Hierarchy, Collectivity & Nature

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All variants of anarchism exist in unified principled opposition to any or most forms of hierarchy. Anarchists universally assert that, individually and collectively, humans are most happy and productive within non-hierarchical or decentralized contexts, processes, associations or arrangements. Anarchism believes that some optimal combination of local autonomy and collective self-organization results in the most robust, just, natural, pleasant, ideal or rational way to organize economic, political and cultural life.

In opposition to hierarchical traditions, Peter Kropotkin (1842–1921) highlighted the existence, desirability and feasibility of human societies based upon federalism, aggregation, amalgamation and collaboration. His anarchism envisages non-territorial, non-centralized global networks and associations emerging from the interactive choices of autonomous individuals and locally self-organized and self-directed groupings. Kropotkin envisaged an advanced, ecologically integrated civilization premised upon the possibility and desirability of collective, inclusive and collaborative non-centralized, non-hierarchical and locally autonomous groupings self-networked or aggregated by globally accessible social, economic, informational and communication systems. Kropotkin's social anarchism involves the replacement of social hierarchies with economic and social networking. Autonomous organic communities self organizing within city suburbs, extended neighborhoods and agro-industrial villages would be federated by non-centralized, locally and globally self-organized and self- directed associations of interest, culture, trade and recreation.

Does the anarchist idea of fecundity, fairness or naturalness of decentralized self-organization in actual fact square with contemporary biological conceptions of natural order? Kropotkin was also a pioneering environmentalist and historically important scientist (in such fields as geomorphology-climatology and evolutionary biology). Let's examine Kropotkin's ideas on collectivity and hierarchy in evolutionary, developmental and ecological processes and systems.

Kropotkin argued throughout the 1890s that scientific findings strongly supported a non-hierarchical view of natural order and process. Kropotkin believed the origins, evolution and development of cells, complex many-celled organisms, intelligence, embryos, and animal and human societies resulted from the collaboration of locally autonomous elements working collectively together.

Symbiotic origins and evolution of single-celled organisms

Kropotkin's more famous contemporaries such as Ernst Haeckel (who coined the word ecology) and August Weismann (founder of gene theory) thought of cells in terms of a cell-state. In contrast, Kropotkin's characterization of cellular evolution and process rejected centralist or competitive hierarchies. Kropotkin argued that cellular-evolution, organization and processes appeared to be symbiotic, cooperative, decentralized and federative:

> "Each microscopic cell is a world of autonomous organisms, each of which lives its own life, looks for well-being for itself and attains it by grouping and associating itself with others. Each cell is a cosmos of infinitely small ones. And in this complex world, the well being of the whole depends entirely on the sum of well being enjoyed

by each of the least microscopic particles of organized matter. A whole revolution is thus produced in the philosophy of life."[1]

Kropotkin believed that scientific observations revealed how the earliest cells evolved and are still maintained by symbiotic and collective processes. Kropotkin's views on the collaborative origins and processes of cells wasn't based upon wishful thinking but upon the results obtained by micro-biologists in his own time whom he befriended (Marie Goldsmith), corresponded with (Patrick Geddes) or whose findings he summarized in his long-running popular science column in *The Nineteenth Century magazine.*

Discussing the evolution and physiology of animal and plant cells, Kropotkin argued that the organelles (bodies outside the nucleus, e.g. mitochondria, chloroplasts, cytoskeleton, etc.) are "independent" and "separate organisms" because, like the cell they "multiply only by subdivision." Kropotkin preferred Altman's characterization of the cell according to which the evolution and continuous functioning of the nucleus and cytoplasm are conceived as resulting from the economic cooperation of once free-living microbes:

> "As to the cell, it is not, in Altman's view, an elementary organism, but a colony of elementary organisms which group together according to certain rules of colonization. These granules, he maintains, are identical with microbes; their shape, their chemical reactions, their movements, and their secretory functions are similar; but the granules of the cytoplasm differ from bacteria in not being capable of a separate existence. They can only live in cells."[2]

Cellular Sense: Autonomy and collective intelligence

Kropotkin, discussing the senses and intelligence of microorganisms, considers experiments upon amoeba and small marine invertebrates. The simplest organisms, he concludes, are discerning about their environment and diet. Unpleasant and pleasant meals were 'remembered' by the organism. After reviewing a number of experiments into the responses of marine invertebrates to warmth, light, narcotics, electricity, etc., Kropotkin concludes that, even at this level, organisms exhibit "discriminative powers" involving choice, memory, free-will and "some rudiments of reasoning." The brain and nervous system developed as an "unbroken continuum" from the sense and behavioral capacities of bacteria.[3]

Cells exhibit intelligence in the sense that they are able to integrate and interpret hundreds of different internal and external signals and respond intelligently to that information. Intelligence (though not of conscious variety) is a key element in cell evolution. Sophisticated forms of cognition have evolved many times over in separate animal groups. Intelligence didn't evolve through successive evolutionary steps such that insects, amphibians, reptiles and birds are extant examples of some linear-hierarchical progression towards more complex brains. This is most clearly illustrated by the collective intelligence practiced by social insects. Groups or circuits of neurons

[1] Kropotkin, "Anarchism: Its Philosophy and Ideal," *Revolutionary Pamphlets* (ed. Baldwin), 118–9.

[2] Kropotkin, "Protoplasm" (Recent Science), *Nineteenth Century Magazine* 31, December 1892, 756–759.

