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INTRODUCTION TO THE SYMPOSIUM ON SCIENCE AND HUMAN VALUES

by Ralph Wendell Burhoe

I am pleased to introduce this symposium on science and human values, which has been made possible by the Institute on Religion in an Age of Science with support from the Alfred P. Sloan Foundation. We are meeting under the auspices of the Section of the History and Philosophy of Science of the American Association for the Advancement of Science.

WHY DISCUSS VALUES AT A SCIENTIFIC MEETING?

During the past couple of centuries, the topic of human values has not been a proper topic of science or a scientific meeting. C. P. Snow's *Two Cultures*[1] has reminded us of the gulf that separates the thinking of men in the scientific disciplines from those in the humanities. Anthropologist Clyde Kluckhohn a dozen years ago told the American Philosophical Society in his "Scientific Study of Values and Contemporary Civilization" that

> it is unfortunate that in the Western world during the last century and a half a divorce between nature (as described and interpreted by science) and values has generally been accepted. . . . It is expressed colloquially in such utterances as "Science provides only a car and a chauffeur for us. It cannot, as science, tell us where to drive." I suspect that the division of territory which ascribed

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to science the realm of "fact" and to religion and the humanities the realm of "value" was, in effect, a temporary resolution of the so-called "conflict between science and religion" which plagued the nineteenth century.[2]

But two factors have been forcing scientists and technologists increasingly in recent years to become *professionally* concerned with human values.

The first factor is the crisis brought about by the declining potency of the disciplines and institutions that traditionally have provided the culturally evolved patterns of human values. During the past few centuries the traditional religious and moral values of the Western world have withered away as the underlying beliefs faded in the face of the radically different images of reality presented by the new sciences, such as those of Newton, Darwin, and Freud. Now, in the present century, men not only in the West but in all of the world's cultures have begun to be aware of the impotence or irrelevance of their traditional faiths and values in the face of the radically new visions of reality and the radically new conditions of life in the world men have created by the use of science and scientific technology. Kluckhohn in the above-mentioned paper pointed out that the "uncertainty about and conflict over values" in the contemporary world result in "personal and social disorganization, individual unhappiness and human misery on a vast scale, [and in] irrational political movements which both manifest and add to these disasters."[3]

The second factor is the pressure of the many crises brought about by men's often unwise and frequently disruptive use of the powers put in their hands by science and scientific technology. This unwise use of new powers has produced crises both of man's internal and of his external nature. The internal crises are both individual and social. Inside individuals, there is a breakdown of the sanity, stability, and peace of mind under the strange new conditions of urban and technological life where the traditional visions of values do not seem credible or relevant. Inside the political and social structures, instability increases as traditional institutions react to a strange new world whose problems they were not designed to handle. The crises of man's external nature include such consequences of the man-made explosions of population, power, and production as the increasing pollution and poverty of the natural resources on which human life depends. The twentieth century is a crescendo of unprecedented billions of people involved in internal and external disruptions of order, where the fiery mushroom cloud of an atomic bomb becomes the ominous symbol of the chaos and despair for which many blame science and technology.

Both these factors—the withering of the traditional sources of cul-

tural values and the radical changes in the circumstances of life made possible by science and scientific technology—have forced scientists to become involved as scientists in problems of human values. At this 1970 annual meeting of the AAAS there are dozens of sessions dealing with the relation of the sciences and scientific technology to problems of human value, although perhaps this symposium on science and human values may be the only one attempting *explicitly* to utilize the sciences, especially the physical sciences, to provide an understanding of human values themselves.

What Are Values, That They May Be Approached by Science?

What are human values? How can we speak about them scientifically? We can use "human values" to indicate two classes of phenomena or observables. First, those things or behaviors that men do in fact desire or seek—their existing goals or aims. Second, "human values" may designate those things or behaviors that men do not yet in fact desire or seek, but which they ought to desire or seek, if. . . . This last, especially the "ought" and the "if," needs a little explanation if we are to include it in a scientific discourse. In philosophy, since Hume and Kant a couple of centuries ago, it has been customary to say that the "ought" cannot be derived from the "is" and that there is an unbridgeable gulf between the first kind of human values (the goals men do in fact already have) and values of the second kind (the goals men ought to have).

