

DISORDER AS A BUILT-IN COMPONENT OF BIOLOGICAL SYSTEMS: THE SURVIVAL IMPERATIVE

by Van Rensselaer Potter

We are living in a time of disorder, which I mean to imply is a high frequency of random, unplanned, uncontrolled, and unpredictable events. In the next three decades there is likely to be a feeling that the disorder goes beyond the capabilities of governments to predict, control, and respond to events in a way that promotes the general welfare. Indeed, there are many thoughtful people who feel that we have already reached that sorry state. Thus, it is not surprising that a simplistic view is rather widespread: disorder is bad and order is good. This oversimplification is only the first phase of a more involved discussion, and it will be my purpose to emphasize two points: (1) that disorder, that is, random, uncontrolled events, is built into biological systems and into the natural world at virtually every level, and (2) that disorder as defined has some features that are worth examining and preserving because they contribute to survival.

We tend to prefer order and to react instinctively to resolve disorder into some kind of rational order because in the process of surviving, the human species had to have a fairly accurate ability to distinguish reality from fantasy. To give an example, a young child learns by experience the reality that a hot stove burns his fingers and henceforth knows that a hot stove *can* burn his fingers without additional experience. Beryl Crowe has concluded that in dealing with more involved problems, mankind has developed an instinct that favors order and is repelled by disorder because "one of the basic elements of man's nature is a low tolerance of ambiguity."¹ He goes on to say that this trait probably has survival value for the species, for once man lost a large portion of his instinctual behavior, the species had to be motivated somehow to reduce an intolerable and random-appearing environment to some tolerable and predictable order. But in the course of his cul-

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tural evolution man developed scientific principles that were at odds with previously elaborated religious beliefs with the result that, again quoting Crowe, "If one of man's primal responses is the resolution of ambiguity, then any ethical system that raises ambiguity to a high level and makes resolution of that ambiguity impossible will produce pathological behavior both at the social and at the individual level. This is the very set of conditions that Protestantism in general, and Calvinism in particular, imposed on Western Man." Later he explains what he means, as follows: "I would suggest that most of us, as heirs to the Protestant tradition, are asking ourselves who we are and what we are worth, and our answer is framed in terms of compulsive consumption. . . . This pattern of consumption is socially pathological because we now have the power to overload our environment. And it is individually pathological because there is no saturation point in our attempt to find personal worth in our consumption of things, to the point where we are committing collective biocide." Here I should emphasize that there is nothing in Calvinist tradition that requires compulsive consumption, although Crowe is probably correct in regarding it as a natural outgrowth of the work ethic that was molded in a time of scarcity.

If Crowe is correct in his basic assumption that "one of the basic elements of man's nature is a low tolerance of ambiguity," or in other words an instinct that favors order and is repelled by disorder, it is high time that considerations of the relation of science and human values should focus in on Wallace's theme and attempt to derive and disseminate a sophisticated perception of the *uses* of disorder.² Among these uses I include the implementation of the survival imperative.

ETHICAL IMPERATIVES AND BIOLOGICAL REALITIES

At issue is the problem of human values, and the role of society's institutions in defining, maintaining, and elevating these values, which are encoded in what may be called "ethical imperatives." The two institutions that are most frequently challenged to defend their role with respect to the ethical imperatives are religion and science, and both of these institutions will have to undergo considerable change if a viable set of ethical imperatives is to evolve. Elsewhere I have argued that human values cannot be maintained in ignorance of, or in opposition to, biological realities, and to emphasize the point I coined the word "bioethics."³ My point is that the ethical imperatives have to be elaborated on the basis of the biological imperatives. Some may ask why "bio-" and not "geo-," "psycho-," or some other scientific discipline—but I will not discuss that issue. The word speaks for itself. What I want to discuss on the present occasion is a particular biological reality

that appears not to have been sufficiently considered in relation to ethical theory. The reality to which I refer, is, of course, the phenomenon of disorder, which as my title suggests, is built into biological systems at every hierarchical level. I shall attempt to defend the thesis that "the most important contribution science can make to society is to increase the degree of sophistication with which mankind perceives 'order' and 'disorder'" in connection with the ongoing search for the ethical imperatives that will guide us through the next three decades of the twentieth century and beyond.⁴ It is my contention that a *misapprehension* of the relation between order and disorder can bring only sorrow and ruin to mankind in the long run, no matter what comfort these misapprehensions in the name of religion may bring to individuals from time to time. On the contrary, an improved understanding of order and disorder can only help us in our search for answers to the age-old questions: "Who am I?" "Whither am I going and what must I do to be saved?" which really means, "and what must I do to be able to live with myself in a state of mental and physical health?" It is possible to argue that, in a world without science, religion could play a saving role even though its misapprehensions were colossal, if only they were believed. But in a world in which the challenges to organized religion are impossible to suppress, and in which the rearguard defenses are broadcast daily to millions who cannot possibly believe all that they hear, it is high time that science as an institution should do something to repair the articles of faith which men must have to survive as individuals and as societies.

