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Yearning to be Round:

A Primer in Ecological Concepts in 16 Parts

For a graphics-rich treatment of this material, go Here.

12. All Lives Belong to the Biosphere

The Biosphere is the Membrane of Life and its Products which Envelops Earth

Much of Earth's Crust and Air was Created by Life: Crust and Air Belong to the Biosphere

The Biosphere is both Process and Community

The More Kinds of Lives in a Community the Stronger and More Flexible it is: This is Biodiversity

This following chapters will focus on all the ways living organisms are connected to each other and depend on each other, and then focus especially on the many ways we relate to each other, and on Life's incredible diversity.

Animal, Vegetable, Mineral?

Not long ago, we played a guessing game in which the first question was, "Is it animal, vegetable, or mineral?" With the answer we could begin to classify anything.

But those categories which once seemed so clear and important have blurred as we have begun to perceive the Whole Earth concept of Biosphere.

The line between plant and animal began to blur with the late 17th century discovery of the microcosmos , the invisible world we cannot see without microscopes.

Is the photosynthetic one-celled creature *Euglena* plant or animal? Blur. Are the photosynthetic cyanobacteria 'really' algae or 'really' bacteria? Blur. Are bacteria 'animals'?

It's clear that we've been asking the wrong questions. We are learning now, we hope, to look at what exists rather than to force the square pegs of reality into the round holes of our habitual

thought.

We are learning to look at life as a system.

We have known for a few centuries that our bodies are formed partly of minerals, and that plant tissue is as well. Animal, vegetable, or mineral?

Now we are re-perceiving the rocks of Earth's upper crust. Many of them are the products of living organisms. The limestones are made of the microscopic shells of diatoms and foraminifera that pulled silica and calcium out of sea water to make them. The bauxites (aluminum ores) are the product of ancient bacterial processes, as are some of the ores of iron.

The distinction between animal & vegetable on the one hand, and mineral on the other, has gotten blurry too.

Petroleum is clearly not alive, but it is clearly the product of animal and vegetable life, as is natural gas.

Life as a whole has been banking energy in the earth's crust for billions of years, and it's also been constructing the bank.

Earth Household

We are now learning to see Earth as a whole system of life. The science of that system is ecology. The word ecology is from the Greek root *"oikos"* (house) The study of ecology is the study of the Earth Household.

The Earth Household is one enormous community. The best name we have found for it is the Biosphere, or sphere of life. The concept of the Biosphere is centrally important to perceiving who and what we are as living beings.

We will explore the biosphere in five directions:

- **As Place--where life lives**
- **As the global Process of life**
- **As the Product of life**
- **as Earth Household/ Community**
- **As Gaia**

Biosphere as Place

To perceive the biosphere as simply the sum of the places on Earth where life exists is a beginning, but it doesn't take us far. If we imagine the biosphere primarily as a spherical region of life enveloping Earth, and ignore its other aspects, we miss its most crucial nature.

Life exists below the depths of the oceans and miles into the atmosphere; this is a commonplace.

Less well known is life's penetration into earth's crust. Anaerobic bacteria live kilometers into the rock. Many algae and bacteria live inches inside porous roicks such as sandstone. But the extreme limits of the biosphere as a region are much less important than where life is concentrated.

Despite our terrestrial bias, the great bulk of life is found in the ocean.

Ocean Plankton

The entire surface of the world-ocean (71% of Earth's surface) is covered with a thin drifting film of algae (phytoplankton) which is invisible to our eyes. These microscopic algae live in layers according to how water transmits light's spectrum.

Green algaes live on top, then blue-green algaes (cyanobacteria), then brown algaes, and finally red algaes, which use the blue rays of the spectrum, the last to be absorbed by water as depth increases.

This "thin" film is thin only compared to the size of earth—it is many meters deep.

The foundation of oceanic food webs is the phytoplankton film. This is where solar radiation is converted into chemical energy.

