To Live is to Know

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Sifting through the evocative etymology of classical myth, we uncover an image both humble and strangely intriguing: *a heap of stones.* Mute and still, this literal translation of the ancient Greek word '*herma'* belies the energy and dynamism of the archetypal trickster eternally couched within it - "the one who stands at the gate of the underworld, on the threshold between the human and divine worlds, at the place of transformation" (Cashford, 2003: 337). Fleet and deft, carrier of words and spirits, *Hermes* was known as the patron of boundaries and the protector of those travellers – thieves, explorers, fugitives, departed souls - who crossed over them. As the emissary of the gods, Hermes' name has now come to mean *messenger*, and from this we inherit *hermeneutics*: the study of the interpretation and analysis of texts. The study, that is, of how we receive and respond to the messages texts offer us as they cross the threshold of our cognition and imagination. Traditionally a theoretical discourse, hermeneutics is now expanding to support a vital inquiry into the nature and origin of meaning within living systems. In other words, we now recognize that actively interpreted texts are no longer necessarily literary or cultural, but are manifest in infinite complexity in the biological and ecological realm as DNA, the membranes of cells, complex biota, and the meta-organism of Gaia herself: the living earth.

Hermeneutic biology, in shifting the emphasis of our scientific inquiry from form to organization, is closely linked to the concept of 'autopoiesis' - literally the 'self-making' of living organisms. Through an exploration of these new ways of seeing within science, we discover threads of meaning that link biology, complexity mathematics, and Gaia theory. Along the way, fragments of myth and metaphor also emerge, enticing and engaging our intuitive selves in the ancient, eternal, and deeply felt question: what is life?

I was first introduced to the idea of hermeneutics, or textual interpretation, as a literature student at Canadian universities. Over several decades, our professors explained, our disciple had been undergoing a rapid and multi-faceted shift, evolving from a discourse concerning itself entirely with original historical context, biography, and authorial intent, to a more radical investigation of humanity and meaning. Keen students were encouraged to experiment with the New Criticism, Reader Response Theory, deconstructionism and post-modern/post-colonial analyses – all schools of thinking that sought, enthusiastically and in various ways, to open diverse texts into engagement with multiple readers and their worlds. We no longer saw texts as static vessels of a singular, ultimate meaning – that of the author – but rather as complex entities that interacted with and evolved in relationship to their environments. Interpretation, then, was a vital process of both uncovering information and experiencing the emergence of insight within us. Through it, we situated ourselves within a great web of meanings and connections – a reorientation that ultimately invited us to participate more fully with a complex and ever-changing world. In their guide to cultural theory and hermeneutics, Edgar and Sedgewick note that "one may move, through the activity of interpretation, to an engagement with the *other*, which is able to re-structure the interpreter's preconceptions, and thereby the basis of their understanding. Interpretation, therefore, is an unlimited, open-ended process" (2002: 167). I can still recall the almost physical sensation of my mind opening to encompass new ways of thinking and seeing in those years. It was an exciting time.

Yet, true to our faculty – the "Humanities" – we never considered that these kinds of active, creative readings could take place anywhere other than within our very human minds. How limited our views still were. In his book "Nature's Due: Healing our Fragmented Culture" holistic scientist Brian Goodwin describes hermeneutic *biology* as "a study of the process whereby organisms make meaning of their genetic texts by expressing them in a form (morphology and behaviour) appropriate to their habitat and their history" (2007: 99). The very exciting implication of this new hermeneutics is that humans, ever proud of linguistic achievements that apparently distinguish them so clearly from other forms of life (and are often used to justify domination over them), are in fact, as Aldo Leopold would say, *plain members of the biotic community* - a group of gifted speakers in a world of wondrous speech. Intelligence and meaning, it would seem, are fundamental characteristics of life.

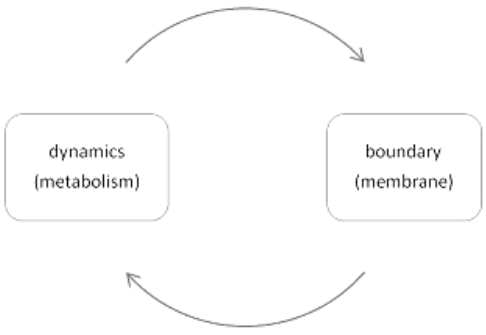
But what does this literally mean? Theoretical biologist Anton Markos explains that the main objective of hermeneutic biology should be to "get rid of the genocentric view that identifies the genome as a recipe for building the body [of the cell or organism]. It should pose questions about the *builder*, who takes the genome as a mere dictionary of the language in which the recipe is written. Proteins – 'words' uttered in the language – enter into complicated syntactic and semantic relations, which constitute the cellular *parole*. The cell is thus a materialized *parole*" (Markos, 2002). This exploration beyond mechanistic genetic determinism signals a paradigm shift in the life sciences. It was a shift highlighted by individuals working on the human genome project around the time of its completion in 2001 as, to their wonderment, an unavoidable gap appeared and grew between genetic "information" and biological expression (E.F. Keller, 2000). Leading scientist Evelyn Fox Keller expressed the humility many researchers – researchers who had for many years believed themselves to be on the cusp of cracking a complicated but ultimately linear code of life – felt upon facing this astonishing and intelligent complexity: "the very successes that have so stirred our imagination have also radically undermined their core driving concept, the concept of the gene. As the human genome project nears the realization of its goals, biologists have begun to recognize that those goals represent not an end but the beginning of a new era in biology" (ibid.).

