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THE MYTH OF THE PUTATIVE 'FIRST ORGANISM'¹

1. THE MYTH

The 'organism' is a fundamental and essential myth of Darwinian biology. In contemporary biology, the 'organism' is conventionally taken as a single discrete and autonomous individual – an observable, genetically-determined entity enclosed within a continuous structural boundary. Further, in the traditional Newtonian/Darwinian scheme of things, 'life' is seen as the sum of discrete units ('organisms') occupying a pre-determined place in the natural world, their 'niches'. The conventional picture shows a variety of such niches, each ready and waiting in the physical world, and various kinds of organisms as passive inhabitants of those pre-established places.

Even more critically, an 'organism' is seen as a single culture determined by a single set of genetic components. To look conventionally at any animal (e.g., a bull) is to look only at what is contained within its topological structure, a hollow doughnut (a torus, if you'll excuse the pun): the hide is clean, the lungs are clean, the lining of the gut is clean. Such a creature is totally defined within the contour of its topological surface and is thus devoid of any endo- or ecto-symbionts, the microbiota without which it could not live. It is this notion of a discrete, passive, and uni-genomic individual that constitutes the mythical 'organism' of conventional biology.

2. A DYNAMIC AND ECOLOGICAL ALTERNATIVE: THE GENERAL VIEW

I wish to claim that this traditional organismic notion is totally inadequate to understand the very real complexity of living systems. In the non-traditional view I discuss below, 'life' appears and persists not as a sum of multiple discrete entities but as a single *ecology*. Here ecology is not a passive issue of real estate – not the static placement of living systems in a pre-established environment – but the multi-leveled embedded consequence of life's active and continuous metabolic operation.

¹ I have Rod Swenson to thank for this most felicitous phrase.

A dynamic and ecological view, this alternative *Weltbild* is altogether different from the traditional view. It provides an operational view of biological 'individuals' – not 'organisms' – with overlapping subsystems, different levels of organization, and the co-presence of multiple boundaries. It is the operational unity of these overlapping systems that marks living systems both spatially and temporally as *ecological individuals*:

- *spatial unity of operation* is evidenced in the expansion of cells, populations and communities into ecological space, using the waste of others as food;
- *temporal unity of operation* is evidenced in the extension of intimate associations retained among living systems over time.

Symbiosis (the protracted association between members of different species) and the endosymbiotic origin of nucleated (eukaryotic) cells are founded on the fact of the unitary and integrated operation of partners: multi-leveled, mutually embedded, and organizationally co-determined. If individuals have boundaries at all beyond cell membranes, they are operational boundaries – and if there are distinctions among living systems, they are operational ones, not structural.