This photosynthetic film in turn supports a wide array of small animal life (zooplankton) ranging in size from microscopic to

centimeters long. These creatures are joined in their drifting by large quantities of animal spawn, eggs, and just-born organisms for whom the surface layers are the cradle.

This floating system of energy conversion and transfer may well be the original cradle of all life.

Ocean Floor

Like the surface, the ocean floor or benthos is also covered with a continuous film of life. It is a layer of sediments and mud rich with bacteria, protists, and microscopic burrowing animals, always renewed by a slow rain of organic debris, mostly from the plankton film.

On the shallow continental shelves, larger animals are abundant, but in the deeps larger animals are relatively scarce.

This benthic film meets the surface film wherever land emerges from the ocean. So life literally envelops the world ocean.

Ocean Shallows

Ocean shoreline, or tidal areas, provide another intense concentration of life.

Solar light and heat penetrate deep into such shallows. Rivers outflow there, bringing mineral riches in solution and organic

remains in suspension.

Such ecosystems as kelp forests, coral reefs, and marine grasslands provide a great flowering of littoral organisms.

Coral reefs are wonderful examples of the animal/vegetable/mineral confusion. The reefs are formed by the adult stages of filter-feeding polyp animals that secrete calcareous shells to house their soft bodies. These skeletons build up to become reefs.The vegetable course is served by symbiotic algae known as zooxanthellae that live inside each coral polyp, supplementing their filter feeding.Coral reefs are clearly animal and mineral and vegetable.

Terrestrial Life Zones

In the ocean the food webs begin with bacteria and algae.

On land they start with green plants, especially flowering plants (angiosperms).

The dominant life forms on land are insects, and the insects and flowering plants have been evolving in intimate response to one another since life invented flowers.

Biomass is a measure of the total amount of living organic matter in a particular living system.

On land, the biomass of plants is 100 times as large as that of animal life.

Most life-materials in the biosphere, in other words, are invested in plants.

Rainforests

The places of greatest life-concentration on land are by far the tropical rainforests. Millions of species of plants and animals live only in these rainforests.

Most are unknown to science, and may go extinct anonymously. In tropical rainforests, most life-materials are invested above the soil in growing organisms.

The soils beneath the trees are poor, and once the living communities above them are logged or burned off, they cannot again support a rich community of any sort.

Grasslands

Other terrestrial biomes rich with concentrated life are the grasslands —prairies and steppes, and savannas.

Unlike rainforests, the great bulk of life in grasslands and savannas is invested in their deep and teeming soils. A teaspoon of prairie topsoil contains millions of lives invisible to our eyes.

Warmth means diversity and density: Tropical regions of land have by far the most diverse life and greater biomass than biomes closer to the poles.

Warmth and stability of climate yield the life zones richest in life.

E. O. Wilson, in his *Diversity of Life*, offers this telling illustration of

increasing diversity in breeding bird species from north to south, in land areas of about the same size:

Location	Number of Species
Greenland	56
Labrador	81
Newfoundland	118
New York State	195
Guatemala	469
Columbia	1,525

Freshwater wetlands

Wetlands are the other terrestrial biomes which are rich with life. Because they are transitional in nature and are adjacent to forests, grasslands, and riverine ecosystems, they experience the edge effect of overlapping communities.

Edges, or ecotones (places of life-tension) have greater species diversity and biological density.

Wetlands also provide a huge concentration of small lives such as protozoans and microscopic multicellular organisms.

Taiga

The great northern conifer forests that girdle the planet--Alaska

through Siberia--have such limited annual sunlight that they cannot support either high diversity or biological density.

Once we describe sunlight as a quantity, we are beginning to think in terms of the biosphere as process.

Biosphere as Process

The biosphere as place is fairly easy to grasp, biosphere as process is less familiar turf.

It is partly a problem of scale. It is hard to wrap your mind around the immensity of Earth and manage a holistic view.

