ECOLOGY AND SOCIAL ACTION *

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That there is an important connection between ecology and social action is now self-evident. Ecology has become the subject of local bond issues, of state and national legislation, of Presidential pronouncements and of a United Nations Conference. Environmental issues are at stake in a current strike against a major oil company; less formal actions — petitions, boycotts, letter-writing campaigns about nearly every major intrusion on the environment — are everyday events. There seems little reason to doubt that there is some connection between what ecology tells us about the degraded quality of life, and the social action needed to improve it.

However, what is much less evident is the kind of social action that is needed to remedy the faults revealed by ecological insights and how that action can be accomplished.

A vast gap separates ecology and social action. Ecology is a science, which is presumably objective and immune, in its truth, to human wishes. In contrast, social action is specifically intended to express what people want : for example, peace, freedom, a decent quality of life. As a result of this fundamental conflict the area between ecology and social action is a thicket of intellectual pitfalls, moral traps and political dangers.

Among the more difficult questions are these : Since, like all living things, people are subsidiary parts of an ecosystem, should not human action be governed by the principles of ecology ? Or, do the obviously superior intellectual powers of human beings relative to other members of ecosystems allow them to escape the ecological imperatives, to be governed instead by principles of morality or politics ? Finally, if it is indeed true that human society must be governed by ecological principles — which are laws of nature not subject to change by the most powerful political force — does this not lead to a system of rigid controls over human behavior, to political repression in the name of ecology ?

These are difficult, troublesome issues. Nevertheless, the need to understand them is overriding and we must accept, I believe, the duty to venture into this wilderness and learn how to bridge the gap between the wisdom of ecology and the urgency of social action. I can only hope here to suggest — in the most tentative terms — how one can begin to grapple with these kinds of questions. The entire area has so many different faces that a variety of approaches are possible. My own plan is to begin with ecology and work outward from that base toward the wilder reaches of the terrain in which ecology and social action meet.

Ecology — the science of the interdependence of living things and the environment which is their habitat — tells us that everything that lives on the earth requires for its survival suitable interactions with other living things and with the non-living environment. A simple, basic, example is the terrestrial cycle : plants (grass, let us say) are eaten by terrestrial animals, (such as cattle); the latter's organic waste, deposited on the soil, is incorporated by microorganisms into humus, a store of organic nutrients; slowly, other microorganisms convert humus to inorganic nutrients (nitrate and phosphate for example); these, taken up by the plants, together with carbon dioxide, are transformed, through the energetic events of photosynthesis, into organic matter, which feeds the animals — and so forth. Ecology reveals no known exceptions to the rule that every living thing which survives on the earth must serve as a fitting member of some stable eco-system. Within each ecosystem each living member must act in a way which is compatible with the continued existence of that system and therefore of the organism itself. Such closed, circular, systems will break down and place their living members at mortal risk if they are disrupted or too heavily stressed.

These arrangements have developed during three billion years of biological evolution. In that time, living things have tried out innumerable possible arrangements of their elaborate internal chemistry, selecting from them a set of compatible processes which are fantastically smaller in number than the number of possible ones[1]. As a result, a substance normally absent from living things, such as mercury or DDT, ought to be regarded as a kind of evolutionary reject and likely, on these grounds alone, to be incompatible with the present chemistry of life. This is the sense in which "Nature knows best", a rule which has been grossly violated as we have inflicted mercury and other metals and an entire alphabet of noxious synthetic substances on the ecosphere.

This much seems clear, and, in my opinion, indisputable. It is equally clear and indisputable that man is a species of animal with specific environmental requirements — for plant and animal organic matter as food, for oxygen, pure water and a suitable range of temperatures — all of these wholly, or in large part, provided by the actions of living things. There was a time, perhaps 18 or 20 years ago, when it was possible to claim without very much opposition that man's special capabilities — as exemplified by technology — could free us of dependence on other living things for food, fiber and oxygen; that the future would be science-fiction come true, with people or whole cities encased in sparkling domes on some distant planet, free of the cares of the body or of the stewardship of a fragile Earth. The environmental crisis has put an end to this notion, not merely by its propagandistic force, but because the crisis has required us to learn some basic scientific truths.

We have had to learn, for example, that an organic fiber synthesized chemically from petroleum is no great technological bargain, for it largely repeats, (with a foolish waste of non-renewable fossil fuels, energy and human effort), what an appropriate ecosystem, based on the cotton plant for example, does with great thrift and efficiency using only that remarkable, renewable, non-polluting source of energy, the sun. The total dependence of human beings on the ecosphere has also, unfortunately, been amply demonstrated by the outcome of the negative experiment to which we have blindly committed the globe by proceeding for so long to use the earth's resources without any regard for the integrity of the environment.

