



Designing Mutualism: Our Biological Role from a Gaian Perspective

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Abstract

Humanity is unclear on what its biological role entails within the global ecosphere. It will be argued that it is prudent to pursue study at this level in order to conceptualize the true condition of the ecology that we are dependent upon. If the fitness of our species is in danger, we must compose the science, the ethics and the means to address that threat for our own sake. The intention is to present a course of thought that attempts to look ahead to times when conceptions may be clear enough to design proactively. Namely, the design of symbiotic mutualism among *Homo sapiens* and other species will be offered as bearing potential to better guard and enrich the fitness of our species distantly into the future.

Introduction

Be it denial, be it ignorance or both, Humanity is out of touch with the ecological systems it depends on for life. In many ways we are an incomparable species; but with unguided freedom a contending amount of burden ensues. Oblivious to what our biological role entails, we risk mortally offending our providers. Arrogantly, we place our fingers in the planet's door jam and deny any possibility they could be harmed, when in all probability a mere puff of wind could swiftly cleave them from our hand. It is said our intelligence is unprecedented. Perhaps an exercise in proactive caution would prove the statement apt. The design of symbiotic mutualism among *Homo sapiens* and other species will be presented as a proactive initiative that bears potential to better guard and enrich the fitness our species distantly into the future.

Life

In the English language 'life' has never been conclusively defined. Characteristics that resolve life may be combined, but they do not add up to a definition. The trouble may be that life seems to be situated within a hierarchy of intensities and complexities (Lovelock 1991). A physicist would describe life as having the capacity to reduce internal entropy (Lovelock 1991). Entropy is a measure of energy disorder. The Second Law of Thermodynamics forces every natural process (living or non-living) towards chemical equilibrium. Death occurs in living organisms as chemical equilibrium ensues since there is no potential energy left to harness. Life must fight to maintain high internal chemical disequilibrium (low entropy). It does this by using free energy low in entropy (potent enough to sever chemical bonds) and by excreting waste high in entropy (Lovelock 1991). Neo-Darwinists would define life as having organic molecular structure with the ability to grow and reproduce. Biochemists describe life as able to utilize free energy to grow. Lovelock admits his attempt to define life remains inadequate: a self-organizing, bounded system open to a flux of energy and matter, able to keep its internal conditions constant despite varying external conditions (1988, 1991). This homeostatic ability (not to be confused with thermoregulation) produces an artificial steady state that resists the decline to chemical equilibrium.

Lifeless planets tend to have the necessary sub-units that when combined would create organic matter (or life). In spite of this, the improbability of having suitable conditions for the creation of life may very well be next to infinite. It is theorized that Earth, at a critical stage in its decline towards chemical equilibrium,

entered a period that, by chance, had also the climatic conditions to allow the assemblage of organic matter. This period must have lasted long enough for the first microscopic life forms to appreciably grow, reproduce and modify their environment. All life is subject to bounds where tolerance may not be exceeded. It is believed that organisms modify their environment to maintain conditions ideal to their living (Lovelock 1988). The collective efforts of life on Earth may equate to more than most of us are prepared to acknowledge.

James Lovelock's Gaia Hypothesis

Earth's atmosphere has a dramatic disequilibrium that has been actively held constant for billions of years. The nature of atmospheric concentrations is exceedingly unique in comparison to all other known planets (Lovelock 1991). This steady state of *disequilibrium* is as improbable as is the existence of life. Non-living processes modify atmosphere on all the planets to greater or lesser degrees, but none have shown the ability to maintain the same gas concentrations in a disequilibrium state, let alone for billions of years (Lovelock 1979). Lovelock theorizes that the explanation is obviously the influence of life on Earth. Global atmospheric homeostasis is the net effect of oxygen dependant life modifying its environment to keep climate within tolerable ranges (Lovelock 1979).

...the molecules in virtually all of the atmosphere, all of the soils and seas, all of the surface rocks and much of the underlying, recycling magma, have been through at least one phase in which they were within living creatures. In fact, virtually every geological part or feature of Earth we can find is a product of our planet's life activity. Further, living organisms have invented 99.9 percent of all the kinds of molecules

we know, almost all of them back when bacteria were the only creatures around, a few billion years ago (Sahtouris 1999, ch 5).

Some of these pioneers that first inhabited the Earth in an anaerobic atmosphere were not lost. They continue to thrive in airtight places everywhere, including in the guts of many oxygen breathing life forms.

