On Incipient Environmental Collapse

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We are living beyond our means. The Earth is our creditor, and demands for payment probably cannot be deferred to our grandchildren, like the national debt. Consider present practices and discernible trends in the exploitation of our environment. At the interface between inorganic rocks and waters and the atmosphere lies the biosphere of which we, creatures capable of thought, form the thin layer of noösphere (as Le Roy, Vernadsky, and de Chardin characterize it — the mind sphere [Thomas, 1956; Chardin]). Noöphere, biosphere, atmosphere, lithosphere of rocks, and bathysphere of the great waters of the earth are all inextricably interwoven in mutual need and dependency on "this precious little Spaceship Earth" (Boulding and Clark, 1966). It is all we have — except for sunlight and adventitious meteorites. There isn't any more that is visible. We, capable of thought, are the stewards of this Spaceship Earth: we must return in our thinking to the ethic of stewardship (an ancient and honorable ethic, undermined by Cartesian dualism and intellectual specialization). Let us then give thought to our environment. Reserving discussion for the evidence and the decision of what needs to be done, I list the basic assumptions, in part repeating — but with a somewhat altered context — some of Douglas Brooks's points.

a) We live in a system essentially closed in the material sense: Kenneth Boulding's Spaceship Earth.

b) It follows that our physical milieu is finite, not only the surface of the earth but the waters of the sea and the gases of the atmosphere. (Take a deep breath or two, the chances are that you took in some nitrogen molecules breathed by Cleopatra and Anthony.)

c) Modern technology is parasitic on our organized resources: coal, oil, mineral deposits. It is not that we will lose the atoms and molecules of carbon, iron, and natural gas, but that in the exploitation of them, large quantities of organized structures are degraded to energy-poor, lower-quality forms, according to the inexorable second law of thermodynamics: In the long run, you never get something for nothing.

d) Destructive forces are usually fast-acting and easily come by; constructive growth is slow and often difficult. (The tree that is cut down in 50 seconds with a power saw may have taken 50 years to develop.) Decay and destruction float with the stream of probabilities toward disorder; growth and construction buck this stream, paying as they go.

e) While there are natural homeostatic controls on many systems, there are limits to all of them. Particularly, these organized resources are not being replaced as fast as they are being used. We won't run out of iron, but it will be progressively harder to separate it out; and as we need more of it, the cost of getting it will rise exponentially. This applies to all naturally organized materials: minerals, gas, petroleum, coal.

f) Our goal is not only that of the survival of mankind, but survival with the maintenance of reasonable quality.

g) The overriding fact is that we cannot exist without our environment: We are linked to everything in this spaceship, sometimes directly, sometimes tenuously — "all things to each other linkéd are" — and damage to one is ultimately damage to all. Let us look at the evidence through six related crises (Haskell, pers. com.). The operational word here is *related*.

Population Crisis

The facts are hard to be sure of — who will believe statistics that emanate from China? — but that a crisis is well advanced is not doubted. J. George Harrar (1965), President of the Rockefeller Foundation, summarized the situation. The population of the world at that time was estimated at nearly 3.4 billion, and increasing at a rate of more than two persons per second. The year before that the Southwestern Assembly (1964), meeting in Houston, Texas, officially suggested that every practical and acceptable means should be used to bring home to everyone in the world that the present rate of population growth cannot be maintained indefinitely; that it has contributed substantially to poor health, nutrition, and overall standard of living for two-thirds of the Earth's people. We cannot at all doubt the fact of rapidly increasing world population. Short-sighted persons happily calculate the increase in the use of diapers; the economic advantages of swarms of easily influenced teen-agers; the increasing size of ethnic or ideological voting blocks, forgetting the prices we are paying for these local effects.

Crisis of Resources

Eugene Ayres (1956) pointed out, with careful qualification, that although oil, gas, and coal fields will undoubtedly continue to be discovered for a long time, it seems evident that we may be reaching a peak of petroleum production in this country, and that the peak of world production may be only 20 years farther off. After that production will fall. Of course, other sources of energy may become available. But costs of energy are bound to increase.