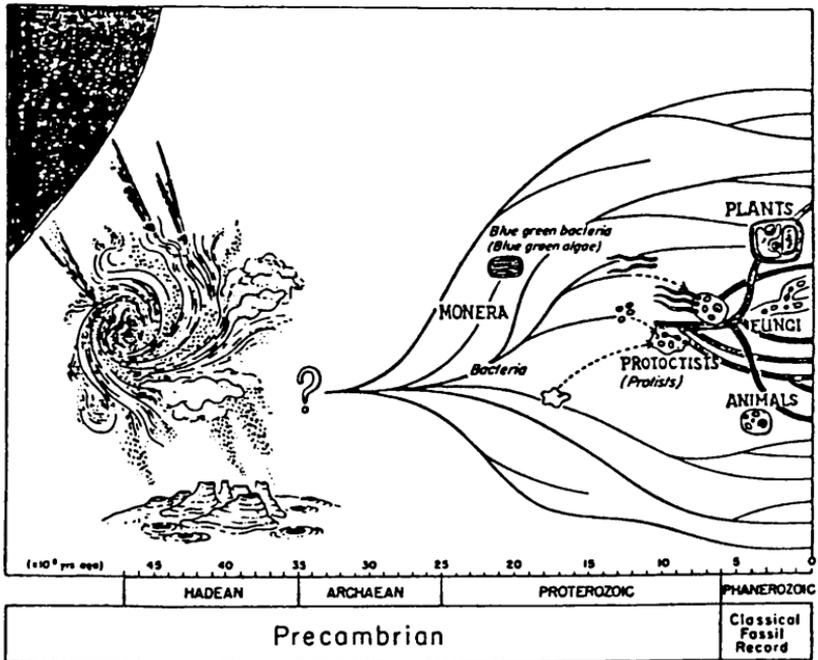


Fig. 1. Geologic time line

3. THE EMERGENCE OF LIFE, THE EXPANSION OF THE LIVING

The figure below shows the stretch of geologic time extending from the origin of the solar system and the Earth, at about 46×10^8 years ago (4 600 million years ago) on the far left, through the origin of life and the expansion of five kingdoms of living systems into the present time on the far right. The branched line extending from the question mark at the early Archean Aeon to the present time traces the evolution of cellular life, charting the paths by which cells proliferated, formed alliances, and invaded each other through time. This temporal extension of cell relationships has produced different kinds of cellular organization, grouped as five kingdoms of living systems. Monera (bacteria), the oldest and simplest of all contemporary living systems, are prokaryotes (of non-nucleated cells) and are different in kind from members of the other four kingdoms, all eukaryotes (of nucleated cells): Protoctists (e.g. amoebae, green algae), Fungi, Plants, and Animals.

Now neither end of this geological time stretch is controversial, nor is there any question as to the fact of life's having originated somewhere between. What, then, is the question that marks the origin of life in the middle of the figure? It has to do with the conditions on the very early Earth between 4 600 and 3 800 mya. While we do not know those conditions exactly, still atmospheric chemists and geochemists have extrapolated, calculated, and modeled them, and scientists in origins-of-life research laboratories can now conduct physico-chemical experiments that simulate reactions under plausible conditions of the early Earth, e.g., under moderately-reducing high-density atmospheres of nitrogen and carbon dioxide (Walker 1985; Kasting 1986). But the question also concerns time as well as conditions: when did life emerge? Answering that second question depends in good part on developing answers to the first: the more we find out about conditions on the early Earth, the better we can adjust the location of the question mark from the left; and the more evidence we gather about early living systems (either physical evidence from fossils or theoretical evidence from metabolic pathways), the better we can adjust the location of the question mark from the right. As we advance our conjectures from the left and press our findings back from the right, the more and more clearly we can designate the time and the conditions under which life must have emerged on Earth – the more we narrow the window in which we can place the question mark.

I wish to emphasize here two particular concepts illuminated in this figure. First, in the *unbroken line extending forward from life's origin* to its contemporary forms, is diagrammed the notion that life is a phenomenon which is continuous from its ancient and simplest possible form to its modern and most in-

tricate. That continuity is the unceasing process of metabolism which began more than 3 500 mya and still operates today. Indeed it is the very operational continuity of cellular metabolism that defines the phenomenon of life – that distinguishes what we call 'life' from everything else we see around us.

Does continuity of metabolic operation over evolutionary time mean that early cells would have had as intricate a metabolism as contemporary cells? Not at all: the intricacy which characterizes contemporary metabolism has resulted from the emergence of different levels of cell organization – is a product of ever-increasing complexification in collective entropic systems over time (Swenson 1991). Prior to complex organization, the first cell systems must have had the very simplest possible metabolic organization. The cell organization that makes metabolism possible provides the minimal definition of the living: while later living systems in their intricacy may exhibit 'more' there could be no living system with 'less'.

Cells now have an extraordinary metabolic intricacy that is based on proteins, required for certain cell structures (e.g., membrane transporters and pumps) and in much of the cell's activity. Contemporary protein-dependency involves all the structural proteins and enzymes, all the structures and molecules specific to protein synthesis (e.g., ribosomes, mRNAs, and rRNAs), plus tRNA and DNA, genetic molecules whose synthesis in the contemporary cell is enzyme-dependent (Fleischaker 1990b).

In contemporary cells, the activity of RNA and DNA is of two clearly distinct kinds: enzymatic activity (resulting from the steric three-dimensional structure of the nucleic-acid molecule) and informational replication (resulting from the sequential two-dimensional structure of the nucleic acid-molecule). It is plausible that in early cells RNA played the dual role, with both enzymatic and replicative activities², and was involved directly in protein synthesis³. In 1986, three independent cases were made for the evolutionary antiquity of RNA: for an "RNA world" (Gilbert 1986), for RNA-based cells as the first living system (Alberts 1986; Lazcano 1986), and for RNA-polymerase as one of the first enzymes (Lazcano 1986). Figure 2 shows three steps in the postulated evolution of present-day cells, culminating in the 'central dogma' of the DNA-genome – an evolutionary product of emerging metabolic complexity in once-simple cells.

