

University of Colorado at Boulder ILL



ILLiad TN: 817891

Borrower: ILU

Lending String:

*COD,IQU,ISM,OKS,RCE,TXA,TXH,AFU,WTU,KK
S,KKU,LDL,LHL,MUU,UBY

Patron:

Journal Title: Slanted truths : essays on Gaia,
symbiosis, and evolution /

Volume: **Issue:**

Month/Year: 1997**Pages:** 265-282

Article Author: Margulis, Lynn, 1938-2011.

Article Title: Big Trouble in Biology'

Imprint: New York : Copernicus, ©1997.

ILL Number: 169351531



Call #: QH311 .M37 1997

Location: Norlin Library--Science
Stacks AVAILABLE

9780387949277

ODYSSEY ENABLED

Charge

Maxcost: 50.00IFM

Shipping Address:

Texas Tech University Library ILL Dept.
Box 40002
18th & Boston
Lubbock, Texas 79409-0002
United States

Fax: 806 742-1920

Ariel: 129.118.6.1

Email: libraries.docdel@ttu.edu

Odyssey Address: 129.118.179.85

BIG TROUBLE IN BIOLOGY

Physiological Autopoiesis
versus Mechanistic Neo-Darwinism

LYNN MARGULIS

The Current Dilemma

More and more, like the monasteries of the Middle Ages, today's universities and professional societies guard their knowledge. Collusively, the university biology curriculum, the textbook publishers, the National Science Foundation review committees, the Graduate Record Examiners, and the various microbiological, evolutionary, and zoological societies map out domains of the known and knowable; they distinguish required from forbidden knowledge, subtly punishing the trespassers with rejection and oblivion; they award the faithful liturgists by granting degrees and dispersing funds and fellowships. Universities and academies, well within the boundaries of given disciplines (biology in my case), determine who is permitted to know and just what it is that he or she may know. Biology, botany, zoology, biochemistry, and microbiology departments within U.S. universities determine access to knowledge about life, dispensing it at high prices in peculiar parcels called credit hours.

As Ludwik Fleck (1979) documented, professional knowledge conforms to political realities. Any attempt to breach the acceptable is summarily dealt with, occasionally by devastating criticism, but far more frequently by neglect and ignorance. Hence biologists receive Guggenheim Fellowships for calculations of the evolutionary basis of altruism or quantification of parental investment in male children, while the tropical forests are destroyed at the rate of hundreds of acres per day and very little funding exists for the study of live plants in their natural environments.

A single example of the current dilemma suffices here: Since the retirement of Professor R.E. Schultes at Harvard University (1986), professional education in the production of food, drug, and fiber compounds by plants from New World tropical forests ("economic botany") is virtually unobtainable in the United States, whereas lessons in neo-Darwinist religious dogma are exceedingly easy to find. Computer jocks (former physicists, mathematicians, electrical engineers, and so forth), with no experience in field biology, have a large influence on the funds for research and training in "evolutionary biology," so that fashionable computable neo-Darwinist nonsense perpetuates itself. I here try to explore some of the roots of this institutional malaise.

The big trouble in biology is directly related to big trouble in our social structure and its priorities. This is a big subject. I necessarily limit my comments to the consequences of one philosophical muddle, an aspect of the academic biologists' assumed truth. Science practitioners widely believe and teach—explicitly and by inference—that life is a mechanical system fully describable by physics and chemistry. Biology, in this reductionist view, is a subfield of chemistry and physics. The idea expressed by physicist Sheldon Glashow (1988) is commonly held even among biologists: "Just as chemistry is ultimately reducible to physics, so is biology ultimately reducible to chemistry." We compare this pervasive mechanistic belief of biologists, most of whom are smitten by physicomathematics envy, with a life-centered alternative worldview called autopoiesis, which rejects the concept of a mechanical universe knowable by an objective observer.

Most practicing biologists do not yet know about autopoiesis; as an organized group of scientists, they do not face the issue, What is life? No tradition in the organization of professional life scientists forces them to ponder life itself. What is life? simply is not a subject of inquiry, even at plenary sessions of ISSOL (International Society for the Study of the Origins of Life). Rather, biologists, convinced that the universe is mechanical, engage in the incessant search for "mechanisms": of life, the human body, and the

environment. By mechanisms they mean sound, light, or chemical signals interacting with carbon-containing matter that determine how life works.