For me a bridge from the "is" to the "ought" was clearly formulated by Richard von Mises, a famous aeronautical engineer and philosopher. A few decades ago he wrote in his *Positivism: A Study in Human Understanding:*

> The outright pronouncement or formulation of commands can in no way be called a science. . . . But if one means the *justification* of commands or norms, one finds oneself again in the sphere of the *usual* forms of science. For a sentence construction of the kind: One ought . . . , because . . . , if it is not completely meaningless, can be immediately transformed into: If . . . , then. . . . In other words, a norm together with its justification is nothing but an ordinary statement. To the extent in which the words and locutions then used are based upon a constituted linguistic usage, the statement is connectible and, in general, verifiable.[4]

In other words, the justification of an "ought" statement or other expression of value can become scientific if one can find that there exists some prior goal that may have only been implicit in the "ought" statement. For instance, the physician's statement may be: "You ought

to take more exercise and eat less sweets." But implict in this ought statement is: "If you want to lose weight and stay healthy," or some such implied goals. The implied goal is an underlying *fact* that is taken for granted or presumed by the speaker. Of course, one may then raise the same kind of question about the prior goal: Why should you want to lose weight and stay healthy? One could answer: "I ought to lose weight if I want to be happy or to live." It is clear that one might never come to a rock-bottom goal or value but might get involved in a swamp of uncertainty in an infinite regression of statements in search of a "next prior" goal on which the present "ought" statement is presumably grounded. I shall deal with this problem later, but meanwhile I affirm that statements justifying values may be scientific.

Mises is only one of several scientists and philosophers who in recent decades have helped break down the two-centuries-old wall between facts and values. I have already mentioned Kluckhohn's 1958 paper and C. P. Snow's *Two Cultures* into which Western civilization was split. In 1956 J. Bronowski, who is here with us today, published his *Science and Human Values,*[5] which is the title of this symposium and which has stimulated many of us to feel that the divorce between the two was wrong and that they could and should be brought back together.

In the past two decades many other workers have been seeking to build bridges across the gulf separating science from human values. I shall mention a couple in which I have been closely involved, such as the establishment in 1954 of the Institute on Religion in an Age of Science, where Harlow Shapley[6] explained the liveliness of a natural and cosmic "God" to theologians who had concluded that "God was dead." Also, in 1966 the quarterly *Zygon: Journal of Religion and Science* was established. The name *Zygon,* meaning union or yoke, is related to the biological *zygote,* the union of the two halves of the heritage of an organism, one derived from the male and one from the female, which must be united if life is to be built, maintained, or renewed. At the level of human culture, the *Zygon* image suggests the necessary union of the reality pictures of the sciences with the human-value pictures of the humanities if the culture is to be made whole and viable. Over seventy papers by scientists seeking to illuminate human values are found in the pages of the first five volumes of *Zygon,* as well as nearly seventy papers by philosophers and theologians seeking to relate the problems of human values positively to the sciences.

Philosophers who have contributed to a new and closer relation to the sciences include the old warrior Stephen C. Pepper[7] and a new

supporter, Ervin Laszlo,[8] who is producing important books seeking to integrate the discipline of philosophy with the relevant elements of the scientific disciplines so as to be able to provide better grounding for the understanding and motivating of human values.

I cannot take the time here to cite much of the growing literature by scientists on insights generated by their disciplines for understanding human values, but I should point out a few of the persons at these AAAS meetings who have recently written books on this matter: Kenneth Boulding,[9] Barry Commoner,[10] Bentley Glass,[11] Garrett Hardin,[12] R. B. Lindsay,[13] and A. F. C. Wallace.[14] I must also mention books by two scientists who are my associates on the Committee on Science and Human Values, which is responsible for this meeting: L. C. Birch's *Nature and God*[15] and Theodosius Dobzhansky's *Biology of Ultimate Concern*.[16]

It should be clear that many good scientists from a variety of disciplines are working on problems of human values. Some are utilizing relevant information from their disciplines as the basis for a warning of threats to existing human values, such as technological pollution or social and psychological disruption. Others use their scientific perspectives as the basis for a clearer understanding of the nature and ground of human values. I trust that this symposium will be found to be of the latter type.