² The possibility of RNA's capability for that early dual role is supported by recent findings of RNA enzymatic activity (Cech 1985) and of DNA-independent and protein-independent production of RNA (Sharp 1985).

³ Protein synthesis is known to take place in the absence of DNA but not in the absence of RNA (Lazcano 1986).

The second concept I wish to emphasize from the geologic time line is this: in the absence of any line extending backward from life's origin is diagrammed an emergentist view that life appeared suddenly and discontinuously from the physical world. That view is quite distinct from the gradualist view that life evolved linearly and continuously in the physical world – that life resulted from 'adequate' prebiotic evolution, from molecular structures having become 'sufficiently complex' over time. In saying rather that life emerged, I contend that the first living things appeared suddenly (over geologic time) and, by the universal laws of physics, inevitably. Where the gradualist

in origins-of-life research may have experimental concerns that are centered on problems of prebiotic chemistry (with chemical properties and the availability, synthesis, and assembly of discrete molecular components), the emergentist in origins-of-life research would be more likely concerned with the organized production and replacement of sequestered molecular components, the component roles played within the unitary operation of a cell system.

Certainly the first living things were *materially continuous* with the physical world from which life emerged. Yet living things are not universally distinguishable on the basis of their structural elements: after all, the carbon, hydrogen, nitrogen, and oxygen atoms are materially continuous with the origin of the Universe. We are quite literally made of stardust, as Nobelist astronomer William Fowler likes to remind us. And just as certainly, because material systems are subject to the universal laws of physics, the earliest living things were *energetically continuous* with the physical world from which life emerged. But the emergence of metabolism, that peculiar dynamic organization of com-

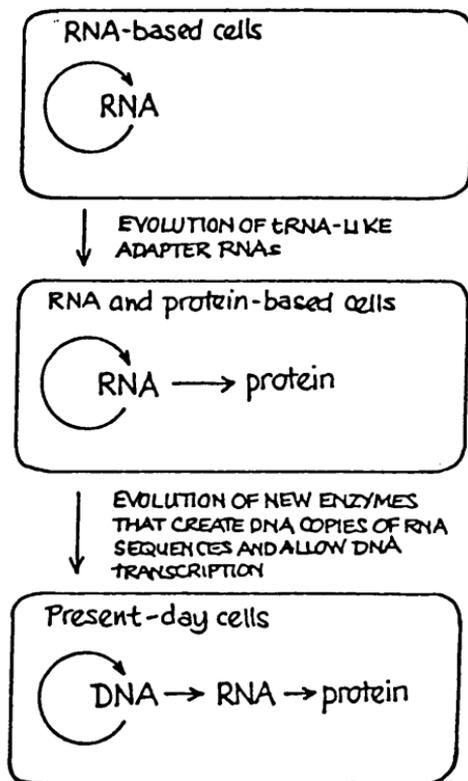


Fig. 2. Three postulated steps in the evolution of cells

ponent relationships which marked life's origin, carved life out from that same electrochemical substrate – a four-dimensional discontinuity, categorically distinct in the world from which it emerged by virtue of its organization.

4. DEFINING LIVING SYSTEMS: A MINIMAL UNIVERSAL CELL

But if the emergence of life is categorical, it seems fair to ask: By what criteria would members of that category be recognized? How would we examine an entity and ask: Is this a living thing?

Peculiar to living systems is the coupling of energetic and material interactions organized in a unitary network of processes whose outcome is the physical production of all system components, including the constituents of its membranous boundary structure.

The drawing of a minimal universal cell (figure 3) diagrams the set of autopoietic operations by which the living is uniquely defined – that is, the single set

of operational criteria by which the living is both minimally and universally defined and by which the living is distinguished from the non-living (Varela et al. 1974; Fleischaker 1988, 1990a, 1992).

To be categorized as living, a system must be physically self-bounding, self-generating, and self-perpetuating. To be *self-bounding* means that the entity in question has an interior and a boundary constituted by discrete components, and that all system components self-assemble, including the boundary structure which is an integral part of the whole system. To be *self-generating* means that all interior and boundary components are produced by component transformations, and that all system components come into being as the result of transformations within the system. To be *self-perpetuating* means that all component transformations are determined by relationships among component properties, and that cycles of component production are synchronous and continuous in time, resulting in the constant replacement of all system components by operations entirely within system. The molecular sum of these general criteria is a biological cell, the physical product of its own activity – a system which maintains its coherence in space and its duration over time by the integrity of its unitary processes of production (Fleischaker 1990a, 1990b).

