BIOCYBERNETICS AND SURVIVAL

by Van Rensselaer Potter

Biocybernetics is a term that can be used to cover the whole range of biological interactions that occur between man and his environment. The term includes the various parts of the environment in the absence or the presence of man. It derives from the broader term "cybernetics," which was coined by Norbert Wiener from a Greek word meaning steersman—in ancient usage, the pilot of a ship.[1] The term today is used to cover the feedback relationships by which parts of a complex system affect the behavior of the overall system and, more specifically, the way the output from any part of the system ultimately affects the input to the same part.[2]

In a society that has tampered with the natural environment on a colossal scale with inadequate knowledge of the ramifications of biocybernetics, there are mixed feelings of guilt, frustration, and defensiveness in various segments of the population when there should be a unified attempt to achieve a societal wisdom that will permit mankind to survive and improve the quality of life. The year 1969 may go down in history as the year in which a rising tide of individuals rather suddenly reached a conclusion that the world had changed. Prior to 1969, most college students, in the United States at least, had assumed that a college or university education constituted some kind of an escalator that would enable them *individually* to achieve the good life, or at least to lift them above the problems that beset the average or below-average family in terms of their control over their own destiny. To the extent that they had altruistic motives, they assumed that, by working at the level of their elevated competence in some suitable specialization, society would benefit and reward them adequately.

During a period of about ten years, the decade of the sixties, there was a growing sense of *orphanization* among the entire upcoming college generation. (By this new word, I mean to imply a *process* rather than a single event.) No longer was the university to be their *Alma Mater* (nourishing mother), no longer were biological fathers and mothers standards for them to challenge, no longer was Mother Nature solid be-

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neath their feet, no longer was their Heavenly Father "out there" to guide and administer. The state of disrepair in all these images and the sense of rage and betrayal in many of our young people justify, in my opinion, the use of the term "orphanization" to describe what has happened to the generation that was coming of age in the 1960s.

Suddenly in 1969 and 1970, the orphanized generation realized that they had no place to hide from technological by-products. Individual solutions in terms of a home in the suburbs or a second home at the lake had little meaning if an increasing haze of smog began to envelop it or a traffic jam with no bypass intervened between home and work. Individuals suddenly became vulnerable to every kind of public emergency, seriously affected by water shortages, garbage collectors' strikes, power failures, a heavy snowfall, an atmospheric "inversion," or by deliberately disseminated toxic chemicals (DDTC) entering their food, air, or water.[3] April 22, 1970 was E-day, the Environmental Teach-in on nearly every campus in the country, a fitting climax to the decade of orphanization that had just passed.

But what of the future? If the concept of Frontier Freedom or Frontier Philosophy is now recognized as fundamentally antisocial,[4] if the life of the Noble Savage is no longer accessible, if the lifeboat dilemma is Everyman's problem, if Earth really is a Spaceship, if we must all hang together lest we hang separately, what must we do? Where can we turn for wisdom? How can we save the natural environment on which we all depend? Mankind no longer can afford the luxury of wars between nations and must join hands in coming to terms with the environment. The problem is too big for individuals to solve alone and too big for individual nations to solve alone. But a nation such as ours could save itself by leading the way toward the solution to every nation's problems by example, and individuals can and must help our nation find the way. Every local problem is a possible laboratory. Prototype solutions could be proposed, tested, and modified by small interdisciplinary groups with adequate feedback from an informed electorate.

The problem is basically a problem in biocybernetics, complicated by the vagaries of human nature. Again, as so many times before, we have the problem of those who want to act on the basis of what they believe and feel they already know and those who believe that no one knows the best "bridge to the future" and that what we are left with is a belief in process, a method that will buy time and remain open-ended along multiple courses of action. Already a dichotomy seems to have developed. It is by no means certain that the conventional wisdom referred to by Galbraith[5] will be able to choose for survival.

Ecology or Economics?

During the next three decades, we are going to witness a fateful contest between two schools of thought, and it cannot be predicted whether they will be harmonized and integrated or whether they will become increasingly polarized, with eventual victory for one school or the other.

But there need not be a dichotomy between economics and ecology. Biocybernetics can provide the link between the two fields since both lend themselves to analysis in terms of feedback. Kenneth Boulding's article on economics and ecology[6] describes several common features or analogies that suggest the possibility of an overall system in which subsets in economics and ecology would interact on each other. McHarg[7] put it very nicely when he said: "It seems to me there is a unity of ecology and economics in terms of energy utilization and the adaptation of organisms to the environment, including each other, and man." I would place survival as the key concept to effect a synthesis of ecology and economics. In meeting the economic arguments, I would argue variety, not for variety's sake, but for survival; beauty, not for beauty's sake, but for survival; adaptability, not as an interesting phenomenon, but adaptability for survival. Technological decisions should not be made on the basis of profit alone but should be examined in terms of survival. This is where ecology and economics must find a meeting ground.