Linked to the incipient energy crisis, and associated with it, is the explosion of artifacts: houses, with all their equipment, automobiles, roads, and so on. These consume structural resources — minerals, rocks, soil — and multiply by retroaction the energy demands. It was said authoritatively in 1952 that in the United States alone the quantity of most metals and mineral fuels used between 1914 and 1952 exceeded the total used by the whole world in all of preceding history (Ordway, 1956), and demand and use has increased. But the prognosis is clear from the story of iron ore. The approaching exhaustion of the Mesabi mines, and the shift to taconite necessitates an increase of thirty-fivefold in the energy needed to prepare the ore for the blast furnace (Scarlott, 1956; McLaughlin, 1956).

Pollution Crisis

With the publicity being given to air and water pollution, hardly anyone needs to be convinced that we are at a stage of crisis. But certain phenomena are not often noticed. One is that of amplification. As Barry Commoner has emphasized, in his address presented at the Scientists' Institute for Public Information, food chains and metabolic processes comprise a biological amplifier which can intensify tremendously an originally small manipulation of the environment. He reports that DDT, sprayed in low concentration, is gathered in plankton, further concentrated in fish, and ultimately kills the birds that feed on the fish. The poison is several hundredfold concentrated in the process from the control of insects to the killing of eagles and ospreys. Another is that of overfertilization. Wastes containing assimilable nitrogen and phosphate enrich surface waters and stimulate the growth of algae and other organisms which so deplete the water of oxygen during periods of darkness (when not photosynthesizing) that the plants themselves die — and further pollute the water.

Add to this the effects described below, and one sees the linkedness of these crises.

Crisis of Health

Pollution adversely affects plants and animals. Consider the recent finding that in Pittsburgh some 610 tons of dust settled per year per square mile — one-and-a-half tons per day in Summer, two-and-a-quarter per day in Winter (Landsberg, 1956). Of this, some was soot, one-fifth was iron oxide, and a little less than a sixth was silica. In addition, 14 or more other metal oxides were found. This total does not include oxides of sulfur and phosphorus. In a study reported in 1954 the pollution products of the City of Los Angeles per day were 85 tons of aldehydes, 14 tons of ammonium products, 460 tons of nitrogen oxides, 400 tons of oxides of sulfur, 1500 tons of organic materials, and 150 tons of acids (Landsberg, 1956). [I have rounded off the numbers conservatively.]

Careful studies have shown that air pollution can damage vegetable crops and, in general, affect plant growth. This is reflected in low nutrient quality of the plant products and consequent ill effect on the health of animals and people who depend on these crops (Landsberg, 1956). Here again we have a remarkable amplification. One can find superficially startling data, as that in the great London fog of December, 1952, when there were 4000 fatalities attributable to the smog. But far more important are the effects that arise secondarily. It is true (Barry Commoner's Address at Scientists' Institute for Public Information) that at Donora, Pennsylvania, in October, 1948, some 40% of the population suffered adverse effects of the smog. This establishes an effect that overwhelmed people not normally clinically responsive to pollution. Let the pollution level fall to that of our large cities, and the clinically affected numbers decrease, but we must realize that subclinical effects are there. This has, indeed, been thoroughly documented by Theron Randolph (1956) for Chicago. In one-third of his chronically ill patients, the leading causative factor was susceptibility to pollutants in air, water, food, and drugs; in another third, it appeared to be a contributing factor. Now, consider the effects of chronic exposure. These are manifested in asocial attitudes, moroseness, sullenness, "seclusive, and sometimes hostile and paranoid behavior," dopeyness, indifference to surroundings sometimes approaching lethargy, etc.

Put all these discoveries together and realize that the people affected are continually making decisions — sometimes major ones, like determining community policy; sometimes minor ones like initiating a quarrel. If irritability is increased, asocial attitudes enhanced, and judgment impaired, the effects can become amplified to enormous proportions. We have here a factor that is not commonly mentioned in listing the causative reasons for riots, crime, and the less spectacular idiocies we see practiced in our cities.

Armament Crisis

Edward Haskell (pers. com.) believes that the psychological and social effects of pollution, leading to the crisis of health and exacerbated by the population crisis, are a major factor in the explosion of physical and psychological weapons that more and more are endangering our culture. What needs to be emphasized, he feels, is that the whole fabric of the world is so closely knit today that the destruction of one pattern of culture by the manipulations of another will inevitably destroy the other, also. We must convince ourselves, as well as our enemies, of this.

