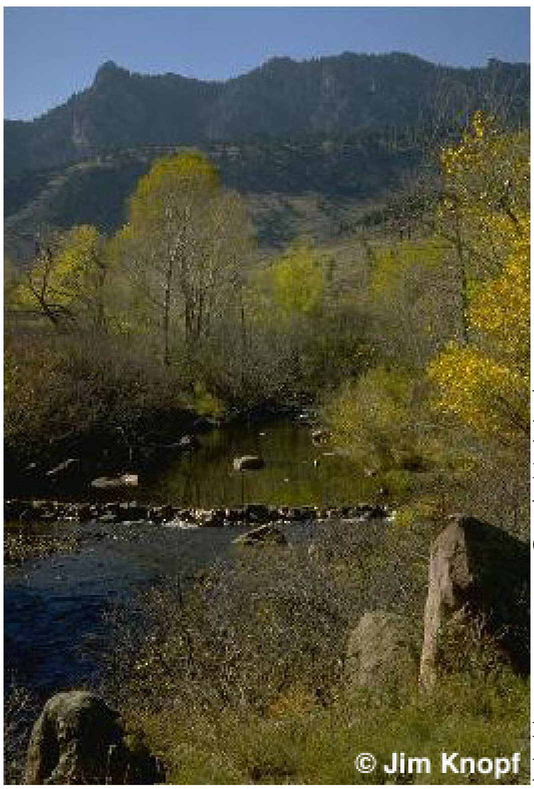
TOWARD A STEWARDSHIP OF THE GLOBAL COMMONS: ENGAGING "MY NEIGHBOR" IN THE ISSUE OF SUSTAINABILITY



The Earth Sciences, broadly defined, will provide important understandings for society in the 21st Century. As the global human population approaches and perhaps exceeds 9 billion people, interactions among the atmosphere, biosphere, hydrosphere and lithosphere will define significant boundary conditions for the future sustainability of the human enterprise and the survival of these Global Commons.

This series of essays will provide pathways to bring the issue of sustainability into the public domain. Engage your students or neighbors in dialogs about the ideas that will influence the quality of their lives and those of their children or grandchildren in the coming decades.

INTRODUCTION TO THE SERIES

Sustainability, in the context of these discussions, refers to the extent to which human populations can persist indefinitely at an acceptable range of living standards. Hence, whatever else sustainability might imply, it requires that vital naturally renewable resources – the air we breathe, the water we drink, and the diverse population of plants and animals upon which human civilization depends – be sustained at some minimum level. The permissible levels of consumption of these "renewable" resources is at the heart of the sustainability debate. Although consumption of "nonrenewable" resources such as minerals is by definition not sustainable, developing interim nonrenewable substitutes as others are depleted may be essential for a successful transition to a sustainable (renewable) society.

The first half of this new century will be a critical time for humanity. Global population is projected to reach 9 billion by mid-century. Consumption of natural resources rises with population, as does the generation of wastes. Earth is a finite place. Sooner or later, and many thoughtful people think sooner, the consequences of these increases will create serious human problems. All people, in all countries, should be aware of the concepts that underlie these concerns about a sustainable future for the human enterprise as we know it. As you read the series of essays developed on these pages, think 2050, a date within the lifetimes of many of us or of our children and grandchildren.

Each essay in this series focuses on a particular concept that is essential to understand the issue of sustainability. The goal is to help bring these concepts clearly into the public domain so that they become integral parts of the education of every citizen in North America, and we hope eventually elsewhere.

A major target audience is teachers and teachers of teachers, because this group provides the greatest probability for a multiplier effect. Although the principal stakeholders in the world of 2050 are college-age or younger today, don't neglect your "neighbor". The concepts in this series of essays were presented with considerable effect in a an Elderhostel course. The essays touch only on some key points. The complexity of Sustainability is evident in the GUIDELINES that accompany these essays.

In the texts that follow, "students" will refer to people of all ages. Teaching need not be confined to classrooms.

Toward a stewardship of the Global Commons:

engaging "my neighbor" in the issue of sustainability

By members of the Critical Issues Committee, Geological Society of America

Part I

WHAT DO WE MEAN BY THE GLOBAL COMMONS?

A. R. Palmer, Institute for Cambrian Studies, Boulder, CO.

In old English law, the common (or commons) was a tract of ground shared by residents of a village, but belonging to no-one.It might be grazing grounds, or the village square, but it was property held in common for the good of all.

Sustaining human civilization on Earth at acceptable levels requires recognition of the place of human beings in the “web of life” and the role human beings play in modifying the world on which we live and the natural systems which maintain the Biosphere of which human beings are just a part. We must take individual personal responsibility for the Atmosphere, Hydrosphere, Lithosphere and Biosphere – the Global Commons – that we all share.

Throughout human history, we let the noxious gases and particles from our cooking, heating, industrial activities, and, more recently, our various modes of transportation and delivery of goods drift away on the wind, without really considering what happened to these materials downwind from us. How much responsibility do we bear for acid rain, persistent smog, increasing atmospheric carbon dioxide, and disturbances of the stratospheric ozone layer?

We have mined water from underground as if the supply was inexhaustible. We have discharged our industrial effluents and our sewage, into streams or lakes, or into the ground, with little thought to the consequences. Some results are dramatic drops in the level of the water table under many key agricultural areas and cities, ground water and surface water no longer safe to drink by humans, and diminished or destroyed fisheries. Even as we deplete our potable water, the population in those areas of depletion continues to increase, further straining an exhaustible resource.

We have plowed the ground and heavily fertilized and/or irrigated our crops, realizing short-term gain, but not readily recognizing the long-term losses. Some results are soil erosion with accompanying loss of soil depth, nitrification of lakes and streams adjacent to farmland, and loss of formerly productive agricultural land by salinization of soils.

We have cut forests for fuel and timber, and to create pastures or cropland. We have further altered the landscape by expanding cities and industries, or by building dams to augment our water needs, supply power for our homes and factories, or control floods that might wash away our structures. We have overfished our rivers, lakes and oceans, and overhunted many of our game animals. We have introduced foreign animals or plants into new areas where they have no natural controls on their spread. We have, as human beings, disrupted ecological systems that have existed in balance with their surroundings for millennia.

We must constantly remind ourselves that we are an interdependent component of those ecosystems that form the complex web of life on this planet. We each have a responsibility to be aware of our dependence on the successful function of all components of the Global Commons for the future well-being of humanity.

Suggestions for illustrating the concept of the Global Commons.

DEMONSTRATION 1: One way to drive home the concept of the limited atmosphere capable of supporting life on Earth is to take the common classroom globe (often about 40 cm in diameter) and ask students to calculate the distance represented by one millimeter (about 30 km). Most people live below an elevation of 5 km (about 15,000 feet). Have the students discover that the portion of the atmosphere upon which the existence of human, plant and other animal life depends– the Biosphere – is about the thickness of a sheet of paper.

DEMONSTRATION 2: One way to make the point about over-pumping an aquifer would be to develop a siphon at one end of a small aquarium filled with water-saturated sand where you can control water input at the other end to be less than the rate the water is siphoned off. The level of saturated sand will drop as withdrawal exceeds supply. With the same setup, pollution can be simulated by a fluorescent dye that could be introduced into the supply end and later detected in water coming out of the siphon.

DEMONSTRATION 3: How much of our food comes from irrigated farmland susceptible to salinization? Salinization can be effectively demonstrated by evaporating the tap water normally used for watering plants, or local well water if available, in a shallow dish and noting the accumulated residue. Successive additions of more water to be evaporated in the same container will demonstrate a buildup of deposits. How deep is the productive soil in your area? If surface soil loss is only 1 mm per year, how long will that productive soil last? How is the soil replenished? At what rate?

DEMONSTRATION 4: Obtain an aerial photograph of your area, or check the landscape on your next airplane flight, note how much of the landscape has been affected by human activities, and what was the nature of those activities. Consider what the area might have looked like before human development and then consider the cumulative effect of this ongoing development on natural ecosystems and regional environmental processes.

Part II

The Context of Humanity: Understanding Deep Time

A. R. Palmer, Institute of Cambrian Studies, Boulder, CO
and E-an Zen, University of Maryland, College Park, MD

Intimations of an understanding that Earth had a significant history are found in the writings of Herodotus during the 5th century B.C. While traveling on the Nile Delta, he realized that the sediments had accumulated from river floods and that thousands of years had been required to form the visible part of the delta deposits. However, the contrast between human history and geologic history did not really become fully articulated for more than two millennia.

A bit over two centuries ago, James Hutton recognized the significance to Earth history of the angular contact between two sets of sedimentary rock layers at Siccar Point on the southeast coast of Scotland which set in motion the modern science of Geology; horizontal beds of sandstone that formed the land surface beneath Hadrian's Wall, already old in terms of Scottish history, rested on the vertically upturned edges of still older sedimentary rocks. Those older rocks had to have been lithified from unconsolidated horizontal sediments before being deformed to their present attitude and eroded to form an ancient land surface beneath the sandstones. Here was indisputable evidence that Earth had a history that far pre-dated human history. Thus the time context for humanity was clearly established and has been reinforced by all subsequent geologic work.

