

Earth's Biospheric Economy

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The biosphere is the fabric that embraces Earth. It is a symphony that sustains all life on Earth, including our own. Living sustainably in the biosphere requires: (1) understanding how the biosphere works (science, or *scientia*), (2) deciding what ought to be (ethics), and (3) determining what we should do (praxis). The way it works is the biospheric economy that provides ecosystem services vital to *sustainability*, including solar energy, soil building, photosynthesis and respiration, cycling and recycling, water purification, fruitfulness, global circulations of water and air and human ability to learn from the creation. Our minds are shaped by the beauty of creation and allow us to imagine and know how the world works (science, *scientia*), allow us to understand what ought to be (ethics) and empowers us to employ our science and ethics to act rightly in the world (praxis).

The world works as a symphony of material and life cycles all powered by Earth's star the sun. Solar heating drives the global circulations of water and air in patterns shaped by unequal heating and topographic relief. Solar lighting energizes through photosynthesis by green plants all of life through a meshwork of molecule-to-molecule and organism-to-organism energy transfers. The biotic and the physical, thus empowered, interactively exchange matter and energy to form and maintain the life sustaining biophysical fabric we call the biosphere.

Teaching Environmental Science at the University of Wisconsin for over three decades has brought me a great appreciation for the way the biophysical world works, as my beginning epigraph describes. The biosphere is a kind of symphony. It is a symphony that sustains all life on earth, including our own. In our day-to-day busy-ness and work, it is easy to take the great gifts we receive from the earth for granted. It is even easy to forget the beauty of the earth upon which our lives depend and by which our spirits can be lifted. And yet, it is important in our lives not only to appreciate and behold the natural world for its own sake; it is also vital for gaining an awareness, appreciation, and understanding from which can come our service of responsible stewardship of the great gift of this biophysical fabric that we hold in trust for ourselves, future generations, and all of life on earth. I live in the northern part of the United States in the state of Wisconsin. My home rests on a raised part of the landscape, called a "glacial drumlin," surrounded by a large wetland. It is the ecosystem of which I am part, and the ecosystem that I personally hold in trust, together with my family and neighbors. It is wonderfully alive with an abundance of plant and animal life, and is grassy in appearance, meaning that it is the kind of wetland that usually is called a "marsh." This is in contrast with wooded wetlands, called "swamps," where trees predominate. Whether marsh or swamp, however, all wetlands are located at the interface of land and water, and many of them like my own marsh, go through a long process of development that begins in open water. My marsh, for example, was once was a bay in glacial Lake Waubesa, and my drumlin was an island in this bay. But now, 10,000 years after the continental glaciers receded, this bay is filled by the remains of plant life that grew out into this bay and formed great deposits of peat. This peat--the remains of wetlands of ages past--underlies what now is an area of 350 acres of wetland plants and animals. In this peatland that surround me with its verdant and vibrant life, is the home to 70 species of migratory nesting birds that are present here during the warmer months of the year. The largest of these birds is the Sandhill Crane, a relative of the great cranes that inhabit the expansive wetlands of China. (see figure 42.1).



Figure 42.1 Aerial photograph showing Lake Waubesa on the upper right and Waubesa Wetlands on the left with its central stream flowing into Lake Waubesa. The city of Madison is in at the upper left. Photo by Nadia Olker, West Waubesa Preservation Coalition, Madison, Wisconsin.

Living on this marsh as I do, has given me the gift of being able to work with my students to teach, learn, and do research on wetland ecosystems---which is much of what I do as a professor and scientist at the University of Wisconsin. But it has given much more! Living here within the verdant of vibrant life of a beautiful peatland has also given me the gift of "stewardship." My living here helped to developed my understanding of myself as a "steward" of this place. This means that my marsh has helped me to discover the privilege of safeguarding this wetland ecosystem and preserving its life. As a steward of this marsh, I work with my neighbors to restore and sustain it by the controlled use of fire. My striving to be a good steward of the marsh has taught me the importance of "fire ecology" as being very important and even necessary for keeping the marsh and caring for it. Once every three to five years, my neighbors and I, along with people who are stewards of other places in my region, come together to do a "controlled burn" of my marsh. We carefully use fire to burn the marsh in early springtime before the migratory birds return, and this process "purifies" the plant species that live here by destroying "invasive species"that otherwise would take drive out the native plants. The native plants are adapted to fire, and even depend upon fire to release the nutrients they need for and abundant and flourishing life.