Information Crisis

The information crisis, which has been recognized by many people, is a crisis of intellectual poverty. There is fantastic proliferation of detail in science (not to mention the daily press and periodical literature), and yet if one asks an wholistic question which requires the correlation of information, the actual poverty of the sources shows up. (This has been a problem in preparing this talk.) Over and over, as one reads conference and research reports, one finds recognition of this. It would appear that our colleges and graduate schools sin in this respect. Specialization has overwhelmed correlation (Mumford, 1956).

We have, then, the picture of mutually retroacting processes. The more people there are, the more artifacts are demanded, the more our resources are depleted, the more waste and pollution accumulates. This degrades the environment and contributes to physical and psychic illnesses that raise tensions and fears, that are studied in isolation from related factors and in specialized disciplines that hardly communicate with each other, much less the general public. Yet, all of us need to be reached if the proliferation of these ills is to be stopped.

In the context of a meeting of biologists there is no need to emphasize the wholistic nature of our problem, for biologists traditionally deal with wholes. Let me therefore, rather briefly, present the problem in cybernetic terms (de Latil, 1957; Ashby, 1958), purely to ensure a common starting point from which to approach these controversial matters.

I think we can agree that no system involving people, animals, plants, and the inorganic world can be considered isolated. We have to divide up an assembly of this kind (at our level of discussion). However we do it, we always have inputs and outputs to the system. If the system involves living creatures, it will also display feedback and feedforward phenomena. Further, it will always be a system in process, so that a snapshot of it will inevitably be somewhat misleading. The environment is what is outside of the system but in contact with it, affecting it through the input, being affected through the output. Both input and output may comprise plural factors, and one of the most important problems for management is to identify these.

Suppose we symbolize a cybernetic system as in Figure 1. In general, input may be classified into two categories: the factors that are operative in the system and that are controllable, and those that are operative and not controllable. The controllable ones are the work components; the uncontrollable are contingent. It is the function of feedback to so control the work components that the contingent ones are circumvented or overcome. The output of the system is usually directed to some end which I have labeled *set goal*. Generally, what we may call the programming of the system, principally that of the detector (D) and the governor (G) sets the goal. (Critical metaphysical problems hide in the fact that

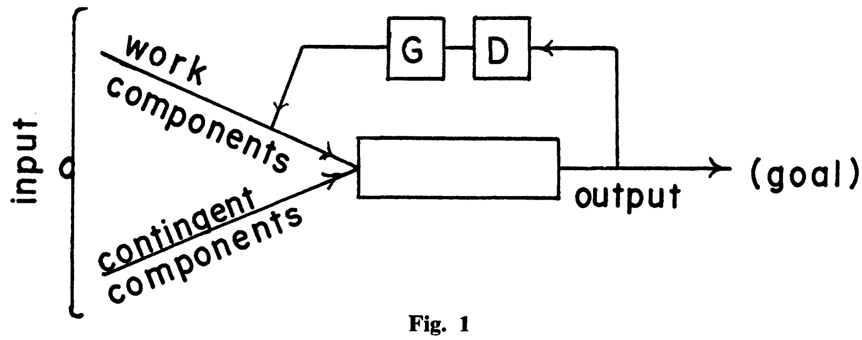

Fig. 1

the cybernetic system does not tell us what the goal *should be.*) Once the goal is decided, the cybernetic system seeks it. As Louis Couffignal (1958) said some years ago, "Cybernetics is the art of ensuring the efficacy of an action."

In general, there are two types of behavior of natural systems of the kind we are discussing (Fig. 2). These have been named constancy and tendency behavior by de Latil (1957). Constancy behavior is that in which the set goal is sought at some level that is constantly maintained, within the limits of the system. This is the type of output produced by a mechanical governor, or a thermostat. It is familiar to biologists under Walter Cannon's wonderful designation, homeostasis.

Tendency behavior is that in which the system seeks a goal which is some kind of limit (Fig. 3). For example, an explosion is the limit of a tendency effect; a forest fire, a riot, a strike, these are tendency effects. When you start your car and step on the gas, a tendency effect carries you through the gears of your automatic shift; when you step on the brake, a tendency effect carries you to a stop — in this instance the tendency effect reaches the limit of nonmotion. There are clearly two kinds of tendency effects, those with positive and those with negative slopes. Sometimes the tendency effect operates through self-induced and self-aggravating oscillations that swing back and forth, increasing in amplitude, until

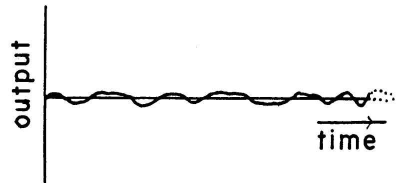

Fig. 2

some limit is exceeded and the system disintegrates.