THE EUREKA FEELING

Ethical imperatives based on ethical theory have always originated in the minds of concerned individuals, and no doubt have crystallized only after months or years of thought and discussion. Undoubtedly, suffering and despair, coupled with high motivation, have contributed to the moment of illumination as in the Handsome Lake episode described by Wallace.⁵ I do not have to possess a Ph.D. in behavioral psychology or to cite the behavioral literature to convince you that the moment of illumination is an event that cannot be willed, cannot be predicted in terms of the time of occurrence, and cannot be guaranteed to occur. I say this because everyone within range of my voice has experienced what I am talking about. It is recorded that Archimedes in his bath said, "Eureka!" (I have found it) when he discovered the scientific law of buoyancy that bears his name. All of us have experienced the Eureka feeling and know that it is accompanied by euphoria, elation, and a momentarily exalted love of life. But if I were to poll the audience as

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to whether every Eureka experience produces a *correct* explanation or model of the problem at hand, some would vote in the affirmative, while others would admit that many Eureka experiences produce incorrect conclusions or false models of the problem. The Eureka feeling applies to art, music, engineering, and daily life as well as to science, the humanities, religion, and ethics; and much has been written about it under the heading of "creativity," which I would like to define as originality that at the lowest level contributes to the self-development of the individual and at the highest level contributes to the welfare of mankind.⁶ The conditions that foster creativity are well known, and in the field of science, as in chess or professional football, it is necessary to focus on a field of attention, to establish a goal, and to agree on rules. Proceeding from this point, it is agreed that the mind should be supplied with the relevant facts, motivation should be high, and outside distractions must be minimized.⁷ But given these preconditions, I repeat that there is an element of disorder or randomness in the outcome: there may be no Eureka event, or it may occur but the idea may be incorrect.

If this conclusion is valid, then I say that in the search for ethical imperatives we can no longer accept the conclusions of men whose claim to validity is based on their own euphoria and whose training has left them unaware of the fact that the validity of an idea cannot be measured by how good it makes one feel. Their motives may be the highest, but if they are ignorant of the rules, uninformed as to the biological realities, and unwilling to submit to criticism from outside their own point of view, they cannot be honored for their convictions. This line of thought leads me to reject the supernatural as a source of ethics.

The foregoing analysis of the Eureka feeling is basic to my thesis that science can contribute to a search for ethical imperatives. I am urging that in understanding this task, science would do well to increase mankind's understanding of the place occupied by disorder or randomness in man's nature, thoughts, and actions, and in the natural world. It was implicit in my argument that the shortcomings in the minds of individual men can be overcome with the purification and refinement of every new idea by ongoing examination by other men with similar motivations but differing inputs.

DISORDER AS A BIOLOGICAL REALITY

In discussing the issue of order and disorder, I wish to emphasize the notion that disorder is built-in, that it is maintained by Darwinian natural selection, that it is an essential part of the biological system, and that our aim should not be to eliminate it, but rather to recognize

it for what it is and to harness it creatively in a continuous tension and balance with order. Trouble and misery are in part the price we pay for the disorder that is necessary for evolution to occur. It can be argued that in biological evolution nature has achieved a kind of "ordered disorder" to achieve survival in the natural milieu.⁸ What I proclaim is that in cultural evolution we should do likewise. It should not be assumed that balance between order and disorder implies 50 percent of each as the image of blind Justice holding the scales might suggest. Biological evolution has proceeded with a ratio of order to disorder in the replication of the DNA molecule that is unbelievably close to perfection.⁹ But without that infinitesimal level of built-in copy error, that is, disorder, evolution would never have occurred, and we would not be here to discuss it.