As a steward of Waubesa Wetlands I have come to realize that I am caring for this marsh in behalf of many other people, including the generations of people that will follow me. As a steward here, I do much like other people do with their gardens, woodlands, ponds, and villages: I help to safeguard, restore, and renew the great gift of vibrant life in all of its symphonic beauty. For me, the giving the gift

of stewardship to the marsh is reciprocated by the marsh. The gift I and my neighbors receive back from the marsh includes the annual return of the Sand Hill Cranes in late February every spring. I am inspired every morning during spring, summer, and fall by their calls that echo across this great marsh; I am inspired by the way they raise their little ones on large nests built on the marsh surface. And this often brings me to think of the cranes of China and the rest of Asia from which some of my graduate students come to study with me at the University of Wisconsin and at the International Crane Foundation where they earn their Ph.D. degrees so they can return to become leaders in the stewardship of the cranes and wetlands of Asia.

As I have lived and learned on this great wetland since 1972, I discovered that I had to do three important things. First, I have had to teach my students about the way the world works (science, or *scientia*), and this is helped greatly by using my wetland as an outdoor laboratory for teaching and learning. Second, I have had to decide what I ought to be doing (ethics) in my wetland habitat and in the wider human community in which I live. And, third, I have had to take care of myself and my family (praxis), and this is helped by our growing vegetables in our garden and fruit from our trees that grow near the edge of the marsh. The words I placed in parentheses (science, ethics, and praxis), are very important not only for the way I live my life in my community and the wider world, but also as a framework for teaching my students. These three important words can be arranged at points of a triangle---to form what I call the "science-ethics-praxis triad" or the "S-E-P triad."

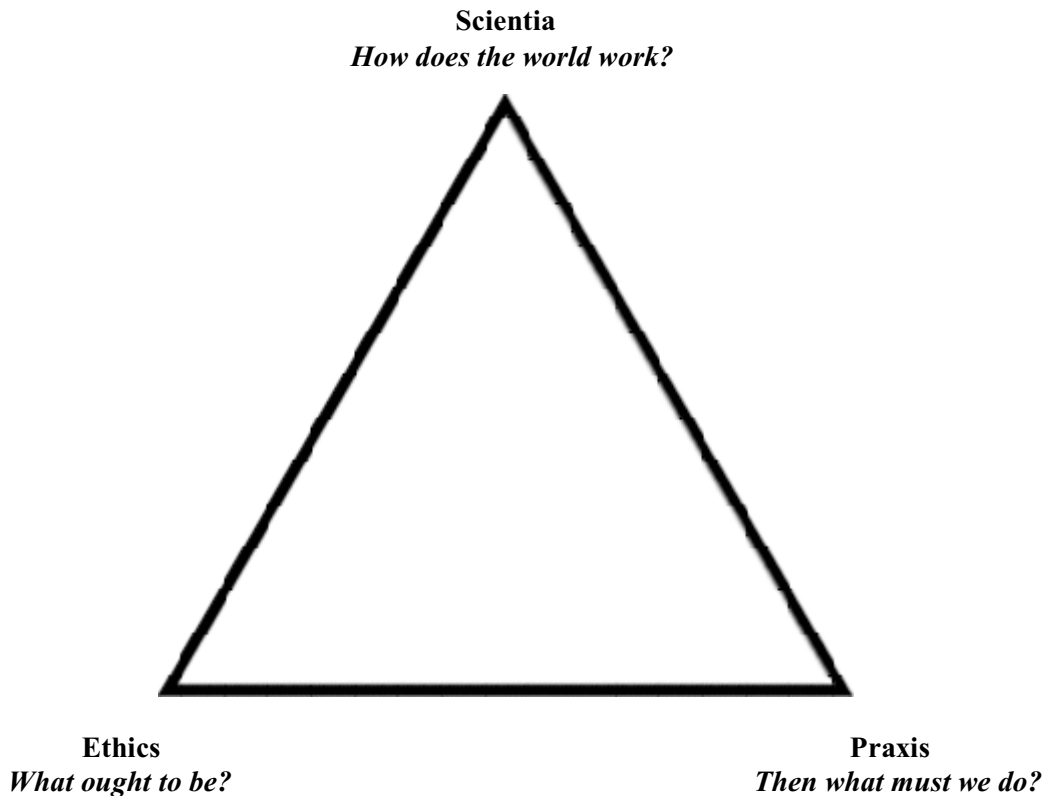


Figure 42.2 Science-Ethics-Praxis triad: an integrative framework for teaching, learning, and living.

Each of these corners has its own question. Scientia (which means all of knowledge, including natural science) addresses the question, "How does the world work? Ethics addresses the question, "What ought to be?" Praxis addresses the question, "Then what must we do?"