[3] Kropotkin, "Senses of Lower Organisms" (Recent Science), *Nineteenth Century,* Aug. 1896. Kropotkin citations include: Haeckel's *Essay on the Origin and Development of Sense-Organs* (1897), Romans, *Mental Evolution in Animals*, and the works of C. Lloyd Morgan.

in brains appear to make collective decisions in roughly the same way as insect colonies revealing how intelligence emerges from robust bottom-up patterns that utilize the interplay of individual or local autonomy and collectivity.

Mutualism and the evolution of many-celled organisms

Kropotkin thought larger and more complex organisms evolved from two complimentary collective processes: Symbiosis and Mutualism. Mutualism refers to collective behavior between individuals of the same species (mutual-aid) or sister-cells within an organism. Symbiosis refers to intimate, long lasting or obligate physical relationships between cells or individuals of different species in the formation and maintenance of novel ecosystems and species (e.g. corals and reefs).

Kropotkin correctly concluded that symbiotic events and processes most plausibly accounted for the evolution and complexification of whole classes of organisms and ecosystems:

> "At the present time, we know that no animal or plant, with the exception of the lowest unicellular beings [bacteria], can be considered as one being—that each of them is a colony of multitude of micro-organisms… All these are evidently but separate instances of a much more general fact, which only recently became known under the general name of 'symbiosis' and appears to have an immense signification in nature. Higher plants depend upon lower fungi and bacteria for the supply of that important part of their tissues, nitrogen. Lower fungi associate with unicellular algae to form that great division of the vegetable world, the lichens. More than a hundred different species of algae are already known to live in the tissues of other plants, and even in the tissues and the cells of animals, and to render each other mutual services. And so on. Associations of high and low organisms are discovered every day; and when their conditions of life are more closely examined, the whole cycle of life changes its aspect and acquires a much deeper signification."[4]

Kropotkin's *Mutual Aid* is without question one of the pivotal or axiomatic works in the historical and philosophical study of biological mutualism—cooperation among groups of individuals or cells of the same species or organism. Kropotkin thought that more complex forms of life emerged from a combination of his favorite political concepts of self-regulation, local autonomy, association, federation and cooperation. These processes occurring between (epigenetically) related specialized sister-cells (e.g. liver or brain cells) allowed for the evolution of larger and more sophisticated organisms:

> "Without solidarity of the individual with the species, the animal kingdom would never have developed or reached its present perfection. The most advanced being upon earth would still be one of those tiny specks swimming in the water and scarcely perceptible under a microscope. Would even this exist? For are not the earliest aggregations of cellules [colonies of unspecialized cells] themselves an instance of association in the struggle?[5]

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[4] Kropotkin, Recent Science, *Nineteenth Century Magazine* 34, August 1893, 259–266.

[5] Kropotkin, "Anarchist Morality," *Revolutionary Pamphlets*, 97.

> "When a physiologist speaks now of the life of a plant or of an animal, he sees an agglomeration, a colony of millions of separate individuals rather than a personality, one and indivisible. He speaks of a federation of digestive, sensual, nervous organs, all very intimately connected with one another, each feeling the consequence of the well-being or indisposition of each, but each living its own life. Each organ, each part of an organ in its turn is composed of independent cellules which associate to struggle against conditions unfavorable to their existence. The individual is quite a world of federations, a whole universe in itself. And in this world of aggregated beings the physiologist sees the autonomous cells of blood, of the tissues, of the nerve centres; he recognizes the millions of white corpuscles who wend their way to the parts of the body infected by microbes in order to give battle to the invaders."[6]

Complex organisms evolve when genomically similar cells perform different functions within a multi-cellular whole. Cell differentiation and memory combined with mutual aid facilitates the emergence of epigenetic systems of inheritance and development. Mutual aid without cell differentiation and memory can only produce a simple aggregation or colony of identical and undifferentiated though related cells. Multicellularity with differentiation allows for cell specialization. The evolution of cells for specific tasks enables organisms to acquire new abilities, undertake many tasks at the same time and occupy new niches. Some slime molds comprise of a single type or uniform cells. In others, cells differentiate into two or three types, including stalk-cells that, unlike those cells that become spores, don't reproduce. The specialized stalk cells of differentiating slime molds forego reproduction but help their genetically related sister cells pass on their genes.

Kropotkin thought local or individual autonomy combined with intense collectivity must also characterize the relationships within the egg and between the differing specialized cells of developing organisms. Embryos, he thought, must also develop and function in dynamically collective, decentralized, locally autonomous and non-hierarchical ways.

However, during and since Kropotkin's time it was generally assumed that genes and embryos necessarily express themselves hierarchically as hypothesized by Kropotkin's influential theoretical opponent Weismann, who formulated the Centralist Dogma of Genetics, Inheritance and Embryology. Weismann's linear, additive, preformist, nucleo-centrist, nonreversible, unidirectional, hierarchical and static notion of inheritance and development dominated genetic-developmental thinking until recently.