In looking at previous discussions on the subject of order and disorder in relation to ethical imperatives, it seems to me that the built-in aspect of disorder has been neglected. Not that the ancients were unaware of disorder. Far from it. But organized religions have never been able to face disorder in the form of random calamities and human suffering without succumbing to the temptation to use misfortunes as instruments of God's will. The story of Job is the classical example of the righteous man who suffered grievously only to learn that his faith was being tested. How many people today accept the idea that the wanton killing of the Kennedy brothers was part of a larger and somehow Divine purposeful plan?

This poignant plea for a supernatural purpose has been underscored by A. F. C. Wallace whose examples of disorganization were wholly negative: "metals rust and corrode, woods and fabrics rot, people sicken and die, personalities disintegrate."¹⁰ He characterized religion and science as both stemming from an "organizational instinct" to "increase the organization of cognitive perception," while noting parenthetically that religions may have gone "beyond what rational use of the data . . . would justify." Meanwhile, science has attempted to "increase the organization of cognitive perception" in an aseptic world of moral relativism free of value judgments, and has avoided any open discussions of the Job syndrome of human suffering in order to maintain an uneasy truce with organized religion.¹¹ It will be an intellectual exercise of heroic proportions to explore the consequences of substituting natural purpose for supernatural purpose in our "perceptions of order and disorder in culture."¹²

THE THERMODYNAMIC IMPERATIVE

Also emphasizing the human tendency to "increase the organization of

cognitive perception," R. B. Lindsay has on several occasions derived an ethical imperative from the second law of thermodynamics—the law of increasing entropy—that is to say, the tendency for all systems to proceed from order to disorder.¹³ This is the same point made more vividly by Wallace—metals rust and corrode, etc.¹⁴ Lindsay goes on to explain entropy in classical terms: "The maximum entropy of Clausius is the state of complete disorder or thorough randomness, out of which no return to order is practically possible because it applies to the universe as a whole; nothing short of an inexpressibly improbable revolution could reverse the process and decrease the entropy."¹⁵ But he then pictures living organisms as examples of local decreases in disorderliness (that is, decrease in entropy) by a transformation of disorder into order, which he assumes is "altogether likely" to be accomplished by an increase in entropy elsewhere.¹⁶ The assumption of a concomitant increase in entropy is correct, of course, and a more adequate discussion would bring out the fact that the term "entropy consumption" is itself misleading. There is no such thing as an energy-requiring reaction in the absence of energy input in living systems, and the decrease in entropy in one reactant is accomplished by an increase in entropy, not somewhere else, but right on the spot by the phenomenon of energy coupling, in which another reactant moves to an increased entropy level.¹⁷ However, Lindsay was not concerned with the details of his proposition but endeavored to move directly to the ethical imperative that he felt could be derived from what he saw as the biological reality. From the fact that all living creatures contain molecules that have been transformed from a less organized to a more organized form he derived what he called the "thermodynamic imperative," which "if reasonably interpreted might serve as a satisfactory basis for an ethical code."¹⁸ He thereupon states the proposition and discusses it in terms that make its interpretation highly constrained and therefore impossible to interpret reasonably. His statement leaves very little room for maneuver when he says, "*All men should fight always as vigorously as possible to increase the degree of order in their environment, i.e., consume as much entropy as possible, in order to combat the natural tendency for entropy to increase and for order in the universe to be transformed into disorder, in accordance with the second law of thermodynamics*" (italics added).¹⁹ Aside from the fact that I deplore the use of the terms "entropy" and "thermodynamics" as examples of shamanism in the present context, I feel that the basic idea has already been stated in the first eighteen words, and that the position taken as an ethical imperative would be rejected as unconstitutional by the U.S. Supreme Court, if not by lower courts. Lest any doubts as to whether the thermodynamic imperative could permit a little disorder to be looked upon as

creative, desirable, constructive, built-in, selected for by Darwinian evolution, or even permissible, Lindsay appears to go completely overboard in his simplistic conclusion that order is good and disorder is bad. I would simply deny that all men should fight always to consume as much entropy as possible. I think the issue is confused by the thermodynamics argument because every *increase* in biological or technological order is coupled to a *greater* decrease in order *in material flowing through the system* with the difference made up in heat. What Lindsay is advocating would simply lead to an increase in thermal pollution as more and more people burned more and more coal to make more and more steel to build higher and higher skyscrapers. But Lindsay makes it clear that he is thinking not only about order in the form of skyscrapers but about order in the form of *ordered thinking*. Now I am sure we all agree with Wallace and with Lindsay that as thinking humans we do have an instinctive urge to see order in our universe, but it is my thesis that the quest for order will be sterile and unproductive without a continual infusion of what Lindsay would apparently regard as undesirable disorder. It seems clear that in Lindsay's world experimentation goes by the book and never involves disorder.