Ethics

As I have compared college and university textbooks in environmental science with textbooks in physics, chemistry, and biology, I have discovered three things that are very significant. First, I have found that the topics in environmental science textbooks nearly always are about environmental problems and issues that people create and also can do something about; this of course is not very surprising. But the second thing I find is surprising! I find that nearly all topics in environmental science textbooks have an ethical underpinning. Even though they might not address the subject of ethics explicitly, almost every topic in these books has beneath it the underlying question, "What ought to be?" Textbook topics such as population, air pollution, and species extinctions, for example, are described not only because they are interesting, but because of the underlying ethical concern of the authors that overpopulation, pollution of the air we breathe, and destruction of the great diversity of life on earth ought not to be. We discover in this, that Environmental Science deals is ethically-relevant. And third, I discover, as you do also, over that the topics in these environmental science textbooks are directed at the need to live rightly on the earth.

Although environmental science textbooks help develop an understanding of environmental degradation and its consequences for human health and life on earth, they have the important purpose of motivating people to prevent and to reverse environmental degradation (praxis). They are written to help people learn about the provisions and services that are given all life by the system of life that envelops the earth, but most importantly are given to encourage people to live rightly on earth--to live rightly in ways that conserve and sustain the living fabric that envelops the earth, including human beings and their communities. And, they are written not only to help people live rightly, but also to help them spread right living through our communities, and across the land!

My vocation, as you can see, includes my being a scientist at the University of Wisconsin and a steward of the great marsh on which I live. But more than that, it also includes my service as Town Chairman in the 1970s. As Town Chairman, I helped to lead my community meet to achieve the goal of living rightly in our lives and our landscapes. The name of the place I live is the Town of Dunn---a rural community across an area about 6 by 6 miles square with a population of 5,000 people, a few miles south of the city of Madison. As my work in science is important for learning how the world works, as ethics is important for learning about trying to live rightly, my work as Town Chairman was very important for working with my community to do the right things in taking care of (praxis) its beautiful landscape of farmlands, woodlands, lakes, and marshes. Most importantly, my work here helped our citizens develop a land ethic that inspired all of us to be better stewards of lives and our landscapes. This land ethic, and the work that it inspired, brought us to write a land stewardship plan for our town and to put that plan into practice (and this is where praxis comes in). It is a plan that has received national recognition as a model of land stewardship for other towns across America and also in some other places around the world. And because all of us here want to help others in land stewardship, we have given the world a window at our official website at <http://town.dunn.wi.us/>. We are interested both in right living and in spreading right living!

What all of this taught me was that science, ethics, and praxis must always be kept together. The S-E-P Triad is a vital framework for learning, living, and acting. And what I come to understand from my experience in science, ethics, and praxis is this: that each of its three corners of the S-E-P Triad need to be held together, interactively. Science without being connected to ethics and praxis is not productive; if it is translated into practice without integrating it with ethics it may even be destructive. Similarly with ethics: if ethics is pursued by itself, without regard to how the world works or what we do as human beings and society, it is not meaningful for the way we live; if ethics moves right to practice without integrating it with scientia, it may be destructive rather than constructive. We have to know both how the world works,

and also need to discover what ought to be if we want to better live our lives and safeguard and renew the ecosystems that sustain us and all other life. And finally, of course, "just doing something," doesn't work either. Praxis without being guided and informed by scientia and ethics does not produce responsible stewardship of land and life. So, science, ethics, and praxis need to be kept together, each one informing the others. This is what I have learned, and this is what I teach.

The Biosphere

Basic to finding the answer to the first question, "How does the world work?" is development of an integrative understanding of the biosphere—the great system that sustains us and all life on our planet. This envelope of living things that embraces the whole earth, both land and sea, is our life-support system. It is an integral sphere of life—symphonically held together by vibrant exchanges, transfers, and connections of energy, materials, and information. This sphere of living fabric has long been recognized by Earth's people as a great gift—given to people and all of life but not owned by any one of us. It is a gift that requires giving back to the system of life, even as we benefit from it. It is a gift that is not only taken by us; it is a gift that has us give something back. Instead of our relationship with the biosphere being one of "taking" it is more richly and more wonderfully a relationship of "care-taking." The service given by the biosphere—its "ecosystem services"—needs to be returned with service of our own. Every living thing, including human beings, are part of the biosphere and every thing gives back in return for what every living thing takes. And so, as we ask what we must give as our service to the earth's fabric of life, it is important first to understand what it gives to us. It is important to understand the provisions and system services of the biosphere.