The great Russian developer of the biosphere concept, Vernadsky, taught us to think in the largest terms. He saw the biosphere as a system for transforming and transferring energy.

Transforming Energy

Solar radiation includes visible light, infrared (heat), and ultraviolet.

Visible light fuels the process of photosynthesis which begins the food webs. The essence of photosynthesis is the transformation of light into chemical energy.

Transferring Energy

Infrared radiation transforms into heat and fuels the great transport systems: evaporation, the ocean currents and the winds.

Evaporation lifts water vapor from ocean to air, the winds transport water vapor around the planet. The ocean currents transport heat around the planet. The El Nino warming illustrates the importance of that circulation.

Gas Exchange

Another enormous transfer process is respiration; all animals and plants must breathe. This process of gas exchange permeates the biosphere. The plants exhale the oxygen we animals must have; animals exhale the carbon dioxide plants must have.

At another scale the global winds transfer gases around the planet. The earthwide transport of the gas called water vapor is essential to terrestrial life.

Feeding as Energy Transfer

Living organisms all must feed.

Photosynthetic organisms (autotrophs or *self-feeders*) feed on sunlight and water and gases and transform the light into chemical energy we call carbohydrates.

Organisms which can't transform light are heterotrophs or *other-feeders*.

Low-level other-feeders eat bacteria, protozoans, algae and plants.

They in turn are eaten by other-feeders called predators.

The energy first transformed from sunlight by plants and algae is passed around in food webs, transferred from life to life.

Rocks & Minerals

The biosphere is also a process of rock creation and mineral transfer. Through rivers, terrestrial minerals dissolved by rain are carried into the ocean.

There, life creates from these dissolved minerals the sedimentary rocks and concentrates the minerals of Earth's crust.

A multitude of one-celled marine organisms (diatoms, forams, cocolithic protists) extract silica, calcium and carbon from the water to build cell walls and exterior shells.

As these organisms die a slow steady rain of their shells falls upon the seafloor. Another steady rain is made of sinking dust particles blown off deserts onto the ocean.

The rock formed by pressure on the ocean floor begins as this sediment, which is all passed through the guts of mud-eating worms to further transform them, just as soil is transformed by the related terrestrial earthworms.

Then the sediment is compressed or squeezed flat by water pressure and the weight of more and more sediment and eventually (after eons of time) becomes limestone.

This unending process of the biosphere has created all the limestone and sandstone in the earth's crust. The action of water on land, over time, completes the cycle by dissolving rock and transporting it into the ocean, replenishing the minerals required by the diatoms and foraminifera.

The geological activity of creatures is greater the smaller they are.

Much of this work is done by bacteria and worms.

Bacteria can concentrate materials. Some contain half a million to a million times as much of some minerals as their environment does.

These are minerals such as iron, manganese, aluminum and silver. The great deposits of iron ores and bauxites (aluminum ores) in Earth's crust which allow our mechanical civilization were deposited through the activity of ocean microbes millions of years ago.

The ancient 'swamp forests' of the Carboniferous period died and became coal. Vegetable or mineral? Petroleum (*"rock-oil"*) is the product of ancient life, as of course, is natural gas.

Biosphere Process as a Whole

The sun happens to life. Weather happens to life.
We may think of Earth as a place that solar radiation happens to.
These descriptions are too passive by far.

In fact, Earth the planet and Life on Earth are active players in this mutual process of radiation from the sun.

The father of biosphere theory, Vladimir Vernadsky, pointed in the 1920s that
***"living matter prepared itself a new cosmic milieu.."* He went on to describe that mutual process:**

- **"…Solar radiation as the carrier of cosmic energy not only initiates its own transformation into terrestrial chemical energy, but also actually creates the transformers themselves. Taken together, these make up living nature…" (76)**

- **"The sun has completely transformed the face of earth by penetrating the biosphere, which has changed the history and destiny of our planet by converting rays from the sun into new and varied forms of energy. At the same time, the biosphere is largely the product of this radiation. "(48)**

Life is endless process. Life-processes shape Earth in many ways.

