Symbiosis Between the Earth and Humankind

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I was born and raised in the farming country of the Ile de France, north of Paris. This is a part of the earth that has been occupied and profoundly transformed by human beings since the late Stone Age. Before it was inhabited, the region was covered with forests and marshes, and it would return to this state of wilderness if it were not for the human presence. Now that it has been humanized, however, it consists of a complex network of prosperous farmlands, tamed forests and rivers, parks, gardens, villages, towns, and cities. It has long been heavily populated and has continuously supported various forms of civilizations. While it has repeatedly experienced destructive wars and social disturbances, it has remained ecologically diversified and economically productive. From the human point of view, it is more satisfying visually and more rewarding emotionally—for me and most people—than it would be in the state of wilderness. It provides a typical example of symbiosis between humankind and the earth.

The historical development of the region where I was raised has certainly conditioned my ecological philosophy. It has convinced me that human beings can profoundly alter the surface of the earth without desecrating it and they can indeed create new and lasting ecological values by working in collaboration with nature. In this article, I shall focus my remarks on the creative aspects of the interplay between human beings and the earth.

I know, of course, that many human interventions into nature have been destructive; history is replete with ecological disasters. I know also that many industrial and agricultural practices of our times have distressing ecological effects and are likely to have frightening consequences in the future. However, I do not find it useful to elaborate on these dangers because they are well known. Instead of describing the manifestations of the ecological crises and of repeating once more that further environmental degradation can be minimized only by conservation measures, I take a more constructive view of the interplay between humankind and the earth. I shall consider how the practices of environmental conservation might be complemented by prospective policies of environmental creation.

For thousands of years, human beings have been engaged in creative transformations of the wilderness and of humanized environments, but the process has been greatly accelerated and intensified since the 19th century. One of the psychological effects of the Industrial Revolution was to encourage the belief that any kind of change was justified if it was economically profitable—even if it caused a degradation of human life and of environmental quality. During recent decades, however, there have been signs of a reversal in this psychological attitude. For the sake of convenience, I take the middle of the 20th century as the watershed in the social view of the relationships between human beings and the earth.

In 1933, the city of Chicago held a World's Fair to celebrate its hundredth anniversary. The general theme of the fair was that the increase in wealth and in the standard of living during the "Century of Progress" has been brought about by scientific technology. The guidebook to the exhibits had a section entitled "Science discovers, Industry applies, Man conforms," and the text proclaimed "Individuals, groups, entire races of men fall into step with . . . science and technology." There could not be a more explicit statement of the then prevailing belief that the real measure of progress is industrial development, regardless of consequences.

Scientific technology is even more creative in 1976 than it was in 1933. Yet, no one would dare state today that humankind must conform to, or fall in step with, scientific or technological dictates. The present view is rather that industry must conform to human nature and be managed within strict ecological constraints. The desire for technological innovation and for industrial expansion is now checked by an equally strong concern for the long-range consequences of human interventions into nature.

The following examples illustrate that the concern for social and ecological consequences is not incompatible with creative human interventions into natural systems.

Artificial Ecosystems in the Temperate Zone

Among people of Western civilization, the English are commonly regarded as having a highly developed respect and appreciation of nature; but the English landscape, admirable as it is, is far different from what it was in the state of wilderness. It is not the native landscape, only one which has become familiar because it has been progressively shaped from the primeval forest by centuries of human intervention. Roadsides and riverbanks are trimmed and grass-verged, trees no longer obscure the views but appear to be within the horizon, foregrounds contrast properly with middle distances and backgrounds. Much of the English landscape is indeed so humanized that it might be regarded as a park or a vast ornamental farm.