The 'Biosphere' describes everything living on the planet. The 'Ecosphere' is everything *living* and all that is *non-living* upon which it depends. The Ecosphere is self-organizing, is a bounded system (the outer limits of atmosphere) open to a flux of energy and matter and able to actively sustain low entropy (Lovelock 1988). Lovelock wanted to modify the meaning of Ecosphere to create an identity for what seems to meet the criteria to be considered a type of **living entity**. He accepted a suggestion from William Golding that this hypothesized entity be called "Gaia" (Lovelock 1979). This title took on unexpected connotations regrettably (Lautensach 1997) yet it is not difficult to leave them uninvolved. This conceptualization of a planetary level of organization of life warrants study from a new science. Lovelock suggested that an interim title for it could be *Geophysiology* (Lovelock 1991). Since its conception, there have arguably been geophysicologists at work.

The Dawn of Geophysiology

The scale and complexity of Gaia must be immense and understandably daunting for one of its minions to perceive. Thinking and studying at this level successfully would truly be a feat for our species. As yet, the other sciences may only offer the foundation of understanding in specialized and relatively isolated collections

(Lovelock 1991). If Ecology were the study of relationships among life forms and life forms with their environments, then it would be a study *within* Gaia. Geophysiology would be the aggregating science, the study of Gaia. Hopefully metaphor will be as helpful in perceiving Gaia as it has been in conceiving it.