As can be seen in figure 3, the only required structure is the boundary structure, its components physically assembled in a 'fluid mosaic' like the membrane that bound all contemporary cells. In physicochemical terms, we

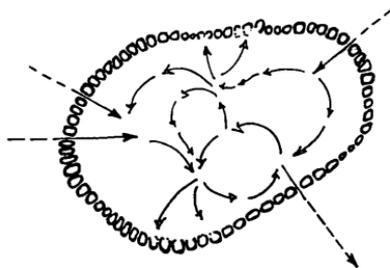


Fig. 3. A minimal universal cell

know that self-boundingness of the cell is accomplished in an aqueous medium by the electrosteric alignment (not chemical polymerization) of molecular boundary components under electrochemical forces of hydrophobicity (Tanford 1978) that encloses an internal domain under thermodynamic constraint (Morowitz 1981). Because the membranous boundary structure is actively and selectively permeable to ions and small molecules, it sequesters a microenvironment in which electrochemical concentrations can vary from concentrations from the outside (Hargreaves and Deamer 1978; Deamer and Barchfeld 1982; Deamer 1985). Self-generation, the electrochemistry of component production, arises as a dynamic consequence of that sequestered microenvironment. Arrows drawn in the figure 3 indicate the capture of energy and intake of matter at the cell's surface, the transduction of energy and the transformation of matter in a network of pathways resulting in production of structural components, and the extrusion of energetic and material wastes (heat, ions, and molecules) into the immediate surrounding. Self-perpetuation, the electrochemistry of replacement and continuous replacement of system components, requires integrity of cell organization over time and, thus, operation of the system at a distance from equilibrium.

In embodying the *unitary organization of the living* and its peculiar *continuity of operation* over time, the autopoietic criteria make explicit the following system-logical truths of any metabolic system: that function of the energetic-metabolic network requires continuous pathways (i.e., the products of one reaction serve as raw materials for some other reaction), that selective concentration of materials requires a topologically-closed structure, and, finally, that because no single metabolic process has integrity apart from the entire network of processes, no single metabolic product has privilege within that network.

As the organizing principle of living systems, autopoiesis provides a set of operational criteria whose enactment results in a living system, a cell: a selective structural boundary, the capture of energy, and the intake of material, all dynamically organized as a network of component production and from which waste (as heat, gases, liquids, and solids) are dispersed into the system's immediate surroundings. Such a system is necessarily embedded both materially and energetically in that surround (and that surround, of course, can itself be a living system).

These criteria define the living minimally in that they establish a set of general cell operations whose demonstration gives necessary and sufficient evidence that an entity is a metabolic system, a 'living system'. The first living system on Earth would have been the very simplest possible metabolic system able to satisfy these general criteria under the early conditions of our par-

ticular planet. These criteria of the living are minimal in another way as well: as the simplest embodiment of those necessary and sufficient operations, the metabolic cell is the minimal physical unit of life – the smallest possible living system, the living *individual* ('individual' from the Latin *individuus*, "indivisible", from *dividere*, "to divide"). This identification of the irreducible unit of life is not to be confused with a reductionist or essentialist account of the living – either structural (molecules as building blocks) or instructional (molecules as informational messages) – in which the (whole) living system is explicable in terms of its molecular components (parts). To the contrary, in pointing out that cells are the smallest single living systems and that all living systems are composed of cells, I contend that operations of whole living systems cannot be reduced to any component part of that cell system. That is, it is not the isolated operation of any step within the system network that defines the system as living but the unity of operations at the whole-cell level. This is one face of the biological problem of 'wholes' and parts, of course, and speaks to the difficulty of the 'assembly metaphor' for living systems: "'Parts' do not have a prior existence in isolation such that 'wholes' are made up by assembling those 'parts'". Behavior of a whole system and the properties of its parts display themselves in different contexts, and "the properties of the parts themselves come into existence only in the whole" (Lewontin 1991).