The geological activity of organisms includes their transfer of groundwater back into the atmosphere, a process that is clearly visible in the pumping action of rain forests (evapo-transpiration).

Oxygen in the air was created by life, the cyanobacteria. (Oxygen is a waste-product of photosynthesis.) The action of solar radiation (ultraviolet) on oxygen in the upper atmosphere creates ozone.

In that creation of the ozone layer most ultraviolet radiation is absorbed (used up in chemical reactions) and does not strike the surface of earth.

So Life and the sun are both active players in this huge process of the biosphere.

Of course, life (in its photosynthetic forms) not only created the ozone protection, which worked well for over a billion years, but life (in its laughing featherless biped form) is destroying the ozone layer, in less than a hundred years.

Biosphere as a Product of Life

The biosphere is a physically real thing. It is air and living organisms and, as we have seen, it is also rock in the earth's crust.

When we see the biosphere as product as well as process, we are able to perceive the whole as an enormous circulation of atoms. Here is Vernadsky again:

- **"Life exists only in the biosphere; organisms are found only in the thin outer layer of earth's crust…In its life, its death, and its decomposition an organism circulates its atoms through the biosphere over and over again…."**

- **"A considerable portion of the atoms in the Earth's surface are united in life, and these are in perpetual motion. Millions of diverse compounds are constantly being created, in a process that has been continuing… since the early Achean, four billion years ago. "**

Biosphere as Earth Household

The biosphere is one all-embracing community of life on earth.

I am a member; you are a member. We're all family. We are all connected and depend on each other in many of ways.

- **Origin: We share a common origin—we are all made of Earth and share the same life–materials.**

- **Descent: We share a common descent—we are all descended from the first microorganisms.**

- **Solar Energy: We all depend on sunlight energy; we capture it with photosynthesis, and transfer it from life to life by feeding.**

- **Ecosystems: We all live in natural ecosystems (except us) which have mutually evolved with the biosphere as a whole.**

As animals who live on land, we have a terrestrial bias. We also have a mammal bias, a primate bias, and we still believe that *Homo sapiens* are the center of the universe. These predispositions skew our ability to accurately see the Earth Household.

Here is our habitual view:

- **land life is more important than sea life.**

- **mammals are the most important land life.**

- **animals are the most important life.**

- **we are half-angel, half-demon.**

Here is the Real Earth Household:

- **Most life on Earth is microbes, archaea and bacteria.**

- **Most life is in the oceans; most of it is microscopic.**

- **Insects are by far the most successful land animals. Insects make up the bulk of living animal matter on land.**

- **On land, the total mass of plants is nearly 100 times as large as the mass of animal life.**

- **We are descended from archaea and bacteria.**

A little humility, please.

The poet Gary Snyder said, "*Nature is not a place to visit, it is home*." How should we behave in our home?

Biosphere as Gaia

The broad systems view of earth that began to develop in the 1870s grew slowly, as large ideas do.

A Viennese geologist named Dr. Suess (yes, really) coined the term "biosphere" in 1875.

The idea evolved and enlarged over the next fifty years into Vladimir Vernadsky's brilliant summation *The Biosphere*, published in Russian in 1926 and French in 1929. But Vernadsky's biosphere, for reasons of censorship in Russia and politics in the West, had no influence on Western science until the late 1970s., when his writing was re-discovered, and when two Western scientists independently had already come to much the same view as Vernadsky.

The two scientists were James Lovelock and Lynn Margulis.

Lovelock is an atmospheric chemist who first discovered the destructive effects of fluorocarbons on the ozone layer. Lynn Margulis is a molecular biologist whose work with bacteria and symbiosis has revolutionized our understanding of evolution.

Together, they proposed a remarkable hypothesis: that Earth could reasonably be regarded as a single living entity, and that working together, life as a whole regulated its temperature, the salinity of the oceans, and the percentages of oxygen and carbon dioxide in its atmosphere.