The mechanistic worldview has many problems, one of which is the failure of neo-Darwinist biologists to think physiologically in general and to recognize the principles of autopoiesis in particular. Biologists are failing to embrace alternatives to a mechanical universe run by their supposed superiors: physicists, chemists, and mathematicians. A few of the destructive consequences of this philosophy on the academy and its students are outlined here. Both experimental work and theoretical analyses within the life sciences are severely affected by this prevalent physics-centered philosophy. Biochemical research, evolutionary biology, and biological education are all suffering the consequences. Neo-Darwinism is simply one example of a mechanistic philosophy used for illustration in this essay.

Autopoiesis

First, then: What is this alternative to mechanistic neo-Darwinism? What is this new concept of life, physiological in outlook, called autopoiesis? Autopoiesis is a set of some six principles developed by Humberto Maturana and colleagues to define the living (Varela, Maturana, and Uribe 1974). Autopoiesis combines the Greek words *auto* (self) and *poiesis* (to make); indeed, the latter root also gives rise to poetry. It refers to the dynamic, self-producing, and self-maintaining activities of all living beings (Fleischaker 1988). The word *autopoiesis* tries to define life by indicating its most indispensable aspects. Properties of autopoietic systems (such as cells, organisms, and communities), along with some physical and chemical correlates of these properties, are listed in Table 20.1. The simplest, smallest known autopoietic entity is a single bacterial cell. The largest is probably Gaia—life and its environment-regulating behavior at the Earth's surface (Lovelock 1988). Cells and Gaia display a general property of autopoietic entities: as their surroundings change unpredictably, they maintain their structural integrity and internal organization, at the expense of solar energy, by remaking and interchanging their parts.

Metabolism is the name given to this incessant buildup and breakdown of subvisible components—that is, to the chemical activities of living systems. If physiology is the study of the functions of living organisms and their parts, then metabolism is the chemical manifestation of those functions. Metabolism can be defined as the sum of the enzyme-mediated

Table 20.1. Properties of Autopoietic Systems

Property	Aspects	Examples of Biochemical/ Metabolic Correlates
Identity ^a	Structural boundaries; identifiable components; internal organization	Membrane-boundedness; nucleic acids, proteins, fatty acids, and other universal biochemical components of living systems
Integrity ^a /unitary operation ^b	Single, dynamic functioning system	Sum of multienzyme- mediated networks and their connection to nucleic acid and protein synthesis
Self-boundedness	Boundary structure produced by system	Lipoprotein membranes; gram-negative, cellulosic, or other cell walls and their connections to primary metabolism
Self-maintenance/ circularity ^a	Boundary structure and components produced by the functioning of the system	Lipogenesis, carbohydrate synthesis, peptidogenesis, nucleic acid synthesis (polymerization), and their interrelations
External supply of component raw materials	External supply of H, C, N, O, S, P, and other elemental constituents	Enzymes that incorporate CO ₂ , N ₂ , and so on into cell material; ribulose biphosphocarboxylase (RuBPC'ase), succinyl carboxylase, nitrogenase, and so forth
External supply of energy ^b	Light or chemical energy supply: convertible into organic bond chemical energy	Chlorophylls: methanogen coenzyme F, bacterial rhodopsin, uptake and incorporation of sugars and other organic compounds into system

^aVarela F.G., Maturana H.R., and Uribe R. 1974. Autopoiesis: The organization of living systems. Its characterization and a model. *Biosystems* 5:187-196.

^bFleischaker G.R. 1988. *Autopoiesis: System, Logic and Origins of Life*. Boston: Boston University, Ph.D. thesis.

network of chemical and energetic transformations of living systems. It is more easily understood as the incessant movements of matter that occur all the time in living systems and that cease when the system dies. Autopoietic systems metabolize, whereas nonautopoietic systems do not. Proteins, viruses, plasmids, and genes are all components of live material. When contained within the boundaries of animal, plant, or other cells, they may be required to sustain cells or organisms and their autopoietic behavior; yet proteins, viruses, plasmids, and genes, intrinsically incapable of metabolism, are never autopoietic in isolation. Metabolism includes gas and liquid exchange (breathing, eating, and excreting, for instance); it is the detectable manifestation of autopoiesis. Autopoiesis determines physiology and hence is the imperative of all live matter. Autopoietic entities, that is, all live beings, must metabolize. These material exchanges are the *sine qua non* of the autopoietic system, whatever its identity. Metabolizing bacteria, of many different types, directly interact with each other via nonautopoietic components (for example, plasmids, viruses). Together, all the bacteria on Earth form a worldwide living system—a huge autopoietic entity. Charles Darwin recognized the continuity of the entire system through time, whereas Sorin Sonea has emphasized its unity through space (Sonea, 1987, 1988; Sonea and Panisset 1983).