We return now to the question of the nature of human values and how they may be approached by the sciences. We have indicated that values are goals or norms and that one class of such norms actually exists in fact and, hence, can be empirically discovered and perhaps explained. Cybernetics is the name of a recently developing field of science that deals with norms or goals which exist in fact in men and animals as well as machines. The general nature of the mechanisms of negative feedback of information, by which mechanisms the goals or norms are attained, is well understood. Something also is known of the highly organized interrelationships of many interrelated and supportive systems that operate to produce goals or values at higher levels of values within and among the complex systems of life known as cells, organisms, societies, species, and ecosystems. Certain rather critical and specific norms exist that broadly characterize or define the immense complexity of organization in living systems. Some of them are rather general or universal, such as the necessity for an energy supply. But the generalized goal of energy supply is subdivided into a complex hierarchy of specific norms as one looks at the levels and special classes of the hierarchies of living systems. Without the maintenance of these norms, living systems would degenerate into dis-

organized and chaotic arrangements of matter and energy. The norms or goals or values of living systems can be said to be the information or the "blueprints" that define some of the various possible and existing arrangements of matter and energy that constitute living systems.

In men as well as in animals a lot of the hierarchical system of goals or norms is known to be "blueprinted" or set by information transmitted genetically in the DNA code and, hence, to have been set by natural selection. But the genetic heritage is only a part of the information input by which human values are structured.

Behavioral scientists have recognized, especially in *Homo,* that inputs generated by the surrounding society may reinforce or may rub out certain behavioral response patterns generated under the previously existing states of the organic cybernetic system, and thus modify or reset the norms or goals and the subsequent behavior. This learning process, made possible by the evolution of the human brain, allows the individual human and the human society to modify their characteristic behavior thousands of times more rapidly than is possible by the natural selection of information from random variations of the DNA patterns. Theodosius Dobzhansky has suggested that today psychosocial evolution is much more significant for man than genetic evolution.[17]

In any case, psychosocial phenomena constitute the important area for a scientific consideration of human values as that term is usually understood by the man in the street as well as by men in the disciplines of the humanities and the behavioral sciences. For understanding the psychological cybernetic mechanisms that provide the norms or goals or values of the individual, perhaps a good model is that of the brain as a hierarchical network of coordinated homeostats, as J. Z. Young has suggested.[18] Organic behavioral response patterns to certain categories of input from the environment can be accounted for in many cases specifically, and in principle generally, by information stored in the nervous system. For man, this behavior includes verbal reports which refer to states of pleasure and pain or desire and aversion. These states of pleasure and pain have long been recognized by philosophers as well as poets, theologians, and men in general as being representative of what they mean by the term "human values."

But if one of two or more persons endowed with the same genotype, an identical twin, can be educated by a cultural milieu to speak and understand a certain language or to respond according to a certain pattern of behavior, feeling, and thought—which the other, educated in another cultural milieu, cannot—then we must look to the transmission of cultural patterns in addition to genetic patterns as primal sources for psychosocial differences and specificities. Human values are

obviously structured by transmission to the brain of complexly evolved patterns of cultural specifications as well as by the genetic transmission of information.

Culturally transmitted heritage is the marvelous emergent feature that has appeared in the evolution of life on earth during the past million years. The information encoded in one brain is transmitted to the next brain by means of some specified behavior patterns, which include gestures and sounds. The receiving brain gets the message, transformed by the filters or transformers in ways already specified by its particular genotype in combination with its prior learning. It then records the message as a basis for directing future behavior. That is, the brain becomes a register of a system of values or norms engendered in and transmitted by a culture but now incarnated in the nervous system, an internalized "superego." One could say that the "id" of Freudian language is the more ancient and rougher formulation of values transmitted to the nervous system by the genotype.

In recent millennia this cultural heritage has become so important in the shaping of the human phenotype (the term "phenotype" has come to include the behavioral as well as the structural characteristics of an organism) that it seems doubtful that man could be viable without his cultural as well as his genetic heritage of values. Certainly, life in man's high civilizations is impossible without the rather narrowly specified cultural patterns that make such a civilization viable.

There have been in the past few decades some new scientific interest and research on how human behavioral patterns and cultures get "selected" or structured.[19] It is quite clear that, on the whole, men have not designed their languages and religions and crafts and technologies in the way in which in this century we design a space voyage—as a single project mostly worked out in advance on the basis of previously accumulated knowledge. Instead, complex cultural patterns, such as languages or religions, arise from multitudinous tiny variations, some of which have been retained because they happened to reinforce, on a statistically significant basis, the existing values in a population. But, since the viability of a behavioral pattern, regardless of whether it was shaped by information originating from the genotype or from the culture type, ultimately depends on whether the behavers can continue to survive in their ecological niche or habitat by means of such behavior, then the particular cultural patterns that survive for many generations would seem to have been tested and selected by the actual nature of the system. Perhaps we have, in the cultural information encoded in the memory stores of brains, a new mechanism analogous to genetic information encoded in DNA. From the multitudinous variations of

the culturally generated patterns that exist in one brain or in millions of brains, certain ones are selected in accordance with how fitting a phenotypic behavior they are capable of producing with respect to the requirements for viability set by the ecosystem which is its habitat. The ecosystem includes people and societies as well as such circumstances as earth, air, water, plants, animals, and fire.