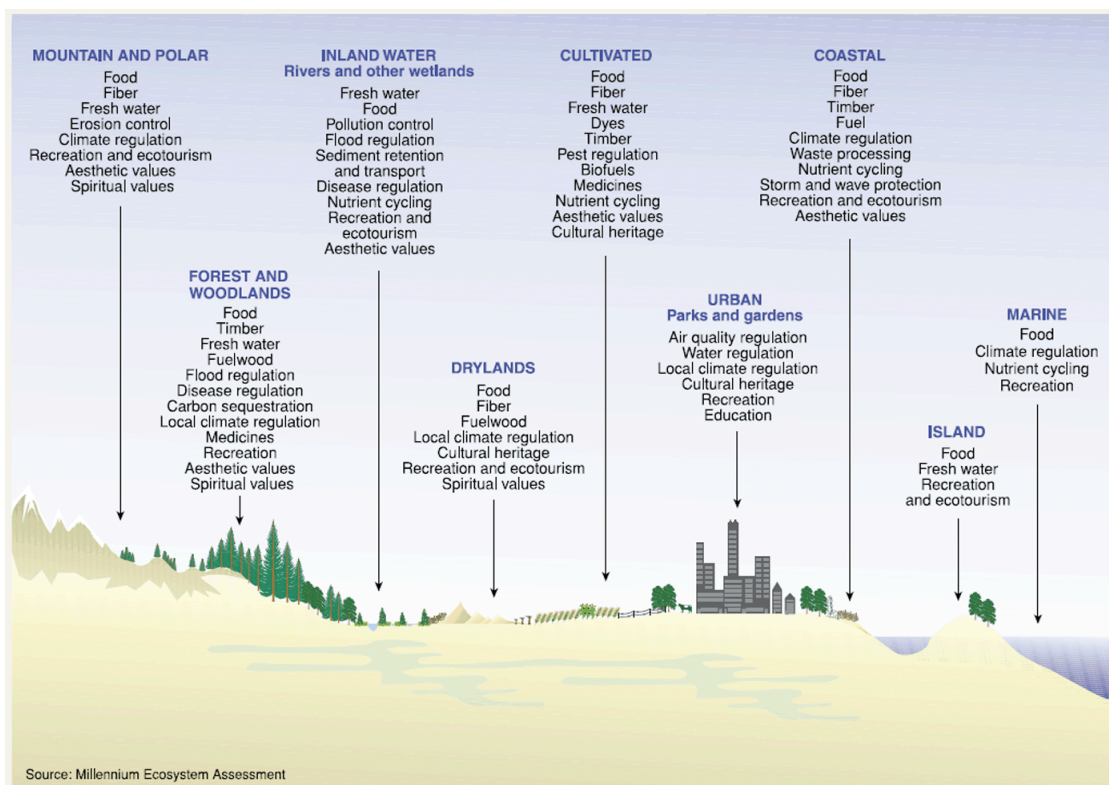


Figure 42.3 Ecosystem services as identified and classified by the Millennium Ecosystem Assessment.

Ecosystem Services

The biosphere gives life to the earth through a myriad of provisions. Many of these provisions have been known and appreciated for millennia, some we have only recently begun to recognize, and others remain to be discovered. They have been and continue to be given within a system permeated with dynamic beauty—whether known or acknowledged, whether one time understood and now forgotten, whether unknown and waiting to be discovered. Whatever the status of our knowledge of them, they have come to be called *ecosystem services*. Joined with other provisions—like our star’s energetic provision of a broad spectrum of light and our moon’s provision of attraction to Earth’s mobile waters in creating tides of seas and oceans—our identification of these help toward developing a sense of provenance and providence, an awe-inspiring realization of a sustaining system of systems that sustains and fosters the abundant life of Earth. In such provision and service—by means only incompletely understood—this biospheric system of systems achieves *sustainability* of life on our planet. Moreover, we know that this remarkable system we call the biosphere is much greater than the sum of its provision and service, warranting our deepest respect and gratitude (see figure 42.3).

Reading the Book of Nature

The biosphere, and the wider world and universe, in many cultures and traditions is considered to be a kind of "book." Not only that, but viewing nature as a book to be read is important also in the development and the doing of science. Scientists, says philosopher of science, Peter Kosso, of Arizona State University in his book, *Reading the Book of Nature* seek to discover and put together a *coherent* description of how the world works, in much the same way that a scholar seeks a *coherent* understanding of a written text. It is from a coherent reading the "book of nature" that scientists come to learn about the provisions for life and breath that are everywhere evident around us. And as these provisions have been the subject of our sages from ancient times to the present, so also are they the focus of environmental scientists in our day, and are called by them in our day, "ecosystem services."

Economy of the Biosphere

The biosphere is the system of ecosystems that make up the living fabric that envelops the earth. The biosphere's economy is the full and coherent actions and interactions of the biosphere's component ecosystems, including its reciprocating services within and among all of its parts. The "economy of the biosphere" is the "symphony" of material and life cycles" in the quotations with which this chapter began. Not one of its ecosystem services operates independently of the other ecosystem services within the biospheric economy; all are integral parts of the whole. And this whole, the biosphere, is an interwoven fabric of life, interlaced with relationships that are material, or energetic, or informational, or combinations of these.