Autopoiesis, in principle, does not depend on any specific material substances. Life may not have to be made of water; proteins containing carbon, nitrogen, and hydrogen; nucleic acid; nor any other particular chemical compounds (see Table 20.1). However, on Earth, since all life today has a common ancestry, all is part of a water–protein–nucleic acid chemical system with continuity for more than three billion years. Thus, knowledge of the chemistry of autopoiesis of life on Earth provides us a framework to evaluate studies of living beings, especially research on the origin and evolution of life (Fleischaker 1988). The autopoietic point of view of dynamic integral systems, using specific carbon-chemical interactions as the basis of self-maintenance, sharply contrasts with the current mechanistic view of life—the parent of neo-Darwinism, which is so highly fashionable in today's academic circles.

Neo-Darwinism

Neo-Darwinism, or the “modern synthesis,” is a scientific school, primarily in English-speaking countries, that has been in vogue among biologists from universities and colleges since the 1930s. This body of work claims

to unite the early twentieth-century discoveries of heredity (transmission, or Mendelian, genetics) with concepts of Darwinian evolution. Mendelian genetics, sometimes disparagingly called beanbag genetics by its critics, is the study of the transmission of traits (eye color, height, enzyme activity) from one generation to another. Evolution, according to the neo-Darwinist oracle, results from the accumulation of random heritable changes (mutations) in individuals.

The monk Gregor Mendel, breeding sweetpeas in the monastery garden at Brno, Czechoslovakia, showed definitively that certain heritable traits are indeed transmitted from parents to offspring without dilution, corruption, or any other change. Darwinian evolution, on the other hand, asserts that inherited changes in characteristics of organisms are established in populations as the result of natural selection; it emphasizes the differential survival and reproduction of organisms with distinct hereditary endowment.

Using algebra based on the Mendelian formalism developed for animal populations, neo-Darwinists proffer formal mathematical explanations for the ways in which organisms evolve. Neo-Darwinism has produced a large body of professional literature that is the sacred text of most evolutionary biologists. Self-identifying neo-Darwinists control what little funding for evolutionary research exists in this Christian country. Since the seventies, leaning heavily on computer simulations, the neo-Darwinist religious movement has generated subfields called population genetics, behavioral ecology, sociobiology, and population biology. The priests and practitioners teach the Mendelian precept that discrete genes act independently and that the interactions of genes determine the characteristics of the organisms that are selected. Fanciful abstractions have been invented by the neo-Darwinists, many of whom are scientists who, beginning as engineers, physicists, and mathematicians, found biology "easy." Several of them (for instance, Richard Dawkins of Oxford, Robert Trivers of Santa Cruz, Robert May of Oxford, John Maynard-Smith of Sussex, W.D. Hamilton of Oxford, and George Williams of Long Island) have become famous darlings of life scientists today. I attribute their popularity in part to the soothing effects of their assertions of mathematical certainty.

Yet, as British molecular biologist Gabriel Dover (1988b), instructor of genetics at Cambridge University, says, "it is unlikely that true Mendelian genes exist which do not contain any internal repetition and whose mutant alleles rely solely on selection or drift for increased representation in the population." If, as Dover is claiming, the assumptions used by neo-

Darwinists are indefensible, we spectators hardly can expect the mathematics of the subfield biologists listed earlier to illuminate the histories of life. Those remaining biologists who actually live among and observe metabolizing animals, plants, and microbes have difficulty measuring the quantities or even understanding general concepts labelled and taken as directly observable by the aforementioned mechanistic practitioners (such as “sexual strategy” and “cladistics” [Patterson 1983], and “inclusive fitness,” “evolutionary stable strategies,” and “cost-benefit energetics” [Maynard-Smith 1978a,b; 1983]). These imponderable immeasurables, in my mind, have no reference in the real world. However, the use of such labels serves a crucial social purpose: It binds the users, a growing group of influential scientists and their students, into a cohesive “thought-collective” (Fleck 1979).

Neo-Darwinists, closet neo-Darwinists, and non-neo-Darwinists argue among themselves about “who selects” and “what is selected.” These intellectual skirmishes become acrimonious (Dawkins 1976, 1982). Dover (1988), for example, attempts to extricate us from some of these evolutionary tangles when he writes: “The study of evolution should be removed from teleological computer simulations, thought experiments and wrong-headed juggling of probabilities, and put back into the laboratory and the field. . . . Whilst there is so much more to learn, the neo-darwinist synthesis should not be defended to death by blind watchmakers.” (Dover is referring here to the neo-Darwinist arguments forcefully presented by Dawkins in his 1986 book.) Abner Shimony (1989), in calling natural selection a “null theory,” exposes the gross inadequacy of the common oversimplifications. Although the contribution of Darwin himself is lauded and his memory cherished, the physics-centered philosophy of mechanism and its runt offspring neo-Darwinism (Maynard-Smith 1983) is causing the “big trouble” referred to in the title of this Chapter. Like most scientists, the neo-Darwinist practitioners see themselves in a simple search for truth, believing they leave philosophy to the philosophers. Of course, they espouse the philosophy in which they are immersed, no matter how strongly they protest, “neutrality,” “objectivity,” and “reason.”