The above picture of the nature of human values as the norms or goals of human organisms and societies is all too brief, and must be supplemented by showing how it may tie in with what philosophers, theologians, and others mean when they use the term "human values."

Equating Humanistic and Scientific Notions of Values

Philosophers and theologians often admit to their discourse about values only those words which we might describe as near the top of some logical or aesthetic hierarchy of levels of words or symbols of human goals or norms. We could agree to use for certain purposes the same cutoff levels of vocabulary as they use. Moreover, the wider spectrum of norms and goals that shape or structure the viable patterns of behavior, which I have suggested in my holistic picture above, is in no way hurt by attempts to translate such traditional terms as happiness, virtue, honesty, truth, beauty, goodness, freedom, etc., as designated phenomena within it. On the contrary, such translations enrich the possibility of practical communication by tying the terms of moral philosophy to the actual organic mechanisms that structure human growth and life. I have already pointed out how Richard von Mises took care of the philosophical hang-up over the derivation of the "ought," or value, from the "is," or fact. There should be no difficulty in understanding how values are an integral part of a single system of reality into which the scientific method can in principle fruitfully inquire.

I suggest our aim here is the opposite of avoiding traditional humanistic, philosophical, or religious concepts of values while turning to some technical and humanly trivial values or norms that may be described by some area of the sciences. I suggest we are more concerned to illuminate and clarify man's supreme values by the new and larger scientific pictures of human origins and potentialities. There are many traditional formulations of man's ultimate concerns, highest goals, or most universal values that we may find still as valid as ever, but perhaps in great need of being translated or interpreted within the scientific conceptual framework to clarify why they may be imperative conditions in reality for man's ultimate salvation and destiny.

But, even if we suppose that we can be scientific about understanding

human values, we have to admit the same kind of limitation to our understanding of values that we have to our understanding of anything whatsoever. Since human goals are found to be arranged in a complex and ever-changing hierarchy that gives different priorities depending on which facet of a multifaceted system of life we are examining, and since the priorities keep shifting with respect to the particular instant of time that is involved, it is usually impossible to go far enough in a series of statements making explicit the implicit premises of "ought" statements—far enough to find the last fact from which one can derive an immutable system of value statements. In the example given of the physician's statement that a certain man "ought to take more exercise and eat less sweets," we may quite easily translate this into a logically necessary, empirically verifiable, and reasonably scientific statement if we presume or actually find in experience that more exercise and less sweets are necessary "if you wish to lose weight and regain health." But we are now faced with a new problem: that of showing why you wish to lose weight or regain health, which we may call a logically prior or higher-order goal. If we say that health is a goal because health is necessary for a still higher-order goal—which we may make explicit in some such statements as "If you want to be happier . . ." or "If you want to live, then you must . . ."—we find ourselves sooner or later unable to ascertain all the "facts," all the "ises," in order to make logical and credible scientific statements about human values.

In fact, such a system of statements about values has a similar limitation to systems of statements in logic or mathematics (as implied by Gödel's theorem) or in the sciences generally, where we commonly recognize how impossible it is for us finite creatures to validate the fit of propositions to experience, for everything in a seemingly infinitely expandable universe of events.