Biospheric provisions and ecosystem services have been recognized for centuries and millennia as operating in accord with each other—all working in together in the universe. The orderliness discovered by Carl Linnaeus (Carolus von Linné), the renowned Swedish student of animals and plants of the 18th century and proponent of our present-day scientific system of plant and animal classification. Linnaeus lived prior to the invention of the word "ecology." In his 1791 essay entitled the *Oeconomy of Nature* Linnaeus wrote:

By the Oeconomy of Nature we understand the all-wise disposition of the creator in relation to natural things, by which they are fitted to produce general ends, and reciprocal uses... Whoever duly turns his attention to the things on this our terraqueous globe, must necessarily confess, that they are so connected, so chained together, that they all aim at the same end, and to this end a vast number of intermediate ends are subservient... It seems to me that a greater subject than this cannot be found, nor one on which laborious men may more worthily employ their industry, or men of genius their penetration. . . ."

It is sufficient for us, that nothing is made by providence in vain, and that whatever is made, is made with supreme wisdom... Most certainly if we are to improve and polish our minds by the knowledge of these things; we should, besides the great use which would accrue to our oeconomy, discover the more excellent oeconomy of nature, and more strongly admire it when discovered."¹

Some 200 years later, we have put this wonder of the biosphere's economy under study in the youthful science of ecology. With this great economy as our context, we now can ask: What are the provisions and ecosystem services of the biosphere and the biospheric economy?

Biospheric Provisions and Ecosystem Services

All of us have had awesome experiences in the creation. Perhaps we stood at the edge of a great canyon, or at the feet of trees in an ancient forest, or in the center of a great storm. Perhaps we ambled onto a flowering meadow in the quietly lifting mists of the morning dew. The provisions we behold---the "ecosystem services---are felt by us deeply. They call forth our attention, and beyond that, even awe and wonder, as this is expressed by our poets and writers of songs. Of the magnificent provisions for The creation, I identify eight here.²

1. Earth's energy exchange with the Sun

Our star, the Sun, pours forth immense energy in all directions, and whatever is in the path of its rays, it heats. A very small part of the Sun's immense radiated energy is intercepted by our relatively tiny Planet Earth, 93 million miles distant, and energizes nearly everything on Earth—living creatures great and small, ocean currents, winds and storms. This energy input tends to heat the Earth, but is balanced by Earth itself radiating energy back into space. If more energy comes to Earth than leaves, Earth warms up; if more is radiated back into space than comes in, Earth cools down. And it is here that the "greenhouse gases" of the atmosphere have a very important function. These gases, including water vapor and carbon dioxide, let much of the sunlight through, but they slow up the re-radiation of energy from Earth itself, and Earth's temperature is stabilized at a higher level than it otherwise would be. This makes Earth warm, but not too warm. It is largely the provision of these greenhouse gases—in just the right amounts—that make Earth's temperatures warm enough to support the wondrous fabric of life we call the biosphere.

The energy that pours forth from the Sun contains not only the beneficial rays that support life and global circulations of air and water; it also contains lethal radiation. Beyond what can be seen by our

¹ Quoted in Worster, op. cit.

² These provisions are adapted from my little book, *Earthwise* published in 2008 (Grand Rapids: CRC Publications).

eyes—beyond the blue and violet end of the spectrum—is ultraviolet radiation. And ultraviolet radiation is deadly. When it is absorbed by living and non-living things, not only does it make them warm up, but conveys such high levels of energy that chemical bonds are broken, molecules break apart, and living tissues are disrupted and destroyed. Of special concern is the breaking of DNA—the genetic blueprint chemical of living things—with consequent death of microscopic creatures and the inducement of things like skin cancer in us and other living things.

But here there is another remarkable provision, for in the gaseous envelope of Earth—high in the atmosphere—there is present a gas that absorbs ultra-violet light. That gas is ozone, and all of it together makes up the "ozone layer" or "ozone shield." Thus, an important divine provision is the protective ozone shield; it prevents damaging radiation from entering the household of life, making Earth habitable by all living creatures.

2. Soil and land building

Soils build and develop. All of us know this from the practice of gardening by us and our neighbors, in which our composting and turning in of plants into the soil, makes the soil better and richer. This process also takes place unaided by human cultivation. Responding to climate, rainfall, and the soil organisms, soils get richer and more supportive of life through time. Topsoil builds up, becoming more supportive, becoming richer, and life increasingly flourishes. The surface soils develop complex arrangements and relationships between a multitude of different species of living things, most of them microscopic. And various remarkable cycles are involved in this development: the carbon cycle, the water cycle, the nitrogen cycle, and much more—a veritable symphony of processes that bring bare landscapes, and even bare rock, eventually, to support a rich and diverse fabric of living things. This soil-building teaches patience. A half-inch of topsoil formed in a hundred years is a high rate of formation; sometimes it is more like an eighth-inch of soil in a century!