Weismann's basic idea is that there is an immortal blueprint centrally located and preserved unchanged in the nuclei of the sequestered egg cells preventing the transmission of acquired variation and controlling the process of development and inheritance in each and every generation. Weismann's static, mechanistic and hierarchical account of genetic inheritance and expression contradicted Kropotkin's locally autonomous and dynamically networked conception of natural process. Kropotkin believed that Weismann's gene-centric account of inheritance and development was insupportable because of abundant evidence of cytoplasmic-nucleus interaction in early embryological development. There is also the indisputable fact of cytoplasmic inheritance: "We learned from the best embryologists that the living substance which is the bearer of inheritance is not localized in the nucleus of the egg-cells; and that an intercourse of substances

[6] Kropotkin, *Anarchism: Its Philosophy and Ideal*, 118–9.

between the nucleus and the cell-plasm must be taken as proved."[7] Kropotkin also asked how it is possible for the nuclei of egg-cells to live a "sleeping beauty existence" in an "inner sanctuary" when they are fed by and live in "close intercourse" with the body cells. An obvious case "in point," he correctly asserts, is the "many well-known cases of infection of the egg-cells by bacteria developed within the body-cells."[8]

More generally, Kropotkin objected to the centralization and hierarchy of Weismann's thesis, according to which nuclear information and processes determine the egg and embryological development in a one-way process: "There is a strong hierarchy among Weismann's determinants"; his conception of "development of the embryo reminds one of the mobilization of an army, of which the determinants are the officers and sub-officers organizing its different parts."[9] Kropotkin thought that Weismann's static and non-dynamic notion of 'immortal matter' and 'controlling determinants' were purely speculative and incorporated scientifically unjustified spiritual, capitalist and hierarchical prejudices and assumptions.

For Darwin the unit of evolution or natural selection was the individual. Weismann reformulated Darwin's ideas in terms of gene selection. Selection of individual organisms by the external environment is complemented by internal or within-individual environments or arenas characterized by competition between genes, cells and specialized cell lineages. Weismann's determinants are conceived as competing for success within individual cells that compete with other cells within organisms. The hypothesis that the evolution of organisms occurred through the natural selection of competing genes has more recently been popularized by Richard Dawkins in his famous book, *The Selfish Gene.*[10] Dawkins considers that the individual organism is simply a vehicle for replicating the competing and selfish genes within it.

Weismann's and Dawkins' conception of internal competition necessitates and implies centralized hierarchical control by the genes over developing organisms involving a one-way flow of power, information and instructions.

Centralized and hierarchical control is also an essential aspect of state-regulated capitalist competition in social and economic spheres. Genetic competition and hierarchy represents an imaginary or hypothetical biological counterpart of liberal economic science and politics according to which the state (centralized control of information, power and authority) and capitalism (individual competition) are necessary, essential and complementary causes of one another. Individual selfishness and competition generates efficiency, robustness, freedom, innovation, etc., in this view, but requires and generates a regulatory structure to moderate selfishness for the good of the economic system and social organization as a whole. The invisible hand of the free market requires the iron fist of anti-monopoly laws, anti-fraud squads, central banks and the World Trade Organization.

The idea that organisms evolved and are maintained by competition between genes and cells that are hierarchically controlled by some regulatory structure is counter-intuitive. Kropotkin believed that collective explanations of embryology were much more persuasive and that empirical evidence strongly supported them.

[7] Kropotkin, "The Direct Action Of Environment And Evolution," 1919, 76. (The last chapter of *Evolution and Environment*, not included in the edition by Black Rose Books). See also: Recent Science, Dec. 1892, 1011–14, where he discusses in detail the ideas of Geedes, Verworn, Hertwig, Van Beneden, etc., upon the issue of cytoplasmic inheritance.

[8] Kropotkin, *Evolution and Environment*, Black Rose Books, 1995, 194, 192, 241.

[9] *Evolution and Environment*, 190–1.

[10] Oxford University Press, 1976.

Animal groups and collectives

In *Mutual Aid* Kropotkin responds to Huxley's myopic individualistic-competitive account of animal life. Kropotkin explicitly states in *Mutual Aid* that his study of sociability among animals shouldn't in any way be considered an objective study. The existence, pervasiveness and importance of animal communalism and egalitarianism (e.g. collective mobbing or flocking by all the birds in a colony) were exaggerated for polemical purposes in his political journalism. Kropotkin suggested that the natural or predominant structure and mode of interaction among social animals is the cooperative and egalitarian group. In his Obituary of Darwin (1882) Kropotkin states that: "Darwin and his successors comprise an excellent argument to the effect that animal societies are best organized in the communist-anarchist manner."[11]

In *Mutual Aid* Kropotkin imaginatively reinterprets the ideas of his friend and colleague A.N. Severtsov. Severtsov was particularly interested in differences between individuals of the same group or species, e.g. age-hierarchies among social-eagles during feeding. Kropotkin when describing how older eagles are shown preference during feeding talks in terms of social "rules of propriety" rather than the more familiar hierarchical characterizations used by naturalists today. Similarly, necrophorous beetles whilst deciding whom shall lay their eggs upon the corpse of a bird are "considerate" and "not at all quarrelsome." Social contests for mates and territories among groups of birds are presented as play rather than competition. The animals are presenting a "dancing performance" to entertain themselves.[12] Such characterizations are designed to emphasize socially pleasurable aspects rather than social competition within animal groups. Kropotkin's assessment is no less valid or more anthropomorphic than the narrowly hierarchical and competitive interpretations of collective behavior favored by naturalists today.