Note that living systems are thus defined not in particular 'metabolic' processes but in the organization of those dynamic processes as a *single unitary operation*. Thus, by this set of criteria it is not the physical replication of component parts that defines the system as living but the *self-generation of a network of component production*. That network of production is the system's end-product and the consequence of its own activity, and it is that network whose operation establishes metabolic activity, itself both effect and cause of system operations (Fleischaker 1992). It is the operational evidence of that network of production that is sought in origins-of-life research laboratories in minimal electrochemical systems (Morowitz et al. 1988; Fleischaker 1990a).

These same criteria define the living *universally* by specifying system processes not restricted to particular kinds of molecules or structures – that is, not restricted to those nucleic-acid/protein/lipid life forms with which we are familiar on Earth. What is critical here are the operations themselves, not the specific mechanisms or molecules employed in those operations. According to this universal definition, if molecules are organized in such a way that a physical system is produced and perpetuated as the result of a self-generating electrochemical network of production, that system is a living system. The strength of these operational criteria is in their potential use in outer space to confirm the existence of life – most plausibly but not necessarily

based on reduced-carbon chemistry – as well as in our laboratories to demonstrate the recapitulation of life's origin on the early Earth.

5. SPATIAL UNITY OF OPERATIONS

As soon as life emerged as a planetary phenomenon, it began an immediate expansion. By virtue of their unity of operations, cells, populations, and communities would have expanded into ecological space, using the waste of other cells as food. Such unity of spatial organization of living systems is found in the metabolic operations within any contemporary ecosystem. A superb example is provided in the microbial mat communities inhabiting the salt marshes and evaporite flats at Laguna Figueroa, Baja California Norte, Mexico, "studied extensively because of their analogy to Precambrian microbial mat communities preserved as stromatolites and microfossils in cherts" (Stolz 1990). In looking across the flats one sees a large stretch of mud broken into desiccation polygons, a pattern of large plates, their edges curled slightly upward, formed in the rapid drying of the mud's surface. The mud is a laminated sediment deposited by communities of phototropic ("light-nutritive") bacteria. It is composed of a surface mat a few millimeters thick and deposited sediments as many as tens of centimeters below. A handsample of the mat shows distinct layers, each predominated by certain microbial species, each with a different color due to the pigment of the phototrophic bacterial species. Each of the top three layers is approximately 1- to 2-mm thick, while the fourth layer (the bottommost layer of the phototrophic surface mat) is only "pencil thin". Beneath the surface mat is the previously deposited mat, its contents now being degraded.

The occurrence of different microbial species in such stratified communities is determined by the wavelength of light and the presence of oxygen in each layer. Community members are distributed according to their light-harvesting capabilities and their oxygen-tolerance such that species which are oxygen-tolerant and utilize short-wavelength radiation are found at the surface (e.g., various cyanobacteria), those which are anoxic and utilize longwavelength radiation are found in the deeper layers (e.g., green bacteria in the second, purple bacteria in the third), and those which are oxygen-intolerant and utilize long-wavelength radiation are found at its deepest extreme (e.g., sulfur-oxidizing purple bacteria). Oxygenic photosynthesis take place in the top two layers, and anoxygenic photosynthesis in the top two layers, and anoxygenic photosynthesis in the bottommost layers.

The community is organized such that single microbial types combine their different metabolic operations so that the waste of one is utilized as food by another. And this is typical of all ecosystems: what is taken in by one living

individual is used nutrient, and the transformed remainder ("waste") is passed on to be taken as nutrient ("food") by another. It is the unity of these metabolic operations that binds members in a community, that makes the whole system itself an operational individual. Each set of operations here in the microbial mat community – operations of a particular bacterium, a bacterial layer, the extended mudflat, or the entire evaporite ecosystem – can be discussed as 'an individual'. The boundary for each is an operational one, not a structural one. And the operations of each imbeds that individual in its surroundings: each is an *ecological individual*⁴.

6. TEMPORAL UNITY OF OPERATIONS

Yet living systems are embedded not only spatially but temporally as well. Temporal unity of system operations is evidenced in the various protracted associations between living systems, associations whose level of partner integration (opportunistic, obligate, or genetic) indicates the length of time over which that intimate associations has been retained (Margulis 1976). Of these three levels of intimacy, for example, opportunistic association is the loosest, the least intimate partner of integration, providing evidence of a fairly recent relationship – a protracted association retained over only a short period of evolutionary time. Similarly, genetic association, the most intimate, is evidence of a protracted integrated relationship that has been retained over a long period of evolutionary time. Examples drawn from contemporary living systems will illustrate these different degrees of operational intimacy.