Markos goes further to suggest that living organisms are communicating coherently not only within their own organizational processes, but with those of *other organisms and systems*, effectively forming a sophisticated ecological system of biochemical dialogue. The study of such dialogue now comprises the growing field of *biosemiotics*, a word composed of the Greek root for 'life' and 'sign' (2002). In shifting our focus to genome-protein interactions and the epigenetic factors of morphology – in entering this 'new era in biology' - we move from an over-emphasis on form to an inquiry into the relational qualities of living systems. We move also into a growing appreciation of life as more complex, mysterious, and beautiful than the reductive thinking mind could ever have previously known.

Self-Organization

These insights into the complex relationships unfolding within organisms on the structural and relational levels have lead to radical re-conceptualizations of how life orchestrates itself. The term '*autopoiesis*' - literally '*self-making*' - captures the self-organizational quality of living systems and points to the mechanism that makes them autonomous. We are now able to see that that the molecular components of a cellular autopoietic unity are dynamically related, embedded in a network of ongoing interactions or transformations that continually produce the unity itself – the organism. As Chilean scientists Maturana and Varela point out, "what is distinctive about [living beings] is that their organization is such that their only product is themselves, with *no separation between producer and product*. The being and doing of an autopoietic unity are inseparable, and this is their specific mode of organization" (1987: 48) (emphasis added). This astonishing and elegant non-linear process is the chief distinguishing factor between living and non-living systems.

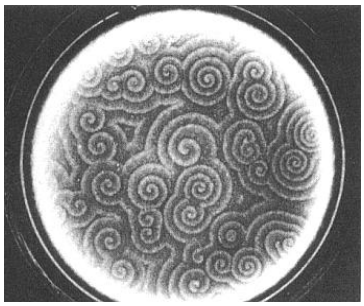
Autopoietic systems likely emerged at the time in the earth's history when organic molecules like proteins, which have enormous complexity and pliancy, were formed (Maturana & Varela, 1987: 46). In the right biochemical conditions, it seems, autopoietic systems arise almost inevitably. The cell membrane is a crucial participant within this process. Semi-permeable and intelligent, the membrane actively chooses which molecules are granted entry and exit from the cell; it not only limits the extension of the transformation network that produces its own components, but also participates in this network (ibid.). Thus the workings of metabolism and the creation of the cell membrane are two different aspects of a unitary phenomenon, rather than sequential processes:



This non-sequential relationship between form and the dynamic leads us back to the hermeneutic circle: the whole comes into being through the parts while simultaneously the parts are contained within, and manifest through, the whole. This wonderfully paradoxical phenomenon of life simultaneously *emerging* from the environment (through its dynamic) and *distinguishing itself* from the environment (through its membrane) also recalls Goethe's sense of morphology as a process of both differencing and relating. Goethe's way of seeing opens our eyes to the unity present within apparently distinct parts, thereby shifting our focus from something fixed (form) into something fluid (dynamical emergence); in a similar way, deep reflections on the autopoietic nature of life prompt us to reconsider our place within a brilliantly coherent, creative, and symbiotic world.

When an autopoietic unity encounters a lack of energy or scarce resource, it is capable of reorganizing its system with incredible ingenuity (a capacity we would do well to cultivate as our own source of abundant, readily available energy - fossil fuels – dwindles). A classic example of this synchronized, spontaneous reorganization is found in slime moulds; when food or moisture in the environment is running low, individual cells begin to signal to one another by means of a chemical called cyclic adenosine monophosphate (cAMP) they release into their surroundings, which stimulates neighbours to both release a signal of their own and move towards each other. This effectively initiates a process of aggregation, and subsequently several thousand previously autonomous cells form a complex multi-cellular organism capable of cellular differentiation at different points within the structure. The organism thus completes its life cycle, sprouting a long stem and fruiting body before releasing spores and effectively reproducing (ibid). The intelligence inherent in this process of sophisticated communication is clear, reminding us that an organism needn't possess a brain to embody mind.