Feedback Loops from Effect to Cause

Biocybernetics promises to provide an intellectual framework for elaborating the principles and actual mechanisms by which the natural environment operates. As such, it should provide a bridge to the future, embracing larger and larger spheres of interaction that will include economic and sociologic systems. The perspectives given here are not intended to offer the hope that disorder can be eliminated from the lives of future generations. Understanding biocybernetics is not for the purpose of establishing absolute control or eliminating all perturbations but is instead a matter of understanding the difference between stable and unstable systems in relation to the perturbations that will inevitably occur.

The biocybernetic viewpoint differs from classic thinking by downgrading the simple notions of sequential *cause* and *effect*. Philosophers have for centuries looked for ultimate causes. They appear to have thought in terms of sequences of consecutive events in a kind of historical linearity as opposed to the concept of feedback *loops* in which the result of an action (effect) acts back on its cause, either to stimulate (by positive feedback) or to inhibit (by negative feedback) the process by which the effect is brought about. I have been unable to discover the feedback concept under any name in the writings of the great philosophers in the period from Descartes to Kant, when Locke, Hume, Kant, and others were struggling with the philosophy of rational understanding of causes and effects.[8] The feedback concept appeared on the scene after these classic philosophers were no longer living, and thus they could not have been affected when James Watt (1736–1819) invented a governor to regulate the speed of steam engines.[9] Even with governors and thermostats in wide use, it was not until the 1950s[10] that the feedback concept became generalized and linked to the word "cybernetics," whereupon it inevitably would be compared to philosophical notions of purposefulness.

Atomic Reactors as Black Boxes

The feedback concept can be described most simply in terms of a "black box" (i.e., a mechanism whose interior details need not be specified at the outset) with an "input" and an "output," such that the output is used to modify the behavior of the "black box" so as to either increase or decrease the flow of energy or material from input to output. There are a number of terms that are used to describe cybernetic or biocybernetic systems or cybernetic instruments, such as servo mechanisms, thermostats, chemostats, tracking mechanisms, adaptive control systems, automatic regulators, automation, self-regulating systems, and others. The essence of understanding the principle is that all of the regulatory devices *must* include *negative* (i.e., inhibitory) feedback in order to achieve stability and control. Any feedback system that contains *positive* (i.e., stimulating) feedback *alone* will be unstable. The rate of change in a purely positive feedback system will accelerate until either all the input material is used up or the system "explodes." A chain reaction, also called an autocatalytic system, is an example of positive feedback. In an atomic bomb or in an atomic-energy generator, a reaction proceeds in which *each individual atom* of a substance A hit by a smaller particle p is converted (decays) to a substance B plus energy $+$ n particles, n being greater than 1. In the form of an equation,

$$A + p = B + \text{heat} + np.$$

If only a spoonful of A is present, most atoms of A will be quiescent, and only a few will be decaying to B atoms plus particles. The particles will be radiated in all directions, and only a few of them will hit quiescent A atoms and generate more particles. If larger and larger masses of A are brought into a "pile" eventually, the mass will "go critical" and become "self-sustaining" as it begins to capture a higher percentage of the particles that convert A to B and still more particles. For example, if the number of particles given off at each decay is two, the sequence of events in a pile of critical mass will be as follows in relation to time:

$$\begin{aligned} \text{At } t_0&: A + p = B + 2p + \text{heat;} \\ t_1&: 2A + 2p = 2B + 4p + \text{heat;} \\ t_2&: 4A + 4p = 4B + 8p + \text{heat;} \\ t_3&: 8A + 8p = 8B + 16p + \text{heat,} \end{aligned}$$

etc., to give 32, 64, and 128, each time doubling the rate until explosion disperses the system.

Such a reaction will clearly go faster and faster until explosion or until nearly all A has been converted to B under the positive feedback of the particles in the process of converting A atoms to B atoms. In a bomb, the whole process is complete in a fraction of a second, with a destructive and, to date, wasteful explosion, in contrast to the process in a useful energy generator in which negative feedback is used to control the system. How can this be done? One way would be to gauge the amount of energy produced and use some of it to move particle absorbers into the pile to capture the particles in a nondecaying substance instead of letting them hit the atoms that are reactive. These particle absorbers would act to slow down the reaction. The output of the pile would be gauged by a *sensor* and compared with a *standard.* If the output were too high, some of the energy would be used to increase negative feedback; and if the output were too low, the negative feedback could be diminished, permitting the autocatalytic process to increase. It should be emphasized that, in the situation of too much negative feedback with energy too low (with reference to the standard), the properly designed system would still have enough energy to *decrease* the negative feedback. This is because only a small fraction of the total energy output is needed for purposes of regulation.