We are a part of the fabric of Earth's biosphere and we are not likely to disappear in the forseeable future, but there is growing concern about our effect on the global ecosystem and the quality of life that can be sustained for our descendants. By recognizing the vastness of Earth history compared to human history, we internalize what John McPhee has termed Deep Time and we gain an essential perspective from which to consider the results and consequences of our human impacts on Earth.

Preserved human artifacts and written records show clearly that we modern humans have essentially experienced only the present landscape. Even if it has been locally modified by geologic processes, the painted caves of the Pyrenees remain as caves and some ancient city ruins of Mesopotamia and tombs of pre-dynastic Egypt remain standing on flood plains. The clear archaeological evidences for recency of the advent of modern *Homo sapiens*, dramatize the awesome changes have been wrought on our planet by humans in the recent historical past. It is only necessary to look out of an airplane window while flying over central United States to see how much of the land surface has been altered by human activity in less than two centuries. Satellite images document how much urban sprawl in the U.S. has changed the landscape and natural ecosystems within even shorter spans of a few decades.

Geologists have no problem with the concept of Deep Time, but it is clearly a concept that is not widespread at a very high level of consciousness in the general public. Raising the level of public awareness of this concept is our challenge and our responsibility. As one contribution to this challenge, the concept of Deep Time and the context of humanity has been captured visually in GSA's affordable 20-minute teaching video "The Earth HAS a History," that can be purchased from the Geological Society of America (1-888-443-4472).

Several other ways to try to get the key idea of Deep Time into the public domain are suggested in the following demonstrations.

DEMONSTRATION 1 - Demonstrating that EARTH *HAS* A HISTORY is relatively easy. GSA's teaching video with that title utilizes the concepts of original horizontality and superposition, and the processes of deposition, deformation and erosion on a virtual field trip to sites all within view of one another around Boulder, Colorado, to make the point that the only landscape known to even the earliest Native American inhabitants of the region contains a rich story requiring vast amounts of time. This approach can be used in many areas by creative teachers to make the point of the antiquity of Earth compared to human history.

Almost any rocks in your area can serve this purpose. A good way to begin is to look for common, ordinary processes that affect the rock. If there is a gravel pit, the sizes of the cobbles in the gravel provide an opportunity to discuss the rate of accumulation of gravel that contains cobbles of that size, the kind of current needed to transport those cobbles, the likelihood of such discharge, and the time it would take to accumulate a gravel bed of given thickness. If a rock outcrop is covered by lichen, some simple library research could determine the identity of the lichen, how fast it grows in the region, and what the size of the colony implies about the age of that particular rock exposure.

Perhaps this is enough. But the clear next question that might be asked is "How do we know how old?"

DEMONSTRATION 2 - The principle by which we arrive at numerical ages can be explained in non-technical terms, but the technical details are difficult to comprehend and perhaps not necessary. In a non-technical approach, we can explain that in rocks that cooled from a molten state (like granite, which cooled slowly some distance underground and thus has large mineral grains, or basalt, which cooled relatively rapidly from a lava flow and thus has much smaller mineral grains), some of the crystallized minerals contain radioactive atoms of an element that decays at a known rate to produce a recognizable decay product (daughter) which is another element. Once that mineral has crystallized, it becomes a closed box, and the radioactive atoms and their daughters will both remain within the box. Although some leakage is possible, there are ways to detect such leakages and make corrections for them. Very sophisticated chemical analyses can detect the amount of the radioactive element and its decay product in the mineral grain (box). The longer the mineral has been a closed box, the more daughter element there is relative to the parent. Because we know the rate of decay of the parent, we can tell from the proportions of the daughter element vs. parent how old the mineral is.

Of course, this doesn't work on sedimentary rocks such as sandstones because the mineral grains were eroded from older rocks and thus any age we get is not the age of the sediment, but the age of the rock from which the mineral grain was eroded. Even so, if we can identify minerals that have formed subsequent to the deposition of the rock, we still have a way to measure the minimum age of the rock itself. If the rock is organically precipitated and is relatively young, like a coral reef, the decay of radioactive uranium, incorporated from sea water into the skeleton by the coral polyps, into its daughter product, lead, allows the age of the reef to be determined.

If students have grasped the idea of metamorphic rocks, then it can be explained that numbers from minerals in those rocks most commonly date the time when those mineral grains were recrystallized during metamorphism and became closed boxes. This time will be much younger than the age of the original rock before it was metamorphosed.

DEMONSTRATION 3 - Many people do not understand that carbon-14 dating can only be used on very young Earth materials. Again, a non-technical explanation may suffice to make the point. Every living organism, plant or animal, is constantly processing carbon dioxide through its system. Some of the carbon in the carbon dioxide is the product of interactions between cosmic rays and nitrogen high in the atmosphere that produce an unstable form of carbon we call carbon-14. This unstable form will gradually decay back to nitrogen, but more is being created all the time at about the same rate as the earlier carbon-14 atoms decay. The unstable form is thoroughly mixed with the more common and stable form of carbon – carbon-12 – so that the ratio of carbon-12 to carbon-14 is essentially constant in the carbon dioxide of the atmosphere and the carbon dioxide dissolved in an ocean or in bodies of fresh water.

An animal or plant builds carbon into its structure (bones, shells, leaves, wood) as it grows, and that carbon has the natural environmental ratio of carbon-12 to carbon-14 because the growing organism doesn't significantly distinguish between the two forms. When an organism dies, it stops adding carbon. Over time, the part of the carbon in the organism that was carbon-14 decays until all that remains is carbon-12. Thus, the longer the organism has been dead, the smaller the proportion of carbon-14 that can be detected, again by tricky chemical analysis, in the remains. With increasingly sophisticated technology, we can now determine when an organism died by using carbon-bearing remains (usually bone, shell or wood) that are as old as 70,000 years. For materials that have been dead longer than that, there is too little remaining carbon-14 to detect.

While 70,000 years sounds like a long time to most of us, it is only a fraction of the millions to billions of years that can be estimated from analysis of minerals found in most granites or similar rocks. Thus, dating of materials using the carbon-14 technique is primarily of value in archaeological studies – that is, dates of happenings well within the geological history of human beings.

Further reading: Taylor, R. E., 2000, Fifty years of radiocarbon dating; American Scientist, v. 88, no. 1, p. 60-67.

DEMONSTRATION 4 - To really put the impact of humans into the deep time perspective, an effective basis for an analogy is a football field (actually a soccer field is better because it has metric dimensions and so the math is easier). If the age of the Earth (4.5 billion years) is scaled to the length of a soccer field, depicted at the top of a sheet of paper or overhead transparency, then one millimeter equals 45,000 years. Enlarge that one millimeter as a horizontal axis marked off in tenths (4,500 years) on the lower part of the page and show the locations of the beginning of the last de-glaciation (13,000 years), the beginning of the agricultural revolution (10,000 years), and other historical events such as the pyramids (5,000 years) – this is usually enough to get the scale across. Then make the point that most of what we commonly study as human history has all happened since the beginning of the agricultural revolution – about ¼ of our original millimeter of the soccer field, or roughly the thickness of a blade of grass on the goal-line! For continuing discussion (below) also show the proportion of that time line that represent the last 500 years. A downloadable image of this figure is provided on the webpage Visualizing Deep Time.

How many other ways can you or your students devise to communicate the concept of deep time?

When discussing deep time with adult audiences, you might bring in this beautiful quote: "In the presence of eternity, the mountains are as transient as the clouds" attributed to Ralph Ingersoll, well known public speaker of the 1930's. The essence of this quote is found in the Qur'an, (Sura 27, Aya 88) written 14 centuries ago – a remarkably prescient geological observation! If you use the quote, it might also be appropriate to distinguish between deep time (something finite, measurable and testable) and eternity (a philosophical concept).

To further emphasize the impact of humans on earth, construct a vertical axis at the present-day end of the one-millimeter time-line, scale off seven tick marks at one-inch intervals representing global human population in billions, and draw a population growth curve for the past 500 years, noting that population prior to that time was probably less than 1 billion, but it was about 1.2 billion in 1910, 2.5 billion in 1950, 5 billion in 1990, and today is 6 billion. On the scale of the time-line, this is essentially a vertical line.

Cover this part of the diagram on the overhead transparency until the point about the time scale has been made. Then reveal the population curve, note its resemblance to a rocket, and point out that this curve shows not only population growth, but also growth in consumption and in production of wastes. This usually gets the audience's attention! The audience is now prepared for discussion of SPACESHIP EARTH, ECOLOGICAL FOOTPRINTS, RESOURCE ISSUES, and other facets of sustainability.

Part III

Doubling time:
it works for ANY rate of change

A. R. Palmer, Institute of Cambrian Studies, Boulder, CO

A parable: “When was the pond half full?”I lived by a large pond with a thriving community of fish, so fishing was good. One day not too long ago some algae began to grow in the pond. Their population was doubling every minute. Yesterday morning I went fishing and everything was fine. Yesterday noon when I looked out at the pond, it was suddenly filled with green algal scum and the fish were dying from lack of oxygen. Why didn’t I see the disaster coming and do something? When was the pond half full [11:59]? One-quarter full [11:58]? One eighth full [11:57]? Suppose, instead of my pond, we were considering an island, or a continent, or Spaceship Earth?