Neo-Darwinist Oversights

My view is that neo-Darwinist fundamentals, derivative from the mechanistic life science worldview, are taught as articles of true faith that require

pledges of allegiance from graduate students and young faculty members. I include as examples of such fundamentals a nonautopoietic definition of life; a bodiless, linear concept of evolution; and an uncritical acceptance of the mesmerizing concept of adaptation. I paraphrase some of these examples from standard textbooks of genetics and evolution:

Life, according to the neo-Darwinist gospel, is a collection of individuals that reproduce, mutate, and reproduce their mutations.

Evolution, according to this same testament, is change over time in gene frequencies (by gradual accumulation of mutations) caused by natural selection in natural populations.

This standard neo-Darwinist doctrine asserts that mutations arise by chance. They are chemical changes that are heritable, that is, changes in the DNA sequence of any cell or of any organism comprised of such cells. Such chance mutations, perceived as physical determinants of life that govern the existence of the organism, are purported to be the source of all evolutionary novelty. (Critics of neo-Darwinism, although they have no well-developed alternatives, have long dismissed the probability that eyes, brains, and flight evolved by chance [Clark 1984; Reig 1987; Vorontsov 1980].*) Neo-Darwinists then explain the strong correlation between structures of organisms and their survival requirements with the soothing idea that organisms “adapt” to their environments.

These assertions seem to me to be misdirected, incorrect, or, at best, grossly inadequate. Indeed, the term “adaptation” is used by late twentieth-century biologists exactly as it was by the early nineteenth-century British geologist William Buckland to describe the clever position of the Earth in the solar system and the deity’s adequacies in his production of durable creations:

In all these [favorable circumstances] we find such undeniable proofs of a nicely balanced adaptation of means to ends, of wise foresight and benevolent intention and infinite power, that he must be blind indeed, who refuses to recog-

*The origin of radically new behaviors and structures is probably heritable discontinuities that are then modified by mutation (hereditary endosymbioses, karyotypic fissioning, and so forth). These ideas of Neil Todd are detailed in Margulis (1993), Margulis and Bermudes (1985), and Bermudes and Margulis (1987).

nize in them proofs of the most exalted attributes of the Creator. (Gillespie 1969)

Although philosophers David Abram and Dorion Sagan are among the few to say so explicitly, such prevailing neo-Darwinist fundamentals, with their pre-evolutionary legacies, are frankly at odds with nonmechanistic, including Gaian, system-philosophies of biology (Abram 1985; Sagan, Chapter 14). Nonmechanists, such as Lovelock, Bermudes, and Dyer, incorporate dynamic, interactive physiological thinking, whether or not they are explicit about their autopoietic perspective (Lovelock 1988; Margulis and Bermudes 1985; Bermudes and Margulis 1987; Dyer 1989). The life-centered alternatives to mechanistic neo-Darwinism recognize that, of all the organisms on Earth today, only prokaryotes (bacteria) are individuals. All other live beings ("organisms"—such as animals, plants, and fungi) are metabolically complex communities of a multitude of tightly organized beings. That is, what we generally accept as an individual animal, such as a cow, is recognizable as a collection of various numbers and kinds of autopoietic entities that, functioning together, form an emergent entity—the cow. "Individuals" are all diversities of co-evolving associates. Said succinctly, all organisms larger than bacteria are intrinsically communities. In this nonmechanistic view, animal and plant physiology becomes a specialized branch of microbial community ecology (Margulis 1993). Individual animals and plants are not selected by natural selection because there are no literal "individual" animals or plants; "natural selection" just refers to the fact that biotic potential is not reached; the ability of populations of cells and organisms to maximally grow is always limited by the growth of different cells and organisms and their associated surroundings.

Although appropriately critical biologists such as Dover have reviled the defensive naivete of the "neo-Darwinist modern synthesis," they have not replaced it with a comfortable philosophical alternative (Dover 1988a). Hence, insofar as I know, the irreconcilable tensions between the autopoietic and neo-Darwinist views have not yet been articulated.