Thus, even if we find we can have a science of human values that in principle is not different from that of the other sciences, we must, nevertheless, find ways to have faith in an unfinished and nonabsolute understanding, with lots of mystery remaining for now and lots of exploration for the future. In this connection I am fond of Karl Popper's image of science as ever unfinished in his *Logic of Scientific Discovery:*

> The empirical basis of objective science has thus nothing "absolute" about it. Science does not rest upon rock-bottom. The bold structure of its theories rises, as it were, above a swamp. It is like a building erected on piles. The piles are driven down from above into the swamp, but not down to any natural or "given" base; and when we cease our attempts to drive our piles into a deeper layer, it is not because we have reached firm ground. We simply stop when

we are satisfied that they are firm enough to carry the structure, at least for the time being.[20]

In Popper's picture of the swamp of relations on which are built the theoretical structures of objective science, we find no greater absoluteness or ultimacy of truth than we find in a similar probing of the swamp of value statements by ascertaining some first steps in a possibly infinite regress of clauses that make explicit, as factual goals, the implicit conditions from which the "ought" statements for human behavior naturally and logically follow as facts. The "is" of a scientific formulation about the ultimate nature of the physical world and the "ultimate ground" of the "ought" on which we understand our human values to be based can both be said to be built up of a moderately firm or coherent network of logically connected conceptual statements and related experiences whose *ultimate* validation may forever elude our grasp. But in neither case does this imply that we cannot find a body of increasingly sizable, valid, and valuable information about facts, including facts about values, for purposes of our understanding and our successful living in the world.

It should be clear that the problems of understanding human values are no easier than those of understanding anything in nature, anything in the world of our experience. But I hope that these prefatory remarks will have made it somewhat clearer to scientists and others here that the nature of human values is a proper, indeed a necessary and urgent, field for scientific investigation, as well as for the application of judgment from the perspective of a scientifically informed mind. But we now should turn to the reasons for our particular approach to values in this symposium.

Can Physics Provide Criteria for Refining Human Values?

For man, values exist not only as preferences and fears generated in the phenotype by information which originated from both his genetic and his cultural heritages as they interacted with and were modified by his existential experiences in the world in the past; values may also exist as projected hopes or fears under the supposition that certain new and different circumstances are to come to pass in the future. Since man is a creature designed to adapt to future circumstances, his system of values necessarily involves information that constitutes norms or goals not previously existing either as patterns of his genes, as neurological patterns inside his head, or as patterns in his sociocultural system or in his actual habitat or ecosystem. The trip to the moon required a radically new hierarchy of values, norms, and goals overlaid on the previously existing systems of transport to destinations or goals,

from the top goal of reaching the moon to complex networks of subsidiary values essential to reaching that goal. On a more complex and moral or spiritual level, it has been observed in history and by the psychosocial sciences that the imagined or actual trend of a society toward extreme states of inequity and of unrest, marked with outbreaks of violence and disorder that threaten the disruption or death of the society, leads to the rise of religious and moral prophets as well as political reformers and revolutionaries. Also, the same phenomenon of response to stress, but within the beliefs and attitudes of an individual man, has been noted to result in the spinning of new interpretations, novel inventions, spiritual genius, and in the less successful cases to wild fantasies and schizophrenia.[21] These behaviors may be interpreted as generated by cybernetic controls that operate to maintain certain overarching goals or values such as the integrity and continued existence of a social or individual life system under circumstances where it is necessary to reform parts of the system in order to be more adequately adapted to different conditions. Men and societies of men are engaged in increasingly rapid transformations and refinements of their values over the past million years as genetics and culture have become symbiotic seeds for this more rapid form of evolution. But there seem to be dangers in rapidity, especially if two or more vital parts of the life system get too far out of phase.

While value hierarchies may have reached remarkable pinnacles of complexity and comprehensiveness in the highest levels of the civilized culture celebrated in the humanities, and while much of the scientific work toward understanding value problems must be expected to come in the psychosocial sciences, it could be that the recent explosively rapid evolution of human individual and social life under the impact of basic physical and biological science and technology has brought us unwittingly to such an extreme crisis in values that if we are to survive we will need to look imaginatively to a much larger horizon of present and future reality conditions, and reinforce or revise our value hierarchy accordingly. This larger horizon of the human scene may require some of the new visions from the natural sciences.

It has entered the imagination of such men as the late physicist Erwin Schrödinger, and others, that it is now becoming possible and perhaps necessary to formulate man's history and destiny in terms of the scientific pictures of the cosmic scheme as that scheme existed before life arose on the earth and as it still does and will exist more or less eternally in a universe whose energies and materials provide the wherewithal and the circumstances for life and human life. Schrödinger's *What Is Life?*[22] published after World War II made some

stimulating suggestions concerning life's sacred values being memorized in molecular codes, and also concerning life's function or purpose being defined in terms of negative entropy. Since its publication, a number of men have in fact shown the nature of the DNA molecular codes which carry the core of our genetic heritage, and cybernetics, information theory, molecular biology, and other sciences have developed models of how life is tied to improbable patterns of information, and how life's advancement is correlated with increasing "information."