They proposed the name Gaia, the ancient Greek name for the Earth Goddess.

At first their hypothesis was met by a thundering silence; scientists are a conservative group, and no one wanted to risk looking foolish by taking such an outlandish idea seriously.

Since that time some decades ago, the hypothesis has been shown experimentally to have merit, and it is now given the status of a theory, and is widely discussed in the scientific community.

Lovelock and Margulis described Gaia as a "tightly coupled system of life and its environment," that includes:

- **Living organisms that grow vigorously, exploiting every environmental opportunity that opens.**
- **organisms that are subject to Natural Selection; the species that leave the most offspring survive.**
- **organisms that affect their physical and chemical**

environment. Animals change the atmosphere by breathing, taking in oxygen and letting out carbon dioxide. Plants alter it in reverse. In numerous other ways, all forms of life incessantly modify the environment.

• the existence of restraints or bounds that establish the limits of life.

It can be too hot or too cold; the comfortable warmth in between is the preferred state. It can be too acid or too alkaline; neutrality is preferred.

Almost all chemicals have a range of concentrations tolerated or needed by life. For many elements, such as iodine, selenium and iron, too much is a poison. too little causes starvation.

The 16th century alchemist and physician Paracelsus gave us the prophetic phrase, *"The poison is the dose."*

As a living organism, the theory claims, Gaia regulates many aspects of Earth's environment to maximize Earth's hospitality to life.

Recall what Vernadsky said: *"…living matter prepared itself a new cosmic milieu."*

Gaia theory says, *"Yes, and life actively regulates that biospheric milieu.*

Temperature regulation

We know that the Earth's surface temperature has remained nearly the same for 3.5 billion years.

But we also know that the amount of solar radiation reaching Earth during that time has increased by 25 %.

Through homeostatic processes, Gaia has prevented Earth's temperature from rising to levels destructive to life. The process centers on terrestrial vegetation and oceanic algaes which, together with the polar icecaps, increase the reflectivity, or albedo, of Earth's surface and reflect increased solar radiation back into space.

Ocean Salinity

It used to be thought that the oceans simply received and retained all the mineral salts dissolved from rock by running water worldwide, and that this made the oceans salty.

More recently we have discovered that if that was the governing process of the ocean's salinity, then after all these millions of years water has been dissolving rock, the ocean would be far more salty than it is—in fact, too salty for living organisms.

Contrary to expectation, the saltiness of the ocean has remained virtually the same for many millions of years. Gaia theory confirms that it is the activity of living organisms that reduces the salts so that outflow equals inflow. The extra salts become sediments, clays, sandstone, limestone and dolomite.

Oxygen Percentage

The oxygen content of the atmosphere has remained constant at 21% for millions of years, which is the result of plants and algae breathing out oxygen.

Similarly, the carbon dioxide content of the atmosphere is regulated by life. (*This last regulation is what humanity's emission of greenhouse gases has thrown seriously off kilter.)*

Nutrient Cycling

In addition to the regulation of temperature, salinity of the ocean, and the gases of the atmosphere, life on Earth is the primary actor in the carbon cycle, the sulfur cycle and the nitrogen cycle, major processes of nutrient cycling which together make these nutrients available to life and thus make life as we know it possible.

Gaia Theory is still controversial, but it is increasingly accepted as a plausible description of the role of life in the evolution of the Earth as a whole, and especially of the role of living systems are in the continued maintenance of favorable conditions for life.

Although Gaia theory is debated, much of the debate seems to stem from a fundamental ignorance of systems thinking.

The loudest objections to Gaia are from those who think Gaia is being promoted as a gigantic human woman, a creature who thinks her processes through and chooses to do things. The workings of homeostatic regulatory processes are apparently not widely known.

Living systems routinely and inevitably regulate themselves in countless and subtle ways.

This homeostatic regulation is not the result of thinking.