Fundamentalism and Fundamentals: The Fleckian Thought-Collective

Ludwik Fleck, beginning at the age of forty-seven (in 1943), directed a microbiology and immunology laboratory in Buchenwald until 1945.

Saved from the gas showers because he was useful to the Nazis, the Polish Jew Fleck (with his coworkers, primarily Polish physician, Marian Ciepielkowski; French serologist and professor, X. Waitz; Eugen Kogon, bacteriologist; and professor Alfred Balachowsky of the Pasteur Institute, and some German technicians) was put to work producing vaccine against *Rickettsia prowazekii*, the causative agent of typhus. For two years, while thousands of prisoners were marched to gas chambers just beyond the laboratory doors, Fleck and his colleagues produced large quantities of totally ineffective "vaccine," which was routinely sent to German soldiers at the war zones. Fleck reserved the real vaccine, in exceedingly short supply, to protect himself, his family, and friends. Surrounded by lives in daily danger, Fleck paid close attention to how easily scientists and technicians mentally imbibe the prevalent "common myth." In the end, Fleck's roughly six hundred liters of harmless "vaccine" was never more than a placebo—with which about thirty thousand SS men at the front were injected.

Daily duplicity not only ensured Fleck's survival, but also substantiated his theory of scientific facts. The theory claims that all "scientific facts" are merely consensus among socially interacting "card-carrying" scientists. Fleck's book develops the concept that "the fact" is a product of a complex social process beginning with individual observation or measurement and terminating with the integration of a stylized "true statement" into the knowledge of the society at large. A practicing microbiologist and scholar for the rest of his life, Fleck—active as a scientist, philosopher, and beloved human being—died in Israel in 1961, some twenty years after his Second World War experiences (Cohen and Schnelle 1986).

Probably the drama of his own experience confirmed for Fleck the validity of his thesis (Fleck 1979). A key innovator in the field of the sociology of science, Fleck invented useful methods to analyze scientific activity. He showed how certain words and phrases become banners for the immediate identification of scientific friend or foe. Typical modern-day Fleckian examples include Lamarckism, Lysenkoism, vitalism, mechanism, Darwinism, sociobiology, and even autopoiesis. Fleck documented the processes by which social activities (including attendance at scientific meetings, contributions to professional newsletters and journals, incorporation of common myths into textbooks, and other instruments of socialization) cement into cohesive groups otherwise unruly scientists and technicians. These groups—which Fleck called "thought-collectives"—are then recog-

nizable. They can be evaluated by the process of identification and naming. Once identified and named, the thought-collective achieves the status of "professional tribe," as do today's neo-Darwinists, whose members are bound together by many ties, including those of common scientific language.

Employing Fleck's concepts, I list in Table 20.2 a small sample of words drawn from neo-Darwinism in general. Sample neo-Darwinist terms in current use by molecular evolutionists are listed in Table 20.3. These "technical terms," I claim, have little significance except to the people who identify themselves as members of the scientific disciplines named in the titles of the tables, that is, as members of the thought-collective. By contrast, the universal terms in Table 20.4 are concepts relatively independent of language and culture. The value of these quantities is easily measured by scientists now, as they were in the past. Because none of the neo-Darwinist "battle cries" (Fleck 1979) in Tables 20.2 to 20.4 are directly measurable, all quantification associated with them is indirect and necessarily involves various assumptions and unstated hypotheses. These terms, devoid of meaning outside the neo-Darwinist context, including the molecular evolutionary context, serve this never-mentioned quasi-religious purpose: they bind practicing biologists into Fleckian thought-collectives that protect sacred knowledge.

Table 20.2. Neo-Darwinism: Words Used as Battle Cries^a

Adaptation
Altruism, altruistic behavior
Cheating, selfish behavior
Fitness, inclusive fitness
Genetic variation, diversity
Genotype, phenotype
Group selection
Individual
Kin selection
Levels of selection, units of selection, natural selection
Sexual selection, sexual reproduction
Species, race

^aThese kinds of criticisms of neo-Darwinist concepts and terminology have been made also in Lambert D.M., Miller C.D., and Hughes T.J. 1986. On the classic case of natural selection. *Rivista di Biologia—Biology Forum*. 79:11–49; and Hughes A.J. and Lambert D.M. 1984. Functionalism, structuralism and "ways of seeing." *Journal of Theoretical Biology*, III: 787–800.