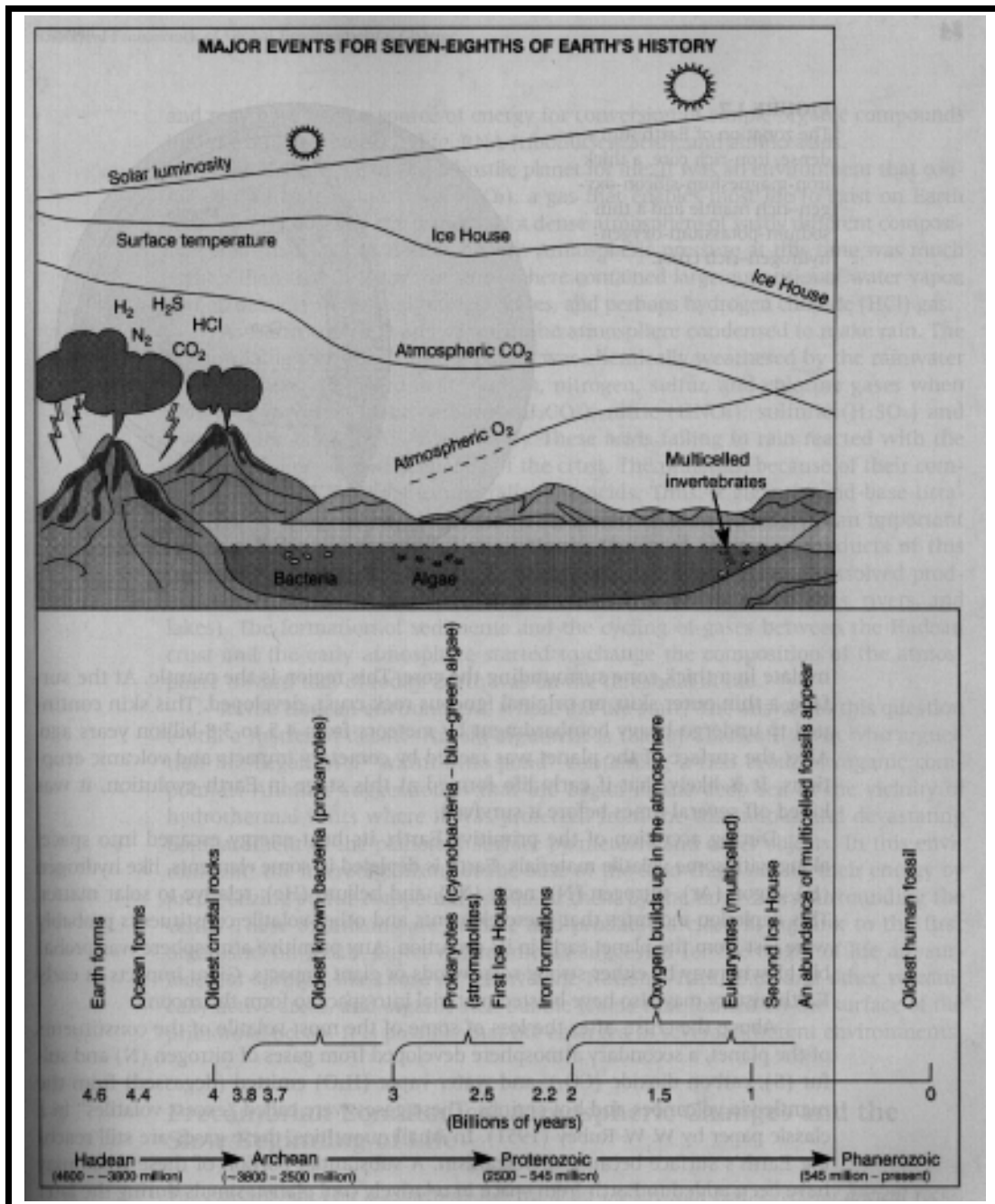


Figure 1 (Mackenzie et al., 23)

Lovelock wastes little time in getting the geophysiology-ball rolling. As an expert in studying the global atmosphere, he is fascinated with how life could possibly govern gas concentrations and temperature the way it does. It seems that homeostasis functions on account of cybernetics (negative feedback) (Lovelock 1979). The "steady state" is only a relative one. The exact level of entropy oscillates. The amplitude of the oscillation increases as the organism experiences more stress (Lovelock 1988). This can be seen very easily in the thermoregulation of human beings. From this example it is possible to infer that the same happens to Gaia. If one were to trace the Earth's mean atmospheric temperatures from the establishment of Gaia, an oscillating trend is clear. Each cooler period is represented at the lower part of the wave and the warmer period the top (Lovelock 1988). At times of extensive glaciation for example, it would be inferred that Gaia is under a significant amount of stress (internally or externally) (Lovelock 1988).

As seen in Figure 1, the sun has steadily increased in luminosity over its lifetime; yet with atmospheric concentrations unchanged (after photosynthetic life was established) these periods of noticeable cooling have still occurred. Lovelock explains that part of Gaia's temperature control abilities may lie in its ability to modify albedo (quality of reflectance). For example, dark coloured plants absorb light and thus heat is produced. If all the plant-life of the globe were dark in colour, it wouldn't be hard to imagine that mean temperature would rise dramatically (Lovelock 1979). If the planet were entirely blanketed with white snow and ice, more cooling would quickly be realized (Lovelock 1979). Figure 2 illustrates how albedo affects surface temperature.

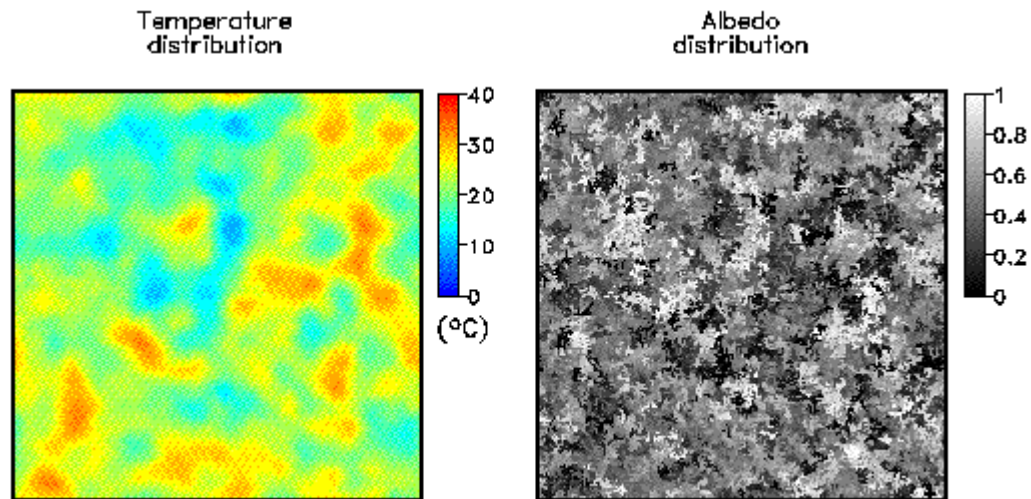


Figure 2 (a) & (b) (Von Bloh 2000)

There are many global scale processes that are understood well enough to be able to make more modest inferences to geophysiology. However, without more scientific study, we will be unable to practise what Lovelock calls *Planetary Medicine*: the study of Gaia to understand, diagnose and treat planetary illness (Lovelock 1991).