After citing case after case in which man endeavors to maximize order in his environment, he states as follows: "Of course the picture is not quite as simple as all this. There are obvious fluctuations in the entropy consumption by living things. We recognize that *destructive tendencies* are exhibited by many human beings, and to this extent they are entropy producers rather than consumers. Arsonists and murderers are clearly in this class, and, in a milder way, the alcoholic shows the same tendency. Not wholly inappropriately is the term disorderly applied to him. The reader can supply for himself plenty of illustrations of those who manage to produce more than their fair share of entropy [read: disorder] in their immediate environment; *they are the nuisances of society*. But society, as we know it, could hardly exist without large scale local consumption of entropy [read: order production]. The very existence of science itself is a good example"²⁰ (italics added).

At this point he exalts science as an institution free from disorder, the epitome of the ethical imperative derived from thermodynamics: "Man's ceaseless urge to force some order on his experience so that he may understand it is to be interpreted as an entropy-consuming drive in the realm of both ideas and manual activities for the production of new experience through experimentation. It is to be noted that these activities *are not haphazard but, in science, proceed according to a definite plan*, i.e., imply a desire for *greater order in human experience*"²¹ (italics added).

For the benefit of nonscientists it may be recalled that accidental or

unplanned discoveries are so frequent that they have been given a special name—Serendipity. And the element of chance plays so frequent a role that we have constantly to remind students of Pasteur’s aphorism, “Chance favors the prepared mind.” Scientists as well as other thinkers proceed frequently by intuitive leaps called “strong inferences” which occur in prepared minds by processes that involve probabilities but not certainties.²² We can increase the probabilities of inspiration but we still require some ordered disorder or just plain disorder to get the Eureka event, and even then we cannot accept the strong inference as a conclusion (see fig. 1).

RELIGIOUS ATTITUDE TOWARD RANDOM EVENTS

Up to this point I have touched upon the creative aspects of an optimized amount of disorder in the human task of problem solving in connection with the Eureka event, and I have deplored the thermodynamic imperative as a scientific approach to ethics, first in terms of thermal pollution and second *insofar* as it seems to imply that all order is good and all disorder is bad. Nevertheless, still seeking ethical imperatives based on science, I cannot ignore what I regard as a failure of *both* religion and the thermodynamic imperative to deal with the phenomenon of random events at no less than two levels: (1) at the level of human suffering in connection with the Job syndrome, and (2)

DECISION-MAKING IN A FREE SOCIETY

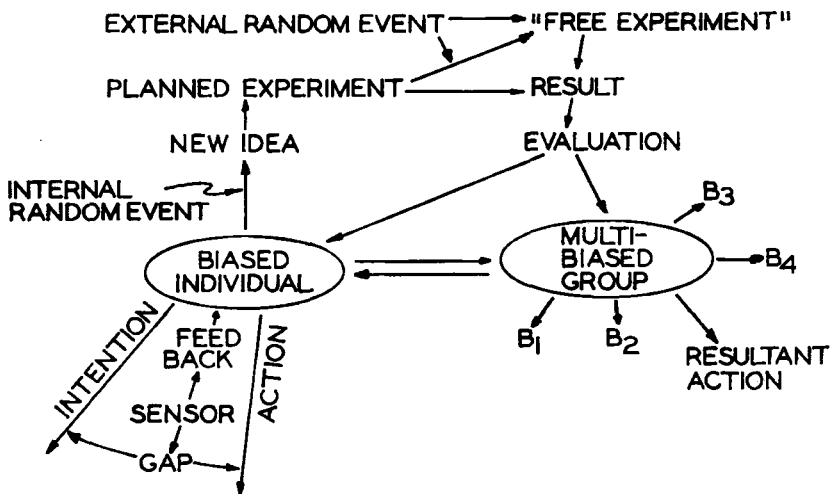


FIG. 1.—Decision making in a free society. (Reprinted from the author’s *Bioethics: Bridge to the Future*, by permission of Prentice-Hall, Inc., © 1971.)