Table 20.3. Molecular Evolution: Words Used as Battle Cries

Advanced, primitive organisms
 Archaeobacteria, eubacteria, metabacteria
 Conserved sequences
 Eucytes, prokaryotes^a
 Higher, lower organisms
 Molecular homology, convergence, divergence
 Quickly evolving/slowly evolving molecules
 Rooted trees

^aLake J.A. 1988. Origin of the eukaryotic nucleus determined by the rate-invariant analysis of RNA sequences. *Nature* 331:184–186.

Table 20.4. Universal Science: Terms and Their Units of Measure

Acceleration (centimeters per second per second)
 Density (grams per unit volume)
 Energy (ergs)
 Heat (calories)
 Length (meters)
 Light intensity (einsteins)
 Magnetism (electromagnetic units per gram)
 Mass (grams)
 Pressure (torr, atmospheres, bars, millimeters of mercury)
 Temperature (degrees Kelvin, degrees Fahrenheit)
 Velocity (meters per second)
 Volume (length, width, height)
 Time (seconds, years)

Why do members of the neo-Darwinist social group dominate the biological scientific activities in U.S. and other English-speaking academic institutions? Probably there are many reasons, but a Fleckian one is that the neo-Darwinist mechanistic, nonautopoietic worldview is entirely consistent with the major myths of our dominant civilization. Our rapacious civilization, identified by the fact that international currencies can be exchanged within it, has been characterized by William Irwin Thompson, that master social critic and analyzer of mythmaking (mythopoiesis), as follows:

We have built up a materialistic civilization that is concerned almost exclusively with technology, power and wealth. . . .

Each culture casts its own shadow, a shadow which is the perfect description of its own form and nature.

The shadow which our technological civilization casts is that of Lilith "the maid of desolation" who dances in the ruins of cities. Now that we have made a single polluted city of the entire world, she is preparing to dance in the ruins of our planetary megalopolis. . . .

To effect a reconciliation [with Lilith] man must not seek to rape the feminine and keep it down under him. If he seeks to continue his domination of nature through genetic engineering and the repression of the spiritual, he will ensure that the only release from his delusions can come from destruction. Lilith will then dance on the ruins of Western civilization. (Thompson 1981a,b)

The myths of our technical civilization are easily contrasted with those of some Native Americans. These great people from Beringia (the landmass present some ten thousand years ago, when glaciers bound huge quantities of water in what is now the Bering Strait) preceded all European and African migration onto these two huge American continents. Perhaps we can assume that Chief Seattle speaks for his ancestors and descendants when he says, "The Earth does not belong to Man, Man belongs to the Earth. All things are connected, like the blood which unites us all" (Campbell 1983).

In the world monetary civilization, geological and biological resources are perceived as infinite. Indeed, their very existence is assumed to be determined by human activities (such as market supply, labor, and so forth). Such myths of our technological civilization cannot accommodate an autopoietic-Gaian view of natural history, like that quoted here from Chief Seattle. The Native American perception, just as any nonmechanistic worldview, must be rejected by neo-Darwinists, in whom such views induce psychic dissonance. A world philosophy based on the recognition of the autopoietic and nonmechanical nature of life must upset the believers in the fundamental myths of our technological civilization. In the world of the Native American, humanity belongs to the Earth; in the world of the money machines, the Earth belongs to humanity. In the autopoietic framework, everything is observed by an embedded observer; in the mechanical world, the observer is objective and stands apart from the observed. In the autopoietic view, the only truly productive organisms are the green photoautotrophs (bacteria, algae, and plants capable of converting sunlight energy into the organic compounds of food) and a few of their bacterial

chemoautotrophic relatives (some obscure forms of life, like those living at great depths in submarine vents, capable of converting geochemical energy into food); in the mechanical view, humanity is truly and infinitely capable of being productive. The autopoietic view, which accepts as given that green linen paper is not food and can never be food, also realizes that garbage never goes out, it only goes around; in the mechanical worldview, economics and politics are thought to be directly related to quantities of money and its distribution.

Central to the autopoietic view is the physiological idea that the material components of all life incessantly move: they cycle at the surface of the Earth in chemical transformation and physical transport that always depend directly on the energy from that brilliant star, our Sun. Humanity has very little to do with the fact that the matter of life is always transporting and transforming at the surface of the Earth. The Earth behaves physiologically and not mechanically. We people (*Homo sapiens*, only one of perhaps 30 million living species) accelerate but do not dominate the metabolism of the Earth system.

We people, for all our architectural maneuverings and hydroelectrical water reroutings, for all our cementing of grasslands and conversion of tropical forests into steak, can never be productive: we can only consume the organic products of the green autotrophs referred to earlier. Our use of energy for automobile and jet-plane locomotion and our consumption of food such as *Zea mays* (corn) and *Triticum* (wheat) is simply the playing out of our autopoietic nature as newly evolved, mammalian-weed apes (Margulis and Sagan 1997).