The Health of Gaia

As in any life form, the health of one part of the 'body' affects that of the others. By definition, Humanity is part of Gaia. Humans are among mammals that are part of a Gaia-servicing terrestrial system, which depends on some level of cooperation with other species. Metaphorically speaking, a species might be considered an organelle in a Gaian cell (Lovelock 1988). Perhaps the kingdoms could be considered Gaia's organs, one of those being animal-life, a type of cell might be mammals and an organelle of that cell, *Homo sapiens*. Those components that are not complementing the organism are eventually replaced with those that will, perhaps comparable to the natural selection of species over the history of Gaia.

When the activity of an organism favours the environment as well as the organism itself then its spread will be assisted; eventually the organism and the environmental change associated with it will become global in extent. The reverse is also true... So long as we continue to change the global environment against [Gaia's] preferences, we encourage our replacement... (Lovelock 1988, 236)

Without a perception of Gaia and its health, Humanity will be unable to gain adequate perspective on our situation within the Ecosphere. We will be unable to assess the implications of our biological role if we do not understand that which we are assessing. Without the science of geophysiology, it is difficult to be conclusive about what might constitute the health of Gaia. Inference using science that studies other levels of organization is a way to begin.

Landscape Ecology studies at a level of organization closer to that of Gaia compared to most other life sciences. It is a relatively new science; although, it has evolved enough so that this level is arguably useful to base inferences from. In essence, landscape health is told by its ability to manage stress in the form of disturbance. A landscape (a definable collection of ecosystems) may be characterized in a variety of ways pertaining to health. A healthy landscape acquires and conserves resources in a way that maintains conditions to support its ecosystems and maximize its *stability*. Stability comes from its *resistance* - the ability to minimize change while being disturbed and its *resilience* - the ability to recover to a steady state having been disturbed (Ludwig 1999). The International Society for Ecosystem Health recognizes a similar indicator of health, as well as two others. Inferring from the ecosystem level, the biological productivity of a landscape, in terms of biomass, is its *vigor* (Rapport 2000). The accumulation of biomass illustrates the

landscape's ability to acquire and conserve resources. Thirdly, *organization* (species distribution and interaction) is a key indicator (Rapport 2000). Biodiversity and a variety of interactions provide a greater variety of exchanges and a multitude of pathways a single flow may take. It wouldn't be difficult to visualize how the significance of stability, vigor and organization could apply to any living entity.

A Gaian Ethic

The diagnosis of Gaia's health will only be **part** of the job of Planetary Medicine. If Humanity is in fact able to acquire a comprehensive diagnosis there leaves treatment begging. Ethically, who are we to be Gaia's doctor? Western society and increasingly the globe worships Science as the epitome of rationality. Morality, spirituality and philosophy are often dismissed as being based on a mishmash of widely varying assumptions and biases; hence these are under valued by our mainstream societies. Ironically though, Science seeks to distill absolutes and predictability out of a realm of relativities and variables. So in a sense, the argument of how to make an argument is in anyone's court. With that said, let's explore some thoughts on the ethical implications for Humanity from a Gaian perspective. This ethic presents humans as doctors in so far as managing our own contribution to planetary illness:

From the status quo of [the **cooperative** part of] our relationship with the rest of Gaia we could deduce a right to a continuation of this relationship, provided we observe our obligations. In practice this would include the moral right to prey on certain species, the moral right to reproduce to maintain our numbers at a mutually compatible level, and the moral right to use the planet's abiotic resources to an extent that is

compatible with Gaia's continued well-being. The limits to our rights are thus described by the compatibility of our actions with Gaia's health (Lautensach 1997, *Gaian Ethics*).

These moral obligations can be justified from an anthropocentric position as well as an ecocentric one. These seemingly opposing perspectives, in this light, ultimately achieve the same things, since we would be servicing ourselves in a manner that services Gaia (Lautensach 1997). This ethic allows instrumental value, inherent value or both to be ascribed to the non-human world. Instrumental value tends to be best supported by Science. Inherent value on the other hand is important to morality spirituality, etc. and to supplant instrumental value when there is often no science available. Note that this ethic emphasizes the principle of *a priori* (or skewed) worth of all species and the fact that while the health of Gaia is absolutely indispensable for our welfare we are not indispensable to Gaia (Lautensach 1997).