at the level of individual inspiration, revelation, or naïve creativity. In terms of classical religions we must ask whether the creation and further evolution of man operate according to a Divine plan, for a purpose, and in response to an infinite wisdom that is recognized by some and not by others; or, alternatively, whether the biological world operates by natural laws that swing into action after each successive perturbation that occurs not by an infinite wisdom but by the caprice of fate, not only at the beginning but on a day-to-day basis throughout time and down to this very moment, operating always on the basis of a survival principle or imperative. In seeking ethical imperatives we must seek out segments of religious thought that can sit down with modern science and work out a system of ethics that does not insist on a belief that is unaffected by knowledge. The stereotype scientist seems to say, "I don't know, and what I believe is irrelevant." The stereotype theologian seems to say, "What I believe is the only thing that matters and what I know is irrelevant." Fortunately, many modern scientists and theologians are now rapidly changing their outlook. The position of anyone concerned with scientific theology, science-oriented ethics, or simply *bioethics* at this point in time must be, "What I know is limited, but I will combine it with the knowledge and opinions of other intelligent and ethically minded men from various disciplines to determine what I believe and do, and I will attempt to develop and disseminate ethical guidelines that will contribute to the survival and betterment of the human species."

THE SURVIVAL IMPERATIVE: SOURCE FOR BIOETHICAL IMPERATIVES

Having rejected both the supernatural and the thermodynamic modes of ethical development, I wish to come down definitively in terms of an orientation that stems directly from a knowledge of biology. My orientation can be stated simplistically as the "survival imperative" and from it can be derived a number of bioethical imperatives that permit ongoing discussion, evaluation, and revision, facilitated by a compass setting that is clearly defined. Whenever *survival* is mentioned as a goal, the question is always raised as to whether we are placing too great a value on survival, or, in other words, is *mere* survival worthy as a goal? Of course we are not talking about survival of mankind at a primitive level such that no recorded knowledge is available. Indeed that is precisely the kind of emergent society that I would regard as having failed. So at the outset I will define survival as the survival of mankind in a form that is capable of preserving the accumulated knowledge of the past and transmitting it to future generations. I believe this definition implies a great deal that can be discussed at length but need not be

discussed at this moment. Suffice it to say that my definition of survival could be called "idealistic survival," and I would place greater emphasis on wisdom than on new knowledge in general. Elsewhere I have defined wisdom as a special kind of knowledge: the knowledge of how to use knowledge for the social good.²³

The concept of the survival imperative as a source of human values or, in my terms, as a source of bioethical imperatives, has been previously mentioned by B. F. Skinner in *Science and Human Behavior*.²⁴ The concept has also been discussed by Ralph W. Burhoe in a recent paper entitled "Values via Science" in which he reviews Skinner's comments on survival as a test of human values, along with a review of many other books and articles on science and human values.²⁵ In most of these earlier presentations, survival was an implicit guideline but seldom was it a central theme. Thus, as a behaviorist, Skinner naturally emphasized behavioral science when he said: "Since a science of behavior is concerned with demonstrating the consequences of cultural practices, we have some reason for believing that such a science will be an essential mark of the culture or cultures which *survive*. The *current culture which, on this score alone, is most likely to survive is, therefore, that in which the methods of science are most effectively applied to the problems of human behavior*" (italics added).²⁶ Skinner was thus aware of the role of the environment in determining long-range survival but did not convey the sense of ecological crisis that prevails today, nor was there a suggestion that survival as I have defined it could someday be in doubt.

I believe that there is urgent need for a synthesis of behavioral knowledge with environmental knowledge in order to develop a viable set of bioethical guidelines not only for individuals as I have attempted, but for international accords.²⁷ I believe that national survival in the face of international ecological disaster will be impossible and that the dangers of nuclear warfare are diverting our attention and effort from the more insidious dangers of ecological disaster of which Paul Ehrlich and Barry Commoner have repeatedly warned us.²⁸ Thus I am discussing science and human values not as an academic subject that is limited to an ivory tower, but from the standpoint of human survival on an international scale. I am saying that, with Wallace, we need to examine "perceptions of order and disorder in culture," and with Skinner, hopefully ameliorated with the insights of Margaret Mead and others who might be considered behaviorists, we need to inquire how the world outlook of Americans and other nationals can be helped to see that "idealistic" survival really is in doubt and that new bioethical precepts have to be elaborated and taught to both young and old. We do not have time to save the world by teaching the young and ignoring

the views of the elders. How much of the developing world crisis can be traced to the American characterization of the Russians as atheistic Communists bent on destroying the capitalistic system, plus the assumption that God is on the side of Western capitalism? From the anthropologists and behaviorists we might ask how we can back away from those twin bastions of American foreign policy without completely losing our national nerve. Elsewhere, Crowe, in a commanding article has questioned the possibility of a political solution and has discussed "the myth of the common value system" as one of three major hurdles in our attempt to survive as a nation.²⁹ Somehow we must back away from a system that produces six thousand babies per day and twelve thousand automobiles per day, and from a system that accepts the idea that in the United States alone *we will need enough electric power for 299 more San Franciscos by 1980.*³⁰