Given that man, like any other living thing, *must* conform to the ecological imperative, there is a great temptation to reduce the relation between ecology and social action to a deceptively simple form : Good social action is simply good ecology. Prescriptions for social action then readily follow : if people are crowded into cities beyond the capability of a restricted space to supply them with food, and good air, and biologically to assimilate their wastes — let them return to the land, where they once lived in harmony with the natural cycles. If, because of an imbalance between fertility and the food supply, the land they live on is not sufficient to sustain the human population at its present size, let the inevitable laws of ecology operate — with an assist from philanthropic foundations and pharmaceutical companies — reducing the population to an ecologically stable size.

This kind of solution has the double allure of simplicity and of an apparent grounding in the firm terrain of science rather than the shifty sands of politics. However, on further examination the approach turns out to be neither simple, nor soundly based on ecology. This becomes evident if we take a closer look at the ecological principles themselves. Let us examine, for example, the operational meaning of the idea that man, as a terrestrial animal, ought to fit into the appropriate natural ecosystem. However let us not merely *accept* that this statement is true, but seek to discover *why* it is true, and what bearing that might have on social action.

To return to the earlier example, let us place human beings in their appropriate place in the terrestrial cycle, to simplify matters a bit, as a predator on the cattle. Now organic matter moves from poant to cattle to man, and the latter's organic waste enters the soil microbial system, so that — as before — the cycle retains a closed, integrated form. All is well, ecologically.

In this system, viewed simply in terms of the basic elemental cycles (e.g.: carbon, nitrogen, and phosphorous), the human being serves, fundamentally, as a means of converting cattle organic matter into soil organic matter. This is a process which the cattle can do quite well without human help, but which retains its original ecological soundness even if the human transit intervenes.

Clearly, if people move off the land into the city, then the cattle (or more realistically, food in general) must be shipped into the city — where it is converted by the population into sewage, which is delivered, under present arrangements, in one form or another not to the soil but to surface waters. The latter process — modern sewage treatment — is, of course, one of the classical ecological failures of current technology. It manages at once to disrupt the soil cycle (since nutrients derived from the soil are no longer returned to it) and to stress the aquatic cycle (which now has imposed on it organic matter, or the inorganic nutrients derived from it by treatment, at a rate beyond the ecosystem's natural assimilatory capacity).

Given these rather primitive but nevertheless meaningful ecological data, we can ask : What constraints does ecology properly place on the relevant social decisions, such as the distribution of population between land and city ? Clearly in order to restore ecological integrity it is not essential that *people* be returned to the land; what is required is only their waste. The present fault, then, is not the movement of the people to the city, but a specific feature of the present technology for supporting that arrangement (i.e. disposal of waste to surface waters rather than the soil). This ecological defect could be readily rectified, for example, by the construction of pipelines to return sewage, intact, to the land, a technological innovation which would simultaneously restore the integrity of the soil cycle and remove the stress on the aquatic ecosystem. The ecological imperative does not require that people live on the land.

Of course even such ecologically sound technological processes do require the expenditure of energy (to transport both food and sewage) beyond that involved in the original land-based cycle — a point which is often raised by advocates of the "return to nature" as evidence that no human intervention is really free of serious ecological damage. Even the mere consumption of non-renewable fuel (apart from the effects of mining and burning it) violates the ecological concept of balanced inputs and outputs, let alone the simple common sense of avoiding self-destructive acts. We must ask then : In what ways is the expenditure of energy by human beings (beyond the 2500 or so calories per day which is each person's essential biological allotment) incompatible with ecological integrity ?

The answer is plain enough : such energy expenditures are ecologically unsound if one or more of the following conditions exist :

(a) The fuel is non-renewable (e.g., oil, gas, coal or uranium); or

(b) The products of combustion are not natural constituents of the ecosystem into which they are intruded (e.g., radioactive wastes from nuclear reactors or SO_2 and mercury from the combustion of fossil fuels); or,

(c) If combustion products which are normal in the environment are produced at rates not readily accommodated by the natural system (e.g., CO_2 produced at a rate which upsets the earth's thermal equilibrium through the greenhouse effect or the comparable effect on surface waters of heat released to a power plant's cooling stream).