The dynamic fabric of roots, soil organisms, and soils that bind together the surface of this biosphere makes many people stand in awe and generates wonder. The soil builds, even from bare rock. And soil development is an absolutely remarkable provision: it nurtures the fruitfulness of the creation. In it resides the richness of the land whose produce we reap and whose creatures are nourished.

Soil development occurs everywhere across the face of the land. In the cool of the temperate zones, this soil building brings prairie and woodland soils; farther toward the poles it brings the soils of boreal forests; and in the tropics it brings the reddish laterite soils. The land is nurtured, refreshed and renewed.

Thus, an important provision is the building of soil; this process helps support the creation's integrity; it helps renew the face of the earth.

3. Photosynthesis and respiration

At the heart of the biospheric economy is the remarkable process of photosynthesis—a process by which the green plants of the earth utilize carbon dioxide from the atmosphere and water from their environments to transform energy from the sun into forms of energy that can be used and transferred through food webs and food chains, and simultaneously capture and arrange carbon to create the carbon backbones used to build all living things. In this economy, every species of living things is engaged in fluxes and flows of matter, energy, and information. And in this economy every species is transferring carbon and transforming its carbon-to-carbon linkages to serve as support—material and energetic—of all

things living. Augmented with a minor contribution from chemosynthesis by organisms that utilize energy obtained from deep ocean vents, photosynthesis powers all of life in the biospheric economy, energizing and sustaining the living fabric of the biosphere, and producing the carbon structures with which this fabric is woven. Along side of the remarkable process of photosynthesis, is the reciprocating process of respiration---a process that sustains plants and animals alike. It is reciprocating because it breaks down carbon-based structures that are put together by plants and animals to return them to carbon dioxide and water that are returned to their environments. And in the process, energy is released in highly-controlled ways that power everything from muscular contractions to nerve conduction, from pumping materials across membranes to producing needed heat. And so, the two processes harmonize; reciprocating photosynthesis and respiration assemble carbon dioxide into carbon skeletons, build cells, tissues and whole organisms, and after productively passing through food webs and chains, dissociate them and return them reassembly.

There is beauty in all of this! We all know that plants are green, that animals eat plants, that people eat plants and animals to sustain their life and health. But we likely are to take these great services of the biosphere with little if any thought. Yet, the outpouring of light from our star the sun, its interception and processing by the biosphere's living fabric, and its sustaining us and all other life is cause for wonder, deep appreciation, respect, and loving care.

4. Cycling, recycling, and ecosystem functions

Recycling is not a recent invention. It is part and parcel of the way the world works. The whole The creation uses, re-uses, and uses again the various substances contained in the soil, water and air for maintaining its living and non-living fabric. Carbon dioxide breathed out by us—and by gazelles, and lizards, and gnats—enters the atmosphere later to be taken up as the basic carbon-based raw material from which to make the carbon-based stuff of life. And this carbon-stuff is transferred to the animals and microscopic life that depend upon it for food. And sooner or later these consuming creatures return the carbon back to the atmosphere through their breathing out of carbon dioxide, or by their own death and decay. This is the carbon cycle.

Water too is cycled and recycled. Taken up by animals, it again is released to through breathing, sweating, panting, and ridding of wastes—finding its way to the atmosphere, or through the route of sewage treatment plants back to rivers and streams. Taken up by the roots of plants, some is pumped right up through the bundles of tubing in the roots, stems, and leaves of plants and back to the atmosphere while some is used together with carbon dioxide to make the stuff of life that after use by plants and animals as building materials and fuels, once again is released to the atmosphere. The water that goes into the atmosphere joins water evaporated from lakes, streams, soil and other surfaces eventually forming rain, sleet, or snow that again waters the face of Earth, some running off to streams and other surface waters again to evaporate to reform the clouds from whence it came. Some percolates through the soil back to roots of plants, and some slips past these roots to enter the groundwater to be pumped by wells for human use, or to emerge as eventually to be returned to the clouds again. As water is evaporated, or transpired to the air, most everything it contained is left behind—a sweet distillation expressing a bountiful provision for the world. And the clouds—great condensations of distilled watery vapors—rain it all down again to water the Earth. This is the hydrologic cycle.

Cycles upon cycles... cycles within cycles... cycles of cycles... the biosphere is permeated with cycles, and each of these is empowered by energy poured out from the Sun. The workings of ecosystems rely upon all

of this cycling in the creation. The biosphere—that great envelope of inhabited world that covers the face of the earth—is what we and all other creatures inhabit. And it is comprised of prairies, oceans, forests, lakes, glades, woodlands, brooks and marshes; it is comprised of ecosystems. And each of these ecosystems has its plants, animals, soils, and climate. These creatures and their interactions, and much more, make up the ecosystems of the creation.