DISORDER IN BIOLOGICAL EVOLUTION AND CULTURAL EVOLUTION

Time does not permit an adequate presentation of the nature and role of disorder in the biological and physical world, and the following remarks and illustrations are a bare outline of what might be attempted.

I would begin at the molecular level, where the motions of individual molecules in a gas or in a solution are completely random. The gas laws covering the relations between pressure, volume, and temperature are based on the assumption of random motion at the level of individual particles.

Next, I would describe radioactive decay, and the fact that the many applications of radioactive isotopes in medical research in my own and other laboratories are based on the assumption that the decay in a single atom is a completely random event, making possible the prediction of the half-life of a population of molecules.

At the level of the gene substance, DNA, there appears to be a finite random mutation rate that can be increased by various physical and chemical hazards. This point, which is widely accepted, has been recently elaborated in an important new contribution by J. Bronowski,³¹ who entitled one section of his essay "The Role of Errors." He pointed out, as we would emphasize in this presentation, that "life is not only a process of accurate copying. . . . Life is also and essentially an evolutionary process, which moves forward only because there are errors in the copy, and every so often one of these errors is successful enough to be incorporated as another step or threshold in its progression. . . . The stable units that compose one layer are the raw material for random encounters which will produce higher configurations, some of which will chance to be stable."³²

At the level of genetic recombination to give the Mendelian Law of

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Inheritance we find that the law results from the assumption of a completely random shuffling of the units of inheritance that come from the parents to the offspring.

At the level of the central nervous system there is a whole new field of animal behavior categorized as "protean" which is disordered behavior based on natural selection.³³

I would draw an analogy between biological and cultural evolution in terms of their components (fig. 2), in terms of the feedback relations within each system (fig. 3), and between the two systems (fig. 4). I would picture the cell as a black box with feedback mechanisms that operate to promote survival under the conditions in which its evolution occurred (fig. 5). Since I have described some of these features elsewhere,³⁴ I have not entered into a detailed presentation here.

BIOLOGICAL EVOLUTION

L.C.D.=DNA MOLECULE

DNA PROPERTIES:

1. INFORMATION
2. REPLICATION
3. MUTATION: COPY-ERROR
4. EXPRESSION
5. FEEDBACK

CULTURAL EVOLUTION

L.C.D.=IDEA

IDEA PROPERTIES:

1. INFORMATION
2. REPLICATION
3. MUTATION: COPY-ERROR
4. EXPRESSION
5. FEEDBACK

FIG. 2.—Analogous properties of biological and cultural evolution. L.C.D. = least common denominator.

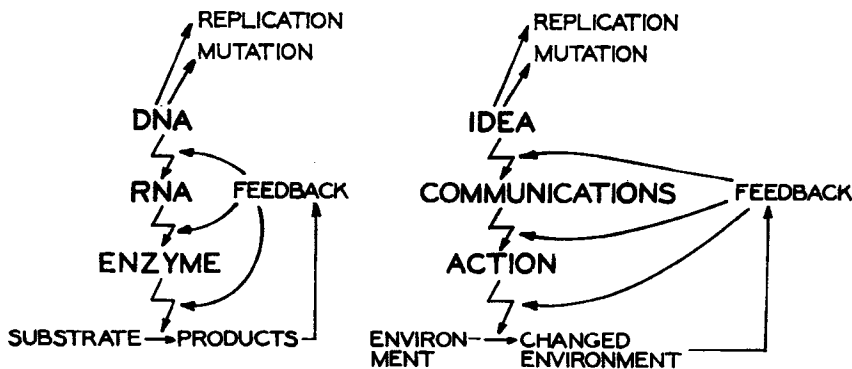


FIG. 3.—Flow of information and feedback in biological and cultural evolution. (Reprinted from the author's *Bioethics: Bridge to the Future*, by permission of Prentice-Hall, Inc., © 1971.)