Notice that these requirements do not automatically preclude all expenditures of non-biological energy. For example, given the appropriate technology, solar energy incident upon the earth could be converted to electric power directly. In ecological terms this would represent only a redistribution of incident energy on the earth's surface, a process which occurs naturally in the form of wind, clouds, and precipitation. That such technological systems are practical is shown by Zener's recent proposal to build devices, to be floated in tropical oceans, for the generation of electric power from the marine thermal gradient (which is, of course, a local expression of the absorption of thermal energy from the sun). Zener concludes that, at a price which would be competitive with the cost of nuclear power, such a system could generate about 60 billion kilowatts, or about 30 times the energy consumed by the U.S. in 1970, with a total ecological impact represented by a 1°C change in the surface temperature of tropical oceans.[2]

Other examples of ecologically-sound technologies — sufficiently new and innovative to excite the most starry-eyed engineer — come readily to mind. For example, Zener proposes to use power from marine thermalgredient generators to electrolyze water, yielding oxygen and hydrogen. Hydrogen is, of course, an ecologically perfect fuel, yielding only water on combustion, and adaptable to various applications where electric power is not suitable. Given this base, one could restore natural fibers, rubber, wood and oil to their proper place in the economy, as the most energetically thrifty and pollution-free means of producing such goods, even retaining power-(hydrogen) driven agricultural machinery for the purpose. All this could rid us of much of the petrochemical industry and its works : photochemical smog, and the other automobile pollutants; synthetic detergents, plastics and fibers; the synthetic additives and non-foods that we are now forced to eat because they are made economically feasible by the very size of this huge productive system. Other technologies can be made compatible with the ecological imperative by the simple expedient of reducing their size; a good example is a small electric generator designed to operate in the free flow of a moderately swift river (no dam, no silting) which generates enough power to supply the needs of a farm house.

Here are some other examples of ecologically sound technology : a rigorously "organic", but nevertheless tended, garden; a windmill; a home moderately equipped with electric appliances, but powered by electricity generated by solar energy; a newspaper, made from wood pulp (by a method which does not release toxic materials into the environment) imprinted with biodegradable ink, so that once read it can be composted. In each case, the technologically mediated process is part of a natural one : the organic garden and the newspaper rearrange, but do not disrupt, the movement of materials through the terrestrial ecosystem; the windmill and the solar-powered home rearrange, to a degree, the normal transfer of solar energy from one place on the earth's surface to another.

I do not intend to propose here an ecologically sound but technologically advanced Utopia. Clearly, some unavoidable human interventions will carry environmental costs that must be balanced against the attendant benefits. Nor do I propose that we can abrogate the self-evident rule that the capacity of the global ecosystem is ultimately finite, and will not sustain an ever-growing population of any species.

Rather, what emerges from these considerations is a modest but nevertheless decisive conclusion : that human, socially-motivated interventions — technologies — which are reasonably useful relative to our present technological accomplishments and yet conform to the requirements of ecology, are possible. Ecological sanity does not *necessarily* require that we return to the pre-technological state. The same result can be accomplished by a technological design sufficiently informed by ecology. So long as the need to obey the laws of ecology is honored, human society can retain the freedom to choose *how* these requirements are met. We can choose whether we wish to meet the ecological imperative by returning people or sewage from the city to the land; by ending all non-biological energy production, or by converting to solar energy.

To clarify matters, it occurs to me at this point that it might be helpful if I were to offer an amendment to the slogan "Nature Knows Best". A new one, more cumbersome, but less subject to misinterpretation, might be : "Nature knows best *what* to do; and people ought to decide *how* best to do it". In this statement, the "how" is technology, properly governed, of course, by the principles of ecology, not to speak of chemistry and physics.

Thus, somewhat laboriously, we have arrived at a fundamental statement about the relation between man and nature, which was long ago expressed much more elegantly and incisively by Friedrich Engels in the form "Freedom is the recognition of necessity". Freedom of human choice — social action — becomes possible in so far as the requirements of natural law are recognized. We can fly through the air, *provided that* we give proper attention to the principles of aerodynamics. We can move people from the land to the city, *provided that* the relationship between the two is governed by the principles of ecology. In sum the principles of ecology provide a necessary but not sufficient condition for the determination of effective social action.