At the heart of the concept of doubling (or halving) is the exponential function familiar to many from mathematics, science and engineering. Geologists are perhaps most familiar with this in its backward-running version, i.e. the description of the rates of decay of radioactive isotopes. Most of us, however, learned about exponential growth as compound interest in the context of a personal savings account. If we put our money in a bank and let the interest accumulate, our annual income grows as the capital increases. Even though the interest rate remains constant - our capital grows at an exponential rate. Recognition of doubling (or halving) time for ANY rate of change was not always emphasized.

Because we are discussing a “doubling” time, i.e. the time for a quantity in question to double (or halve), the exponential function has a user-friendly aspect that is very helpful. It turns out that any finite rate of change expressed as a percent (e.g. 5% per year) can be converted, to a good approximation, to a doubling time simply by dividing it into 70. For example, if the rate is 2%, you might expect to have twice the number, i.e. 100% more stuff, in 100/2=50 years, but because of the compounding effect the correct answer is 70/2 = 35 years. The proof of this statement makes a good exercise for a math class at the appropriate grade level. Rates of loss (for instance, depletion of resources) have a halving time that is calculated the same way. For anything diminishing at 2% per year there will only be half as much in 35 years.

This simple way to calculate doubling time (or halving time) should be an essential part of everyone's education. When the mayor is proud because the city has a healthy growth rate of 3% per year, that means the city will double in about 23 years if that rate continues, and double again in another 23 years, and double yet again in another 23 years, thus octupling from its original size in 69 years. One might ask if a city with 8 times the present population is viable. Garbage also has a rate of growth, as does traffic, pollution, schools and housing.

A city is not a closed container, thus its limits to growth will be determined by cultural factors, but Earth IS a closed container for all practical purposes (more on this in Part IV). Growth in a closed container will ultimately fill it up. Thus, we should look carefully at anything in our culture with a growth rate, calculate its doubling (quadrupling and octupling) time and make a judgment about whether we think this is healthy for our future. We should do similar calculations and make similar judgments about those aspects of our culture where, as a result of our consumption habits, a resource is diminishing at a measurable rate. Thus, calculations of doubling (or halving) time are critical components of the issue of sustainability – by which we mean the indefinite continuation of the entire human enterprise within some steady-state limits imposed by space and resource availability (see Part X in this series).

Global population growth rates may be diminishing, but they are still positive. Thus population is still growing and it has a doubling time. Currently the rate is about 1% per year (thus doubling in 70 years). Consumption of resources (Part IV) increases with population size, even if individual rates of consumption do not increase.

If we could slow the present population growth rate to 0.1% per year, it would still be double its present size of about six billion in 700 years, quadruple in 1,400 years, and octuple in 2,100 years – equivalent only to the time represented by the Christian era. Forty-eight billion people may make things a bit crowded. Such a population, with its attendant FOOTPRINTS (the areas of productive land necessary to support each one of us, see the upcoming June essay), may not be sustainable. It is not even clear that we can handle one more doubling with a reasonable quality of life for all.

Such doubling-time scenarios should make us wonder if there is such a thing as the politically popular "smart growth" – perhaps it's a euphemism for "predictable and voluntary disaster". Every time you see a headline or magazine article mentioning rates of change (either increase or decrease), do the quick mental math to calculate the doubling (or halving) time. It is a very revealing exercise.

DEMONSTRATION 1 - Challenge the computer skills of the students by having them write a program that can check the statement that any rate of growth or loss, divided into 70 will give you its doubling or halving time.

DEMONSTRATION 2 - Have the class check the newspapers and news magazines for mentions of rates of change (these could include population size, waste generation, growth of GNP, inflation, depletion of forested land, or demands on natural waters) and then do the calculations of doubling or halving time. Discuss the implications of the calculations.

Part IV

SUSTAINABILITY & RESOURCES

E-an Zen, University of Maryland, College Park, MD

Whenever we ponder the future of the human enterprise, questions about material resources come up. Will they run out? Will they replenish themselves? Will the demand for them diminish, or will alternatives be found? Without a good estimate of those resources, we will never be able to predict or improve human welfare. "Malthusians" have a doomsday outlook; "Cornucopians", a more optimistic view (McCabe, 1998). Yet whichever school of thought seems more persuasive, the fact remains that we live in a materially closed system. The Earth's resources are finite, so we must choose how best to use them.

A society needs reliable information on the resources available to it and on the consequences of their use. How it will act on that information will depend on its value system. For example, a society may place a high priority on fair distribution of wealth. We in the developed nations have an opportunity to demonstrate a commitment to use resources in a sustainable way. Do we want to act responsibly toward future generations of our species and toward other life forms as well?

Material resources are whatever the society at a given moment either uses or recognizes as potentially usable. Because that list changes with society's needs and technology, what is useless one day may become vital the next. As recently as a century ago, aluminum, petroleum, and uranium were not significant resources.

Geologists tend to think of "resources" as the stuff we take from the ground: metal ores, coal, petroleum, groundwater, limestone, phosphate, quartz sand and rock. The earth's resources, however, also include living things that are subject to human exploitation.

Trying to inventory resources for the future, thus, is like aiming at a moving target. Yet some statements will remain valid for three reasons: (1) except for energy input from the sun, which supports and maintains our “ecosystem services”, the earth is a closed system having a fixed quantity of materials. (2) Both the extraction and processing of materials and preservation of the environment require energy, itself a resource. (3) Using a material generally changes its state of aggregation, and its adaptability for future use. Thus, the processing of materials, including recycling or re-aggregating waste material into usable form, causes a thermodynamically inexorable loss of useful energy and/or material. With regard to Earth's material resources, there is no free lunch!

To these factors must be added both an increasing global population (projected to reach about 9 billion people by 2050), and a higher per capita consumption rate reflecting "improved" standards of living. Obviously, resource considerations are crucial for the success of the human enterprise.

Traditionally, resources are grouped as "nonrenewable" and "renewable". Nonrenewable resources (examples: ores, petroleum, coal) replenish at geological rates that are much too slow to benefit human society. Once consumed, such finite resources are effectively removed from our inventory. New discoveries or more efficient extraction methods merely postpone their inevitable exhaustion.

"Renewable" resources (examples: timber, fishstock, groundwater) have rates of natural replenishment commensurate with the time- scales of human society (see DEMONSTRATION 1 below). However, to consume such resources faster than they can replenish themselves is like withdrawing funds from a bank account faster than we make deposits; sooner or later that account will run out. We have often been guilty of just such overwithdrawal. Examples include overfishing, poor husbandry of arable and pasturable land, overpumping of aquifers, destruction of entire ecosystems such as Russia's Aral Sea. Such "local" losses can have large systemic effects (see DEMONSTRATION 2 below).

More effective use of substitutes, recycling, and conservation can slow down depletion of a renewable resource (i.e., the amount of consumption that exceeds its renewal by all processes, natural or engineered), but they cannot halt the process. To make a "renewable" resource truly renewable, the rate of consumption must not exceed the gross rate of renewal. Reaching a "sustainable world" will demand many changes to our priorities regarding resource utilization.

Some vital resources, such as the "environment", are not material objects. A healthy environment is a composite of many other items (e.g., water chemistry and temperature, nutrients and other chemicals in the soil, good habitats for wildlife). A natural place of beauty and wonder is an intangible but valuable resource. A less obvious intangible resource is the future generation's options, i.e., their capability to make real choices. Options are not fixed commodities, but surely they will be important for future societies. Like the options available to us today, many future options require the availability of material and energy. Even if an earth material is not dispersed through use, their very processing automatically reduces future options of their use.

The results of human exploitation of resources cannot be predicted by looking at one commodity or one social force at a time. Calculation of the effects of use and depletion of materials on the public commons (see Part I) must also include human values and cultural habits. Justus von Liebig, a 19th century agricultural chemist, recognized the complexities that arise in a situation where humans and natural forces work interactively. Historian Elliott West put von Liebig's view this way: "an organism's limits are set, not by the maximum profusion of necessary things, but by those things' minimum availability.. Look .. for how much is available when vital supplies are the tightest, lowest, stingiest".

What is true for an organism is true for ecosystems. Can we identify the "vital supplies", their mutual relations and their future trends? Can we recognize the factors of "minimum availability" while there is yet time? Or will they surprise us and perhaps blindside us? Surely we need to be thinking about these issues.

To maintain a society's standard of living requires consumption of resources at some level. In Part XX of this series, we will explore this subject within the "sustainability" context.

The author thanks Christine Turner of the US Geological Survey, Denver, for her contribution to the ideas and her critique of the text.

DEMONSTRATION 1

(1) Ask your students to list the resources that they encounter in one day of their activities, using the following categories:

A. "Nonrenewable" resources are those that may be replenished only at rates much exceeding the human time scale: for example, fossil fuel (what should be included here?), metals (where do they come from?).