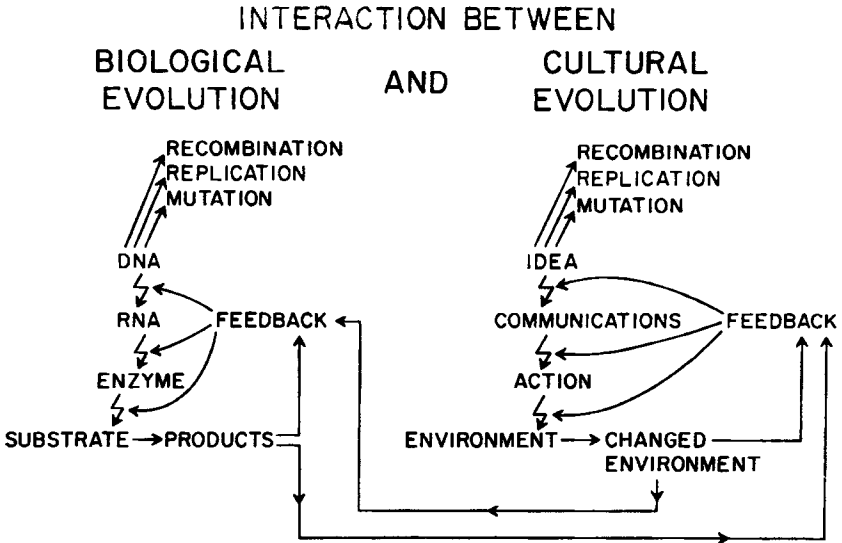


FIG. 4.—Feedback between processes of biological and cultural evolution (modified from fig. 8.1, p. 107, in the author's *Bioethics: Bridge to the Future* [New York: Prentice-Hall, Inc., 1971]).

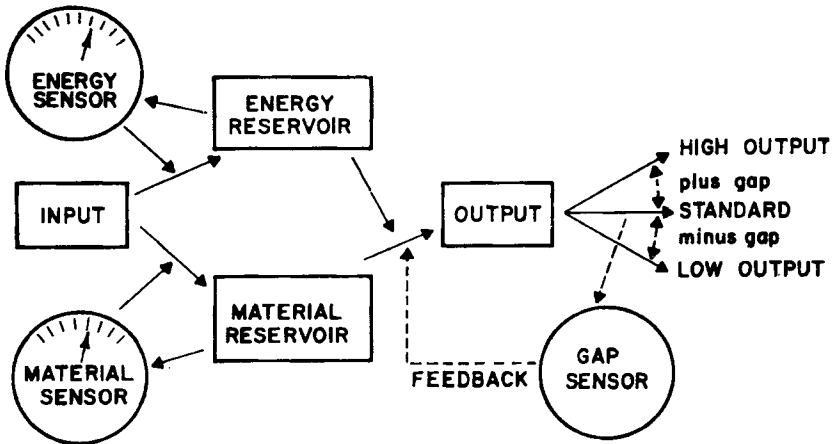


FIG. 5.—The cell as a black box with survival as its purpose. (Reprinted from the author's *Bioethics: Bridge to the Future*, by permission of Prentice-Hall, Inc., © 1971.)

CONCLUSIONS

We cannot avoid the conclusions: (1) that our survival as a nation is inextricably wrapped up with the survival of mankind; (2) that the combination of expanding populations with expanding "compulsive

consumption" and widespread pollution by a misled majority has been encouraged in the United States by the advertising policies of an industrial economy based on planned obsolescence and inferior repair arrangements at the consumer level, while at the same time millions are without adequate food and shelter; and (3) that a drastic revision of our national perception of human values and biological realities will be required if we are to survive during the next thirty years.

On the basis of these conclusions we are led to bioethical imperatives such as:

1. Religious opposition to population control should be overcome and emphasis should be on a rate of population increase no greater than permitted by a state of positive health in harmony with environmental constraints.

2. Conspicuous consumption and pollution in the United States should be discouraged by public discussion, new advertising and production policies, and by excise taxes, in order to conserve natural resources, feed and shelter the needy, and restore the environment to a state that will improve the quality of life and provide leadership by example for world society.

