Article) Philosophical Transactions of the Royal Society B | Biological Sciences 373 (1747) 09 April pp1-9 DOI:https://doi.org/10.1098/rstb.2017.0145

117 Valerie Hunt (1996) Infinite Mind: Science of the Human Vibrations of Consciousness. Publ. Non Basic Stock Line; 2 edition ISBN-13: 978-0964398818 http://neuronresearch.net/vision/

118 James L. Oschman (2015) Energy Medicine: The Scientific Basis, 2nd edition. Publ. Churchill Livingstone ISBN-13: 978-0443067297

119 Julie J. Morley (2019) Future Sacred: The Connected Creativity of Nature. Publ. Park Street Press ISBN-13: 978-1620557686

120 Carrie Arnold (2017) Choosy Eggs May Pick Sperm for Their Genes, Defying Mendel's Law. The oldest law of genetics says that gametes combine randomly, but experiments hint that sometimes eggs select sperm actively for their genetic assets. Quanta Magazine, Nov 15 https://www.quantamagazine.org/choosy-eggs-may-pick-sperm-for-their-genes-defying-mendels-law-20171115

121 Gerald Pollack (2001) Cells, Gels & the Engines of Life: A New Unifying Approach to Cell Function. 320pp Publ. Ebner and Sons ISBN-13: 978-0962689529

122 Molecular Visualizations of DNA (wehi.edu.au) - Original High Quality Version https://www.youtube.com/watch?v=OjPcT1uUZiE

123 http://www.basic.northwestern.edu/g-buehler/cellint0.htm

124 So the average of the measured distribution also shifts. This raises significant questions about all research into biology and medicine, since the statistical framework usually applied assumes that the mean is stationary.

Notes : Chapter 2

125 Natalie Wolchover (January 22, 2014) A New Physics Theory of Life. An MIT physicist has proposed the provocative idea that life exists because the law of increasing entropy drives matter to acquire lifelike physical properties. Quanta Magazine https://www.quantamagazine.org/a-new-thermodynamics-theory-of-the-origin-of-life-20140122/ The various ways that emergence may be interpreted is something of a barrel of worms. Whilst I fundamentally disagree with the opinion in this article as to what the science means, the principle that life reverses entropy is incontrovertible. The author of this study sees life as an automaton (see Chapter 6), and so he is drescribing it from the point of view of a universe full of automata (himself being one of them).

126 David Wade (2007) Li: Dynamic Form in Nature. Publ. Wooden Books ISBN-13: 978-1904263548

127 Jonathan Lambert (January 2, 2019) Ancient Turing Pattern Builds Feathers, Hair — and Now, Shark Skin. A primordial developmental toolkit shared by all vertebrates, and described by a theory of the mathematician Alan Turing, sets the growth pattern for all types of skin structures. Quanta Magazine https://www.quantamagazine.org/ancient-turing-pattern-builds-feathers-hair-and-now-shark-skin-20190102/

128 The same Alan Turing famous for his part in developing the first modern computer and cracking the Enigma code during WW2.

129 https://vimeo.com/223069653

130 https://freelyhuman.com/neuroscience-of-awe/