B. "Renewable" resources are those that may be replenished on a human time scale, but only if the rate of withdrawal or destruction does not exceed the rate of replenishment: for example, timber, fishstock, soil, groundwater, environmental quality, mixed forests, ozone layer.

(2) Pick any material object: the gasoline you pump, a metal paper clip, the bricks of the building, the gravel in a driveway, a toothpaste tube, or a molded plastic chair. For that object, ask the students to identify the resources embodied in it: where did the material come from, and in what original form? Ask them to discuss what processes were needed to produce the object (e.g., mining, harvesting, refining, waste disposal, ecosystem disturbance, transportation, energy use). What renewable or nonrenewable resources were used in the processing? Are there substitutes that would require less energy and material? How essential is this particular product to the students' comfort or well-being? Could they make do with less? What would be the tradeoff in making a more frugal choice? Who might benefit from that choice, and in what way?

DEMONSTRATION 2

In a recent book, "Waiting for Aphrodite", Sue Hubbell, author-naturalist-apiarist, described recent stresses to communities of the green sea urchin, *Strongylocentrotus droebachiensis*, which lives off the rocky coast of Maine. The population density of this sea urchin seems to go through cycles; in the 1980's they thrived. Sea urchin eggs were a delicacy for the affluent Japanese. When their local stock was becoming depleted at about this time, the Japanese merchants turned to Maine for a substitute. Meanwhile, needing an alternative source of income because the coastal cod and haddock fishery had collapsed through overfishing, the fishermen of Maine started to dive for the green sea urchins. Soon, however, the catch began to fall alarmingly. Green sea urchin eggs are fertilized by sperm which last only a few minutes in seawater, so large congregations of urchins are essential for the species to survive. Large congregations attract fishermen as well, but, luckily for the urchins, the Japanese yen weakened, the demand for pricey urchin eggs fell, and a Russian source became available. Sea urchin "farming" is now being explored as a steady source of supply, so the natural communities of Maine sea urchins might yet recover.

How might the disappearance of green sea urchins affect the ecology of the coastal waters? We do not know. Some years ago scientists thought that the long-spined black sea urchin, *Diadema antillarum*, of the Caribbean region was a useless species. Then it was discovered that coral and sponge larvae can attach themselves to reefs only on surfaces kept clean by the sea urchins, which graze on the algae. So the "useless" sea urchins turn out to be essential to the coral reef ecosystem, after all.

This particular story may be minor in the scale of things, but it provides a good example of the intricacies of an ecosystem. If we act without adequate knowledge, we can easily throw an ecosystem out of balance, possibly irreversibly.

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Part V

EARTH SYSTEMS: THE CONNECTEDNESS OF EVERYTHING

A. R. Palmer, Institute of Cambrian Studies, Boulder, CO
and E-an Zen, University of Maryland, College Park, MD

At all scales, from microscopic to megascopic, from atoms to galaxies, natural processes are interconnected. The discrete categories that have given rise to the increasing proliferation of academic disciplines and subdisciplines are nothing more than an artifact of the human mind.

The concept of a grand scale of connectivity in natural systems is already familiar to most Earth scientists. By contrast, laboratory-based studies commonly make efforts to simplify any system being studied so that cause-and-effect relationships can be brought into focus and verified by repeated observations. Although the two approaches are mutually complementary, this point has not always been made clear to students or the general public, much less political and social decision makers. Sadly, policy decisions that directly impact civilization today and the Earth for generations yet to come too often make the mistake of assuming that we can independently alter or modify one element of a natural system and not expect changes elsewhere.

On the grand scale, the theory of plate tectonics brought together information from many seemingly independent scientific disciplines to present to the world a general conceptual framework for understanding everything from global climates and the genesis of mineral deposits to an understanding of many natural hazards and the peculiar patterns of present and past biogeography. The uplift of the Himalayas, the closing of the Isthmus of Panama and the restrictions of Arctic oceanic circulation, all significantly influence the system of global climate as strong feedback elements which positively and negatively contribute to maintaining equilibrium of a constantly changing dynamic system.

Dynamic crustal forces have played a role in the production of economically accessible concentrations of fossil fuels, mineral phosphates and metallic minerals. We are constantly learning more about factors contributing to earthquakes and volcanic eruptions and the frequency and violence of their occurrences. Shifting geographical configurations as continents have broken up or merged and as global sea levels rise and fall over millennia have powerfully influenced biodiversity.

At the other end of the scale, molecular biology is showing that there are many genes common to all organisms, including humans, and that affect our development in subtle ways. Some of the development of civilization can be attributed to the success of molecular biology and pharmacology in increasing the longevity of human beings. Unfortunately, compounds produced and consumed by human beings for their positive health benefits can also damage human beings and disrupt other living systems in unforseen ways. And out of these studies of molecular biology has also come much of our understanding necessary for chemical and biological warfare. Our increasing understanding of the subatomic world inside the atom has led to remarkable breakthroughs in medical technology, but also to terrible weapons of mass destruction.

The point of this year-long series of essays is to show the interconnectedness of a series of concepts that are not necessarily related in all of our minds and those of "our neighbors". The concepts of the global commons (Part I), the context of humanity (Part II), the consequences of doubling time (Part III) and the limits to resources (Part IV) are all interconnected components of a much larger concept — sustainability. There are more still to come. Together, they provide a basis for evaluating the challenges facing us during this new century if we continue to grow as we have been growing in both human population and resource consumption.

Because so many of the core concepts of sustainability are components of the basic training of in the Earth Sciences, Earth Scientists have a personal responsibility to make sure that these concepts and their interrelationships are understood and internalized by ourselves and "our neighbors" – or at least brought into the forefront of our consciousness. Natural processes are intricately related and changes in one process or parameter can feed back to other processes and parameters, often with unanticipated consequences. Events in the oceans such as temperature changes in the southwest Pacific affect the atmosphere, which affects the terrestrial hydrosphere and biosphere. Events in the lithosphere — mountain uplift; volcanic eruptions — affect the atmosphere, oceans and biosphere. Human activities affect all of these "spheres", even including the cryosphere; witness advances of glaciers, changing patterns of sea-ice flow, sea-level rise, permafrost stability, changes in snowfield area…

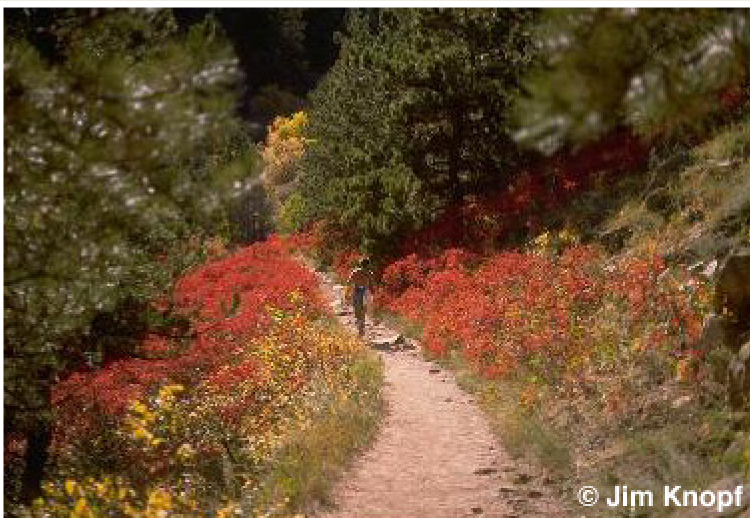
The separate lines of inquiry formulated by various disciplines of the Earth Sciences, when viewed as a whole, are mutually dependent and complementary. We now call this big picture perspective Earth Systems Science. But we can take one further step and see that when we discuss the human impact on Earth and its ecosystems, even Earth System Science is only a subset of the entire picture of Environmental Systems Science. Other areas of natural science, social science, political science, and all the other areas of human inquiry that aspire to the designation "science", contribute to the consequences of our decisions in the personal and public domains. In our exploitation of the Earth's endowments, we have the potential to unravel or tangle this complicated web if we fail to appreciate the interconnections.

Use the ideas in these essays in conversations with students, with colleagues at work or in other academic disciplines, with friends, and even with strangers – these are "our neighbors". The grass roots in a democratic system will require nurture if our common lawn, human civilization, is to have a future. Communicating our thoughts, understandings, and the spirit of inquiry as Earth Scientists can become a vital element of these interconnections, perhaps in unanticipated ways.

Part VI

ECOLOGICAL FOOTPRINTS AND CARRYING CAPACITY: MEASURING OUR IMPACT

A. R. Palmer, Institute of Cambrian Studies, Boulder, CO



Every one of us requires a finite area of Earth's surface to support his/her existence. This is our Ecological Footprint (Wackernagel and Rees, 1996). Its principal components are our food footprint, our wood products footprint, and our degraded land footprint.

If I eat potatoes, in the course of a year I consume a measurable quantity of potatoes. There is thus an area of potato production somewhere in the world that is dedicated solely to me for my annual consumption of potatoes. Ditto for every other terrestrial food product I consume. That's my food footprint. This footprint is not fixed in size. I can change it by changing my eating habits – beef carries a bigger footprint than chicken.