Our Parasitism

'Symbiosis' has become as much of a buzzword as terms like *niche*, *habitat* or simply *ecological*. Symbiosis is any interaction between or among **distinct** forms of life. So long as *interaction* and *effects* are not confused, neither will be the meaning of symbiosis. Interaction is an exchange. There are a variety of forms of symbiotic relationships. They have traditionally been described by measuring the resultant **net** fitness of parties. Fitness, in simplified terms, is the potential quantity and quality of future generations of a species or other unit (Burns 1993). Generalized types include:

- ◆ *Mutualism and Cooperation* (+ +) both party A and B benefit
- ◆ *Commensalism* (+ 0) party A benefits while party B is relatively unaffected
- ◆ *Amensalism* (0 -) party A is relatively unaffected while party B suffers
- ◆ *Predation and Parasitism* (+ -) party A benefits while party B suffers
- ◆ *Competition* (- -) parties A and B suffer as a result of interaction

There may be as much danger in creating an identity Gaia as there is a benefit. Gaia is a discrete form of life and we are discrete, but **not** in relationship to one another. What if humans are said to have a symbiosis with Gaia? By definition, two entirely separate entities (party A & party B) are compulsory. In our scenario, party A (*Homo sapiens*) **is** party B (Gaia). This means that comparing the fitness of Humanity with that of Gaia (as if they were discrete) is paradoxical. Our species has no symbiosis with Gaia. However, this does not assert we have no interaction with it at all. The interaction is simply non-symbiotic. Our fitness is derived directly and indirectly from the life and non-life distinct from humans. All of these living components influence and embody the health of Gaia upon which we are dependent.

There is nothing unnatural about *Homo sapiens'* behaviour, but what has been setting humans apart from other species has been our recent unbridled and unguided freedom to exploit (Agrawal 1998). At a smaller population for the majority of our existence, our exploitation was of little consequence to Gaia. Our demands were within the tolerance of most other life forms. Nevertheless, as our intellect and rationality grew the complexity of our tools did also. "By Gaian standards we evolved with incredible speed, our brains blossoming suddenly, expanding in size almost explosively from the much smaller brains of our apelike ancestors" (Sahtouris 1999, ch 10). With tools we harnessed previously unusable energy sources and we

accelerated far beyond our traditional limits. Our fitness as a species then came principally at the parasitic expense of others. Now our 'overshoot' may be the greatest threat to our own security (Wackernagel 1996). A successful parasite is one that allows its hosts to live (Agrawal 1998). If the fact that we are rapidly debilitating our ecological support systems doesn't concern us perhaps Gaia's wrath will. With time and the amplification of our parasitism we may be destabilizing and plundering Gaia's body.

Apartheids and Such

Support for unbounded and shortsighted growth and consumption the world over will not relent easily due to the degree that it is entrenched politically, psychologically, socially and economically in mainstream society. The only hope is if the alternative is understood as sensible by and *beneficial* for the power-holders and masses of the globe (Wackernagel 1996). Luckily some abstract thinkers have been able to gain enough perspective to offer us some insight on ourselves.

The fact that death is necessary for multicelled life to continue virtually without end has been hard for us humans to grasp and accept. If new creatures kept coming to life without others giving up their lives, the supplies in the Earth's crust would soon be used up and the mass of creatures would all die together of crowding and starvation... (Sahtouris 1999, ch 8).

Our psychological dilemma is that we have created a mental separation of everything human and the rest of reality ('mental apartheid') to the degree that we do not adequately sense our *physical* reliance and inter-relationships with our ecological support systems (Wackernagel 1996). The less aware we are in this respect, the less

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sensitive we are to perceive critical change, which ironically can be very subtle ('boiled frog syndrome' – *ibid.*). A frog may be boiled very slowly to death while completely unaware. Entirely immersed, the frog is unable to sense the water is growing much hotter than the exterior environment (Wackernagel 1996). Not having a Gaian perspective on our biological role is a critical failing. As far as we know, Gaia may be planning to cook up some *Homo froglegis*.

Humans have developed a tool to facilitate the exchange of life-supporting products and services: currency. Global economics value the human-made part of a product or service, but has not incorporated the natural value. Gaia's operations provide everything that sustains our economy (Odum 1993). The economic system is significantly flawed if it does not recognize the entire value of a product or service. There is no argument to insist that it is impossible to pay non-humans (Brooks 1999) for the services and products it provides. Currency itself is not a life-supporting product or service, it's only a way to exchange them.