Perhaps in the myth of genesis about our origins and our relation to the ultimate powers of creation or the world is still, for the twentieth century as it has been in the history of religions for millennia, the best way to get a perspective on the basic and most sacred values of man. But today we have new and vastly extended versions of the myth of genesis through all the sciences from physics to anthropology that have helped clarify the story of man's origins in the cosmos and his relation to the ultimate conditions and powers of the universe in which we were created. While psychosocial phenomena derive much of their detail from their own more rapidly evolved store of information that shapes their value patterns—information encoded in such readily modifiable structures as neural synapses and library books—we can never properly analyze a system of human values independent of the information stored in our genetic input. Also, any analysis of a system of the values of a living system of any kind can never properly be analyzed apart from the matrix or environment of the "underlying realities" of transhuman and ultimately transbiological nature, relative to which the living system already is, and must continue to become, adapted.

Significantly in this connection, Kluckhohn cites Filmer S. C. Northrop as arguing that "the culture of any people rests, in the last analysis, upon that people's philosophy of nature." Also, "Northrop explains the ideological conflict between the democracies and the U.S.S.R. by stating that the former's assumptions came from the results of Galilean and Newtonian physics, while the Russian assumptions derive from the results of mathematical physics in the first half of the nineteenth century. He urges upon us the necessity of getting some objective criteria outside the social sciences and humanities against which the postulates of these subjects can be checked."[23]

The scientifically grounded imaginative hypotheses about the origin and nature of life in the cosmos made by such men as A. I. Oparin, Erwin Schrödinger, and Norbert Wiener some forty, thirty, and twenty years ago may be guides for us in their suggestion that life's values arise out of and are integral with the processes of the physical cosmos.

Perhaps in portraying some universal and basic characteristics of life, the physical sciences may have begun to uncover or reveal a touchstone for ethics, a general principle according to which various potential choices for future behavior can now be judged by men as more or less probable to success in maintaining and advancing the values of the life systems of which we are a part. They have suggested, and it has since been at least partially confirmed, or modified with better detail, that life has been produced by the very nature of the physical cosmos, constructed out of the very stuff of the physical cosmos. If we added the testimony of various behavioral sciences concerning the human phenomenon, we might also say that even the highest reaches of human aesthetic, cognitive, and moral behavior are also operating under the same general requirements or needs for adaptation to the environing realities.

One key concept of physics that these men have shown to be related in some way to the organization of information and life values is the rather comprehensive Second Law of Thermodynamics and the concept of entropy. Following this line in his *Science and Information Theory,* Leon Brillouin noted the "remarkable likeness between information and entropy" and the role of information or negentropy in the design of a machine or a living organism. He was careful to point out that all the "elements of human value are ignored by the present theory" of a scientifically defined meaning of the term "information." However, he continued, "this does not mean that they will have to be ignored forever, but, for the moment, they have not yet been carefully investigated and classified. These problems will probably be next on the program of scientific investigations, and it is to be hoped that they can be discussed along scientific lines."[24] In the nearly ten years since that was written, perhaps we have made some progress.

The relation of the Second Law of Thermodynamics to life and its evolution is significantly illumined in J. Bronowski's "New Concepts in the Evolution of Complexity: Stratified Stability and Unbounded Plans," which was given at the Boston AAAS symposium last year and which has now been published in *Zygon.* In it he points out that "the Second Law describes the statistics of a system around equilibrium whose configurations are all equal" or equally likely, and "chance can only make such a system fluctuate around its average. . . . But if there are hidden relations in the system on the way to equilibrium which cause some configurations to be stable [and there are in our universe], the statistics are changed. . . . Since the average has no inherent stability, the preferred stable configuration will capture members of the system often enough to change the distribution."[25]

Bronowski further points out that it is exactly the chance fluctuations around an average or norm that provide the possibility for some of the elements of a system to attain the particular, newly emergent configurations that are stable at a new level, removed from the previous norm. These random fluctuations are provided by the flow of energy from some source, such as that from our sun, whose gradual "death" gives us our life.