Thus, once a given ecological requirement can be specified (e.g. that organic matter derived from the soil ecosystem must be returned to it), it is likely that alternative social means for meeting that requirement can be devised. This, I believe, is the most meaningful interpretation of Engels' phrase. It means that we can have the freedom to solve an ecological problem in alternative ways — *if we understand its cause.*

But causation, in ecology, is not a self-explained concept, and the sense in which I use it here needs some discussion. In an intact, natural ecosystem, the concept of causation is fundamentally meaningless. This is due to the circularity of ecosystems. Causality is a property of a linear system, in which event A determines (is the cause of) B, B determines C, and so on. Suppose, however, we carry the progressions linearly to event N, and then arrange matters so that N determines A. Now, of course, it makes little sense to speak of A as "the cause" of B, since B, acting through the cyclical progression of events, is itself an equally effective "cause" of A. This is, of course, the situation in a natural, intact ecosystem.

However, in a *disrupted* ecosystem the natural cycle is converted from a circular system to a linear one, restoring some sense to the concept of cause : the "cause" of the resulting change in the ecosystem can be thought of as the locus, in the cycle, at which the normal event is disrupted. This might be regarded as the one real virtue of a man-made ecological disruption — at least it considerably simplifies the problem of causality.

An example might be useful here. In a normal forested water shed, a well-known hydrological cycle (to focus on this single aspect of the system as a whole) is at work. Rain and snow fall on the forested land; this sustains the growth of vegetation, which by the arrangement of its aerial and subterranean parts protects the soil from erosion under the force of heavy rains. Moreover, the biological process (transpiration) which governs the relationship between the trees' roots and branches draws water effectively from the soil back into the air. The remainder gradually seeps to the valley, forming a stream which finds its way downward to the sea. Here in the sun's heat, much water is evaporated to form clouds and generate wind — which together eventually return the water to the forested land, where it can embark, once more, on the cycle.

An all-to-familiar way in which this cycle is disrupted by the hand of man is lumbering. If the trees are removed, the soil is less stable, and exposed to the full force of rain with no water diverted by transpiration a heavy silt-laden flood engulfs the valley. This change in the ecosystem presents itself to us in a specific and intrusive way : the river floods.

Now consider two contrasting methods of analysing this problem — of seeking its cause and devising a cure. Looked at superficially (charity suggests that we do not say by whom), the problem is seen as too large a flow of water through a river valley. In turn this suggests an equally superficial solution : a dam is erected upstream to hold back the springtime flow, and to release it more gradually later on. But the solution is temporary, because the dam silts up, losing its retentive capacity and floods, often worse than before, recur.

Properly analyzed as to cause, the problem becomes quite different : it is discovered that the reason *why* the river flow has increased is further upstream than the flood. Because it has been denuded of vegetation, the soil of the watershed has lost its former capacity to retain the precipitation that it receives; the proper solution, of course, is not a dam but reforestation of the upstream area.

The lesson here seems evident: to remedy successfully a man-made ecological problem, its effect – however evident and immediately important – must be *traced back, step by ecological step, until the point in the natural cycle is found at which the thoughtless hand of man intruded.* This is the cause; here the cure – restoration of the ecological link – must be made. Within these requirements technological choices are open to us: the original vegatation can be regrown or replaced by faster-growing trees, or even by pasture. All this is, of course, only the familiar practice of soil conservation.

The recent history of the environmental crisis is replete with similar examples of ecological problems which have been superficially analyzed and "solved" in ways which merely worsen them. The failure of modern sewage treatment has already been mentioned. This technology has failed because it is designed to correct a symptom of the problem, (oxygen depletion) rather than its cause, which is the diversion of organic matter that belongs in the terrestrial ecosystem into the aquatic ecosystem. Another example is given by the increasingly futile effort to control automobile smog by means which side-step its fundamental cause – that modern cars have become generators of nitrogen oxides, which trigger the smog reaction. Present exhaust controls regulate everything *but* nitrogen oxides and simultaneously increase fuel consumption; while smog levels may fall, concentrations of nitrogen oxides – which are themselves toxic – rise sharply. Then there is the matter of recycling bottles by melting them down to make new ones, at considerable expenditure of energy (and its resulting pollution), when a rather simple, more fundamental analysis reveals that at far less cost in energy, recycling can be accomplished by simply washing the bottles and reusing them.

Thus, the failure to seek out the real cause of an ecological problem is likely to result in actions which worsen rather than improve it. At the least, our experience with current ecological problems should serve as a warning that in such complex situations there is often a tendency to confuse symptom with cause, a failure which is very likely to produce a superficial and necessarily faulty solution.