First, illustrating opportunistic association, is the protracted relationship between *Hydra viridis* (an animal) and *Chlorella* (a protocist) – a partner integration with a relatively low degree of intimacy (Margulis 1981; Ahmadjian and Paracer 1986). *Hydra viridis* appears green because of the unicellular green algae it ingests from the pond or lake water in which it lives. *Hydra* does not digest these algal cells but retains them in vacuoles of the cells lining its gastrovascular cavity. There the symbiotic algae take up nutrients and photosynthesize; their photosynthetic products are taken up in turn as nutrients by *Hydra*. A *Hydra viridis* deprived of its photosynthetic symbiont can survive and grow, if provided with enough nutrients. Thus this association is 'opportunistic' in that while *Hydra viridis* preferentially takes up the photosynthesizing *Chlorella*, it can also survive without it.

⁴ Subsystems of the larger individual are neither hierarchically expandable (e.g., conventionally "cells, tissues, organs, organism") nor are they hierarchically reducible (e.g., conventionally "cells, molecules, atoms, subatomic particles").

Second, illustrating obligate association, is the protracted relationship between a fungus and a photosynthetic microbe (either algal or cyanobacterial) that results in an altogether different structural entity: a lichen. Lichen partnerships have a very high degree of intimacy. The fungal *hyphae* or threads that make up most of the lichen grow around the cells of the photosynthetic partner to form a tightly-woven matrix which we observe in macroscopic form as the stable *thallus* or body of the lichen. The physiology of the partners is altered as a result of the symbiosis, producing chemical compounds that are unique to the lichen partnership. While there is a wide variety of fungal partners in the approximately 15 000 'species' of lichens, there are only about 30 different photosynthetic partners (Ahmadjian 1982; Ahmadjian & Paracer 1986).

Third, to illustrate genetic association and the greatest degree of intimacy, is a report of the acquisition of an obligate *Amoeba* – bacterial symbiosis and the integration of bacteria "as hereditary cell components" (Jeon 1983, 1987, 1991). In 1966, Kwang Jeon found that his long-standing laboratory cultures of *Amoeba proteus* had become heavily infected with bacteria on the order of 60-150 000 bacterial cells per single amoeba, with harmful effects leading eventually to death in most of the amoebae. The extraction of bacteria from infected amoebae and their introduction into otherwise -healthy amoebae resulted in the death of the newly-afflicted amoebae after only a few cell divisions, demonstrating the virulence of the bacterial invaders. The originally-infected amoebae were carefully tended and cultured, and over several years the severity of infection began gradually to diminish. (The invading bacteria were dubbed 'X-bacteria' to indicate that their origin was unknown.) After 200 cell generations of *Amoeba* (about five years), the X-bacteria had decreased to a stable carrying number of 42 000 cells per amoeba and could not survive outside the infected *Amoeba*. The infected amoebae grew well and had become metabolically dependent upon their bacterial invaders: removal of bacteria brought death to the deprived amoeba in less than a week, and deprived amoebae could be 'rescued' by reintroduction of the X-bacteria. What had occurred here, over a short period of time in the scientific laboratory, was the effective evolutionary transformation from an initially pathogenic infection to an obligate genetic association between two once-distinct kinds of living systems.

7. CELLS AS MICROBIAL COMMUNITIES

The retention of ever-closer association over time means the integration of partner functions such that a distinct and different, co-determined entity comes into being – a newly-organized individual emerge with a new repertoire of functions not available to any of its ancestral partners – is the basis of the

endosymbiotic theory for the origin of eukaryotic cells: from the merger and protracted association of different ancient bacteria (prokaryotes) has emerged a distinctly different type of cell organization (eukaryotes) (Margulis 1981; Margulis & Bermudes 1985; Bermudes & Margulis 1987; Taylor 1987). Thus, according to the theory, cells of all eukaryotes – protoctists, plants, animals, and fungi – are singular microbial communities which have emerged over evolutionary time from ancient bacterial alliances (Margulis 1985; Margulis et al. 1986; Margulis 1992).