Living Systems as Black Boxes

Not only an atomic pile but also a living cell can be described as a model feedback system but still a black box as far as all the details are concerned.[11] A living cell is a community of molecules in a black box in the sense that we can look at the input as a flow of molecules (and energy) and we can look at the output as a flow of molecules plus energy and a periodic division into two cells in the case of the unicellular organisms, or in mammalian cells in laboratory suspension cultures, or in special sites in higher organisms. Many of the interior details of this dynamic system are known, and the number of feedback loops must number in hundreds. Although we do not have information on all of these loops, we can specify the broad outlines of the feedback requirements of the cells. In the presence of an adequate supply of essential nutrients, the cells have an input of nutrient molecules and an output of waste molecules and energy. In living cells or living multicellular organisms, all of the molecules that are present are usually referred to as "metabolites," a word for "molecules undergoing change in the course of *metabolism* (sum total of processes associated with life)."

In a cell that is not engaged in cell division, there is still a need for a continual, if not continuous, input of nutrients, and there is an ongoing need for feedback (see fig. 1). Internally, the cell must monitor

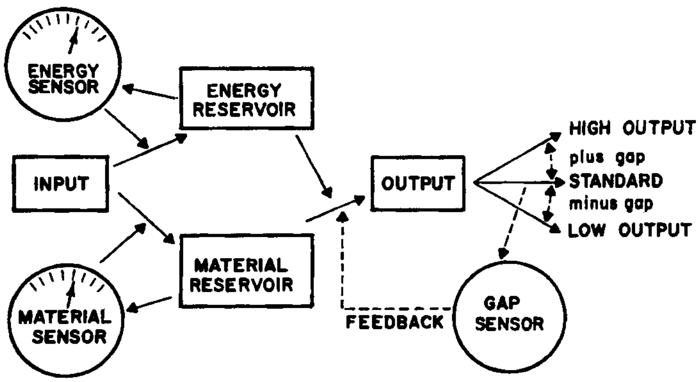

FIG. 1.—Feedback controls in living systems give purposeful behavior: The purpose is to survive.

the status of its energy reserves and its structural elements. As essential structures decay, they must be replaced. Incoming molecules must be altered in one way to maintain energy reserves and in another way to replace structural elements. All of these decisions must be made according to standards that are built into the total hereditary substance (DNA), which, interestingly enough, appears to be uniquely stable and not to decay unless the cell dies. The cell is built in such a way that its actions are guided by the feedback loops that indicate whether the energy reserves and structural elements are being maintained. Within certain limits, it can alter its behavior and composition and *adapt* to environmental conditions. Whenever the environmental conditions exceed the ability of a cell to adapt, we see *pathology:* a sick or a dying cell, which at times can be recognized by either microscopic or chemical signs. The finding that all cells have built-in feedback controls that automatically tell them what to do to survive makes cells appear very purposeful, and, indeed, they are purposeful—their purpose is to survive; and if they have an independent existence, their built-in purpose is to survive and multiply.

Their adaptive stratagems to accomplish these ends are many and marvelous, especially in the area of starvation and lack of water. The usual tactic in single-cell organisms is to go into some kind of spore formation and "hibernate" until conditions are favorable again. Small wonder that early biologists could find *design* in every form of life they studied! Design arrived at by trial and error, with death to the individual and curtailment of procreation the penalty for a faulty feedback design. If the cell survives for us to see, it can be shown to possess design features that are similar to the mechanisms in other successful forms of life. In the laboratory, we can produce by random methods and selection what I have referred to elsewhere as "idiot cells."[12] These cells survive and live under laboratory conditions because we can make up for the foolish things they do *in terms of their survival.* We can give them the special nutrition and conditions they need to survive and multiply, but what they do does not make sense. They will make vast amounts of an enzyme that makes a product they cannot use, and they will divert major amounts of their nutrition to making the enzyme and the product. Placed back in a natural environment, these cells would soon die; and only the few that could undergo mutation to correct the defect would survive for more than one generation.

When we move from single free-living cells to higher organisms, we find that cells no longer divide as rapidly as they are capable of dividing when not under negative-feedback control. Within each animal, the internal feedback loops are still monitoring the energy supply and the structural elements, but now we find that the feedback loops extend from the output from each cell to the sensors of all the other cells. Cells in the liver are in molecular feedback communication with all the other liver cells, but, in addition, they are in molecular communication with heart cells, brain cells, kidney cells, and so on. All these cell types are organized into a higher organism by virtue of the built-in standards set by their hereditary material and their ability to adapt within limits to changes in their environment. Again, as in the single cells, when the organism encounters an environment that is too unfavorable for its adaptive powers, the result is pathology, sick cells, and sick or dying animals or people, with pathology now visible to the unaided eye, in many cases, in addition to the microscopic or chemical evidence. Again, here one senses the overwhelming feeling of design, and again the repetition of successful feedback loops in species after species, with many modifications of the underlying theme: stimulus perturbs the system and response restores the system through feedback loops within the cell, within the organ, or within the organism.