How do these lessons apply to the problem of social action ? Here we need to deal with a system which, like the ecosphere itself, is a fabric of interconnected processes: the technological processes which intrude upon the environment; their use as a means of satisfying the needs of the population; the economic considerations which govern the design and use of technologies; the political processes that determine for whose benefit the natural and technological resources are used, which in turn influences the design of technology and the intensity of resource exploitation; the social and ethical values that are embodied in all of the foregoing. Or, to refer again to the earlier example : why were all the trees cut down ? To what material end ? For whose profit ? Under the protection of what political power ? In the name of what social or moral values ? In sum, what fault in this system brought the logging machines onto the land and set off the ecological events that culminated in a flood ?

With this as a background let us examine some of the social actions that have been proposed for crucial ecological problems. One of these is overpopulation.

On its face this has all the appearances of a straightforward ecological problem : People, like all living things, have an inherent tendency, if provided with suitable environmental circumstances, to multiply geometrically. Since one of their essential requirements, a supply of food, cannot grow in amount at a comparable rate, population is certain to outgrow its food supply - unless some countervailing process intervenes. One can argue about details in specific instances, but taken as a general summary of the problem the foregoing statement is one which no environmentalist can successfully dispute.

Thus far the problem. We turn now to its analysis and possible solution. Among those concerned with social action, perhaps the best known analysis of the population problem is Garrett Hardin's paper "The Tragedy of the Commons".[3] The nub of Hardin's argument is contained in the following passage :

> "The tragedy of the commons develops in this way. Picture a pasture open to all. It is to be expected that each herdsman will try to keep as many cattle as possible on the commons. Such an arrangement may work reasonably satisfactorily for centuries because tribal wars, poaching, and disease keep the numbers of both man and beast well below the carrying capacity of the land. Finally, however, comes the day of reckoning, that is, the day when the long-desired goal of social stability becomes a reality. At this point, the inherent logic of the commons remorselessly generates tragedy.
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> "As a rational being, each herdsman seeks to maximize his gain. Explicitly or implicitly, more or less consciously, he asks,

'What is the utility to me of adding one more animal to my herd ? '

"...the rational herdsman concludes that the only sensible course for him to pursue is to add another animal to his herd. And another; and another... But this is the conclusion reached by each and every rational herdsman sharing a commons. Therein is the tragedy. Each man is locked into a system that compels him to increase his herd without limit — in a world that is limited. Ruin is the destination toward which all men rush, each pursuing his own best interest in a society that believes in the freedom of the commons. Freedom in a commons brings ruin to all."

Based on this analysis, Hardin then goes on to conclude that "Freedom to breed will bring ruin to all" and urges that breeding be controlled by "mutual coercion, mutually agreed upon".

Thus, in this analysis of the population problem Hardin concludes that it is caused by unrestrained breeding, the countervailing force — the death rate — having been weakened, in his view, by social progress. It follows that the solution is a reduced birth rate. How far into the problem does this analysis penetrate; has Hardin uncovered the cause or only a symptom ?

Hardin asserts that given the freedom to do so human beings will inevitably produce children faster than the goods needed to support them. As it happens, this assumption is amenable to an historical, scientific analysis. In most modern societies (with the notorious exception of Nazi Germany), the freedom to breed has been deeply engrained in social mores, and strongly protected by law. Hence, if Hardin is correct, we should find, in the history of these societies, evidence that population growth is largely governed by a simple relationship between death rate and birthrate, and that the latter has been governed by biological factors rather than social ones.

The trends in world population are the subject of a large and complex literature, which covers a vast array of subjects : reproductive physiology, and its psychological background, the sociology of families and larger groups, agricultural and industrial technology, economics, world trade, and international politics. Demographers have delineated a complex network of interactions among these various factors. This shows at once that population growth is not the consequence of a simple cause and effect relationship between birthrate and death rate. Instead there are circular relationships, in which, as in an ecological cycle, every step is connected to several others.

Thus, while a reduced death rate does of course increase the rate of population growth, it can also have the opposite effect; since families often respond to a reduced rate of infant mortality by opting for fewer children. Thus, a negative feedback develops which tends to modulate the effect of a decreased death rate on population size. Similarly, although a rising population increased the demands on resources, which worsens the population problem, it also stimulates economic activity. In turn, educational levels improve. This tends to increase the average age at marriage, culminating in a reduced birthrate — which mitigates the pressure on resources.