My use of printer paper, the packaging of the products I buy, the magazines and newspapers I read, the wood in my furniture and my home, and the firewood I consume if I have a fireplace, constitute my personal wood products footprint. This puts real demands on an area of the global forest that must be dedicated solely to me. However, this footprint must also include my share of the wood products in the infrastructure that supports me. I can change the overall footprint only a bit with decisions about my personal consumption.

My degraded land footprint is comprised of the area under my house and driveway. For others, it maybe a part of the shared area under our apartment buildings and adjacent parking lots. We also share a part of the land under our city streets, businesses and public buildings and under the industrial infrastructure that supports us, as well as a part of the land beneath our highways, railroads, airports and garbage dumps. I can’t do too much to change this, which is a reflection of our culture.

It is possible to calculate a semi-quantitative estimate of our food, wood products and degraded land footprints and thus a measure of our minimal land-use needs at current levels of consumption. If this level of "need", when projected to the global population, exceeds the available land areas of earth, we have a problem. On the other side of this coin, if we decide on the desirability of a particular level of consumption, we can get a rough idea of how many of us can be supported at this level by the land resources at our disposal – i.e., the carrying capacity of the land.

In addition to the "accountable" elements of our footprint cited below, there are other less tangible footprint elements represented by our use of fossil energy and water. Approximately 50% of the carbon dioxide we generate burning fossil fuels cannot be accommodated by existing terrestrial or oceanic sinks. If we had to create new forest to serve as a carbon dioxide sink, to keep the human contribution to atmospheric carbon dioxide from increasing, we would need to more than double the world’s area of forest – an improbable solution. And warming oceans will hold even less carbon dioxide than they do now. It appears that the human component of carbon dioxide buildup in the atmosphere will remain with us until we stop burning fossil fuels. The footprint effects of water use are more subtle. When the lower reaches of the Yellow and Colorado rivers, for example, run dry because of upstream human water use, this seriously impacts downstream ecosystems in ways that are difficult to measure.

I have calculated the accountable components of the per-capita Ecological Footprint for the United States (Palmer, 1999). Our food footprint, using figures from the U.S. Department of Agriculture and related sources is about 1.5 acres. In simple terms, this is obtained by determining yields in pounds per acre for each foodstuff. That number is easily converted to acres per pound. Data on our per-capita consumption of each foodstuff in pounds is also available. The per-capita area required for each foodstuff is then calculated by multiplying these two figures. The sum of the resulting areas is our per-capita food footprint. Similarly, our annual U. S. per-capita demand on the world’s forest for all wood products needs is estimated to be 0.04 to 0.05 acres. This sounds trivial, but that area cannot be reused until it has regrown. On average, this takes about 40 years. Thus the estimated area of forest that must be dedicated to each one of us to sustain our present level of wood products consumption – our wood products footprint -- is about 1.6 acres (40×0.04 acres). Our U. S. per-capita degraded land footprint is estimated to be about 0.4 acre. Therefore, the total ecological footprint for the average American is a minimum of about 3.5 acres.

Lets put this in perspective. Earth has about 22 billion acres of ecologically productive land. This is comprised of about 3.3 billion acres of arable and crop land, 8.4 billion acres of pasture land, and 10.1 billion acres of forest land. Not all of the arable land is of high quality, and improving agricultural productivity by use of fertilizers and insecticides, or shifting to monocultural forestry, affects ecosystems in other, often deleterious, ways. Expansion of land use in any of those categories can only be done at the expense of one of the other categories, and development of the land for human structures of all kinds competes for this same area. Not only that, but we have to share this land with the other organisms on Earth who might not be able to tolerate our land use ‘improvement’ measures, or to survive as a group as environmental fragmentation becomes extensive.

If we maintain our current footprint and the human population of 2050 (estimated at 9 billion) reaches consumption levels similar to ours, which is a practical goal for the developing world, humanity would need 13.5 billion acres of land for food production and 14.4 billion acres for wood products on a steady-state basis to be sustainable, and we would have degraded about 3.6 billion acres for human structures. For humans alone, excluding the needs of other organisms, there is not that much land available simply by considering these three computable sorts of personal footprints!

Furthermore, the food footprint calculations cited above used U.S. yields, which are significantly higher than average global yields. If global yields were used in those calculations, our food footprints would be closer to 3 acres. Earth’s carrying capacity for a population with 3-acre food footprints might be no more than about 4 billion people (12 billion acres of arable, crop and pasture land ÷ 3). Each year more of our most productive farmland is buried under human structures, and both good and marginal farmland becomes unusable due to poor farming practices, so even the estimate of a sustainable carrying capacity of 4 billion people eating and living as we do may be high.

The simple calculations cited above should raise some warning flags that humanity already has a problem with the demands we make on Earth. And we seem to be continuing our present course unabated! Refinement of footprint and carrying capacity figures should be an ongoing part of the process of evaluating and monitoring the sustainability of the human enterprise.

DEMONSTRATION 1. Have students estimate their annual consumption, in pounds, of various non-meat food items that they eat most often (beans, corn, potatoes, apples, etc.) – for meats, see Demonstration 2. On the Web there are data about U.S. food production where yields for most common agricultural products can be calculated in pounds/acre (sometimes with a little clever manipulation), and these figures can then be converted to acres/pound.. Multiplying the acres/pound figure by the student’s personal annual consumption in pounds for each foodstuff gives the area of the Earth dedicated to each individual for consumption of that food item. The Web also has tables of data on U.S. annual per capita consumption of various foodstuffs in pounds. The student can then compare her or his own footprint with the U.S. footprint for the same product and begin a discussion about whatever differences are found. The relevant websites are: www.usda.mannlib.cornell.edu and www.nass.usda.gov.

DEMONSTRATION 2. Do a similar exercise to Demonstration 1 but regarding the beef footprint, using the following data: Each beef animal on average needs 10 acres of pasture; when the animal goes to a feedlot, it consumes grain equivalent to 0.4 acre of a grainfield to reach the desired slaughter weight of 1,200 pounds. About half of that weight returns to the supermarket as the beef that we buy. Thus, 600 pounds of beef at the supermarket had a footprint of about 10.4 acres. What is the footprint of 1 pound? What is the per capita level of beef consumption, in pounds, in the U.S.? What is the student’s annual consumption of beef in pounds? Multiply the annual consumption in pounds by the footprint for one pound to obtain a beef footprint. Compare the two beef footprints, and also compare them with the footprints of the agricultural products from Demonstration 1. Develop a general discussion of ways in which the food footprint can be used to evaluate the impact that we make on earth just from our eating habits. How might the food footprint be used to evaluate carrying capacity?

DEMONSTRATION 3. Our footprints directly impact land areas that were balanced parts of the natural ecosystem prior to the advent of human activities. Have students consider what is lost or disrupted, versus what is gained, by conversion of former forests, temperate grasslands (savannah), or semi-arid prairie to human agricultural use or human habitations. How might we determine when ecosystem losses outweigh human gains?

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Wackernagel, M., and Rees, W., 1996, Our Ecological Footprint: Reducing Human impact on the earth: Philadelphia, PA, New Society Publishers, 160 p.

For a current discussion of Ecological Footprints with most of the important literature citations, check the March 2000 issue of the journal Ecological Economics (v. 32, no. 3, pp. 341-394),which can be found in many larger university libraries.

Part VII

SPACESHIP EARTH: THERE IS NO PLACE ELSE TO GO

A. R. Palmer, Institute of Cambrian Studies, Boulder, CO

Space travel has stirred our imaginations for more than a century and inspired not only writers of science fiction, and trekkies, but also the scientists and engineers of space agencies worldwide. At frequent intervals, presentations in various media speculate about human travel far beyond the international space station to other planets in our solar system in the not-too-distant future.

To some people, this could solve Earth's population problem because they believe we will be able to emigrate to other worlds when push comes to shove. Space travel may be the special privilege of a few adventurous astronauts, but as a solution to our earthly problems, there is need for a reality check.

Let's start with a trip to the moon and a look back to our Blue Planet – a spectacular view now common on many advertising pages. But look elsewhere in the Universe. Nothing else that we see looks any bigger than it did from Earth. Planets are still points of light, as are the stars and galaxies. We are a long way from even our nearest planetary neighbor!

And then there's simple math. Earth's current population (about 6 billion) is increasing by about 1% annually. The U.S. Census Bureau projects that by 2050 there will be a somewhat smaller rate of increase of 0.46%, and a probable median population of nearly nine billion people. The ANNUAL population increase in 2050 (9 billion X .0046) will be an estimated 41.5 million persons, down from the present annual increase of about 60 million. On a DAILY basis (41.5 million ÷ 365), population increase in 2050 will be about 115,000 persons, down from the present DAILY increase of about 170,000 persons. Daily permanent emigration of that many people, even given possible technological advances in space vehicles and propulsion by 2050, might be a bit optimistic.

For all practical purposes, we must internalize and make plans for Spaceship Earth as the only realistic habitation for humans. Bringing human occupancy of this planet into balance with available ecological areas and terrestrial and oceanic resources, must be one of our highest priorities if we wish a sustainable future for our descendants.