To anyone who examines the feedback systems of living organisms from an evolutionary standpoint, it is clear that the arguments between reductionist and holistic viewpoints are absurd. The molecular communication within and among the simplest organisms has been amplified and extended to a community of cells of the organ or organism, transmitted no longer by environmental water or air but by blood, lymph,

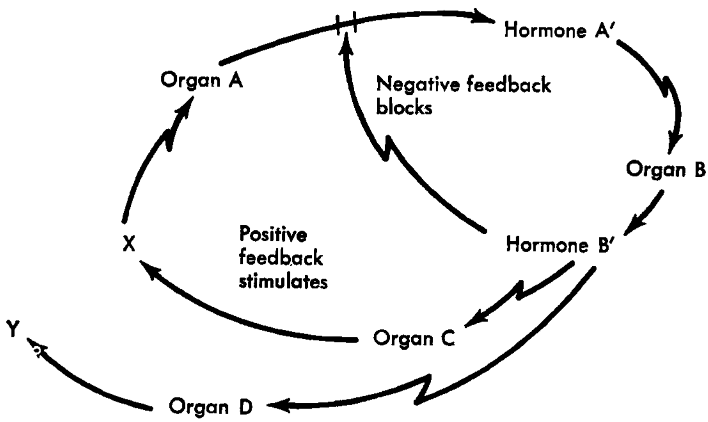

FIG. 2

and nerves, and completing a feedback loop from the output of one cell to the sensor of another cell. In higher organisms, we find dozens of feedback loops between organs by means of hormones (messenger molecules) with a given hormone from one organ affecting receptors in cells of several organs. In the major loops, it is quite usual to find organ *A* sending hormone *A′* to organ *B*, whereupon organ *B* sends hormone *B′* to a variety of other parts of the body but also closes a feedback loop to organ *A*, where it inhibits the production of hormone *A′*: (fig. 2).

Organ *A* puts out hormone *A′*, stimulates organ *B* to put out hormone *B′*, which inhibits *A′* production but stimulates organs *C, D,* and *E* (fig. 2). In this kind of a multiple feedback system, the concentration of hormones *A′* and *B′* in blood will oscillate somewhat out of phase. These feedback loops are necessary for the survival and day-to-day function of the organism. They evolved from the molecular communication between cells of the simplest kinds, and they lead to the production of adaptive control systems[13] that give the appearance of having been designed for a particular environment, just as a giraffe appears to be designed to eat leaves from tree tops. Darwinian evolution has constantly operated in terms of feedback systems to evolve characteristics in addition to form and color, and without effective feedback the design does not survive!

Population, Feedback, and Ecosystems

When we look at a major ecosystem in terms of the plants and animals therein, it is frequently found that populations are not constant but tend to oscillate. The earliest attempts to understand the phenomenon were based on a commonsense observation that many species are preyed upon by other animals that are sufficiently dependent upon a single kind of prey to be influenced by the numbers available as a food supply. A classic example is the observable fluctuations in the number of lynxes in Canada[14] which could be judged by the volume of the fur trade. There was a maximum and a minimum approximately every ten years, and this was attributed to the relative number of rabbits. A large rabbit population would lead to an increase in the number of lynxes, while a large lynx population would decimate the rabbits. As the rabbit population decreased, the lynx population would go down for lack of food. With fewer lynxes, the rabbit population would rise again, and so on (figs. 3, 4).

In addition to predator-prey relations, the vegetative food supply for the herbivorous animals could affect the number of herbivors in a cycle that would resemble the predator-prey relationship. Operating at

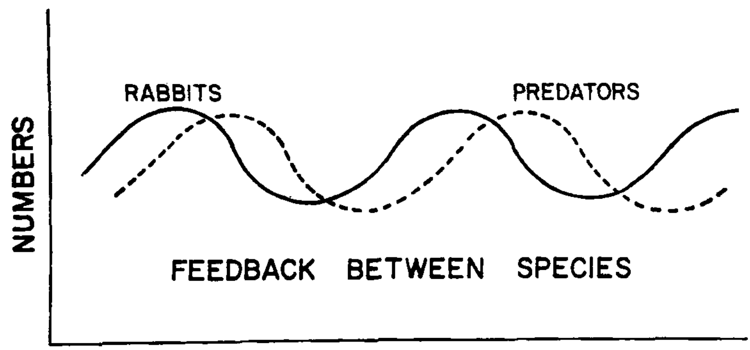

Fig. 3.—Oscillating populations of rabbits and predators. The abscissa is a time scale covering a period of about thirty years.