None of this fits the assumption made in "The Tragedy of the Commons". Birthrate is not at all free of social controls, when the "freedom to breed" is assured. In particular, there is a powerful social force which, without compulsion — or even persuasion — leads people voluntarily to restrict the production of children. That force, simply stated, is the quality of live : a high standard of living, a sense of well being and of security in the future. A simple test for the quality of life is infant mortality; in *both* industrialized and developing nations, as soon as infant mortality declines to a minimum level of about 12-20 per 1,000, there is a sharp decline in birthrate, which begins to approach death rate — and the condition for a balanced population[4]. Thus, human societies have developed a social means of bringing the birthrate into balance with the death rate. It consists of the improvement of the standard of living. Birth control is, of course, a necessary adjunct to this process; but it can succeed — barring compulsion — only in the presence of a rising standard of living, which of itself generates the *motivation* for birth control.

It seems to me that the failing here is the same as that exhibited by the flood-control engineer : elevation of a symptom to the status of a cause. Like the rising waters of a flood, a growing population is a symptom of a deeper set of causes. In both cases the problem is not likely to be solved for long unless action is directed toward the cause rather than the symptom.

It is particularly illuminating to note that a faulty analysis of the deeper causes of the population problem restricts the range of apparent social actions that might be taken to solve it. The simplicity and poverty of Hardin's solution to the population problem contrasts sharply with the complexity and intellectual richness of the literature of demography. Given the multiplicity of alternative influences on population growth, one can only wonder why it can only be regulated by the singular method of imposing direct controls on the birthrate. It seems to me that the reason is ecological myopia — a failing to look beyond the most immediate simple symptom toward the far richer realm of its cause and alternative cures.

As a second example I should like to consider the problem of defining the arena of social action designed to correct the problem of environmental pollution, specifically as it has developed in an advanced country such as the United States. To begin with let me review briefly the analysis of the origins of the United States pollution problem which I have already discussed elsewhere[5].

The general problem is to account for the sharp post-war rise — about an order of magnitude or more in size — in pollution levels in the United States. It can be shown that the major reason for this rise in pollution levels is neither the concurrent increase in population size or in affluence (goods produced per capita). Rather it is due chiefly to post-war changes in the technology of agricultural and industrial production. In that period there has been a striking replacement of natural materials (cotton, wool, silk, wood) by man-made plastic materials; there has been a remarkable increase in the amounts and varieties of other man-made synthetic materials (e.g., detergents, pesticides, herbicides); automobile engines have been redesigned to operate at increasingly higher compression ratios; electric power, generated in very large power plants, has increasingly replaced geographically-spread home heating directly by fuel; materials, such as aluminum and certain chemicals, the production of which is intensely power-consumptive, have increasingly replaced more power-sparing materials; at the same time there have been striking changes in agricultural practice, especially the increasing tendency to feed livestock separate from pastures, reduced crop rotation, large increases in the use of inorganic fertilizers, and the massive introduction of synthetic pesticides and herbicides. These changes, which are intense and coincide with the period of rising pollution, result from the massive introduction of new technologies, especially in the period following World War II.

These new technologies are drastically unsuited for accommodation by natural environmental processes; they therefore lead to environmental pollution. Manufacture of plastics in place of natural fibers means the use of fuel-generated power (with its attendant pollution) in place of the power of sunlight, absorbed by plants, and transmitted by natural (and therefore non-polluting) environmental processes. Synthetic man-made products, such as detergents, plastics and pesticides, which are outside (and therefore incompatible with) the coordinated system of biochemical processes that living things have evolved, are therefore not assimilated by natural environmental cycles; consequently they accumulate as pollutants. The increased manufacture of synthetic organic chemicals has resulted in increased production of chlorine — an important ingredient in many organic syntheses. In turn, the use of mercury in electrolytic production of chlorine has also increased. This is the source of much of the mercury pollution in United States inland waters. The development of the modern high-compression gasoline engine, with its attendant high temperature, causes oxygen and nitrogen in the air to combine as nitrogen oxides, a substance otherwise rare in nature and not readily accommodated by natural environmental processes. Nitrogen oxides are the basic cause of smog. Intensification of power generation in large electric plants results in the production of several major substances, which are incapable of being accommodated by natural environmental cycles and therefore become pollutants, especially sulfur dioxide, nitrogen oxides, and (in the case of nuclear plants) radio-isotopes. The new agricultural techniques have disrupted soil cycles, so that natural soil fertility is reduced and fertilizers — which contribute to water pollution — leach into surface waters. The new pesticides disrupt the balance between insect pests and their natural predators and parasites — with the resultant appearance, increasingly, of insecticide-induced outbreaks of insect pests and the accumulation of insecticides in wildlife and man.