DEMONSTRATION 1. - Have your students check the Web for information about the energy and material requirements, including support infrastructure, for a single Space Shuttle launch. Have them consult the World Resources Institute's annual compilation of human demands for resources and estimate how emigration of all excess population, if possible, would affect the present crunch on Earth resources..

DEMONSTRATION 2. - Have the students calculate how far from Earth, within our solar system, an astronaut would have to travel so that Mars, or one of Jupiter's moons, would look the same size as the Blue Planet does from our moon. What does this tell us about the reality of regular daily exodus of humans (and their life support) on such trips?

Part VIII

WE ARE A PART OF, NOT APART FROM, THE GLOBAL ECOSYSTEM

A. R. Palmer, Institute of Cambrian Studies, Boulder, CO

Photo courtesy of early pioneer with a sample of alfalfa copyright by Denver Public Library.
See BASIN Gallery.

"Humans aren't the only species on Earth, they just act like it"

Prior to the agricultural revolution (about 10,000 years ago), humans had lived off the land for perhaps hundreds of millennia. Survival depended on knowledge of local ecosystems for hunting, food gathering, medical assistance and shelter. The passage of time was measured by natural seasonal cycles; the rhythm of life was the rhythm of the seasons. We were an integral and integrated part of the global ecosystem.

With the invention of agriculture and accompanying technological innovations, villages and finally cities developed, artisans appeared, and social structures and communications became more elaborate. Exploitation of natural resources for enrichment of the human enterprise became a part of the more urbanized cultures. There seemed to be no limits to those resources. The creative human mind and the advent of commerce found increasingly more sophisticated ways to obtain the resources and to use them. Thus, today, although we are still integral parts of the system, we are less integrated. We are somewhat analogous to the exotic species that disrupts the ecosystems into which it is introduced.

One of the tragic and unintended consequences of the exponential increase (Part III) in urbanization, particularly in the past century, has been the increasing isolation of human beings from the natural rhythms and conditions that both nurture and constrain them. This is especially true in the so-called developed world where, aided by the ease and rapidity of transport of goods, our city markets have fresh vegetables, fruits, milk and meat more or less continuously available. There is very little understanding among consumers of the unique combinations of soil, water, weather and climate that determine the seasons of harvest for the fruits and vegetables we enjoy directly, or of the processes which make it possible to bring meat and milk to our tables. There seems to be even less understanding of the complex interaction among elements of the lithosphere, hydrosphere, and atmosphere that sustain populations of fish in our oceans and lakes.

Many of us are far removed from our heritage as peoples of the land. As a consequence, we are dependent on specialized technology, skilled artisans, global commerce, and large-scale exploitation of the commons (Part I) for food, shelter, and clothing. Most of us have lost the personal knowledge needed to do even simple farming. That loss may come back to haunt us because large cities are the most vulnerable human habitats in a sustainable future. We, or our families, may have to learn again how to plant, nurture, harvest and hunt. We may have to re-learn how to live with the seasons and in balance with our surroundings.

The geological sciences have taught us that we live in a universe of change. This lesson is embodied in a beautiful paraphrase of a verse from the Qur'an (Sura 27; Aya 88), "In the presence of eternity, the mountains are as transient as the clouds". Geologic studies of the environmental record since the last deglaciation (about 13,000 years ago) show that this change includes global ecosystems (e.g. Ruddiman and Wright, 1987). Nature is quite dynamic and interactive. We need to understand that the complex of systems that makes up our present-day environment has never been steady-state.

Increasingly sophisticated biological studies demonstrate that all organisms share some common elements, if only at the genetic level. Although we humans seem to feel and act as if we are distinct from all other organisms in the web of life, this is not really the case. If we look back in geologic time (Part II), our self-determined uniqueness within the web blurs. This blur involves not only our biological relations to other organisms, but also the cultural development of our human species. We are truly a fundamental part of the global ecosystem.

The western cultural attitude that nature is to be "tamed" and that the environment is somehow an adversary is one of the roots of our conflicted response to the issue of sustainability (Berry, 1999). Once we come to terms with the imbalance we have created in the global ecosystem by failing to remember that our context is WITHIN that ecosystem, we can face the challenges of sustainability creatively.

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Ruddiman, W. F. and Wright, H. E., Jr., eds., 1987, North America and adjacent oceans during the last deglaciation: Boulder, Colorado, Geological Society of America, The Geology of North America, v. K-3, 501 p.

DEMONSTRATION 1. - Ask your class to discuss what knowledge they might need if they had to become personally responsible for their food, clothing and shelter and live in the countryside. If your community is already rural, ask the students what foods and other material goods they feel are essential to their lifestyle. How many of these can be obtained locally?

DEMONSTRATION 2. - Have the students determine the optimum size for a sustainable city in the region where you live, in terms of a variety of variables such as the true cost of energy required for transportation of goods and services, the distance between producers of food and clothing and the consumers, and the number of people required to provide for the basic needs of a single individual resident of the city..

DEMONSTRATION 3. - How has the natural landscape in your vicinity been modified by human activity? How has this helped or hindered your possibilities for a sustainable future? What actions can you take locally to ensure such a future?

Part IX

WE LIVE IN A WORLD OF CHANGE

Christine Turner, U.S. Geological Survey, Denver, CO and E-an Zen, Reston, VA

Photo of Flatirons copyright by Denver Public Library. See BASIN Gallery for more.

If it is true that our consumptive lifestyle, in combination with a burgeoning world population, is harming our ecosystems and the prospects of a sustainable future, what should we do? Some of us might want to restore the idealized halcyon days of yore, when human, technology-caused changes were slower and, we assume, less harmful.

Whether or not humans have in some time past lived more sustainably, we certainly are not doing so now, given the way that we are altering the earth's surface, water bodies, and atmosphere in support of our own material wants. However, we do not know whether we should, and how to, reverse, halt, or even slow the undesirable changes to our collective habitat.

If it is true that our consumptive lifestyle, in combination with a burgeoning world population, is harming our ecosystems and the prospects of a sustainable future, what should we do? Some of us might want to restore the idealized halcyon days of yore, when human, technology-caused changes were slower and, we assume, less harmful. Whether or not humans have in some time past lived more sustainably, we certainly are not doing so now, given the way that we are altering the earth's surface, water bodies, and atmosphere in support of our own material wants. However, we do not know whether we should, and how to, reverse, halt, or even slow the undesirable changes to our collective habitat.

Our uncertainty about how to take responsible action to mitigate planetary damage arises partly from our lack of agreement about the human contribution to environmental and climate conditions, and also about the ability of both the earth and its inhabitants to adapt to those changes. Geologists' traditional interpretation of earth's history told us that geologic changes affecting climate and ecosystems were relatively slow, allowing organisms to adapt, and that when these changes were too fast, life forms would transform or become extinct. In the geological past, there were times when "fertile" land was reduced to desert, when sea level rose and inundated lowlands, and when the air temperature increased to the point where animal and plant life were stressed. Nobody was there to protect the threatened species. Contemporary humans, in contrast, seem disposed to engineer the earth to suit our perception of "comfort" and "progress". We tend to view extinctions in the geologic record as the consequence of natural geologic processes, yet we resist the idea that either natural or human-enhanced or -induced changes might similarly affect our own species.

Contrary to the traditional interpretation of the geologic record, recent studies of ice cores have identified rapid fluctuations in climate over very short periods of time, from years to decades (Severinghaus and Brook, 1999). These data suggest that perhaps our perceptions of rates of change in the geologic past need to be revised. For much of the geologic past, our time markers are few and far apart. Actual rates of some changes may have been much faster than our present ability to define them. Even so, some changes related to the earth may be truly slow by human standards. How do we deal with these conflicting perceptions and realities of the rates of change?

The history of many human societies has been one of attempting to control or harness nature, with man using his ingenuity to build levees to contain rivers, build jetties to retard wave erosion, and maintain farmland in the face of water shortages. What are the long-term consequences of these large-scale, engineered interventions? Do they create more harm than the condition we were originally trying to forestall or ameliorate? Do they subject us to using materials and energy for perpetual maintenance of all that we build? Should we put our faith in technology as a panacea, or is that taking too large a risk for future generations, who must live with the results of our choices?

As aspiring members of a "civilized" society, we must examine our role as overseers and instruments of change on the planet. We can choose to continue our present rates of unbridled use of earth resources and our alteration of the earth's environments, or we can assume the role of responsible stewards. If our knowledge of the earth has expanded, so must our humility in the face of new theories of complexity, and the chaotic nature of natural phenomena. We have more evidence about the interdependence of all things natural, but less ability to develop precise predictions about the consequences of change. Presumably, if we share the broadest goal of maintaining a modest "comfort zone" for human habitation, we must also seek to learn where our intervention is necessary. We may need to reverse certain deleterious changes now happening to the earth system, based on reasonable scientific judgments and our collective value system.