Physiologically oriented biology, studies of life that recognize that autopoietic entities are qualitatively different from other countable matter, tends to be ridiculed or ignored by current practitioners of neo-Darwinism. I suspect that neo-Darwinists, upon observing physiology and contemplating autopoiesis, suffer cognitive malaise. Their mathematized formulations systematically ignore physiology, metabolism, and biological diversity; they fail to describe the incessant, responsive, reciprocal effects of life embedded in environment. Suffering philosophical distress, physics-worshipping neo-Darwinists must reject autopoiesis and its attendant life-centered biology with the same zeal with which the Spanish true church, guarded by its Inquisitors, rejected the mescal- and peyote-eating religions of the Native Americans.

Until the present, only scientists outside the great wall of the English-speaking academy have espoused nonmechanistic, non-neo-Darwinistic

philosophies. Such scientists develop Gaian philosophies (Lovelock 1988; see also Chapter 13) or are engaged in building secondary biospheres (Sagan 1987, 1990a). In the meantime, inside the monastery, in university life-science departments, victims are accumulating.

Who are the victims of these latter-day religious wars for the souls of the biological science practitioners? Primarily graduate students, young investigators, and teachers, in whom direct observations of life and experience in the field often foster an expansive autopoietic attitude. The study of physiology and immersion, especially in tropical nature, tends to lead students to a perception that the living planetary surface behaves as a whole (the biosphere, the place where life exists on the Earth). Yet the academy guards, using neo-Darwinism as an inquisitory tool, superimpose a gigantic super-structure of mechanism and hierarchy that protects the throbbing biosphere from being directly sensed by these new scientists—people most in need of sensing it. The dispensers of the funds for scientific research and education, and other opportunity makers, herd the best minds and bodies into sterile laboratories and white-walled university cloisters to be catechized with dogmatic nonsense to such an extent that many doctoral graduates in the biological sciences cannot distinguish a nucleic acid solution from a cell suspension, a sedimentary from an igneous rock, a kelp from a cyanobacterium, or rye from ergot. The English-speaking biology academy has lost sight of the biological priorities. Furthermore, young investigators or students, potential ecologists, botanists, and zoologists who stray from the neo-Darwinist fold are threatened with expulsion from this prevailing Fleckian thought-collective with its mechanistic thought-style. Were today's budding biologists to take seriously Thompson's mythopoiesis, Varela and Fleischaker's autopoiesis, and Lovelock's Gaian analysis, they would, en masse, have to walk out on the university (Thompson 1981b). In other words, if an individual with ambition to study nature rejects neo-Darwinist biology in today's ambience, he becomes a threat to his own means of livelihood—that is, to his own autopoietic integrity.

One lesson of the autopoietic concept of biology is that in general, for any organism, many potential threats to its autopoiesis exist. Examples include lack of food, restricted living space, and improper salt balance. A commonly employed name for any general threat to autopoietic integrity is "stress." All organisms—swimming bacteria, surf-battered algae, and hormone-exuding college students—can behave to reduce stress. All organisms respond in ways determined by their hereditary endowment and

their environmental astuteness to lessen threats to the self-maintenance of their internal organization. Stress-purging, stress-avoiding, stress-reducing behavior is intrinsic to all autopoietic entities. Nonautopoietic entities do not respond, they are passive. Neither automobiles nor DNA molecules can resist stress.

From these comments it can be concluded that among academic biologists inside the convent walls, neo-Darwinist reductionism will prevail until the suddenness of a new planetary culture replaces the technological civilization to which Thompson refers. Only after the new civilization binds us consciously to our nonhuman planetmates, especially the truly productive green ones, can the physiology of autopoietic visionaries replace the mechanics of the neo-Darwinists inside the academic cloister. Alternatively, neo-Darwinism is expected to prevail until overpopulation (with its concomitant toxic water, polluted airways, and garbage) destroys technological civilization and its money-machine stockpiling thought-collective, of which neo-Darwinism is only a tiny part.

Neo-Darwinism and Gaia

Gaia is the idea that certain environmental surface properties of the Earth—for example, the temperature and chemical composition of the lower atmosphere—are directly controlled by the biota. (The biota is the sum of the organisms inhabiting the Earth: live animals, plants, and microorganisms. The biosphere, which extends some 8 kilometers above and 12 kilometers below the surface of the Earth, is the place where the biota resides.) The validity of the Gaia idea, of the self-regulating biosphere, has been forcefully argued by Lovelock (1988). Indeed, the Gaia hypothesis has been called a “grand unified theory” of biology (Sagan 1988); it also has been recognized as more a point of view than a scientific hypothesis (Sagan 1990b; Chapter 14).