It is the result of negative feedback loops. (see 10. Balance)

We, as living systems, learn to ride a bicycle. Thought has little or

no part in the process. Certainly, we cannot explain in words how we manage to not fall down. (Oddly, the only time we may fall is when we consciously think about how to ride.)

It is the continual adjustments we make in response to input from our senses and our muscles that allow us to ride.

These circular processes of ever-changing input, adjustment toward balance, then more new input are feedback loops which all living organisms, brainy or brainless, use everyday.

There is no consciousness involved. There are no choices made by a mind.

Barriers to understanding Gaia theory include our heritage of anthropomorphic deities.

Gaia has been warmly embraced politically by some who take her to be the very Mother Goddess who perhaps was once worshipped. Gaia theory has in fact no connection to theologies.

Biosphere is the more useful word. It does not carry all the associative 'freight' that the term Gaia carries.

Life Pressure

Living systems try hard to survive. Barren soil never remains barren for long. No matter how we pave and repave our parking lots, the biosphere manages to insert a blade of green into every asphalt crack.

This insistence of life on spreading to fill every possible living place is what Vernadsky called life pressure.

The old saying “Nature abhors a vacuum” purportedly refers to physics—how very well it applies to living systems.

Life pressure includes reproduction and dispersal.

As evolutionary process, life pressure is called adaptive radiation, the endless branching and rebranching of the tree of life.

Life on earth now is much more complex than it was two billion years ago. There has been an amazing increase in diversity since the biosphere began.

Enlarging Biosphere

Vernadsky said life prepared its own cosmic milieu, notably in its creation of an oxygen atmosphere. The biosphere is self-creating in another way. It keeps getting bigger.

Life was originally a phenomenon of the shallow ocean.

As life adapted to and radiated into ever less promising environments, it enlarged the biosphere to include the entire ocean, including the abysses, to include dry land, and to extend miles into the atmosphere.

Living bacteria penetrate the crustal rocks to miles deep, carried there by water.

The biosphere includes whole ecologies of snow and ice, extending life into the polar regions. Apparently, life has no limits to its ability to adapt.

Highly radioactive containment pools in nuclear power plants are

plagued by a bacterium that not only survives the radiation but thrives.

Many small organisms have learned to live in hot springs at temperatures approaching boiling. Effectively, life has covered the entire surface of the planet, plumbed its ocean depths, flown and floated high in the sky, and even penetrated miles into rock.

Coevolution

In 11. Interliving, we argued that the unit of evolution is not the individual, not the species, and not even the geneticists' population.

It is the biological community which evolves. It is an array of populations which evolves.

Put another way, it is the ecosystem which evolves. Like the concept of biosphere, the concept of ecosystem includes materials which are not currently alive, but which may be swept up again into the web of life at any moment.

The biosphere is the largest ecosystem, and it does seem to evolve as a whole. Our eyes may not be wide enough to see it all, yet.

Summary

The Biosphere is many things:

• Biosphere is Place: the region of earth where life exists.

• Biosphere is Process: geological process, chemical process,

biological process. It is a system for transforming and transferring solar radiation. It is a system of gas exchange.

• Biosphere is Product: it is a system of rock building. It makes iron ore, aluminum ore, limestone. It is a system that even created the air it breathes.

• The Biosphere is Earth Household: We all belong to one vast community of life.

Reality check:

• Most life is in the oceans; most of it is microscopic.

• Insects are by far the most successful animals. Insects make up the bulk of living animal matter on land.

• On land, the total mass of plants is nearly 100 times as large as the mass of animal life.

• We are descended from bacteria.

• The Biosphere may also be seen as Gaia, the biosphere seen primarily through its homeostatic (regulatory) processes. Life itself maintains the conditions life requires.

Perhaps the best metaphor for the Biosphere is Dance. Dance is both process and product.

In this great dance, coevolution is the choreographer. Animal, Vegetable, Mineral—one enormous circle dance with no one sitting out.

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