In England, as in many other parts of the world, the prodigious and continuous efforts of settlers and farmers have created an astonishing diversity of ecosystems that appear natural only because they are familiar, but that are really of human origin. For example, the enclosures so characteristic of East Anglia were created in the 18th century to facilitate certain types of agricultural improvements. At that time, the farming country was divided by law into a patchwork of semirectangular fields, each 5 to 10 acres in area, often without much regard to the natural contour of the land. The fields were divided by drainage ditches and straight lines of hawthorn hedges, and trees were planted in regular rows. This famous landscape is thus a very artificial human creation. When it first came into being, in fact, it greatly shocked farmers, nature lovers, and landscape architects. Within a very few generations, however, it has evolved into a pleasing and highly diversified ecosystem; its ditches and hedges harbor an immense variety of plants, insects, song birds, rodents, and larger mammals. It has come to be regarded as a "natural" environment.

While the enclosure type of landscape

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was developed for a certain kind of agriculture, it is poorly suited to modern practices. As a result, ditches, hedges, and trees must now go in order to make possible the creation of larger tracts of land, more compatible with the use of high-powered agricultural equipment. This change is destroying the habitats for the many kinds of wild animals and plants that lived in the hedged enclosures, but the open fields will certainly develop their own fauna and flora and, furthermore, have the advantage of permitting large sweeps of vision.

Thus, the ecological characteristics of an environment are determined not only by geographic and climatic factors but also by sociocultural imperatives. In addition, the genius of the place is profoundly affected by purely cultural values, as is illustrated by the great English parks created in the 18th century.

The English landscape architects transformed the humanized land of East Anglia by taking their inspiration from bucolic but imaginary landscapes painted by Claude Lorrain, Nicholas Poussin, and Salvatore Rosa. They obviously did not believe that "nature knows best," but instead tried to improve on it by rearranging its elements. They eliminated vegetation from certain areas and planted trees in others; they drained marshes and channeled the water into artificial streams and lakes; they organized the scenery to create both intimate atmospheres and distant perspectives. In other words, they invented a new kind of English landscape based on local ecological conditions but derived from the images provided by painters.

The English parks are now the envy of the world. However, as can be seen from 18th-century illustrations, they were then far less attractive than they are now. The planted trees were puny, the banks of the artificial streams were bare and raw, the masses of vegetation were often trivial, and, in any case, were poorly balanced. The marvelous harmony of scenic and ecologic values that are now so greatly admired did not exist in the 18th century except in the minds of the landscape architects who created the parks. The sceneries composed from the raw materials of the earth acquired their visual majesty and came to fruition only after having matured with time. Their present magnificence symbolizes that human interventions into nature can be creative and indeed can improve on nature, provided that they are based on ecological understanding of natural systems and of their potentialities for evolution as they are transformed into humanized landscapes.

Planning for the Ecological Future of Semidesertic Areas

Every part of the world can boast of humanized lands that have remained fertile and attractive for immense periods of time. From China to Holland, from Japan to Italy, from Java to Sweden, civilizations have been built on a variety of ecosystems that have been profoundly altered by human intervention. Many of these artificial ecosystems have proved successful even in regions not highly favored by nature. In Greece, for example, a large olive grove in a valley near the Delphi site has been under continuous cultivation for several thousand years; many rice paddies of tropical Asia also have been successful for millennia. Israel, which was once the land of milk and honey, then became largely desertic after Roman times, has once more achieved agricultural prosperity as a result of skillful ecological management, including irrigation and reforestation.

In our own times, the development of the world's arid regions will continue to require the creation of new artificial ecosystems. The oil countries of the Middle East are now wallowing in petrodollars, but the wealth underground will virtually disappear within 30 to 40 years. To prepare for the future, the income now derived from oil must be invested in the development of human and material resources that will remain productive after the wells have dried up. To this end, some Arab countries have initiated programs aimed at determining what kinds of crops and livestock suitable to semidesertic conditions can be introduced and improved. Giant irrigation programs, focused on desalinated water, are also being considered in the hope of converting several million acres of sand into agricultural land.

Since irrigation projects of such magnitude will probably be ecologically unsound, it has been suggested to create in the desert self-contained cities so designed as to be able to grow their own food, perhaps in greenhouses located on the roofs of buildings. The economy of these hypothetical cities would be based not on scarce and unreliable water supplies, but on the abundant sunlight that can be used to produce solar energy for the development of intensive agriculture and of certain specialized industries. By concentrating agriculture and industry in a limited area with a fairly high population density, most of the desert could be kept as wilderness—a natural resource that may be much in demand when the earth becomes overpopulated.