Scientists broadly following the mutual aid tradition during the 20th century (e.g. Allee, Bonner, Wynne-Edwards) see social or group hierarchies as a universal feature of animal behavior and examine them empirically and theoretically in great detail. The role of hierarchies and territories in the collective allocation and conservation of resources is central to Edwards' theory that many ritualized contests, represent socially generated structured interactions for allocating and managing scarce economic resources (nest sites, food, cover, etc.) in a civilized manner for the overall good of the group and the species.[13] Without such mechanisms food may be come overtaxed or nesting sites overcrowded. More generally, innumerable and beautifully produced wildlife documentaries reveal how individuals within many groups of animals establish and defend their individual territories, nesting sites and mates through social competition. But these same individuals when faced by intruders and predators may immediately mount a general, unified and organized collective defense of themselves and/or their communal territory.

Although territories and hierarchies are structures produced by competition, they are collectively or socially generated. Unlike Huxley's individualistic anti-social conceptions of competitive struggle, hierarchical dominance or structuring is in fact collectively enacted or produced through the application of social rules or conventions particular to each species or group. Species-

[11] Kropotkin, "Charles Darwin," *Le Révolté*, April 29, 1882, 1.

[12] Kropotkin, *Mutual Aid*, popular edition 1915, 24 (eagles), 18 (beetles) and 48 (birds).

[13] V.C. Wynne-Edwards, *Evolution Through Group Selection*, Blackwell Scientific Pubs. 1986. A readily available, readable, bite-size summary of this book can be found in S.J Gould's essay "Caring Groups And Selfish Genes," in his book *The Panda's Thumb*, Penguin Books, 1983

specific and group-specific rules of engagement or propriety inform, stratify and civilize in-group and inter-group economic and reproductive competition of many social animals.

Group or collective living creates dynamically structured arenas for both socially competitive and intensely cooperative and/or pleasurable forms of collective behavior in animal societies. As Kropotkin suggested, there is no doubt that egalitarian non-hierarchical economic cooperation is an ethologically and ecologically real dimension of both animal groups and living systems of all kinds. Pods of sharks and dolphins have been videoed performing distinct functions in a cooperative and coordinated rounding up and devouring of massive schools of sardines. In this example a non-hierarchical, egalitarian and economically mutually beneficial system of collective behavior is practiced between mortal natural enemies.

Collective evolution of intelligence

Kropotkin thought intelligence is directly attributable to sociality resulting in much greater survival chances. "Intelligence is an eminently social faculty,"[14] and those species showing the "greatest development of sociability lead first of all to the better development of the mental faculties."[15] "Language, imitation and accumulated experiences are some of the many elements of growing intelligence of which the unsociable animal is deprived."[16]

Kropotkin was particularly interested in the adaptive plasticity of animal behavior in social groups. Social animals adaptively modify behavior and transmit, through imitation, play or instruction, knowledge to other members of their social group. Animals able to communicate and learn from information provided by others, Kropotkin thought, would be much better able to survive in changing or newly colonized environments. Intelligent animals compensate for their lack of genetic and morphological flexibility by instinctual or behavioral flexibility. The ability to adopt and evolve novel behavior is especially prevalent among highly social species. The collective transmission of information between organisms, both within and between generations, is an important and often overlooked factor in evolution.

Both Bakunin and Kropotkin thought that the hierarchical separation of brainwork and manual work in human society was based upon a false conception of the mind/body relationship. Kropotkin correctly maintained that brains functioned in a radically decentralized way in which every neuron is autonomous within a self-organized and infinitely plastic collective system:

> "The modern psychologist sees in a man a multitude of separate faculties, autonomous tendencies, equal among themselves, performing their functions, independently balancing, opposing one another continually. Taken as a whole, man is nothing but a resultant, always changeable, of all his diverse faculties, of all his autonomous tendencies, of brain cells and nerve centers. All are related so closely to one another that they each react on all the others, but they lead their own life without being subordinated to a central organ—the soul."[17]

Brain systems are integrated with all bodily systems at all levels simultaneously as a unified organismal system. The skin is the largest organ of the body and is connected by a web of nerve

[14] *Mutual Aid*, 50.
[15] Kropotkin, *Ethics, Origin and Development*, Tudor Publishing, 1947, 321.
[16] *Mutual Aid*, 50.
[17] Kropotkin, *Anarchism: Its Philosophy and Ideal*, 119–20.

cells over its entire surface area to a brain that is as equally influenced by bodily hormonal signals as it is by the electrical signals of the nervous systems. The development of meaning is social, collective and non-locatable in some organ called the mind. The responses of individual brain cells are only meaningful in the context of the entire nervous system and the behaving organism in which they are embedded.

Whilst attempting to discover some 'atlas' of the brain or mind (like a world map), scientists analyze brain slices of mice in terms of which genes are activated in which geographical groups of epigenetically different brain cells. It is suggested that such methods will help to define thousands of different brain regions. In a normal functioning brain, specific regions may be the preferred residence for particular activities—but brain systems very quickly reorganize or reroute themselves when these regions are removed or preferred routes to them are blocked. Brain systems aren't composed of compartments or regions and don't function as regional federations, even as headless or non-hierarchical ones. Brain systems are not static, they are integrated functional systems existing in a much more dynamic, distributed and non-linear form than we have yet been able to conceptualize or model.