Beloussov-Zhabotinsky reaction



Aggregating slime mould amoebae

Turkey Tail Fungi (*Tramestes versicolor*)

Complexity Theory

Complexity theory (or dynamical systems theory), while not a theory of physical phenomena, presents concepts and techniques that contribute to a more refined understanding of natural systems. Significantly, through mathematics and advanced computer technology, we are able to make underlying patterns in nature visible in distinct shapes that contribute to the revelation of coherence in life. This "new mathematics", as Fritjof Capra explains, "is one of relationships and patterns. It is qualitative rather than quantitative and thus embodies the shift in emphasis that is characteristic of systems thinking – from objects to relationships, from quantity to quality, from substance to pattern" (1996: 113). In the new mathematics, people from diverse backgrounds may access another sophisticated language with which to communicate something of the dynamic nature of life.

Chaos theory and the theory of fractals are branches or subsets of complexity theory. Fractal geometry, famously referred to by its creator, Benoit Mandelbrot, as "a language to speak of clouds", enables us to describe and analyze the real, irregular shapes in the world around us rather than abstract, perfect shapes existing only in the mind. Fractals, those stunningly detailed, self-similar patterns, are plotted differential equations that reveal to us the *dynamics of relationships*. These dynamics are continually unfolding all around us: in the Romanesco cauliflower Satish Kumar prepares so beautifully for our meals, in the tributaries of veins and capillaries running through our living bodies, in the patterns water makes on the surface of the earth. In the Pacific Northwest I could happily pass days on the soft forest floor, simply gazing up through a delicate and infinite fractal web of fragrant cedars, whispering and shifting against the paler sky. Beyond the cedars, long clouds gather and drift, effortlessly performing their own exquisite, fractal dances. Unlike the Mandelbrot set or the Koch curve, the fractals manifested in nature are always slightly irregular – and yet meditating upon them is a powerful way to connect with the eternal, unfolding patterns of the natural world.

Chaos theory, deeply influenced by the work of Mandelbrot and fellow fractal mathematicians, explores other manifestations of the process of *iteration*, the mathematical characteristic underlying strange attractors (Capra, 1996: 140). Attractor basins, plotted in phase space, reflect a complex system's process of settling into a particular type of strategy, or a pattern of self-organization, in response to its surroundings: "when the system has settled into that region it will tend to remain there if environmental conditions are fairly stable; it is said to self-regulate or to be homeostatic or autopoietic or in dynamic equilibrium" (Boulton, 2011: lecture). Strange attractors beautifully illustrate these general dynamic properties of chaotic systems, namely that of 'bounded freedom' – a quality of being that is neither completely random nor regularly ordered, patterned, or predictable. A chaotic system operates within a certain range of values but never repeats itself exactly, and is extremely sensitive to initial conditions and feedback; thus simple and apparently linear equations may generate enormously complex attractors, like the butterfly image meteorologist Lorenz discovered when he plotted millions of iterations of an apparently straight-forward calculation on his computer at MIT in 1962. Examples of chaos can be found in the rhythm of a healthy heartbeat, the social activity of termites, the population dynamics of wild animals (Goodwin, 1994: 65), and even the elegant wobble of the moon and planets on their epic, elliptical journeys (Harding, 2011: lecture); when plotted in phase space, all reveal processes of self-organization occurring within strange attractor basins.

The Living Earth

From the work of Maturana and Varela we have learned that the key characteristic of living systems is self-organization. This new understanding of life prompts us to ponder the greatest and most complex dynamical living system – Earth. James Lovelock's Gaia hypothesis (elaborated with the help of Lynn Margulis) and his subsequent Gaia theory propose that the surface of Earth operates as an organism in which geology and biology are tightly coupled to regulate key surface parameters such as atmospheric composition and global temperature, at levels comfortable for life over vast stretches of geological time (Harding, 2010: lecture). Gaia theory thus very elegantly reconnects living elements (biota) with non-living elements (geology, hydrology, and atmosphere) of the Earth in postulating a scientifically rigorous model of the earth as a holistic, living organism.

The Gaian system operates via feedbacks among autopoietic biota and the earth, atmosphere, and water they have arisen in relationship with over 4.6 billion years. While examples of both positive (self-amplifying) and negative (self-limiting) feedback loops are ubiquitous on our planet, the stability of Earth's temperature and atmospheric composition seem to indicate that negative feedback systems dominate on the surface of Gaia. "In Gaia the exquisitely delicate receptivity of living beings to their surroundings acts as an environmental sensor for the planet as a whole" (Harding, 2006: 74).

Through such feedback systems, the composition of Earth's atmosphere and climate are regulated around "set points", as in homeostasis, but those set points change with time. Such slowly but steadily changing set points distinguish Gaia as a *homeorrhetic* system, and a complex one: to the bewilderment of scientists attempting to make accurate climate change models, Gaia is coherent and patterned but also inherently unpredictable and eternally dynamic.