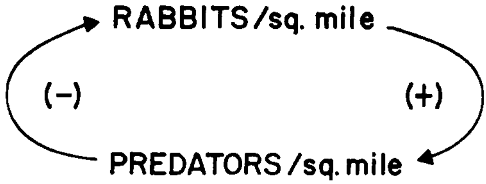

FIG. 4.—A proposed feedback loop between predators and prey

another level, the cycles in rainfall would affect the vegetative abundance, and perhaps the rain cycles would be affected by sun spots or other planetary phenomena (fig. 5).

The human population appears to have been increasing exponentially to what would seem to be a disaster level in the next three decades. In modern times, we have increased the ability of people to have children and raise them to the age at which they could have children of their own. Particularly during the last few centuries, neither war nor famine has been great enough to stem the explosive increase that has resulted from an interference in the birth and death rates that may have been in balance for survival of the species in prehistoric and in

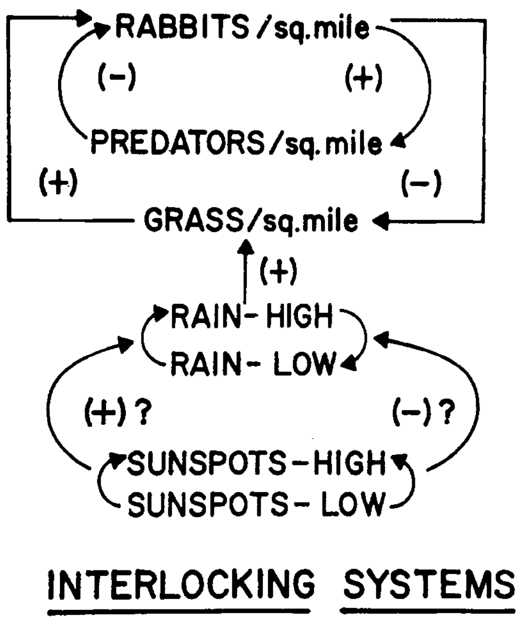

FIG. 5.—Possible theories of factors relating to oscillating populations

primitive times. When we look at the exponential increase in the human population, it is usually drawn as a smooth curve emphasizing the phenomenon of positive feedback, but of course the curve would not be smooth if we had precise data for the past five thousand years. It seems quite likely that during much of man's history the population curve may have had ups and downs that tended to cancel each other and prevent the emergence of what we now refer to as the "exponential rise" or population explosion. The shape of the human population curve is difficult to reconstruct even when the areas are islands and the time is comparatively recent, as emphasized in a recent paper on "The Demography of Primitive Populations."[15] But in the last few decades the rise in the human population has indeed been so great that war, famine, and disease have not canceled the overall increase, for which the data, though imperfect, are certainly adequate to establish the fact that even the rate of increase is increasing.[16] If the animal studies are relevant to the human situation, it would seem that changes in reproductive behavior would have to occur in individuals by a modulation of their genetic expression (i.e., by physiological or cultural adaptation) rather than by genetic selection.

Zero Population Growth

It appears essential to lower the birth rate by every possible educational and public health measure that can be instituted on a mass scale and to develop a worldwide political and economic situation in which large families are not looked upon as a solution to the problems of individual parents, to minority groups, or to large or small nations.

In the world situation, the "demographic lag" is assumed to describe an inevitable decrease in birth rates when a primitive agriculural society becomes urbanized and attains a higher standard of living. The acceptance of this idea of inevitability may be very dangerous in a world that can scarcely afford the increased population that must occur in the interval that is required even under the most favorable conditions for the hypothesis. The increased crime, disease, illiteracy, and human degradation that is presently associated with urbanization in most parts of the world seems a high price to pay for any decrease in fertility that may result. We should be very critical of the motives and the professional and religious bias that may affect the judgment of world leaders who advocate more and more urbanization for *any* reason. Granted that the bias involved in the opposite view should also be subject to critical examination, it can be plainly stated that the bias in my own case is claimed to be a biological bias, an ecological bias, and a humanistic bias. We should look upon earth, man, plants, and animals, sea and atmosphere as a balanced ecological system.

We should begin now to monitor all the parameters that may be relevant, and we should do this on a worldwide basis so that it can be analyzed in terms of hypotheses that attempt to identify "survival parameters." In other words, we need to know whether we are losing or winning the game of survival. We need to aim for "zero population growth" on a worldwide basis, which means that on the average each family would be limited to only two children. Means should be found to change the birth rate by voluntary means on a year-to-year basis. This should be perfectly feasible in a literate world population, using economic rewards and the power of reason.[17] If the reproductive rate could be brought under control, it would be possible first to decrease the rate of population growth until a stable population was attained and then to lower it further until the survival parameters indicated a favorable balance in the total ecosystem.