These basic changes in industrial and agricultural production and in transportation account for most of the exponential increase in pollution levels in the United States since 1945. This process — the tendency to displace technologies which are relatively benign environmentally, with new ones that sharply increase the ratio of pollution emitted to goods produced — much more than increased population and per capita consumption is the "causal relationship" that couples productive activities to the environment.

But this is only one point in the complex web of social and economic processes that operate in the United States productive system. To avoid the trap of dealing with a symptom rather than the cause, we need to press further and ask : how can we account for the striking tendency of new technologies to be far more stressful toward the environment than the older ones which they replace ? This is a very complex issue, and I shall consider only one of the relevant factors here. This is the evidence that the chief driving force behind this counter-ecological trend in the development of modern productive technologies is that production is generally motivated by the desire for short-term gain (in the United States economic system, private profit; in the Soviet system, meeting the production quota). As a result, changes in the design of industrial and agricultural production and transport are governed not by environmental compatibility, but by the short-term gains which they promise.

The new counter-ecological technologies, which have displaced the older less-polluting ones, are also more profitable than their competitors. Thus, the profit in making detergents is considerably greater than that derived from the manufacture of soap; truckung is more profitable than railroads; and to quote Henry Ford II, "minicars make miniprofits". Here than, is a *benefit* — to the entrepreneur — from the social costs of environmental pollution.

All this is a strong reminder that ecological problems and environmental degradation, are not free-floating phenomena, but are firmly built into the operation of the economic system. They represent a debt to nature, a mortgage incurred by productive operations, which — now that it must be repaid — is going to cost someone something. A simple rule common to ecology and economics is at work here : "There is no such thing as a free lunch".

When we speak of environmental pollution as a "debt to nature", it is well to ask who benefits from the debt and who has to pay it.

When, as in the United States, an economic system operates in such a way as to concentrate a major part of its wealth in the hands of the relatively few, then any major effort to combat environmental degradation is very likely to *widen* the gap between the rich and the poor.

Consider an example — the often proposed idea that the costs of environmental control or improvement can be met by "passing them along to the consumer". Suppose, as predicted, the cost of exhaust controls adds several hundred dollars to the price of a car. To the rich person who buys an expensive car, the added expense is easily borne; but to the poor person the added cost may make the difference between having a car or not having one. Similarly, if as anticipated reduction in the use of agricultural chemicals increases the cost of producing food, it will be the poor who would suffer most from the added burden.

Consider another example, the difference in access to air--conditioning among different economic classes. Recent United States census figures show that the poorest families (less than $ 3,000 income per year) operate 1/4 as much air-conditioning per household as the richest families (more than $ 15,000 income per year). Recall that air-conditioning inevitably *adds* heat to the environment (as does every use of energy, for whatever purpose). Thus we have a situation in which the wealthy residents of a city, while enjoying cool surroundings, add to the city's temperature — making the environment that much worse for the poor people who cannot afford an air-conditioner. Again the poor are forced to pay an extra share of the environmental debt to nature.

The outcome of these considerations is this : where, as in the United States, there are sharp economic inequities — between entrepreneur and worker, and between the rich and the poor — any serious effort to combat environmental degradation is likely to intensify these inequities, to widen the gap. There appears to be no middle ground; if, as we must, we resolve to end the environmental crisis, we will need to choose between two paths — one leading toward a more just distribution of the nation's resources and wealth, and the other toward further intensification of the present unequal and — in my view unjust — distribution of wealth.

Thus, when any environmental issue is pursued to its origins, it reveals an inescapable truth — that the root cause of the crisis is not to be found is how men interact with nature, but in how they interact with each other — that, to solve the environmental crisis we must solve the problems of poverty, racial injustice and war; that the debt to nature which is the measure of the environmental crisis cannot be paid, person by person, in recycled bottles or ecologically sound habits, but in the ancient coin of social justice; that, in sum, a peace among men must precede the peace with nature.

I should like to conclude by returning briefly to the questions raised earlier. First let us remind ourselves that although human beings — like all living things — are indeed subject to the laws of ecology, they are sharply set apart from the rest of nature by their *understanding* of these laws. Like grass and cattle, we are members of a terrestrial ecosystem; but unlike grass and cattle we do, after all, comprehend the nature of the ecosystem to which we belong and — belatedly, it is true — know that we must maintain its integrity. Recognizing this necessity, we become free to choose among alternative, ecologically equivalent ways of meeting it. Living on the land as part of the terrestrial ecosystem, or living in a city which is suitably integrated into it by means of a sewage pipeline, are, at least to a first approximation, ecological equivalents. For that reason, ecological considerations are not a suitable basis for choosing between these alternatives; rather, the choice is a matter of personal judgement, of social values, or of political wisdom.