The phylogeny in figure 4 shows the proliferation of the five kingdoms of

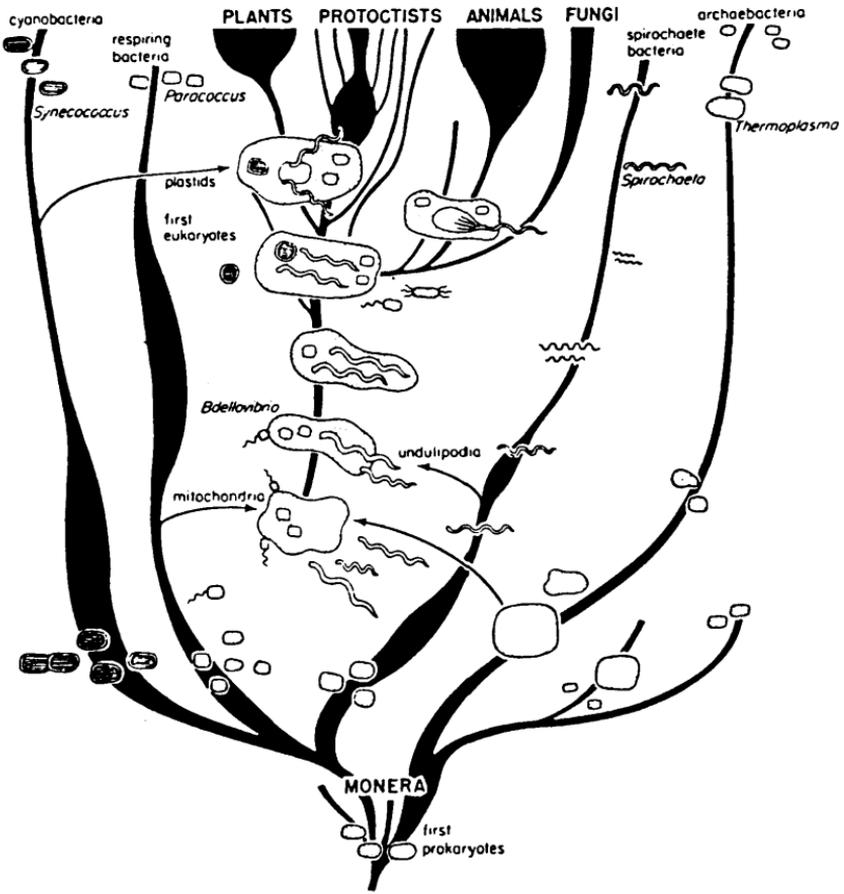


Fig. 4. A phylogeny of the five kingdoms: cells as microbial communities

life's phyla⁵. The oldest kingdom, and the most diverse, is the Kingdom Monera (bacteria) whose earliest members root the phylogeny; Moneran types and representative members (e.g., cyanobacteria, *Synechococcus*) named across the top of the phylogeny are modern counterparts of partners in ancient symbiotic associations. The four kingdoms of eucaryotes named across the top – Plants, Protoctists, Animals, and Fungi – group the modern descendents of those symbiotic associations. At the origin of the eukaryotic branches are primitive amoeboids, direct descendents of the first merger (between archaeobacteria such as *Thermoplasma* and mitochondria-like respiring bacteria such as *Paracoccus*) and the second (an alliance with spirochete bacteria by which the symbiotic association acquired intracellular motility via undulipodial structures). Plants emerged from yet another alliance, a merger of the symbiotic association with plastid-like cyanobacteria such as *Synechococcus*, by which the symbiotic association acquired photosynthetic capabilities. As you can see, this scheme is not unidirectional or hierarchical at all, and the branches of this phylogeny are non-contained: instead of progressive linear development along any established line there are sideways connections, anastomoses, among phylogenetic branches.

This gives us contemporary living beings, which are very complex and whose organization gives evidence of longtime association between once-distinct subsystem parts, once-free-living bacteria. But where is 'the individual' in all of this? Is it some unitary ancient bacterium? Is it the merged bacteria who are the progenitors of eucaryotic cells? Is it the plant or animal cells hierarchically arranged as tissues, organs, and bodies? Is it the social aggregate of cells operating as a unified population or community? My answer is that all are 'individuals' because the metabolic processes at each level are organized in a unity of operation.