Experience generates specific modifications in brain structure, biochemistry and behavior. This specificity is achieved by biological malleability at the whole systems level, and not through a series of determinable mechanisms or processes that begin at some temporal-geographical point, either at the bottom or at the top of some molecular, bio-chemical-physiological, mental hierarchy of linear events, levels or processes. Indeterminancy and constant flux at the level of the neuron and its synaptic interconnections means that mental phenomena—Consciousness, intelligence, memory—emerge as systems-level properties. The study of individual contributing components or the search for some determined process of neural change or reconstruction is looking for wholly inappropriate mechanisms at the entirely wrong level. Brain systems are autonomous, richly interconnected, non-locatable self-organizing emergences that can't be mapped like physical terrain. This is because the map and the terrain are in a constant state of self-organized flux. It is the recognition that the brain is not hard-wired that has led to the contemporary predominance of the concept of neuro-plasticity in both our explanations and medical treatment of mental phenomena and pathology.[18]

Tall trees and entangled webs

The diverse web of life is genetically unified. Every human cell carries 60 percent of the same genes found in fruit flies and, nearly all of those possessed by mice. The complexity and fecundity of evolutionary and ecological intertwinement was perfectly captured by Darwin in his metaphor of the "entangled bank." Kropotkin employed the term "integrated" to describe the non-hierarchical elements and lateral processes of natural systems and their evolution.

But despite these insights, life's development has generally been conceived hierarchically; analogous to an elevator or ladder such that biological history and process was most usually represented as an evolutionary tree pinnacled by intelligent vertebrates. The entirely discredited hypothesis that the 'laws of nature' inevitably resulted in humans, although rejected by professional biologists, remained a popular myth among the general public. But now these once widely held misconceptions associated with the idea of a single hierarchical evolutionary 'Tree of Life'

[18] See S. Rose, *The Making of Memory*, Verso 2003 and N. Doidge, *The Brain That Changes Itself*, Penguin.

have been supplemented and surpassed by a general ecological understanding or appreciation of the non-hierarchical interconnectivity of Life's Entangled Web.

Collaborative origins of life

Life was necessarily premised or initiated by collaborative interaction of proteins, RNAs and metabolism within a membrane-bound chemical structure. Unrelated molecules became entangled and then collaborated and integrated themselves with one another. The internal systems of membrane-bound metabolic-protein chemical structures hosted the complexification of RNA replicators, resulting in the utilization of their informational and constructive potentialities in a synergetic partnership evolving into the first cells.

The hypothesis that solitary virus-like replicating elements of RNA or DNA spontaneously evolved and then began competing whilst hierarchically organizing the components of cells is an absurd, illogical and physically improbable scenario. Rather, life originated when molecules collectively formed web-like intelligence-networks of information, energy and meaning within integrated, replicating membrane-bounded structures.

The evolution of basic life forms (bacteria and archaea) with DNA information and replication systems didn't progress in some linear or tree-like fashion. Genes don't stay put, they have continuously traveled between and merged with many other species during the evolution of life. Reports in mainstream scientific journals during 2008 and 2009 suggest that genes were swapped or transferred between 80 percent of bacteria and archaea including taxonomically very distantly related species of these simple unicellular organisms.

The first oxygen respiring and photosynthetic unicellular organisms with a nucleus, such as amoeba and algae, evolved through the symbiotic merger of bacteria within larger and more complex cells.

Although evolution has been honed by natural selection the most important speciation, mega-mutation or complexification events during the first 3 billion years of evolutionary history emerged from entangled webs of migration, invasion, incorporation, collaboration, fusion and merger of both genes and whole species of differing single celled organisms.

These processes and events overturn and collectivize the traditional hierarchical-competitive tree of life conceptualization of evolution. Recent research suggests that 14 percent of living plant species evolved through the fusion of separate species by processes variously known as symbiosis and hybridization (*New Scientist*, Jan. 21 2009).

Bacterial infection of nuclear material appeared to Kropotkin to be both a fact and a potential source of evolution. It is now known that animal genes migrate laterally between species ferried by bacterial invasions and other vectors, resulting in genomic integration with the DNA of their new host. The parasitic wolbachia bacteria

> "has implanted itself inside the cells of 70 percent of the world's invertebrates co-evolving with them. We've found at least one species where the parasite's entire genome has been absorbed and integrated into the host's. The host's genes actually hold the coding information for a completely separate species. Large-scale heritable gene transfers may allow species to acquire new genes and functions extremely

> quickly. Lateral gene transfer may happen much more frequently between bacteria and multicellular organisms than previously believed."[19]

The ancestors of cows didn't directly adapt their genomes to code for an ability to digest cellulose. Herbivorous dinosaurs and cows evolved through symbiotic amalgamations that directly integrated the necessary genomic information encoded inside bacteria that colonized their stomachs. In cattle the mother "licks her calf, ensuring the continuity of her rumen ciliates." Margulis continues: "The 'standard' neo-Darwinian evolutionary theory claims that cows evolved by 'gradual accumulation of favorable mutations' while it ignores the cellulytic activities of cow symbionts."[20]

The role of symbiosis, amalgamation and collaboration in our own evolution is only just beginning to gain scientific attention. Like our brain and immune systems, human gut micro-ecosystems develop over a period of about two years beginning at birth. Our lower gut biota symbiotically assist humans digest much of what we eat and synthesize a variety of essential vitamins.

The entire sum of genetic material from microbial communities in the human lower gut alone is more than 60,000 genes—twice as many as are found in the human genome. The human microbiome contains at least 1,000 different types of broadly beneficial bacteria that specifically collaborate and evolved with our species. The skin is the largest organ of the body with around 200 bacterial species. By some estimates only one out of every 10 cells in the body is human and a human micro-biome project has been conceived to aggregate data upon the DNA contained within our symbiotic bacterial and micro-fungi.