In this way, by recognizing that we must conform to the ecological imperative, we become free to exercise a personal or political choice as to *how* that is to be done. Our capacity to understand ecology frees us from the narrow singularities which govern the ecological behavior of all other organisms and opens up a broad array of options. These range from the survival of the aboriginal Bushman in an incredibly harsh terrestrial system by means of a marvelously intimate understanding of its ecological features, (which he disturbs as little as possible), to the feasible if still unrealized productive system based on devices — windmills, solar heaters, thermoelectric generators, sewage pipelines, and compost heaps — which are human artefacts, technologies, if you like, but ecologically sound ones.

Thus, once we recognize that human beings are not bound to a singular ecological solution, but can choose among a variety of optional ones, social action — which is, after all, the process of choosing among such options — becomes a reality. It is encouraging that this view of the relation between ecology and social action is, in political terms, liberating; that it calls for societal arrangements which enable political choice; that it fosters democracy.

If, in contrast, one accepts a view which elevates ecology from its true position as an aspect of biological science to a principal of social governance the political consequences are repressive rather than liberating. Examples of this tendency are not hard to find. Garrett Hardin, who would have us governed by the principles of ecology in order to avoid the "tragedy of the commons", finds it necessary, when he turns to the requisite social action, to speak of coercion, and to suggest in one astonishing passage that :

> "How can we help a foreign country to escape over-population ? Clearly the worst thing we can do is send food... Atomic bombs would be kinder. For a few moments the misery would be acute, but it would soon come to an end for most of the people, leaving a very few survivors to suffer thereafter."[6]

Another example is the *Blueprint for Survival*[7] — a detailed, step by step plan to transform British society according to the principles of ecology. The plan cites a former U.S. Attorney General, John Mitchell, on "crime in the cities", concluding that "crime is part of the price of affluence" and specifying a system of elaborate control over where and how people live. Yet, curiously, the plan fails to tell us who will be in charge of this elaborately "orchestrated" (to use the report's word) social plan, and how democracy is expected to survive in it.

Nor is it surprising that the sponsors of a similar report *(The Limits of Growth)*[8] which attempts to analyze the future course of human society on purely "ecological" grounds — carefully omitting the options which could achieve ecological soundness by altering present economic and political arrangements — should question the need for frequent elections stating : "A further difficulty arises from the four to five-year cycle of parliamentary elections in the democracies which, with the need for election, or reelection, forces all political parties to concentrate on short-term issues which are the subject of public concern".

Here, then, we are confronted with the basic choice : between blind application of ecological principles to human society and making the effort to understand these principles well enough to devise new ways of fulfilling them; between slavish acceptance, in the name of ecology, of a rigidly controlled society, and the freedom to choose, on the basis of judgements informed by ecology and guided by humanism, how we would live on this earth; between ecology and social *in*action, and ecology and social action

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REFERENCES AND NOTES

**The Horace M. Albright Lecture in Conservation for 1973, University of California, Berkeley.*

[1]Thus, Walter Elsasser points out that if one molecule of each of the possible protein moleculares (i.e., each a polypeptide containing let us say 200 units of 20 different amino acids, in any serial order) were produced, their combined mass would be greater than that of the known universe. Obviously living things actually produce only an extremely small fraction of the number of *possible* protein molecules.

[2]Clarence Zener, "Solar Sea Power", *Physics Today*, January 1973, 48-53.

[3]Garrett Hardin, "The Tragedy of the Commons",*Science*, Vol. 162, 1970, 1243-8.

[4]Barry Commoner, "The Humane Preservation of Human Life" (Given as the Samuel H. Cosgrove Lecture of the Annual Clinical Meeting of the American College of Obstetricians and Gynecologists, San Francisco, May 6, 1971).

[5]Barry Commoner, *The Closing Circle*, (New York, Alfred A. Knopf, Inc., 1971).

[6]Garrett Hardin, "The immortality of Being Softhearted", *The Relevant Scientist*, Vol. 1 (November 1971), 18. (Reprinted from the Stanford University Alumni Almanac, January, 1969).

[7]"A Blueprint for Survival", *The Ecologist*, Volume 2, Number 1, (January, 1972).

[8]Meadows, Donnella, *et al.*, *The Limits to Growth*, (New York, Universe Books, 1972).