Life relies on a one-way throughput of matter and energy as mandated by the Second Law of Thermodynamics. There is no escaping the need to lower entropy to live. Humans, as well as other life, need to degrade free energy and excrete waste. Gaia has dynamic, cyclical processes that assimilate waste and rejuvenate sources of energy. It is the demand and method of consumption of energy resources combined with the form and volume of waste that makes all the difference to the health of Gaia (Lyle 1994). It seems then that our parasitism is rooted in our reorganization of ecosystems (Rapport 2000) and the over-consumption, inefficient use and the harshly toxic structure of our throughputs. The symptoms indicating that

Gaia no longer has the capacity to rejuvenate or assimilate at the rate we now demand are undeniably present. Simply the examples of massive depletions in global 'natural capital' and the equally pungent accumulations of effluence are proof enough.

We need to understand Gaia to understand ourselves (our role in Gaia). We need to understand our role to understand the implications to our fitness. Our fitness is our future. The entire argument for study and change hinges on the individual's inherent value for others of our species. The criminals of our society are those who perceive themselves as left out of the greater whole and act in a harmful way towards others. They are forced or arguably chose to be 'unequal'. Intragenerational equity (equity among the living) is a serious social threat, which is highly attributable to our environmental woes. However, the marginalized individuals do have representation in their court battle with the affluent (inadequate as it may be). Who speaks then for the unborn - our future, our legacy?

I have no qualms about exploiting nature... we will be fine for many generations to come. Resource depletion is not our problem. It is the problem of some unfortunate future generation. I feel absolutely no sense of duty to future generations. [My parents taught me that] the benefit of those here and now should be of more concern than the welfare of people who do not exist (university student quoted by Miller 1991).

Admittedly taken slightly out of context, this position isn't only characteristic of a student once a desperate, 3rd World child. Many of the most affluent justify their life this way. How is it rational for it to be criminal to harm the present but not the future? Isn't 'do unto others as you would have them do unto you' cross-cultural **and** cross-generational? Perhaps inequity is of the residual instinct to compete for not knowing

anything better... The current generation needs to take responsibility in every way and represent the interests of future generations.

Mutualism Breeds Stability

What of this 'distinctiveness' issue in symbiosis? What makes one form of life autonomous of another? Lynn Margulis worked with Lovelock to develop aspects of Gaia Theory. Truly a versatile scientist, she also specializes in cellular biology, which combined with Gaia Theory noticeably supports the value of metaphorical inference.

Margulis' discovery, that eukaryote protists evolved cooperative internal schemes to overcome the problems caused by competition among prokaryote bacteria, was almost as much a shock to the world of science as was the Gaia hypothesis itself. Besides showing that cell 'mechanisms' such as mitochondria [and chloroplasts] are creatures in their own right, she was suggesting that harmonious cooperation played a big role in evolution. This ran counter to the beliefs stemming from Darwin's work, adopted by scientists in western countries, that evolution was just a survival race driven by competition (Sahtouris 1999, ch 6).

Do mitochondria remain distinct entities? They once lived apart from cells. Could they live autonomously again? These questions illustrate how complex and perceptual defining autonomy may be. A mitochondria-cell interaction is an example of symbiotic mutualism where previously thought to be a structural, non-symbiotic interaction like with any other cellular component. The existence of plants and animals has been dependent on mutualism. The fact that this mutualism has lasted since the emergence of plant-life is even more profound. Likely the primary reason it has lasted is its holonomy:

Any holon [unit of life] containing smaller holons, such as an Earth full of bacteria or a body made of cells, tempers the individual autonomy of its components with its own autonomy, which is their holonomy. Any individual human, for example, must transcend simple self-rule and integrate him or herself with the rules of family and society, while human society must transcend its autonomy and integrate itself with the holonomy imposed by the autonomy of the planet. The balance between any holon's autonomy and holonomy must be worked out as mutual consistency if the holon is to survive as part of a holarchy, and it cannot survive in any other way if we accept the fundamental notion of mutual consistency (Sahtouris 1999, ch 4). [Mutual consistency] is the concept that the universe is a dynamic web of events in which no part or event is fundamental to the others since each follows from all the others, the relations among them determining the entire cosmic pattern or web of events. In this conception, all possible patterns of cosmic matter-energy will form, but only those working out their consistency with surrounding patterns will last (Sahtouris 1999, ch 2).

If nothing else is taken from the notions of autonomy, holonomy and mutual consistency, let it be that unless Humanity is integrated with the operations of Gaia, it won't last.