Yet Daisyworld, the computer model programmed by Lovelock and refined alongside ecologist Stephan Harding, is an elegant example of how mathematics can still reveal essential characteristics of natural systems to the human mind. Created from just six simple but interconnected equations, the original version of Daisyworld showed that one property of the global environment – temperature – was "regulated effectively over a wide range of solar luminosity by an imaginary planetary biota without invoking foresight or planning" (Lovelock, 1998: 39). As such, Daisyworld offered a direct rebuttal to the accusations of scientists like Ford Doolittle and Richard Dawkins that Gaia would have to be teleological (that is, conscious and purposeful) in order to self-regulate (ibid.). Experiments with modulating characteristics and conditions of the model later demonstrated very conclusively that complex ecological communities with more species and more interactions between these species – that is, *biodiverse* systems – are better able to recover from disturbances than simple communities (Harding, 2006: 82). Perhaps increasingly refined models of earth's systems will eventually quantify the intuitive, felt sensation many of us experience already: that biodiversity, the richest possible profusion of life, is key to planetary resilience.

Such an exploration of the Earth as a whole system, as a living entity, leads us back to our inquiry into expression and meaning: "in the hermeneutic circling of Gaia, the parts (biomes, atmospheric and geo-chemistry, etc.) express the wholeness of Gaia, while the whole of Gaia (global climate, mass extinction events, liquid/solid water balance, etc.) comes into being through the self-interpretation of its constituent parts and their interrelations" (Croft, 2010: 16). Through this greatest of all hermeneutic circles, we begin to discern the dance of Gaia and her manifestation within our own consciousness; connected again to the unity and intelligence of all participatory beings on the planet, we discover Gaia in the deepest sense. In fact, the return of this ancient mythological name, *Gaia*, to our daily language, and most especially our scientific language, is extremely significant. Jules Cashford and Anne Baring point out that "underlying this phenomena is the idea that only a personification of the Earth can restore a sacred identity to it, or rather, her, so that a new relationship might become possible between humans and the natural world" (Baring & Cashford, 1991: 304). We can no longer justify or defend a conception of Earth as a mere *herma*, a heap of stones, scattered over with happenstance life forms fumbling across it; the most sophisticated science behooves us to embrace Gaia as a living being suffused with intelligence, mystery, and power. And this life of the world, this quality of soul or psyche, is everywhere manifest:

'For animists, matter and psyche are indissoluble, for the psyche of the world resides nowhere else but in matter itself. Thus the great archetypes of Gaia and anima mundi that figure so importantly in the human soul could well be prefigured in some mysterious way not in some abstract realm far from this world, but in the very molecules and atoms that constitute our palpable, sensing bodies' (Harding, 2006: 88).

To fully embrace this realization, the world invites us to gather together and celebrate the thinking, feeling, sensing, and intuitive aspects of our own selves. Conscious of our own wholeness, then, the wholeness of Gaia may likewise be illuminated.

A New Mythology

In weaving our way lightly through hermeneutic biology, autopoiesis, complexity mathematics, and finally Gaia theory, we discover iterations of the same, most inspiring message: life is dynamical, unpredictable, self-organizing, and coherent. These insights profoundly affect our understandings of this planet - our home - and our place within it. They also signify our entrance into a "place of transformation" like that mythical threshold attended by Hermes, within which we might heal some of the damage we have inherited from generations of reductionist science and runaway industrial growth - in essence rediscovering our relationship to all of life. As Brian Goodwin writes, "the recognition that every single species has evolved a language within a text, the genetic thesaurus, from which meaning emerges in the process of creating the individual organism, means that we now take our place as simply another instance of this expression of living meaning" (2007: 109).

In the words of Fritjof Capra, "instead of being a machine, nature at large turns out to be more like human nature – unpredictable, sensitive to the surrounding world, influenced by small fluctuations.

Accordingly, the appropriate way of approaching nature to learn about her complexity and beauty is not through domination and control, but through respect, cooperation, and dialogue" (1996: 193). Capra and others suggest that through the related methods of inquiry we have explored, "a theory of living systems consistent with the framework of deep ecology [is emerging], including an appropriate mathematical language and implying non-mechanistic, post-Cartesian understanding of life" (1996: 157). Perhaps this theory of living systems, united with our own phenomenological, sensual experience of the sacred Earth - the sacredness that, as Gary Snyder writes, "helps us out of our little selves and into the whole mountains-and-rivers mandala universe" (1995: 43) - offers us something of the new mythology so many of us are seeking: that of wholeness, relationship, and intrinsic value. It is a mythology, then, that our bones already know; it is one of remembrance.

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