The very realization that we cannot predict the future with certainty suggests that it behooves us to preserve our options – for ourselves, our fellow inhabitants of the planet, and for future descendants of all living species. We need to consider possible effects of large-scale, human-induced changes that might interact with natural processes and magnify the effects. For example, carbon dioxide from human activities could lead to global warming sufficient to cause major shifts in ocean circulation patterns. These shifts, in turn, would drastically affect the productivity of the agricultural land in the circum-Atlantic region (Broecker, 1996, 1997). The geologic record of the last 10,000 years shows that major changes in ocean circulation patterns could be rapid even by human standards (years to decades; see Broecker, 1997, and Bond and others, 1997). Do we understand that we may be contributing to such changes? Do we have a right to cause such major changes that could affect the habitability of large tracts of our planet? Should we try to remove at least the human-induced changes from the trends?

These are difficult questions, and involve our most basic values and responsibilities. As we acquire new, reliable data and new insight about earth processes and earth history, we are in a position to make better, informed choices about what changes we might cause or enhance in our habitat. For instance, should we continue down certain potentially harmful paths that accompany our current lifestyle choices? The geologic record shows that change is inevitable. Nevertheless, we can make use of our hard-won understandings of our earth, and the humility that should accompany such understanding. It will take both humility and the thoughtful use of the knowledge that we have acquired, and continue to acquire, to preserve our options for the future. We can thus challenge ourselves to become better stewards of a planet that we inhabit for only a brief geologic moment, for the benefit of future generations of man and of other inhabitants of the planet who cannot protect themselves.

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Severinghaus, J. P. and Brook, E. J., 1999, Abrupt climate change at the end of the last glacial period inferred from trapped air in polar ice: Science, v. 286, p. 930-934.

DEMONSTRATION 1. Describe two or three man-made changes in the natural world in your neighborhood. When were these made? For what reason? How have they affected the ecosystem and human activities? Are these changes "irreversible", i.e., would it take much longer to reverse them than your lifetime? Why do you say so?

DEMONSTRATION 2. Describe two or three NATURAL changes in the world that you observe, or have read about. Are these changes affected by human activities? How do these changes affect human welfare? How do they affect the local wildlife (and what is the composition of the wildlife)? How did you determine that?

DEMONSTRATION 3. Find out how geologists determine the rates of change of one natural phenomenon (for example, siltation of a pond, or the rate of sediment deposition along a river), and discuss how precise and how reliable these determinations are.

Part X

WHAT DO WE MEAN BY A SUSTAINABLE WORLD?

E-an Zen, Reston, VA


Photo of sunflower from Community Gardens by Mark McCaffrey

In earlier articles of this series, we saw that if on our Earth, which is a materially closed system, population and consumption are allowed to grow exponentially, then the basis for a sustainable world of which we are a part will be destroyed (Palmer, 2000a). But what do we mean by a "sustainable world"?

Sustainability requires humans to learn to live within our means. Major factors, such as human population size, biosphere robustness, resource stock, food supply, and environmental quality must remain in balance, on a global scale. This state of balance must last long enough so that it will not be merely a blip on the curve of unsustainable growth (Zen, 2000a). Even though we might not really attain that balance, we must move in that direction if humanity and the ecosystem are to survive.

Because the Earth is a closed system, a sustainable world is not compatible with "sustainable growth" (Palmer, 2000b). A closed system might conceivably accommodate "sustainable development," a term popularized by the World Commission on Environment and Development (1987; the "Brundtland Commission"), but how that could be done is not obvious (see, however, Daly and Cobb, 1994, Appendix). Another way to look at the issue is to consider the idea of a transition towards sustainability (Board on Sustainable Development, 1999), which, however, needs a complementary discussion of the destination, or end-state, of that transition.

Most of us probably accept the proposition that everyone should have access to fair shares of food, water, shelter, and health care. Surely we want to sustain a healthy environment and a robust ecosystem. Certainly we want to promote equity among societies, to reduce disparity between the rich and the poor, to protect human dignity, and to minimize state terrorism. While moving toward that goal, we need to protect the capability of future societies to make real choices for themselves, whatever their social organization or cultural and religious affinity. If these goals seem incompatible with steady growth of population and our present rates of material consumption, then we need to do some careful soul-searching about our national obsession for ever-increasing economic throughput (Demonstration 1).

To take sustainability seriously requires us to reexamine our ideas about growth, social equity, consumption, and "standard of living", that putative indicator of social well-being. Sustainability is constrained at both ends of the economic throughput. At the starting point it is constrained by the availability of resources, and at the end point by the accumulation of the products of their use: waste, loss, and pollution. Consumption and systems of material distribution, the processes that link those two ends, go to the heart of the matter. The scale of global consumption, both public and private, depends on population size and on the intensity of resource use.

What are some of the implications of sustainable consumption of resources (Zen, 2000b)? For those living at a subsistence level, to consume is to survive. This is true today for about a third of the world's human population. For them, amenities beyond survival are largely luxury. Such "luxury", while arguably marking civilized societies, too easily degenerates into extravagance. One possible approach to "sustainable consumption" is to support and strengthen the "ecological middle consumers" (Durning, 1992). Globally, the increasing number of people living in abject poverty, combined with the number among the better-off who lapse into ostentatious consumption, threaten to endanger the future existence of the middle consumers. Equity and social justice may well be keys to a durable and sustainable world.

To discuss sustainable consumption, we need to know why people consume beyond their civilized needs. Kates (2000) eloquently explores the intricacies of the issues and gives useful references. Several essays in Crocker and Linden (1998) discuss the motivations behind consumption. Why are commercial ads such a powerful driving force? Is it the attempted fulfillment of daydreams (Campbell in *ibid*), the emulation of neighbors, or a display of enhanced wealth? If display is the motivating force, then it might help to substitute the assurance of material capability for the actual implementation (Sen, in *ibid*). For instance, I don't have to stay aloft all the time in order to prove that I can afford all the plane trips I want to take. Such a shift in measuring the standard of living, which Sen calls a "positive freedom," might help to bring sustainability closer to reality.

In the end, whether we can attain equitable sustainability depends on the aggregate effects of individual choices (see Part XII.) Institutions can provide incentives and even role models, but every one of us must make his/her own decisions. Certain choices may require us to give up things, or even some of our dreams, for the good of "others" which include those without voices and those yet unborn (Ashby, 1993). A suggestive metaphor is the choice that would face you in an overcrowded lifeboat (the Titanic; the ecosystem). If taking on one more passenger would swamp the boat, do those already aboard have a right to fend off newcomers? Awful though such choices appear, we in fact face them daily. How we live and how we act affect species extinction, environmental quality, and local and national attitudes toward immigrants and refugees. The scale and complexity of real societies may help to buffer our individual impact, yet among all the living species, humans alone are capable of being guardians for global sustainability buttressed by justice. We must act because we alone can choose to make a difference.

DEMONSTRATION 1.

Ask your students to order their priorities for approaching their own versions of a sustainable society, and to explore and develop their arguments through class discussions.

DEMONSTRATION 2.

Discuss the reasons people buy things. Ask students to trace the history and rationale on examples of their own decision-making, and the fate of the things bought (a good target might be Christmas presents or an electronic gadget).

DEMONSTRATION 3.

Explore the issues involved in Lifeboat Ethics, and relate the metaphor to the future of a livable world. In the lifeboat example, a person could conceivably solve the personal moral dilemma by leaving the boat, making room for another; but would that solve the problem? Are there better metaphors to depict the situation facing our crowded Spaceship Earth? (hint: using the Titanic theme, other metaphors might include: better navigation; better preparation against disasters; more and better equipped lifeboats). What moral and value issues do our personal choices entail (see Paddock and Paddock, 1967 and Hardin, 1999)?

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Part XI

AN EARTH SCIENCE PERSPECTIVE ON THE CULTURAL CONTEXT OF SUSTAINABILITY

George W. Fisher, Johns Hopkins University, Baltimore MD

Most of the essays in this series have highlighted the Earth science dimensions of sustainability. The previous essay (Part X), however, noted that our ability to live sustainably will depend upon the aggregate effects of individual choices about how to live, and so suggested the need to expand the scope of our discussion (Zen 2000). The importance of choice means that the shape of a sustainable society will be determined not just by our scientific understanding of how Earth works, but also by our values - our sense, individually and communally, of what is right and what is wrong.

One way to approach the question of values is to characterize the shift to a sustainable way of living as a necessary step in our cultural, moral, or spiritual evolution (Fisher 2000a, 111). For humans, cultural evolution has replaced biological evolution as the primary way of responding to environmental challenges because it is so much faster than biological evolution and because we are often tempted to believe that we can manage cultural evolution (Stebbins 1982, Ayala 1998, and Sirageldin 2000). Although the two kinds of evolution depend upon different mechanisms, there are illuminating parallels between them. Both require mechanisms for preserving current ways of living and transmitting them to the next generation. In biological evolution, these functions are provided by the system of genetic instructions; in cultural evolution, by the system of cultural mores. Both kinds of evolution require ways of inducing variation in the way we live.

Biological variation is produced by mutation, and cultural variation by social innovation, often by groups on the margins of society. And, to be successful, both kinds of evolution require ways of retaining changes that are beneficial and rejecting those that are harmful. Biological retention results from a more effective phenotype, cultural retention from more effective social systems. Successful phenotypes and social institutions both diffuse through the population as the result of personal decisions, spreading slowly at first, and eventually dominating the population (see Demonstration 1).