Collectivity and genetic expression

For a century the dogma in genetics has been that, genes or protein-coding DNA located in the nucleus produce and transcribe messenger RNA, conceived as a passive signal that, upon arrival activates the cell's protein making units that manufacture the specified proteins that somehow achieve everything else in development. The 'central dogma' has predominated since the 1890s (when it was first conceptualized by Weismann) and was simply updated to accommodate new empirical discoveries in the 1940s and during the following half-century after DNA was discovered. But the central dogma—although in a general sense commonsensical—is rapidly being abandoned as a biological gospel because contemporary research into the RNA universe continues to reveal that, far from being a mere copyist or passive transmission signal, it is the case rather that an abundance of ribonucleotide episystems generated by the activities of a plethora of small versatile molecules are major players in embryogenesis through shaping, informing and interfering with the messaging processes that informs (not instructs) development.

Weismann's centralist dogma and hierarchical metaphors are being replaced[21] by Kropotkin-like characterizations of genomic expression and inheritance in terms of collective, fluid, multi-directional, self-regulating, decentralized emergent interacting networks or systems. The human genome contains some 1,000 types of microRNAs networking below and above the level of the

[19] Hindu Newspaper Science Bureau Report 2007 based upon research published in *Science.*

[20] L. Margulis, *Symbiosis as a Source of Evolutionary Innovation*, 11.

[21] For a readable popular introductory outline of the Centralist Dogma and why it is clearly wrong see Mae-Wan Ho, *Genetic Engineering: Dream or Nightmare*?, 1998.

DNA, regulating some 30 percent of the protein encoding genes and performing diverse roles in developmental and biological processing ranging from tissue differentiation, apoptosis (cell-death), organ development and insulin secretion.

The expression and functioning of genomes and organisms is not the result of centralized DNA control and hierarchy because it involves the interpretation and coordination of that DNA by a wealth of locally autonomous and self-organized ribosomal (RNA) systems collectively and meaningfully integrating their activities in life's maintenance and reproduction.

Collective meaning and the evolution of complex organisms and societies

The idea that 'nature speaks' is a biological fact, not just a pleasing metaphor. Collective semantic systems are everywhere that life exists; in all spheres, levels or dimensions from bio-molecular to social-ecological self-organization.[22] Semantic systems are seen in the codes used by molecules to speak to each other in organizing the type, place, timing and pattern of a cell's development in an embryo, pheromones or chemical signals are passed among groups of beetles, electrical and hormonal systems cooperate in creating meaning between neurons in the brain, vocal or gestured signals between members of a wolf pack. Specific molecular response in the presence of a specific organic compounds or signals are one of the essential building blocks in the evolution of living cells because any system or community of meaning requires specificity, structural information and a means of communicating that information. These capabilities are all provided within the cell by signaling and receptor processes.

Internal and external cell signaling involves interpretation by signal transduction processes where large molecules interpret the meaning of any internal or incoming signal according to collective rules in a specific context. These abilities possessed by individual cells were later evolved by a process of mutual aid into complex collective semantic systems coordinating different but epigenetically related specialized functional cells. The evolution of differentiation, adhesion and pattern codes in epigenesis involves the evolution of emergent systems of meaningful mutualist evolutionary complexification among cells in the construction of a new organism.

Organic or biological codes are collective systems tools that have facilitated the complexification, development and maintenance of life. Life at all levels has evolved and reconstructs itself, not only with informatic (DNA) and metabolic (energy) systems, but also, builds its structures aided by systems of natural conventions. Molecular, cellular, animal and linguistic communities share, follow or understand common or collective codes or conventions. Unlike information and energy, meaning doesn't exist in any particular place. Community, group or collective semantic properties, processes and systems, whether practiced or utilized in the nucleus or the mind cannot be measured quantitatively.

Systems of collective meaning are convergent emergences appearing in many different levels of natural living systems—from epigenetic to social and linguistic systems of meaning. By giving meaning to information through systems of collective rules, semantic processes connect autonomous molecular worlds, independent cells and individual organisms.

[22] For a fascinating readable popular introduction to Semantic Biology see Marcello Barbieri, *The Organic Codes: An Introduction to Semantic Biology*, Cambridge University Press, 2003.

Embryo development describes two distinct but related phenomena: cell memory and the collective memory matrix of the body plan. Cell or epigenetic memory is remarkable in that inheritance is highly stable and relatively error-free. This is necessary as the specialized cells that compose the liver or produce pancreatic insulin are continually replaced and must be reproduced very accurately over many generations during the life of an individual organism.

In addition to individual cell memories there is the collective or supra-cellular memory of the body of the whole organism. The supra-cellular or collective memory or body plan is the body's reconstructed memory. Body memory can be compared to the memory carried in the mind. This three-dimensional information is preserved in the body plan of the organism throughout its life.

The collective memory matrix of the body is not straightforwardly or simply a morphological product of the genes. The body is a self-assembled collective cellular state involving energetic, informational, structural and semantic input in a variety of forms from different sources—only one of which is the nuclear or genetic DNA.