In many natural processes there are combined sequential overall tendency and constancy effects. For example, the history of an organism may broadly be graphed in some such way as in Figure 4 (Hardin, 1963). Here the period of growth is one of tendency behavior; the period of maturity is one of constancy; and senescence is another period of tendency behavior.

In summary, then, to characterize our problem in these terms, I illustrate the cybernetic analysis of a controlled tendency, constancy behavior. This was drawn, appropriately enough, to illustrate the behavior of a nuclear energy plant (Fig. 5). In *a*, the plant starts up. The curve is like the start of a nuclear explosion: the physical processes occurring are basically those of a bomb. At *b* the system goes over to constancy behavior — homeostatic behavior — at a desired, set, power level. If demand increases, the machine may be carried to a new power level *d* through *c*. When the need disappears, it may be brought back to a lower level.

According to this analysis, this Ple-

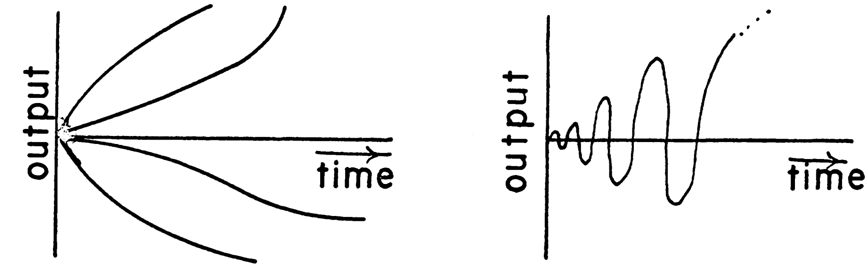

Fig. 3

nary Session deals with tendency effects and the means of converting them to constancy effects. Dr. Brooks is concerned with the first part of the tendency effect curve — the part where the slope of the curve is low. Here is where proponents of laissez faire may claim that this is just the oscillation of a "natural" homeostatic mechanism. There is something to be said for this possibility. My concern is with the sharply sloped part of the curve, for here there is no doubt that a critical tendency effect is in operation. Dr. Brooks's problem is, in part, to distinguish an induction phase of an autocatalytic process (to put it in the conventional jargon) from an oscillatory adjustment of a homeostatic process.

I would like to emphasize, by means of one more figure (Haskell; de Latil, 1957; Ashby, 1958), that we are all dealing with an wholistic concept: no entity without its environment; the output of one is the input to the other. (Fig. 6).

With this brief survey of some of our environmental crises and of the cybernetic analysis of the feedback that exacerbates them, the question arises — what has to be done?

We must accept certain facts:

1) There is no such thing as instant redemption of a situation that has been developing as long as this. Sir Charles G. Darwin (1956) has emphasized that in human affairs there is a time scale such that the experimenter is going through the same stages of development, growth, maturity, aging, at the same rate as his subjects. He therefore cannot himself hope to put into practice what is learned. He expects that no matter how vigorously one may attack such problems as overpopulation, the trend will continue for two or three generations at least. So we must expect no instant solutions.

2) We cannot hope to attack a situation as massive as this on as massive a scale. Fortunately, cybernetic analysis tells us that a small effort by the governor in a sensitive feedback loop can cause massive changes in output. Consider, for example, that a few ounces of silver iodide crystals or a few pounds of dry ice particles can set in motion changes which can affect the weather of a huge area by setting off ice crystal formation in a super-cooled cloud, re-

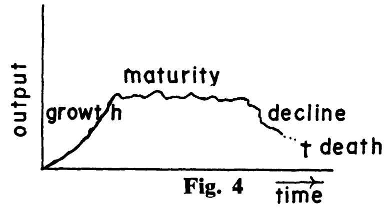

Fig. 4

leasing heat (millions of B.T.U.), effecting charge (lightning display), etc.; the amplification factor can be enormous. Vincent Schaefer (1956) found that under optimum conditions a gram of dry ice might produce 10^{16} ice crystals. Or consider a human case, reported by Charles Einstein (1967). A heat wave in San Francisco, late in the summer of 1966, had triggered racial unrest that was reaching riot proportions. The Giants were playing in Atlanta, and were still in the pennant race. By an heroic cooperative effort it was arranged to televise the game that evening. Willie Mays taped a message to San Francisco fans: "This is Willie Mays. As you know, Channel 2 is going to telecast our game from Atlanta tonight. I hope all of you will be at home rooting for us. We'll be out there doing our best to win another one for you." During the next 4 hours this message was carried more than 300 times; the evening papers headlined the telecast. The effect, says Einstein, was that the rioting stopped except for a few isolated incidents.