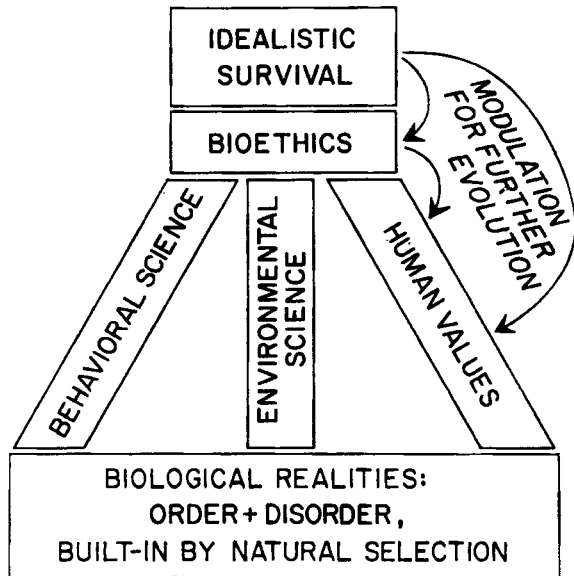


FIG. 6.—Order and disorder as biological realities arrived at by natural selection; bioethics as the integration of behavioral science and environmental science with human values for idealistic survival.

3. The educational system should be reorganized to help the needy achieve independence and to reeducate the independent to their responsibilities in terms of man's survival.

Each of these proposals requires an increased knowledge of human behavior, coupled with a knowledge of ecological realities and a decent respect for human dignity and human values. Knowledge in the field of human behavior is dangerous knowledge unless adequately constrained by bioethical guidelines that evolve into law. The overall concept that I have presented is summarized in figure 6, in which "Idealistic Survival" is supported by *Bioethics*, which in turn is based upon *Behavioral Science*, *Environmental Science*, and *Human Values*. Fundamental to the overall structure are *Biological Realities: Order and Disorder* built into living systems by *Natural Selection*. Indicated on the right is the concept that new concepts of appropriate human values will emerge from bioethics and the vision of idealistic survival.

NOTES

1. Beryl Crowe, "Whose Hidden Hand Is Destroying the Environment: Victoria Regina's or Adam Smith's?" (paper delivered at the First Congress on Optimum Population and Environment, Chicago, Ill., June 7-11, 1970).

2. Anthony F. C. Wallace, "Perceptions of Order and Richness in Human Cultures," published elsewhere in this issue of *Zygon*. Wallace's paper was read in abbreviated form as "Perceptions of Order and Disorder in Human Cultures" at the symposium on science and human values during the annual meeting of the American Association for the Advancement of Science, Chicago, Ill., December 29, 1970.

3. See Van R. Potter, *Bioethics: Bridge to the Future* (Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1971).

4. *Ibid.*, chap. 4.

5. Anthony F. C. Wallace, *Religion: An Anthropological View* (New York: Random House, 1966), pp. 31-33.

6. Modified from a proposal at a symposium on creativity, University of Southern Illinois, Carbondale, November 1-3, 1968.

7. *Bioethics*, chap. 8.

8. See D. A. Humphries and P. M. Driver, "Erratic Display as a Device against Predators," *Science* 156 (1967): 1767; and *Bioethics*, chap. 7.

9. M. Kimura, "Evolutionary Rate at the Molecular Level," *Nature* 217 (1968): 624.

10. *Religion*, p. 38.

11. Cf. *Bioethics*, pp. 85-90.

12. Wallace (see n. 2 above).

13. See R. B. Lindsay, "Entropy Consumption and Values in Physical Science," *American Scientist* 47 (1959): 376; and *The Role of Science in Civilization* (New York: Harper & Row, 1963), esp. chap. 9, "Science and Human Behavior."

14. *Religion*, p. 38.

15. "Entropy Consumption," p. 382.

16. *Ibid.*, p. 383.

17. *Bioethics*, chap. 1.

18. *The Role of Science*, p. 292.

19. *Ibid.*

20. "Entropy Consumption," pp. 383-84.

21. *Ibid.*, p. 384.

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22. See John R. Platt, "Strong Inference," *Science* 146 (1964): 347; also cited in *Bioethics*, p. 8.
23. *Bioethics*, p. 183.
24. B. F. Skinner, *Science and Human Behavior* (New York: Macmillan Co., 1953), p. 446.
25. Ralph Wendell Burhoe, "Values via Science," *Zygon* 4 (1969): 65-99.
26. As quoted in *ibid.*, p. 71.
27. *Bioethics*, pp. 194-96.
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