The physio-chemical-spatial relationships between cells in multi-cellular organisms aren't in any way simply the result of genetic commands. Robust and convergent spatial order pre-exists in virtue of the fact that a large number of 'simples,' in this case cells, generate distinctive types of dynamic collective physical patterns, morphologies and architectures. The forms that plants and animals assume emerge from the distinctive properties that fields of interacting simples or cells collectively typically generate within given physical-chemical-spatial constraints. Regeneration is observed in simple single celled organisms when their nuclei are removed. This occurs because of the emergence and existence of robust autonomous and dynamic self-organizing physio-chemicalspatial systems contained in the cell-architecture. The robustness, predictability and dynamic plasticity of collective cellular fields or patterns are manipulated by genes and cells in a myriad of ways, but, their organization is autonomous and independent of them. Complex collective self-order comes for free and is independent of the biological systems that have evolved by manipulating and refining innate physical creativity.[23]

Levels and hierarchies in nature

Net and Web analogies have been extended to describe the technological ability of data in cyberspace to automatically route itself down one path or another in an evolving network when one or another route in the network is blocked or lost. Simple organisms such as pond hydra, lacking any kind of nerve centers, possess perfectly decentralized nerve nets. The headless hydra's nerve cells are directly connected to all the others and sensory information is eventually passed on to all others in the nerve network. The one dimensionality and lack of specificity in hydra's nervous system provides an example of a perfectly nonhierarchical and non-centralized integrated collective system, but one lacking in multi-dimensional complexity—neurologically analogous to crystals whose one dimensionality limits them to a single structure.

A diversity of organizational platforms, centers, specializations, levels, dimensions and spheres in ecological systems, organisms and brains is an essential element in the emergence of complexity. The nerve clusters of insects and the brains of more complex animals have, through the evolution of collective levels, centers and specialization of organizational function combined

[23] For an entertaining introduction to morphological self-organization see Brian Goodwin, *How the Leopard Changed Its Spots.*

with, the non-centralized or generalized adoption of collective systems of rules of signaling, convention interpretation and action operating from the molecular to the social levels are able to facilitate the autonomy of local specificity and meaning within a vast integrated functioning whole.

Natural systems involve collective processes where autonomous elements organize their context, meaning and well-being from the evolution, development and maintenance of complex self-referential integrated systems functioning at many different levels, dimensions and scales.

Natural systems don't generally develop or function as command hierarchies. But natural systems do often typically share the surface features of being multi-leveled, multi-dimensional and multi-scalar. Integrated, self-organized and interacting levels of natural systems aren't connected through linear or additive flows of command hierarchy. Natural systems are typically autonomous within each level or sphere of action. Rules or conventions of collective behavior and interaction observed at one level or context simply vanish in the next emergent level, or in a different scale (e.g. nano), dimension, time or place. Different dimensions or emergent levels or timings don't rule or govern all the others. Convergent systems are collectively self-constructed and self-maintaining. They are not constructed from above and cannot be reduced to the properties of their individual elements or constituent systems at the micro level. Systems exist in collectively constructed space.

Complexity in ecosystems comes from a diversity of dynamic interacting elements and organisms competing and cooperating for energy in its myriad of different forms, strategies and niches. Within organisms, complexity is increased through the collective evolution and diversification of new organizational levels, specialties or dimensions of energy, information, structure, memory and meaning. There are levels in organisms, brains and ecosystems, but these result from greater differentiation and collective complexity or integration—not from the appearance of a single, better, centralized or dominant form of organization within or rising above the system, controlling or eliminating local, pre-evolved, pre-developed or pre-conditional complexity and autonomy.

Natural systems emerge, integrate and operate in radically decentralized ways. Traditional hierarchical concepts of nature fit very awkwardly with both the structure and the concept of organisms and ecosystems in terms of both development and function. Military, monarchal, governmental and corporate metaphors are, for the most part, completely inappropriate in describing the operational processes of natural systems at many levels in different molecular, biological and ecological realms: genomes, organisms, brains, ecosystems, planetary climate systems, etc.

Scientific Reductionism is a reversal of religious hierarchy. According to Scientific Reductionism, systems functioned hierarchically but their organization was determined by simple micro-level mechanisms from below. It was thought that systems complexity might be explained when the natural laws of supposedly less complex lower-level mechanisms were fully understood. Nowadays it is appreciated that natural systems are not mechanistically determined but are emergent processes that cannot be reduced to their machine-like components at the micro, molecular, nano etc., level. Autonomous, complex, collective self-organization is present at all systems levels and emergent processes. The collective rules informing one level or scale of a system's organization are inapplicable at another. This is in contrast to hierarchical concepts that hypothesized universal divine or scientific laws that determine natural organization from the top downwards or bottom upwards.

When attempting to characterize natural systems without reference to God, law and authority, humans have struggled to find words and ideas that capture the inclusive, collective and self-referential nature of multilevel, developmental and emergent systems. The holistic idea of the 'highest' level as being a particular state of a whole system is complicated by the almost complete autonomy of organization in the great diversity of matter, space and time scales in which systems exist. Turbulent water appears chaotic at the surface or macro level, but at the molecular or micro level it is robustly and dynamically organized. It is almost as if the two levels, scales or dimensions of the same reality were completely unrelated. Here we have the idea of systems composed of many different complex emergent systems in different scales or dimensions of time and space existing together. But each level, dimension or scale acts according to characteristic, particular and locally autonomous rules and correspondences.