If the population could be lowered, it could also be increased; and there seems to be no reason why a "managed" decrease in the world population should be regarded as a disaster. The aim should be to achieve an optimally functioning ecosystem with the human population at a level that could survive indefinitely, instead of blazing like a supernova star that burns brightly for a short time and then fades to blackness. The science of biocybernetics is proposed as a guide for attaining an optimum human world population and for defining the standard of living that would be possible at the various levels of population. With this information at hand, it would be possible to choose which "luxuries" could be produced to supplement the necessities of life. It would become apparent that many of the luxuries of life such as clean beaches, spacious parks, fine music, clean air, and variety in food, clothing, and home decorations were easily within the reach of all. But before we begin to think about improvement in the quality of life, we have to attain a world consensus that faces up to the necessity for zero population growth and an abandonment of the goal which had the American rate of material and energy consumption as its ideal. This is what the great debate of economics versus ecology is all about. Ecology says first we should agree on survival as a goal, leading to population control, leading to an improvement in the standard of living. Economics says, first, an improvement in the standard of living, then an automatic control of population, then an automatic survival. The experiment is already in progress. All we need to do is look around us, measure the parameters, and face the facts of *life*, spelled "biocybernetics."

Wisdom: The Discipline for Action

In the last three decades of the twentieth century, we become increasingly aware of the dilemma posed by the exponential increase in knowledge without an increase in the wisdom needed to manage it. Wisdom may be defined as the knowledge of how to use knowledge for the social good. Albert Schweitzer was keenly aware of the problem more than twenty years ago when he said: "Our age has discovered how to divorce knowledge from thought, with the result that we have, indeed, a science which is free, but hardly any science left which reflects."[18]

Today we are beginning to realize that somehow we have to decide what proportion of our scientists shall be free to pursue pure science and what proportion shall be paid to look for solutions to the problems of society. Surely the search for wisdom cannot be undertaken without some agreement as to goals and common values, which many people seem to feel pertain to an area outside the realm of science and indeed constitute metaphysics, philosophy, or religion. There is beginning to be doubt as to whether we can achieve a common set of values.[19] There is a new wisdom that respects the delicate balance of nature as a kind of humility that is equivalent to the ancient admonition that "the Fear of the Lord is the beginning of wisdom,"[20] but it seems not to be much accepted at this time.

It is my intent to suggest that the issue of survival may provide a measuring stick that may attract the attention of reputable scientists. If as much effort were directed to global survival as to space exploration, scientists could be mobilized in search for wisdom that might promote survival and keep open the possibility of improvement in the quality of life.

That the issue is urgent is strongly stated by a contemporary scientist who has taken the option of going beyond his specialty to deal with the priority problems of our time. In an important paper entitled "What We Must Do," John Platt[21] suggests that "a large-scale mobilization of scientists may be the only way to solve our crisis problems." Platt points out that what makes our crises even more dangerous is that they are now coming on top of one another. He insists that nothing less than the application of the full intelligence of our society is likely to be adequate. He grants the importance of nonscientists but concludes that scientific research and development groups are needed to convert new ideas into practical invention and action. His article is useful for its classification of our problems into degrees of intensity and estimated time toward crisis if no effort at solution is attempted. Platt concludes: "In the past, we have had science for intellectual pleasure, and science for the control of nature. We have had science for war. But today, the whole human experiment may hang on the question of how fast we now press *the development of science for survival*" (my italics). Humanistic biology may be an appropriate discipline for the organization of a code of bioethics for survival.

Any attempt to develop a science of survival will have to include the methodology for harnessing the profit system to reward individual initiative and responsibility when they are directed toward the enhancement of the viability and stability of the civilization. It appears that nations will have difficulty enough achieving a stable relationship with the natural environment without trying to dominate each other. The realization that survival requires cooperation may be hard to sell, but the idea must be delivered convincingly.

There is no reason why we must accept the inevitability of the fall of every civilization although we may see many reasons why eventual collapse has occurred in every past civilization.[22] If we realize that there is possibly a natural succession of events in the rise and fall of civilizations and that the problem is one in which the methods of systems research may be applicable, we may be able to see "what we must do" to survive. It seems doubtful whether any previous civilization had the means by which it could monitor the critical parameters of its survival, sense what was happening to it, and apply corrective measures soon enough to be effective. Even though our own situation, taking the world as a whole, may seem much more desperate than the previous world situations, we should realize that we have the means to monitor and chart the important survival parameters with the help of modern computers and data banks and to pick up danger signals long before the man on the street is aware of them. There were many who were aware of danger signals long before the present public clamor about a deteriorating environment, but their communications of it were not effective. There is no point in wondering why it took so long. What is important is to agree on what the survival parameters are and to get busy with the monitoring systems. One of the things that is *not* a survival parameter is the GNP or Gross National Product, which is highly misleading just because it is Gross.[23] We need to subdivide the GNP into components that promote survival, those that are possibly neutral, and those that decrease the chances of survival. The importance of getting into the monitoring business is that it is the only way we can apply a corrective measure and sense whether it is failing or succeeding without waiting for the results to become so obvious that the individual voter can smell or see the result. People need to agree on the overall goals and need reliable technical information to tell them whether they are moving toward them or away from them.