Mutualisms promote the coexistence of life, even those having diverse ecological niches (Kawanabe et al 1993). Mutualists, by nature, will often drift between mutualist and parasitic status in relation to the greater whole over evolution and time (Janzen 1985). There is a wide variety of mutualisms: pollination, seed dispersal, protection and harvest interactions known to be present among viruses, bacteria, fungi, insects, plants and animals (Boucher 1985). The nature of these interactions varies greatly in duration, relative size, specificity, interdependence, integration and type of physical contact (Lewis 1985). However, the fitness is always greater while in the partnership than if there was none. It is widely accepted that indirect mutualisms are the most predominate in Nature (Patten 1993). This

phenomenon is termed 'network mutualism' (Odum 1993). The interaction with one species affects its interaction with another and so on. Those that benefit within this web are considered to have an indirect mutualism with the others that are benefiting. Unfortunately, indirect symbioses are the least tangible to us due to their complexity (Patten 1993). The relative importance of directness versus indirectness is yet undetermined (Kawanabe 1993).

The most distantly related organisms tend to do well together since they often best counter the other's effect cyclically. Each **participates** in selling the other otherwise unattainable goods and services. Efficiency is high when both parties are selling that which is fitness-cheap and buying what is fitness-dear (Janzen 1985). Mutualism expands ecological ranges in terms of niche, increases the availability of food/energy, slows evolution (Darwin hypothesized that competition drives more rapid evolution) and often improves species richness and diversity (Janzen 1985). Perhaps most importantly for human purposes, mutualism stabilizes environments. It is obvious that the less stable an environment is, the more resistant and resilient a species must be to cope ('Fittedness Hypothesis' - Burns 1993). Most mutualisms are adaptations that exist primarily to resist and reduce environmental variability (biotic and or abiotic) which threatens fitness (Burns 1993). It decreases unpredictability in the mutualists' environment thus increasing stability ('nesting effect' - Burns 1993). In the case of a species like our own (enjoying mass-production of genetically modified monocultures and fossil fuel consumption) the more specialized a species gets in an unstable environment the more it will be selected against (Burns

1993). If we reject diversification and individual adaptability by insisting on being a specialized species, our environment must provisionally be stable.

Designing Mutualism for Humanity

John Tilman Lyle discusses what he calls 'Regenerative Design'. He states clearly that we can only meet the needs of humans if other species needs are also met (1994). Regeneration would seem to equate to the concept of working to achieve greater environmental stability. It is dependent on creating cyclical flows at our energy sources, consumption centres and sinks. There needs to be a continual replenishment, through its own functional processes, of the energy/matter used in our consumption. This may only come realistically on a finite planet from the assimilation of our waste (Lyle 1994).

The list of fundamental problems we face in designing mutualism is not easily made concise. They are both scientific and social as previously discussed. The inequity and disaggregation within our society and our environment is undoubtedly our greatest social constraint.

Nature teaches us that evolution depends on competition and cooperation, on independence and interdependence. Competition and independence are both important to individual survival, while cooperation and interdependence are both important to group, or social, or species survival (Sahtouris 1999, ch 17). The industrial countries that set up the international economy, with its World Trade Organization management, simply have more money and power to make political and economic decisions than do the poorer countries that supply their raw materials and cheap labor. If we continue the analogy with our own bodies, we can easily see why this is an unhealthy situation. The parts of our bodies -- its 'nations' -- work together as organs and organ systems, such as bone,

blood, muscle, and digestive organ systems. If all these organs and systems did not work harmoniously within themselves and with one another, our bodies couldn't function (Sahtouris 1999, ch 16). Capitalists were right that people must work in their own interests, and communists were right that society must work in its collective interest, but both were are wrong in claiming that one or the other will do by itself. The present worldwide shift toward free-market capitalism will work in the long run only if it incorporates the best aspects of socialism -- the concern for the whole as well as the parts, including concern for the welfare of the entire body of humanity and its planet (Sahtouris 1999, ch 16).

Hopefully the scientific side of the road will be less congested. As expected though, assorted hold-ups are found without ado. If holon fitness is considered, how can costs and benefits be made measurable and put in a comparison framework (Templeton et al. 1985)? The sad truth is that the mechanisms are not yet understood adequately to use in design, let alone to launch a global campaign of enlightenment. For example, behavioural variations among individuals in any symbiosis are hard to account for when the social structure of the species eludes us (Boucher 1985).

What conceptually needs to be done to attempt birthing new mutualisms with other species? Besides solving the host of problems, it will be necessary to identify how that species works to satisfy a human need(s). If we take the fitness model, it would be critical to identify the species most involved in the assimilation of our wastes. As we are sobbingly becoming aware, if wastes are generated in forms and volumes that cannot be readily assimilated, they accumulate and form what we describe as pollution (Lyle 1994). We would also be interested in the species that reorganize the matter and energy that we are interested in using long-term. Besides

a declining nuclear furnace in the planet's gut, solar radiation is the only source of usable energy available to Gaia's systems (Lovelock, 1988, 1991). The most highly evolved energy converter in Nature is the photosynthetic plant. Virtually all of Gaia is fed intimately by these magical autotrophs.