Unlike the mono-structural simplicity of crystallographic order in which its essential completeness is restricted to a single static level of structure, living organisms and systems must be expressed in multiple levels and dimensions because no single level of structure contains the grounds for its own production or stability. DNA is not robust. It can achieve little by itself. It can only act and survive through mediated association with other equally complex and adaptable molecular realms and systems, the RNAs, proteins and the cell.

The nucleus or the brain does not control the individual cell or the whole body like the manager of a corporation. Talking about the biosphere being the highest level in some categorization of ecosystems is meaningless in the context of the real systems world. What was in the past characterized as higher or controlling levels or functions we now describe in terms of emergent collective properties. This does not refer to a governing structure in some way apart or above the rest of the system. In natural systems all levels possess complexity and are autonomously organized yet interact to construct inclusive collective structures. The problem with using the term hierarchy to describe integrated interdependent dimensions, levels or systems is that natural order is achieved through a whole system of fluid but convergent constructive relationships, in which the levels are mutually defining and co-evolving. Natural order is maintained through functional, meaningful and/or self-referential interactions between dimensions and levels. But no dimension or level has priority over the other. In natural systems, one integrated level is no more organizationally important than any other. Organizational participation rests with individual components and levels as much as it does within the entire system.

More complex systems emerge through the convergent interaction of other systems. These 'other' systems are usually referred to as sub systems or processes. These concepts convey subordination or automatic functioning and don't attribute to the composing or micro-level systems their full existential and organizational autonomy as full-bodied and complete systems.

Hierarchy implies the additive, linear and unidirectional organization of things. But natural systems are not things, reducible to the things of which they are composed. Natural systems are expressed as emergent interacting levels, with a common body of rules, behaviours and constraints at each level. Patterns of macro-evolution are not derivable from patterns of micro-evolution. The brain is not reducible to the bio-electrical-physiological processes of its individual neurons. Nature must be conceived as systems beyond systems beyond systems.

Hierarchy implies not only levels of function, organization or composition but, additionally, levels that can be characterized as superior, higher, controlling, centralized, more evolved or complex. In the classical concept higher levels also create, construct, constrain, control or determine what happens at the lower levels. Hierarchies in human societies are associated with programmatic, centralized-corporate-statist, vertical or top-down command systems where subordinates follow the instructions of superiors. It is necessary to differentiate between levels, scales or dimensions of systems and hierarchical systems whose levels have evolved and are arranged to function hierarchically. Ecosystems, genomes and organisms characteristically interact with all layers of organization simultaneously such that they are in constant communication or co-activity through multi-directional patterns of local autonomy and global communication and interdependency.

Hierarchical characterizations are useful ways to describe natural systems in certain levels and contexts, particularly social hierarchies and territorialism in animal and human communities. This is because hierarchy is a socially generated practice dependent upon a complex community of meaning that the participants understand and to which they respond. But outside of the context of competitive social systems, hierarchical concepts are generally of only very limited validity when attempting to characterize the systems state in any level or context. Even then, not all animal societies are fiercely hierarchical. Bonobos aren't and chimps are. Both are our nearest living relatives. Among those animal societies that do have competitive hierarchical mechanisms, these may only be exercised at a specific season or in particular contexts. For example, on the Scottish moors grouse give up their hard-won territories during the summer months when food is plentiful. At any time of the year the presence of a golden eagle leads them to form flocks for safety and these occasionally contain a few hundred individuals.

Ecologists and biologists now characterize natural processes in more non-hierarchical terms, e.g. systems, networks, relationships, webs, communities, etc.

The systems concept is a collective concept. The social-scientific philosophies of atomistic reductionism and individualism didn't grasp that individuals or simples, even if they in some sense really exist, can't evolve into anything more complex by themselves. However, many similar individuals or forces and different sorts of them, by collectively following a few simple rules, achieve a great deal. There are no elementary entities but a complexity of subatomic, atomic and molecular systems relationships in which many and various charges, particles, energies and tendencies relate to one another in a variety of ways. Subatomic systems are no more or less existent than ecosystems or human minds. This is because systems at whatever level are collective relationships that need not take up any space at all.

The inappropriateness of hierarchical metaphors is particularly apparent in the consideration of biospheric or global ecology. The top or most inclusive level is the biosphere within which all ecosystems are housed. However, the chemical composition and systems of the biosphere evolved and are maintained by bacterial processes that can equally well be viewed as the bottom, smallest or lowliest component of local ecosystems. Scientific knowledge and consideration of the role of microbiological life in the evolution and the maintenance of the biosphere and its local ecosystems reveals a situation that is not amenable to hierarchal interpretation or analysis.

The capture and metabolic processing of energy and biospheric elements by plants and animals occurs through the agency of their bacterially derived cell organelles and other resident micro-symbionts. Animals and plants don't contribute anything necessary to the maintenance or stability of biospheric processes at the planetary level—the immense super system maintained and regulated by bacterial processes.

The biosphere's local ecosystems need not be complex and were composed solely of micro-organisms for most of biological evolution. Humans are a biologically inessential species of organism in the functioning of local ecosystems. Plants and animals are dependent upon certain quite specific biospheric parameters as the prospect of climate change is now revealing to us. Unlike bacteria that thrive miles underground and at the lips of volcanic ruptures in the deepest oceans, the natural range of our species exists upon just a few patches of arable land occupying the thinnest sliver of the earth's surface. Rather than being at the top of some ecological and evolutionary ladder humanity is waking up to the fact that we are hanging precariously somewhere off the side.

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