The most interesting aspects of these approaches to the development of arid regions is not their technical boldness but a vision of the future in which a transient form of natural wealth—oil—would be converted into agricultural, industrial, and social creations of lasting value. Whatever the financial resources available for these projects, however, the ultimate success of any venture will depend on the creation of artificial ecosystems designed within the constraints of local environmental conditions.

Ecological Aspects of Renewable Resources in Energy and Materials

A century ago, wood was the fuel used to heat most homes, as well as to fire steam engines and even locomotives. In our times, fossil fuels and nuclear fuels have almost completely displaced wood for such uses and several other sources of energy are under consideration. It is not impossible, however, that trees and other plants will again become important sources of energy; they may also come to compete with petroleum and coal as a source of raw materials for the chemical industries. The potentialities of these uses can be surmised from the magnitude of the role played by the vegetation of natural areas (wilderness) in the economy of the earth.

Only 3 percent of the incident solar energy on the earth is fixed by the photosynthetic activity of plants, yet the amount of energy produced by the total vegetation of natural areas, in any given year, vastly exceeds the total amount used by humankind for its daily life and for driving even its most extravagant technologies. The precise figures are not available, but what matters is the magnitude of the difference.

It has been estimated that organic materials equivalent to 840 trillion kilowatt-hours are produced yearly on the whole surface of the earth by photosynthesis. Of this grand total, about two-thirds is produced by the land vegetation, especially the forests; the other third is fixed by the vegetation growing in water, especially the various wetlands, the marine estuaries, and the areas of ocean plankton. Surprising as it may seem, the contribution of agriculture to the energy derived from photosynthesis is rather small—much smaller than one-tenth the contribution of the natural areas. Cultivated lands produce only the equivalent of 50 trillion kilowatt-hours per year, and from this must be deducted the enormous amounts of energy used in the form of fossil fuels by modern agricultural techniques.

In contrast to the 840 trillion kilowatt-hours produced yearly by photosynthesis in natural areas, the total energy consumption by humankind was only 70 trillion kilowatt-hours in the year 1973. Another way of formulating this relationship is that the present annual production of biomass on the land areas alone is of the order of 100 billion tons (dry weight) with an energy equivalent about six times greater than the current utilization of energy by all human activities. These figures indicate that the energy needs of the world and even of the United States might be met in theory by devoting only a small fraction of the land areas to this purpose—as could the production of organic materials derived from plants to serve as feedstocks for the chemical industry. In practice, of course, many agricultural and chemical techniques have to be developed or refined before vegetation can be used on a significant scale to provide a renewable source of energy and of substitutes for petrochemicals. But the problems as a whole have been sufficiently well defined to warrant some long-range ecological speculations.

Plant materials have an obvious advantage over coal and petroleum, that they are renewable. Furthermore, their use as sources of energy and of chemicals would probably result in less environmental contamination than the use of fossil fuels, especially with regard to sulfur compounds and carbon dioxide—an environmental hazard of unknown magnitude; since plants use this substance for their growth, the result is a closed cycle instead of accumulation, as is the case with organic fossil fuels.

One of the objectionable aspects of vegetation as a source of energy and chemicals is that it is more diffusely distributed and more difficult to transport than coal or petroleum. This will probably require that the biomass be handled in fairly small industrial units, a limitation that has some advantages. One of them is that it may favor social decentralization. Another is that decentralization will facilitate the return to the land of the waste products from plant materials which can then serve as plant nutrients.

Granted that the techniques for production of energy and chemicals by photosynthesis are still in a primitive stage, the ecological prospects are sufficiently encouraging to justify a vast program of research in fields pertaining to the production and utilization of plant materials, such as photosynthesis; plant physiology; plant genetics, including the production of new artificial species; ecological association of different plant species; and development of techniques for the fermentation of plant materials to produce methane and for their hydrogenation to produce combustible liquids. While the new technologies that could thus be developed are not urgently needed in the United States, they might be of immediate practical importance in some countries that have abundant vegetation but lack other resources. Furthermore, the production of energy and materials by photosynthesis points the way to long-range global solutions based on biological techniques compatible with the ecological health of the planet.