Second, we will without argument need to identify and value the things that contribute to our partner's health and fitness. Mutualism is a cooperative exchange; participation in our partner's well being is part of the deal. Be reminded that the relationship is not evolving - it is being designed. Hence, it will be **our** consumption and excreting patterns modified to be harmonious.

Thirdly, we must understand all the implications of our proposed network with transparency and be motivated to continually assess our success (namely from the Gaian perspective) in order to revise our design routinely. Designers have the bad habit of creating designs that impose static structure to dynamic environments. This gives us the excuse to absolve ourselves and hand over responsibility. Too often function is forced to follow form when the fundamental goal is the very opposite. Designers must continue to be involved in the evolution of these relationships since they are the ones most capable of defining the means to manage.

Closing

The ability of life to fight the Law of Entropy is unique. The battle is only possible so long as life forms have each other. The Ecosphere invariably harbours the potential to be considered a living entity within which we ought to conceptualize our role. We must be mindful of Gaia's health for it inherently is our own. We are

subject to the same laws as our partners. There is nothing unnatural about what we do, but there are consequences. If Humanity overcomes the impedance to change, proactive and often seemingly abstract initiatives will best honour our species and its legacy.

Acknowledgements

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Key Terms

Albedo - the measure of solar insolation reflected back from the surface of the Earth (Allaby 1994)

Amensalism - interaction whereby one party is inhibited and the other is relatively unaffected (Lincoln et al. 1982)

Biodiversity - a variety of components at every level of biotic community organization (Callicott 1995)

Biological role - all actions or use of a structure by a party (Lincoln et al. 1982)

Biology - the science of life: the study of living organisms and systems (Lincoln et al. 1982)

Biosphere - the part of the Earth's environment in which living organisms are found, and with which they interact to produce a steady-state system (Allaby 1994)

Commensalism - interaction whereby one party benefits and the other is relatively unaffected (Lincoln et al. 1982)

Competition - interaction whereby both parties at the same trophic level are inhibited by seeking a common resource (Allaby 1994)

Cooperation - a non-dependant, mutually beneficial symbiosis (Lincoln et al. 1982)

Cybernetics - the study of control and communication systems in life, including feedback controls of homeostasis (Allaby 1994)

Ecology - the study of interaction among organisms and between them and all aspects of their environment (living or non-living) (Allaby 1994)

Ecosphere - the extent of all living organisms and the environment with which they interact to produce a steady-state system (Allaby 1994)

Ecosystem - nested sets of linked process-biological roles with temporal boundaries, not tangible super-organisms with spatial boundaries (Callicott 1995)

Ecosystem Health - a condition of normality in the linked processes and biological roles that compose ecosystems (Callicott 1995) - stability, fitness and organization (Rapport 2000)

Entropy - a measure of disorder (Allaby 1994)

Fitness - a measure of a party's time-integrated abundance and stasis of an entity's attributes in its descendant exemplars (Burns 1993) [the potential quantity and quality of future generations]

Holon - any definable unit of life (Sahtouris 1999)

Holonomy - a holon's integration with a greater unit of life (Sahtouris 1999)

Homeostasis - the tendency of a living system to maintain a steady-state using intrinsic regulatory mechanisms (Lincoln et al. 1982)

Mutual Consistency - the concept that the universe is a dynamic web of events in which no part or event is fundamental to the others since each follows from all the others, the relations among them determining the entire cosmic pattern or web of events (Sahtouris 1999)

Mutualism - an interaction between two parties whereby both have a degree of dependence on the mutual benefit (Allaby 1994)

Niche - the ideal ecological situation for a given holon (environmental features and processes) (Patten 1993)

Parasitism - an interaction between two parties where party A is metabolically dependent on party B to the relative detriment of party B (Lincoln et al. 1982)

Predation - an interaction between two parties whereby party A consumes party B (Lincoln et al. 1982)

Stability - a condition dependent on (a) *resistance* - the ability to minimize change while being disturbed and (b) *resilience* - the ability to recover to a steady state having been disturbed (Ludwig 1999).

Symbiosis - an interaction between two distinct living entities, often characterized by measuring net fitness (Odum 1993)

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