Monitoring alone cannot solve our problems. There must be some competent interdisciplinary thinking on the subject of what to monitor and how to express the result. There must be some thought as to what short-range goals will contribute to the goal of survival. The survival of world civilization will be impossible unless there is some agreement on a common value system, especially on the concept of an obligation to future generations of men. Many people in the United States regard those who differ in both nationality and religion as something to be either killed or converted. Yet there are many in the world community who hold strikingly similar views about the nature of man and of the world, but these views have not been clearly articulated. Perhaps the stress of the times could lead to a revitalization of the religious impulse in terms that could bring a unifying movement into the world community. In order to contribute to survival, such an articulation must clearly identify the obligation to future generations and must proceed on the assumption that this world is the only one we will ever have.

Toward a Common Value System

If the nations of the world are to find a "bridge to the future," they will have to realize that they must unite to preserve the fragile web of nonhuman life that sustains human society. From this moment on, we are fighting a desperate war for survival and we cannot indulge in fratricidal forays to uphold value systems that may no longer be relevant.

Science, and particularly biological science, can offer guidelines for the development of value judgments based on the concept of survival.[24] Scientific guidelines will not be identical with existing religious statements of belief, but they should be compatible with the paradigms of the worldwide network of biological scientists, many of whom are more deeply religious in their reverence for life than many of the religious devotees of "holy wars." In thinking about biological science as a source of value judgments for humanistic biologists, I recalled the concept of the paradigm in the sense employed by T. S. Kuhn in *The Scientific Revolution.*[25] A paradigm is in essence a statement of a theory that no one expects to be disproved, yet is open-ended enough to provide for further action. I asked myself what paradigms might be formulated in the case of issues usually considered outside the realm of science. In my opinion, there are three main areas in which some existing religions have failed to revise their beliefs in accord with the advance of science. These are (*a*) an unwillingness to accept the idea of mortality, (*b*) an inability to understand the meaning of random suffering, and (*c*) an inability to understand novelty in biological and cultural evolution as historically conditioned rather than as arising *de novo* as creations or revelations.

In agreement with Kant's idea that wisdom is a guide for action and not merely *possession* of knowledge. I shall attempt to state acceptable courses of action based on the proposed paradigms of accepted belief. The result is the following Bioethical Creed, which presents five statements, each beginning with a statement of belief followed by a statement of proposed action, to provide a future-oriented system of morality that is based on the hopes that all races and creeds have for their children and grandchildren. The attempt to construct a creed is based on a strong feeling that beliefs are important because they determine what men do, and they provide the emotional drives that energize both learning and action. It is hoped that the following statements of belief and intent might be accepted by students and leaders of all races and nationalities:

A Bioethical Creed for Individuals

1. *I accept the need for prompt remedial action in a world beset with crises.*
I will work with others to improve the formulation of my beliefs, to evolve additional credos, and to unite in a worldwide movement that will make possible the survival and improved development of the human species in harmony with the natural environment.

2. *I accept the fact that the future survival and development of mankind, both culturally and biologically, is strongly conditioned by man's present activities and plans.*
I will try to live my own life and to influence the lives of others so as to promote the evolution of a better world for future generations of mankind, and I will try to avoid actions that would jeopardize their future.

3. *I accept the uniqueness of each individual and his instinctive need to contribute to the betterment of some larger unit of society in a way that is compatible with the long-range needs of society.*
I will try to listen to the reasoned viewpoint of others whether from a minority or a majority, and I will recognize the role of emotional commitment in producing effective action.

4. *I accept the inevitability of some human suffering that must result from the natural disorder in biological creatures and in the physical world, but I do not passively accept the suffering that results from man's inhumanity to man.*
I will try to face my own problems with dignity and courage. I will try to assist my fellow men when they are afflicted, and I will work toward the goal of eliminating needless suffering among mankind as a whole.

5. *I accept the finality of death as a necessary part of life.*
I affirm my veneration for life, my belief in the brotherhood of man, and my belief that I have an obligation to future generations of man. I will try to

live in a way that will benefit the lives of my fellow men now and in time to come and be remembered favorably by those who survive me.