Creative Stewardship

There are different kinds of satisfactory landscapes: on the one hand, the various types of wilderness still undisturbed by human intervention; on the other, the various humanized environments created to fit the physiological, esthetic, and emotional needs of modern human life.

There will be less and less wilderness as the world population increases, but a strenuous effort must be made to preserve as much of it as possible, for at least two different reasons. As was mentioned earlier, the wilderness is the greatest producer of renewable sources of energy and of materials—as well as of biological species—and is, therefore, essential to the maintenance of the ecosystems of the earth. Furthermore, human beings need primeval nature to reestablish contact now and then with their biological origins; a sense of continuity with the past and with the rest of creation is probably essential to the long-range sanity of the human species.

In practice, however, most people spend most of their time in humanized nature. They feel most at ease in landscapes that have been transformed in such a way that there exists a harmonious interplay between human nature and environmental forces, resulting in adaptive fitness. The quality of this interplay requires a constant expenditure of efforts because any environment, left to itself, tends to return to a state of wilderness no longer adapted to the physiological and mental needs of modern man. Even though a landscape has been economically productive and esthetically attractive for many generations, it will be invaded by brush and weeds as soon as it is neglected. The rapid degradation of abandoned gardens, farmlands, or pastures is evidence that humanized nature cannot long retain its quality without constant human care. Conservation practices are as essential for the maintenance of humanized nature as they are for the protection of the wilderness.

The stewardship of the earth, however, goes beyond good conservation practices. It involves the creation of new ecosystems in which human interventions have caused some changes in the characteristics of the land and in the distribution of living things, to take advantage of potentialities of nature that would remain unexpressed in the state of wilderness. Throughout history and even prehistory, humankind has tempered with blind ecological determinism. Forests have been cut down or managed, certain swamps have been drained, and agricultural productivity has been increased by practices designed to modify the physical structure, chemical composition, and microbial life of soils. The fauna and flora have also been managed by introduction of new plant and animal species, selection and improvement of strains, crop rotation, control of weeds. Ever since Neolithic times, human life has taken place in managed environments.

Experience shows that most natural situations can be converted into several different ecosystems involving different kinds of relationships to humankind. As was mentioned earlier, East Anglia was at first completely forested, then it was cultivated in open fields, then the fields were converted into hedged enclosures, and the tendency is now to return to large open fields. In the American Southwest the Navajos, the Zunis, and the Mormons have established viable relationships with nature based on very different ways of livelihood and different social relationships; these three ethnic groups relate to the same kind of soil under the same sky but march to different social drums in their own artificial ecosystems. Until our times, the photosynthetic activity of plants has been used chiefly for the production of food, fibers, and building materials, but there are now projects to use it for the production of various kinds of fuel and of feedstocks for the synthetic chemical industries.

Nature is like a great river of materials and forces that can be directed in this or that channel by human intervention. Such intervention is justified because the natural channels are not necessarily the most desirable, either for the human species or for other species. It is not true that "nature knows best." It often creates ecosystems that are inefficient, wasteful, and destructive. By using reason and knowledge, we can manipulate the raw stuff of nature and shape it into ecosystems that have qualities not found in wilderness. Many potentialities of the earth become manifest only when they have been brought out by human imagination and toil.

Just as the surface of the earth has been transformed into artificial environments, so have these in turn influenced the evolution of human societies. The reciprocal interplay between humankind and the earth can result in a true symbiosis—the word symbiosis being used here in its strong biological sense to mean a relationship of mutualism so intimate that the two components of the system undergo modifications beneficial to both. The reciprocal transformations resulting from the interplay between a given human group and a given geographical area determine the characteristics of the people and of the region, thus creating new social and environmental values.