And these are 'ecological individuals' because at each level the operational whole embeds itself by those very processes. The very smallest such individual is a single biological cell; the very largest, the single global system, Gaia the operational unity of living systems at all levels. That global system is treated in the philosophical or system-theoretical discourse as a 'population of one' – a concept that allows accounting of its persistent operation and evolution in terms of discontinuous (emergent) change, of micro-nondeterminacy and macro-determinacy, and of non-summative collective effects, i.e. the correlated actions of multiple entities acting back on the single whole (Weiss 1969, 1978; Swenson 1991).

⁵ See Margulis & Schwartz 1988 for thorough descriptions and illustrations of all phyla assorted over the five kingdoms.

The neo-Darwinian biological discourse is inadequate to a description of such a unitary global system. Claiming the single planetary system either as "global organism" (Lovelock 1986, 1988) or "superorganism" (Wilson and Sober 1989) must fail since the whole-Earth system lacks processes even analogous to ontogenic development or reproductive capacity, requisite characteristics of the putative organism. And neo-Darwinian claims either for or against evolution of the single planetary system must fail since there is no population of developing, reproducing, and competing whole-Earth systems on which natural selection can act.

8. AN EMERGENT ECOLOGY OF BEING: THE PHILOSOPHIC BOTTOM LINE

First, underlying my working assumptions throughout is *an ontological commitment* to the experiential world, both material and non-material, and *an epistemological claim* that the material world is logically and existentially prior to the nonmaterial. Discourse is not our experience (ontological) but its *post hoc* description (epistemological). This ontological commitment and epistemological claim are made from a philosophic position of natural realism – position located between two necessarily contradictory metaphysical views: *phenomenalism* and *physicalism*. In its avowed monism, natural realism can be seen to have the best of both views: in granting *existential and causal primacy* to organized matter in the natural universe, it avoids the extremes of 'mere' physicalism (a commitment to the physical at the expense of the mental); in granting *epistemological primacy* to our perceptual observations of that natural universe, and in requiring as science a public testing and consensual validation of those observations, natural realism avoid the extremes of 'mere' phenomenalism (a commitment to the mental at the expense of the physical).

In broadest terms, the ontological commitment of natural realism is to a continuous and emergent universe (Blitz 1992). In it, the phenomenon of life is itself one result of the continuity of global evolution, subject to the universal laws of physics, that underlines *an emergent ecology of being*: the world of discourse has emerged from the cognitive world and its processes; the cognitive world and its processes have emerged from the biological world and its processes; the biological world and its processes have emerged, in turn, from the physical world and its processes. While we may distinguish among those 'worlds' intellectually, they are not ontologically distinct.

Second, is a cautionary note drawn from this philosophic position: while the operations of the living are real, 'individuals' as such exist only in our description of those operations. That is, the ecology of nature is seamless. Living systems are not compartmentalized and are not reducible to autonomous

units: the distinctions of nature are carved in our dichotomous (descriptive) observations, the product of human scientific discourse. We as scientists, as philosophers, as discursors of any kind, observe the natural world at very particular focal levels – we focus 'here' to the exclusion of 'there', we draw 'this' as boundary to compartmentalize 'that' – and it is that act of focused observation which brings 'the individual' into being. Contrary to what is held true in conventional biological thinking, 'autonomy' of the living is in the eye of the beholder.

FIGURE CREDITS

Figure 1. Geologic time line [© Lynn Margulis, reprinted with permission. Originally appeared in L. Margulis, *Life on the early Earth*, "Engineering & Science" 1977, May-June, p. 13-19.]

Figure 2. Three postulated steps in the evolution of cells [© "American Zoologist", reprinted with permission. Originally appeared in B.M. Alberts, *The function of the hereditary materials. Biological catalyses reflect the cell's evolutionary history*, "American Zoologist" 1986, v. 26, s. 781-796.]

Figure 3. A minimal universal cell [© A. Deepak Publishing, reprinted with permission. Originally appeared in G. R. Fleischaker, *Three models of a minimal cell*, in: C. Ponnampertuma, F.R. Eirich (eds.), *Prebiological self organization of matter*, Hampton VA 1990, Deepak, p. 235-246.]

Figure 4. A phylogeny of the five kingdoms: cells as microbial communities [© L. Margulis, reprinted with permission from Yale University Press. Originally appeared in L. Margulis, *Origin of sex*, New Haven CT 1986 Yale University Press.]

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