Seen in this way, human values lie at the very heart of cultural or moral evolution. They constitute the fundamental fabric of social and religious institutions that tend to preserve current ways of living. Religious institutions, especially, can stabilize value systems for thousands of years. The ten commandments are one example. But value systems can and do change. Attitudes toward slavery, human sexuality, and the use of military force have changed dramatically in this country within the last two centuries. Values change by a complex process that depends upon individual decisions about what is right and what is wrong. But individual decisions are not made in a vacuum. They are influenced by the value systems prevalent in the community within which deciding individuals live. And yet communal value systems really have no existence apart from the evolving personal and institutional consensus of the men and women who constitute the community.

Individual decisions are related to community values in a way reminiscent of the link between individual species and the global ecological system. No advanced species can exist alone. All depend upon the ecological system to supply needed nutrients and energy and to dispose of waste products. And yet the global ecological system has no existence apart from the species that constitute the system. Like the ecological system, the cultural system is hierarchical, operating simultaneously at the level of the family, the local community, the national community, and the global human community. As in ecological systems, local influences tend to be felt most intensely. But the effects of communities at higher social levels are important also, especially over longer time periods. As global communications become more rapid, global cultural systems seem likely to become more influential.

This image of ourselves as embedded in a complex, interactive, hierarchical system with both ecological and cultural dimensions provides both a rich ground for scientific debate (Sober and Wilson 1998) and a wealth of insight into the probable complexity of value systems and cultural institutions. For example, it suggests the vital importance of cultural diversity as a source of social innovation. And it suggests that we need to be suspicious of values proposed as absolute. What seems good from the perspective of one cultural group (or species) may seem harmful from the perspective of another. It also suggests that good is to be found in a judicious balance between the welfare of individual groups (or species) and the welfare of the global cultural (or ecological) system, rather than the dominance of one over another. This sense of balance suggests that Nature is more attuned to complex, "both/and" solutions that the "either/or" positions that so often emerge from philosophical discourse. It suggests, for example, that the debate between those arguing for an anthropocentric view of environmental ethics and those favoring an extreme eco-centric view may be resolved by adopting strategies that benefit humans *and* the ecological system rather than those that benefit either at the expense of the other.

For the Earth science community, this image provides a familiar starting point for discussion with social scientists, ethicists, and theologians about the issue of sustainability, and suggests how a deep understanding of Earth science may contribute to understanding the cultural questions implicit in sustainability as well as the ecological questions. For all of us, this image suggests that the sense of humility, awe, and wonder that emerge from both the scientific and religious views of nature (Fisher 2000a, b, and DeWitt in Hope and Young 1995) provides an appropriate place to ground our reflections on sustainable living.

DEMONSTRATION 1

Experiment with the Innovation Diffusion Model of Alan AtKisson (1991) to sense how cultural innovation can diffuse through a model group.

DEMONSTRATION 2

Have your class read a set of essays that advocate anthropocentric and eco-centric perspectives on environmental ethics such as those in Chapters 7 and 9 of Botzler and Armstrong (1998), then invite the class to discuss the strengths and weaknesses of both positions in light of their understanding of how the global ecological system works.

DEMONSTRATION 3

Ask your class to read passages from the work of Matthew Fox, John Muir, Aldo Leopold, Saint Francis, other eloquent nature writers (see Botzler and Armstrong 1998 for examples), or from the Bible (try Psalm 104). Then invite them to reflect on their own experiences of nature and the feelings that those experiences elicited in them.

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Part XII

WE HAVE THE OPTION OF CHOICE: THE FUTURE IS UP TO US

E-an Zen, Reston, VA, A.R. Palmer, Boulder, CO & P.H. Reitan, Buffalo, NY

In this series of essays we have focused on key elements that comprise the issue of sustainability -- the central issue that faces humanity in the 21st century. It should be abundantly clear that to continue as if the world has unlimited resources to support an expanding economic system, and unlimited space for all life forms in addition to humans, is to invite the calamity of a ruined environment and exhaustion of many key resources, which would affect the ecosystem of which we are an integral part. Because we all share the global Commons of forests, agricultural lands, atmosphere and oceans, as well as more regional Commons (e.g. rivers, wetlands, wilderness areas), we will also all share the consequences of such a calamity (Hardin, 1968; Palmer, 2000).

Our future thus hangs in the balance. But we humans have one thing going for us: we are sentient and reasoning beings; we have the gifts of vision, of imagination, and of social structures that allow concerted action. Unlike other life forms that inhabit the Earth, we can choose to make a difference in our future. We can choose to change the focus of our value systems, and emphasize stewardship rather than exploitation of the global Commons. Even though each of us individually can only make a small contribution to the sustainability of the Earth as a habitat, in the aggregate humans can, through changed social values, significantly improve our collective prospect for an enduringly habitable world. To do that, however, we must agree on the needed changes in the ways we think and conduct our lives, and we must act on our resolutions on the basis of both enlightened self-interest and altruism (see Palmer, 2000; Zen, 2000; Fisher, 2000, also Meadows and others, 1992).

How to bring about the necessary changes? This series of articles has advocated that we and "our neighbors" should become aware of the major issues of sustainability, and think about them. The authors have tried to avoid advocating specific actions beyond the broad and obvious (reduce consumption, reduce rates of growth, etc.). Social changes, to be beneficial and sustainable, must be carefully considered and made, in our political system, by common consent. They should be reversible, lest things do not go as intended; they should probably be locally based, so as to improve communication among stakeholders and reduce the risk of failure through lack of understanding and support (see AtKisson, 1999; National Research Council, 1996).

Each of us probably can think of physical and policy changes that would bring closer to reality a program of sustainability. For such changes to work, however, we also need to make perceptual modifications, including changes in our personal value systems and challenges to our habits of thinking (see also Kates, 2000). The draft Charter from the International Secretariat of the Earth Charter Campaign (2000) contains a good summary of the issues involved. Here, we suggest a need to re-examine some of our entrenched values and attitudes, such as:

- Economic growth as an innate virtue and as an adequate index of social health.
- Indefinite extension of human life expectancy as a virtue even though it aggravates the population problem.
- Conspicuous consumption, rather than frugality, as the socially desirable norm of behavior.
- Equating "change" with "human progress", with its corollary that what humans <u>can</u> change, humans <u>should</u> change.
- Equating a more opulent material life with an intrinsic improvement in the standard of living.
- Assuming that science and technology are adequate to "fix the problem" for society, and that scientific knowledge is adequate by itself for understanding the complex human issues and the pathways to their solution.
- Assuming that humans have a license to exploit and use the non-human world with little or no ethical restraint.

Wise home owners maintain their houses in such a way as to minimize the risk of fire and they do not wait until after their home is leveled by fire before buying a fire insurance policy. A faulty electrical system in a home may be a real fire hazard; repairing the system immediately may prevent a catastrophe. Working toward sustainability - preservation of the global ecosystems -- is analogous to reducing the fire hazard. For sustainability, however, the insurance policy is to prevent or mitigate damage rather than to indemnify victims after the damage.

A year ago, the world engaged in a large-scale exercise to verify compliance of computer codes with the Y2K turnover. The motivation was simple: to prevent a massive collapse of systems of electronic information, data storage, and services that people perceive as useful to their ways of living. Although the consequences of such a failure would be miniscule compared to the consequences of failing to achieve sustainability, stakeholders invested billions, perhaps hundreds of billions of U.S. dollar equivalents to ensure Y2K compliance, by and large willingly.

Choosing to pursue a sustainable future through stewardship of the global Commons will at times require us to give up some cherished ways of doing things and may be personally painful. Sustainable human societies, however, cannot be brought about through coercion, but through people seeing the need and willingly acting upon it. In our political system, this will mean having informed citizens who by their votes and their buying power will support courageous political and business leadership in this transformation (Ashby, 1993).

To be motivated to move toward new and sustainable patterns of behavior requires, first, recognition that the threats to the adequacy of resources and the health of ecosystems are real, and second, that the goals and aspirations of individuals and of societies can be moderated. Because sustainable human societies are inseparable from healthy Earth systems, humans must accord value to the non-human world as well. Science, environmental philosophies, and religions (Fisher, 2000), though different in many ways, can come together in support of stewardship of the Earth system. We need to seek out common ground and cultivate ways to work together toward this enterprise of global sustainability. Surely this work will constitute the most important insurance policy we could ever buy.

DEMONSTRATION 1.

What other prescriptions can you find for the idea of a sustainable world, and what actions are implied by these other prescriptions? Check up on Internet sites for these alternatives, and discuss how they differ or agree with one another and with the ideas expressed in these articles.

DEMONSTRATION 2.

Ask your students to put down, in their own words, what is meant by "sustainability". Can this state of affairs be accomplished within the scale of a town, a county, a State, or the United States alone? Discuss the need to enlist other members of the society and how to motivate them.

DEMONSTRATION 3.

Ask your students to list the five things each of them considers essential for accomplishing global sustainability. What bearing each item has on that goal? Which of these things can be done by individuals, and which of them must be done in concert with others? How would one go about getting started?

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