Symbiotic relationships mean creative partnerships. The earth is to be seen neither as an ecosystem to be preserved unchanged nor as a quarry to be exploited for selfish and short-range economic reasons, but as a garden to be cultivated for the development of its own potentialities of the human adventure. The goal of this relationship is not the maintenance of the status quo, but the emergence of new phenomena and new values. Millennia of experience show that by entering into a symbiotic relationship with nature, humankind can invent and generate futures not predictable from the deterministic order of things, and thus can engage in a continuous process of creation.

NEWS AND COMMENT

Carter as Scientist or Engineer: What Are His Credentials?

Jimmy Carter, if he beats his Republican opponent in November, will become the first American president, at least in recent times, who can lay claim to any significant degree of scientific and technical knowledge. Carter's claims are in fact quite substantial, even if in at least one aspect they appear to be somewhat in excess of what is strictly justified by the record.

In his standard campaign speech Carter used to introduce himself as a "nuclear physicist and peanut farmer." The term "nuclear engineer" is now preferred at the Carter campaign headquarters in Atlanta. "It's a matter of semantics whether you regard there being an important difference between the two words as a pressing matter," a Carter spokesman told *Science*.

In describing himself as a nuclear physicist Carter probably meant simply to imply that he knows a fair amount of nuclear physics, which indeed he does. But the term is misleading insofar as it implies he has a degree in the subject. The nominee's only degree is the Bachelor of Science he got from the Naval Academy at Annapolis in 1946. The program lasted for 4 years, with roughly half the time being devoted to scientific subjects such as mathematics, physics, and engineering, and half to other pursuits such as foreign languages and seamanship. There was no course on nuclear science.

Carter's nuclear expertise stems from the year he spent at the conclusion of his naval career in the atomic submarine program. From November 1952 to October 1953, when he returned home to Plains, Georgia, he was assigned to the Atomic Energy Commission's Division of Reactor Development at Schenectady, New York. His task was to train himself and the prospective crew of the *USS Sea Wolf*, the second nuclear submarine to be built. As senior officer of the crew, Carter says in his biography, he taught the men mathematics, physics, and reactor technology. He also helped General Electric workers construct the prototype power plant for the submarine at a site near the Knolls Atomic Power Laboratory. He and another officer "studied special graduate courses in reactor technology and nuclear physics at Union College."

Does this experience make a "nuclear engineer" of Carter? The "special graduate courses" lasted only one semester. One of the two professors who taught the courses was Kenneth Baker, now dean of faculty at St. Lawrence University in Canton, New York. Baker has lost his course records, cannot remember Carter, and does not know if it was he or the other professor who taught him. The courses, Baker recalls, were introductions to nuclear physics and reactor engineering. They were intermediate between the undergraduate and graduate levels. "No one who took that program could be classed as a nuclear engineer—it was at quite an elementary level," Baker says.

But the term engineer is used in a range of senses. A professional engineer is often understood to be someone who has undergone a 4-year course in a particular engineering specialty, such as electrical, mechanical, or civil. Carter is not an engineer in this sense. But from his course at Union College and the practical work at the Knolls Atomic Power Laboratory he probably picked up as much experience as is possessed by many who call themselves engineers. "The officers in that program participated very directly in the construction process [of the nuclear reactor] and they certainly functioned on board as engineers—anybody who examined the question would say that Carter is an engineer," comments National Science Foundation official Joel Snow, who from 1958 to 1961 used to be an instructor in the nuclear power program that Carter attended. Snow adds that the program, under Hyman Rickover, was a "very rigorous experience" for its participants. "Rickover required phenomenal things from his officers. He required them to be polymaths and to penetrate into every aspect of the problems they were studying," Snow remarks.

The practical expertise acquired by Carter and his team seems to have been in demand outside the navy. "Because of our security clearance and experience in the field," Carter relates in his autobiography, they were asked to help disassemble an experimental nuclear reactor at Chalk River, Canada, which had gone out of control and suffered a meltdown. The radiation intensity, Carter says,

> "meant that each person could spend only about 90 seconds at the hot core location. . . . When it was our time to work, a team of three of us practiced several times on the mock-up to be sure we had the correct tools and knew exactly how to use them. Finally, outfitted with white protective clothes, we descended into the reactor and worked frantically for our alloted time.