Although it might not first meet the eye, ecosystems are places of immense ecological harmony. Not every creature plays the same tune, so to speak, but they all in so many ways are in tune with each other—in harmony, in polyharmony. A great marsh, at first seemingly unstructured and disordered, is in time discovered to be a highly ordered system in which each creature interacts with the other creatures to form an integrated whole. And what is true in this regard of wetlands is true of forests, and prairies, and lakes, and deserts. Each is a kind of symphony, and the biosphere is a symphony of symphonies, where all creatures great and small are so related with each other that they continue to produce after their kinds generation after generation, continue to maintain and sustain the living fabric of the biosphere, continue to bring forth life from death, continue to cycle and recycle the basic stuff of the creation—all powered by our star, the Sun. Creation's ecosystems are provided with everything needed for their continuance through the years and generations, everything needed for their creatures to interactively sustain the whole system in which they have a part.

5. Water purification - Water purification systems of the biosphere

In the cycling of water on Earth some water percolates through the soil to the groundwater below and eventually supplies the flowing springs that feed the wetlands, lakes, and ravines; it is the process of **percolation**. Some water is returned to the air by evaporation from the surfaces of water, land, and organisms and from transpiration through the pores of leaves; it is the process of **evapotranspiration**, or simply, **ET**. As water is evaporated, or transpired to the air, most everything it contained is left behind—"a sweet distillation." Evapotranspiration is one important provision for purifying water in The creation.

Percolation is another important provision for purifying water in The creation. In many water treatment plants in our cities, water is treated by having it percolate through beds of sand; this results in removal of many impurities in the water. In similar fashion water that percolates through the soil is treated, but usually over much greater distances through soil and rock. The result is that by the time we pull up the groundwater to our homes by our wells, or the groundwater emerges as springs, it usually is fit to drink. Percolation, and the movement of groundwater through aquifers of soil and rock, is another important provision for purifying water in the creation.

Still another important provision are the brooks, streams, and rivers. At normal levels of waste input in natural ecosystems, these flowing waters and their living inhabitants remove the impurities so that by the time water moves a few miles downstream the impurities—especially the demand for oxygen—put in upstream are largely removed. And so, the processing of water by flowing streams is another important provision for purifying water in the creation.

Evapotranspiration, percolation, and flowing rivers... And there is yet one more: wetlands. Many wetlands of many types across the globe serve as water purifiers under natural conditions. When water that has picked up eroded soil as it flows across upland areas enters wetlands, the soil particles are filtered out. And, in many instances, dissolved chemicals also are taken up by wetland plants. The result is that water entering rivers and lakes by way of wetlands are cleaned before entering, keeping flowing waters

and lakes habitable for other life.

There is wonder in all of this! All of us know what water is. And yet, it is so common in most of our lives that we take it for granted. And so we need to be reminded that water is what often is called "the universal solvent," meaning that it dissolves practically anything. This should cause us to think about how then water can ever be purified. Since it is the universal solvent, should it not always be contaminated with dissolved materials from everything through which it passes? Water also is the only major liquid substance in the world, and as such flows from place to place, bringing with it all sorts of particles held in suspension, and so should it not be contaminated with all sorts of suspended material. The answer, we have found, is "no," because of the natural "distillers," "filters," and "extractors" that operate to purify waters in the creation. There is remarkable provision in the biosphere for the production of pure water; once having been contaminated by sediments and dissolved substances, it is made pure again... and again... and again! And this provision makes a vitally important contribution to the fruitfulness and abounding life.

6. Fruitfulness and abundant life

The whole creation flourishes with fruitfulness and abundant life! Of the known flowering plants we have 250,000 species—such as orchids, grasses, daisies, lilies, sedges, maples and palms, lilies—in amazingly colorful abundance and beauty. Each of these inter-relates with water, soil, air, and numerous other kinds of organism as each conducts its life, in its own distinctive way. It is a fabric of life that envelops the earth—a sphere of life that provides the interwoven threads of the household of life, the oikos we call the biosphere. Beyond these there is another quarter million species of still other kinds, and still another, and another! And these are not merely scattered but situated in intricate dynamic relationships with the rest of the species with whom they inter-relate. At mid-century we thought there were about 1 million different kinds of living creatures! In the 1960s we thought there were about 5 million species, and today we believe there is something between 5 million and 40 million species of living things on Earth! The biodiversity of Earth is so great that we are just now beginning to realize that we have just begun to name the creatures—we have named only about 1.5 million thus far.

It is difficult to convey our own utter amazement at the seemingly infinite variety of life on Earth, and even more so the fact that each of these several million kinds of creature perpetuates itself from generation to generation with rare exception. Despite the dangers nearly every species faces as it goes through its life cycle they largely persist generation after generation, reproducing after their kind. Even as the situation of these creatures changes, due to shifts in climate, landscape, forest cover, etc., each creature continues generation to generation because each also is endowed with the capacity to adapt to changing conditions. Hardly any two offspring are exactly alike with the result being that each generation itself has new variety, and it is this variety that provides the individuals who will be well adapted to new and unanticipated changes in the environment. Thus, not only is there provision in the creation for continuance of each species, but also for their adaptation to new situations—and through such provision, life not only persists, but flourishes.