Future Action

If the above statements of individual belief were acceptable to a substantial fraction of influential scientists in different parts of the world, others would perhaps gain the courage to join in a worldwide movement. The more immediate issues of war and peace, population control, and conservation of natural resources could be taken up in *legislative* terms. Statements of creed should not be considered as finished products but should undergo continual reexamination and refinement, and new statements should be added.

If our goal is the survival and improvement in the quality of life for the human species in keeping with the potentialities that can already be seen to exist and in keeping with the constraints imposed by the total ecosystem, we must be able to carry on a humanistic biology that is truly multidisciplinary. We must maintain our idealism, and we must be aware of the imperfection and disorder that are natural components of the biological and physical worlds. We must also learn about the natural rhythms of all biological hierarchies and interlocking feedback systems and their components. With better understanding of the basic mysteries and an appreciation of the idea that "ordered disorder" is built into biological systems[26] and that "disorder is the raw material from which order is conceived and selected,"[27] we may be able to monitor the survival parameters and to make open-ended decisions that can avoid positions of no return. Whether the survival of the human species in an acceptable form of civilization can be accomplished without the revision of many ancient and diverse beliefs is purely conjectural, but it would be surprising if survival could be based on erroneous beliefs. It seems likely that survival is possible only when the system of beliefs is compatible with the world situation. In earlier times, the results of erroneous superstitions were local and the disasters were local. Now the whole world is influenced by events in any part of it. Change in outlook is needed, but will the change come in time?

NOTES

1. Norbert Wiener, "Cybernetics," in *Science, Conflict and Society* (*Readings from Scientific American*), ed. Garrett Hardin (San Francisco: W. H. Freeman & Co., 1969), pp. 119–25.
2. Arnold Tustin, "Feedback," in Hardin (n. 1 above), pp. 126–33.
3. Durward L. Allen, *Population, Resources and the Great Complexity*, Selection

no. 29 (Washington, D.C.: Population Reference Bureau, August 1969). Allen contrasts the life-style of a resident of a small town in the 1920s with that of an urbanized man of today to the disadvantage of the latter. R. L. Meier emphasized a different view (see F. Fraser Darling and John P. Milton, eds., *Future Environments of North America* [Garden City, N.Y.: Natural History Press, 1966], p. 277; this book is a detailed record of an important symposium).

4. C. W. Griffin, Jr., *Frontier Freedoms and Space Age Cities* (New York: Pitman Publishing Corp., in press). See also his article of the same title in *Saturday Review*, February 7, 1970, p. 17.

5. John K. Galbraith, *The Affluent Society* (Boston: Houghton Mifflin Co., 1958), chap. 2.

6. Kenneth Boulding, "Economics and Ecology," in Darling and Milton (n. 3 above), pp. 225–34.

7. Ian McHarg, "Discussion," in Darling and Milton (n. 3 above), p. 307.

8. T. V. Smith and M. Grene, *From Descartes to Kant* (Chicago: University of Chicago Press, 1940).

9. See Tustin (n. 2 above).

10. See ibid.; and Wiener, "Cybernetics" (n. 1 above).

11. Cf. Van Rensselaer Potter, *Bioethics: Bridge to the Future* (Englewood Cliffs, N. J.: Prentice-Hall, Inc., in press), chap. 1.

12. V. R. Potter, "The Present Status of the Deletion Hypothesis," *University of Michigan Medical Bulletin* 23 (1957):401–12.

13. See Potter, *Bioethics*, chap. 1.

14. See Tustin (n. 2 above).

15. Norma McArthur, "The Demography of Primitive Populations," *Science* 167 (1970):1097–1101.

16. Paul Ehrlich, *The Population Bomb* (New York: Ballantine Books, 1969).

17. Margaret Mead, *Continuities in Cultural Evolution* (New Haven, Conn.: Yale University Press, 1964).

18. See Potter, *Bioethics*, chap. 3 (n. 11 above).

19. Beryle Crowe, "Tragedy of the Commons Revisited," *Science* 166 (1969):1103–7.

20. Psalms 111:10.

21. John Platt, "What We Must Do," *Science* 166 (1969):1115–21.

22. Shepard B. Clough, *The Rise and Fall of Civilization: An Inquiry into the Relationship between Economic Development and Civilization* (New York: Columbia University Press, 1957).

23. Galbraith (n. 5 above).

24. Ralph Wendell Burhoe, "Values via Science," *Zygon* 4 (1969): 65–99. Professor Burhoe provides an extensive bibliography in addition to his thought-provoking discussion. The same issue contains six other papers on the general subject of human values and natural science with many additional references.

25. See Potter, *Bioethics*, chap. 1 (n. 11 above).

26. Ibid., chap. 7.

27. Ibid., chap. 4.