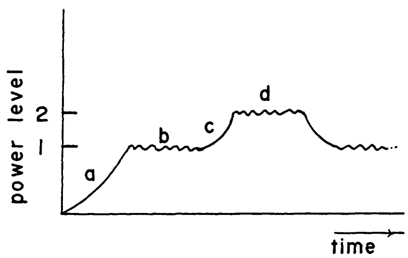

Fig. 5

Spot checks showed that in the sensitive sections of the city some 70% of home sets were tuned to the station. (I owe this example to Dr. Orville F. Rogers.)

3) We must accept that unless we count on Malthus' positive checks on population growth, disease, hunger, and war, to bring the situation to manageable dimensions, balancing birth and deaths, the problem requires personal action by individual pairs of persons.

The proponents of business-as-usual may say that there is nothing to worry about — after all, succeeding children are bigger than their parents; there's plenty of room in great areas of the earth, etc. But we must realize that although information is inadequate, the data I have presented are conservative. Further, very little effective work can be done short of one to three generations (at an optimistic estimate). With the present trends, the problem will be worse before it begins to get better.

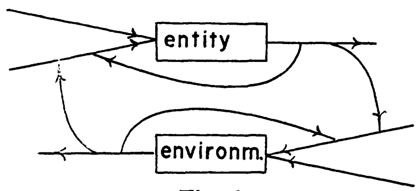

Fig. 6

There is no doubt at all that we are exploiting the earth the way a parasite exploits its host. But if our host earth is killed, we have nowhere else to go. People will point to our partially affluent society to show how good things are. To that I would oppose the remark of Thomas N. Carver in 1910 (Gregg, 1956) commenting on the decreasing need to fear Malthus' positive population controls. He said that the struggle of the future would be to survive prosperity, not adversity. We know a lot about surviving adversity, he said, but very little about surviving prosperity.

Basically, as in all problems requiring human action, the solution must be in the moral realm, the theory of which is ethics. Let me put it this way. If all we know about propaganda and other forms of influence by advertising were to be applied to teaching facts to people in all the world — just the facts, not any persuasion to do as we think is right — and if at the same time more of our scientists would forego specialization after finishing their degrees and plunge into the life world determined to find out what our data and problems are and to treat them wholistically, we would have the greatest chance of coming out of this phase of history alive.

The fact is that there is plenty of information available about these problems, but that the necessary creative synthesis, employing the powerful tools of cybernetics and other systems theory, although available in part (Haskell, pers. com.), is not widely known, evaluated, and practiced. We do not have much time. Vice President Hubert Humphrey is reported in the *New York Times* of August 20, 1967: "I want very much to alert the American people to the necessity of understanding that the problem we have in the cities is not one that is subject to piecemeal approaches. . . . You have to mobilize your national resources, public and private. You must make a long range commitment."

I am inclined to believe that we must develop in a majority of people a sense of stewardship. We must be parsimonious (Boulding and Clark, 1966) and self-denying where it counts: parsimony with nonrenewable resources. We must be prepared for cultural changes to accompany spaceship life. Our stewardship will involve a change from the exploiting "I–It" conflictive interaction between man and environment (Gutkind, 1956) to an "I-Thou" concern; from the fragmenting cultural fission (Cassidy, 1962) that we have largely been practicing to an wholistic, integrated, and pluralistic culture. Carl O. Sauer (1956), summarizing the effects of man's activities on the face of the earth, remarked at the Princeton Conference of The Wenner-Gren Foundation that "The high moments of history have come not when man was most concerned with the comforts and displays of the flesh but when his spirit was moved to grow in grace. What we need more perhaps is an ethic and aesthetic under which man, practicing the qualities of prudence and moderation, may indeed pass on to posterity a good Earth."

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