7. Global circulations of water and air

Because of its 23 ½ degree tilt, Earth gets unequally heated from season to season, with the Northern hemisphere getting far more solar radiation in the northern summer than in winter; the opposite is true of the southern hemisphere. And of course, the daily rotation of Earth also unequally heats Earth. Both these seasonal and daily differences in heating by the Sun's energy cause differentials in Earth's

temperatures from place to place, and this produces temperature gradients which drive the flows of water and air from place to place. But the unequally heated water and air, due to the presence of the land masses, and air, due to the presence of mountain ranges, cannot make simple one-directional moves, but must stay within the constraints of land masses and mountain ranges. It is this that is basic to Earth's atmospheric and oceanic circulations.

Atmospheric and oceanic circulations are extremely important provisions for maintaining the life of our planet. The carbon dioxide produced by animal and plant respiration, and oxygen produced by photosynthesis are released to air and water—the fluids whose circulations are driven by these temperature differences, and thus get moved around and mixed in such a way that they can again be picked up by the organisms that need them. Thus the carbon dioxide produced by animal and plant respiration is moved around such that it eventually comes into contact with plants that take up the carbon dioxide to re-incorporate it into the stuff of life. And oxygen, produced by photosynthesis of plants, is similarly circulated by air and water currents to supply the respiration of animals and plants.

Beyond moving these vital gases, global circulations are also vital to the movement of other materials. One of these movements, that of water vapor, of course is vital to the hydrologic cycle, for when evapotranspiration brings water into the air from plants and water evaporates from various surfaces, it is circulated by moving air thus moving water away from its immediate source to places that subsequent precipitation will occur in the form of rain, sleet, or snow. Global circulations are in a very real way the ventilation system of the biosphere. Global circulations provide the "breath" of life at the planetary scale, and they are vital to the watering of the fabric of living things that encapsulate the Earth.

8. Human ability to learn from the creation

Human beings have the remarkable gift of being able to learn from the creation. And, while the natural sciences often are credited with teaching us how the world works, we ultimately learn what we know from the creation—that is what scientific research is all about. But that does not end the matter. We have been provided with the ability to probe and investigate this wonderful world; we have been given the ability to record in our mind's eye what we see, feel, hear, and smell; we have been granted minds that integrate what the book of nature teaches us—we have minds that create images of our world, representations of the world in our thoughts upon which we act when we plan and do our work in the world. The images we have in our minds—of our home town, our family, the great expanse of a wondrous forest or marsh, the microscopic life we observed under a microscope—are continually tested against our experience. We learn from our mistakes, learn from others whose observations and experiments we trust, and revise our models of the world better to represent the world in which we live.

This ability is not one that has come through science, although science in a very real way reflects this gift. The ability to learn from what the creation teaches us is an endowment provided to all human beings across the world, and throughout human history. A 1975 study of the Hanunoo tribe of the Philippine Islands, for example, found that an average adult could identify 1,600 different species, all without the help of recent science. And this knowledge, gained from study of the creation by these people themselves showed that they had learned some 400 more plant species than previously recorded in a modern systematic botanical survey. Beyond the knowledge of scientific botanists, these people also knew their uses for food, construction, crafts, and medicine and, they knew where to find all of them—they knew their homes and habitats, they knew their "ecology." For Nigeria and elsewhere in tribal cultures there are

similar findings.³ Of course, knowledge of such a large number of plants is just part of the learning that has been gained by people and incorporated into their mental models—their understanding—of how the world works.

This ability of building mental models of the creation—in all its aspects, from plants and atoms to home and cosmos—is essential for meaningful human life. And our models are nurtured and often refined by the human culture with which we also are endowed. Early on we learned the warmth of our mother's love; in the days our youth we were imbued with our parents' care; and in our vocations we daily learn from the people and writings that touch us. The representations of the world that we hold in our minds are remembered—we are "re-minded" by persons and situations—and upon what we hold in our minds to be true we respond and act in the world. And when presented with concrete evidence or convincing arguments, we might even "change our minds." We have minds that can be and are shaped by the beauty of the creation and all that it contains.

The most marvelous provision for us and all people, are our minds and nurturing cultures that allow us to imagine and know how the world works. Beyond this is the provision that we can use what we have in mind to act on our knowledge. We human beings have been granted the ability to know the creation and to act upon that knowledge.

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³ Awa, N. 1989. Participation and indigenous knowledge in rural development. *Knowledge* 10:304-316.