In autopoietic language, Gaia is the largest unit we know of that displays the properties listed in Table 20.1. For those unfamiliar with the Gaia hypothesis, probably the best way of thinking about it is to contemplate the assertion that the atmosphere and surface sediments of the Earth are part of the living system. That is, life does not “adapt to” a passive physicochemical environment, as the neo-Darwinists assume. Rather, life actively “produces and modifies” its surroundings. The oxygen we breathe, the humid atmosphere inside of which we live, and the mildly alkaline ocean waters in which the kelp and whales bathe are not determined by a

physical universe run by mechanical laws. In stark contrast with a mechanical, physics-centered world, the metabolizing biosphere is physiologically self-controlled. The breathable oxygen, humid air, and mildly alkaline oceans result from the growth of bacteria, plants, and algae that produce oxygen using solar energy; water transportation is driven by the activities of great forests, primarily of neotropical trees; and the neutralization of the acid tendencies of the planet is accomplished by the production of alkaline substances such as urea and ammonia by myriad sea creatures (for example, by urination and bad breath). These are simply three examples of Gaian Earth-surface regulatory activities. Many others exist (Lovelock 1988; Hinkle 1988).

The Gaian worldview is an autopoietic one; the surface of this third planet is alive with a connected megametabolism that leads to temperature and chemical modulation systems in which humanity plays a small and only very recent part. (After all, humanity as *Homo sapiens sapiens* evolved only some forty thousand years ago, long after the Gaian system, which is more than three thousand million years old, was completely in place.)

Neo-Darwinists, who ignore chemical differences between living beings, who never factor autopoiesis into their equations, and who consider organisms as independent entities evolving by accumulation of chance mutations, must hate and resist autopoiesis and the Gaian worldview.

If we can assume that consistency is a scientific virtue, then acceptance of a Gaian-autopoietic worldview requires that we reject the philosophical underpinnings of neo-Darwinism as it is currently practiced. Neo-Darwinism, in the Gaian perspective, must be intellectually dismissed as a minor, twentieth-century sect within the sprawling religious persuasion of Anglo-Saxon biology. As yet another example of a thought-style in the great family of biological-scientific weltanschauungen, past and present, neo-Darwinism (like phrenology and nineteenth-century German nature philosophy) must take its place (like British social Darwinism) as a quaint, but potentially dangerous, aberration.

The current dilemma, the big trouble of conflicting myths and thought-styles in professional biological science, is not likely to see resolution soon. Speaking for the practitioners of autopoietic-alternative worldviews, who recognize the embeddedness of all people in the great Gaian system, I must applaud the philosophy of Chief Seattle. With him we realize that "Man belongs to the Earth," and money, only green linen paper, is indigestible for all autopoietic entities like us who lack lignases (lignin-digesting enzymes). At the same time, we must face our social fate and

scientific destinies. Regrettably, the destinies within academia of the proponents of physiology and autopoiesis probably more resemble those of Seattle and other Native Americans than those that await practicing neo-Darwinists.

After all, the glorious, greedy tribesmen of western Europe (the aggressors) and their African slaves from whom most people on this green new North American continent are descended and from whom we imbibed our myths of domination, are the true fathers of neo-Darwinism. These ancestors, sharing a racist and anthropocentric thought-style, easily confiscated the land and decimated the people to replace the nature-knowing Native Americans. Thus, any of us academic biologists who welcome a lively biology should be naive indeed if we conclude that the neo-Darwinist thought-collective will abrogate its powers and succumb to logic and reason without an intellectual battle to the death. The academic groves and wet field-stations, the university corridors and DNA-recombination laboratories, the governmental funds for missions to planet Earth, the ribosomal RNA-sequence data banks, the column chromatographs, the shuttle payload bays, and the contemplation of the Amazon River Basin will not be surrendered by the neo-Darwinists nor any other money-machine representatives until a punctuated discontinuity in thought-style penetrates their thought-collective from the outside. Circumstances beyond their control must lead the presently powerful to relinquish their strongholds. Forces beyond their present awareness must overtake these entrenched servants of greedy masters. Perhaps this is what Thompson, (1981a) means when he writes:

When we have moved beyond the desolation of all our male vanities, from the stock market to the stockpile of rockets, we will be more open and receptive. Open and bleeding like that archaic wound, the vulva, we will be prepared to receive the conception of a new [planetary] civilization. . . .