In Bronowski's picture, it would seem that the evolution of forms from simpler to more complex levels of organization can be explained by the use of two characteristics of the universe. The first is the existence in the universe of actual or potential strata of stability such that the statistical probabilities of the Second Law of Thermodynamics do not fully apply because the probabilities of certain configurations are not equal to those of other configurations but are preferred. The second characteristic is the existence of a source of energy to provide the random fluctuations in each level to assure that some few elements from each prior level will by chance attain a position in a higher level of organized complexity. There seems to be much evidence for both characteristics. If there be in the universe an indefinite series of such potential levels of stability or preferred configurations, then, as Bronowski suggests, "local systems of a fair size can climb up from one level of stability to the next. . . . When the higher level becomes the new average, the climb is repeated to the next higher level of stability; and so on up the ladder of strata."[26]

In a commentary on Bronowski's paper, I suggested[27] that in his picture of the existence of the hidden layers of stability or preferred configurations and of the operation of randomizing energy Bronowski has provided a clarification for understanding the phenomena of evolution in terms of the cosmic elements out of which it arises, and especially the factor of natural selection. Ludwig von Bertalanffy has pointed out that the biologist's terms "selection, competition and 'survival of the fittest' already presuppose the existence of self-maintaining systems."[28] Bronowski's picture points out the source of these self-maintaining systems. We could say that selection or survival is another way of saying that a stable arrangement or configuration has been found as some chance variations have hit upon one of the potential strata of stability existing in some ecosystem or particular section of the universe.

A current doctrine of biological evolution can be expressed by the words "replication," "variation," and "selection." Bronowski's levels of stability suggest the nature of a *selection* process which operates under the common rules from atoms to cells as it does from cells, to

organisms, to societies, to ecosystems. Bronowski's energetic randomization of events in any particular stratum of stability would seem to correspond with the biological doctrine of *variation,* sometimes known as random mutation of genes or random assortments of genotypes in sexual recombination, by which is generated the potentiality of achieving new levels of life's values. We have also noted a similar variation in brains and cultures that on a statistical basis provides the chance of attaining newly emergent levels of stability, that is, selection of higher levels of organized complexity. The third of the three terms in the biological account of evolution, *replication,* is not touched on directly by Bronowski's paper and is not likely to be treated in this symposium.

However, I wish to suggest that replication is a function that can be seen as a division of Bronowski's levels of stability (preferred configurations), except that in biological replication this relates to a structural pattern newly emergent in the role of aperiodic DNA (Deoxyribo-Nucleic Acid) crystals[29] at the dawn of living systems. DNA molecules provide the especially stable memory record of information necessary for structuring the complex patterns of dynamic stability in cells and organisms such that the species can continue after the individual organisms dissolve, as well as for their contemporary structuring. As such memory stores, DNA crystals may be said to live in a sort of symbiosis with the amino acids or protein of the cytoplasm of organisms and species, similar to the way the memory stores of a culture—e.g., books—live in symbiosis with people and societies. In any case, the term "replication" in evolution may be viewed as a special segment of the problem of stability or continuity of pattern of structure and function characteristic of a living system, which as I have suggested is also equivalent to nature's selection of a particular pattern as stable or viable. That is, selection and replication may be understood as closely related functions, or both of them may be understood as special functions of a phenomenon (Bronowski's preferred configurations) of which they are each special phases.[30]

In this symposium on science and human values we are taking some further looks at life values in terms of some of these basic pictures of life coming out of the physical sciences, and in particular at how some of the conceptual systems of thermodynamics, information theory, cybernetics, and evolution (molecular, biological, and cultural) may be connected with human values. We are continuing the search for some relation between the cosmic scheme of things and human destiny. Hopefully, we may discover some general characteristics of the cosmos that may enable us not only to clarify and justify some traditional

"ought" statements but also to provide some rather general criteria for judging the values for man of some as yet nonexistent or hidden configurations that are preferred in the cosmic scheme of reality and to which we must bow or adapt, or else become unstable—that is, perish.

NOTES

1. C. P. Snow, *The Two Cultures and the Scientific Revolution* (New York: Cambridge University Press, 1964).
2. Clyde Kluckhohn, "The Scientific Study of Values and Contemporary Civilization," *Zygon* 1 (1966): 235.
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27. Ralph Wendell Burhoe, "Commentary on J. Bronowski's 'New Concepts in the Evolution of Complexity,' " *Zygon* 5 (1970): 36–40.

28. Ludwig von Bertalanffy, *General System Theory* (New York: George Braziller, Inc., 1968), p. 152.

29. Schrödinger (n. 22 above), p. 3.

30. I wish to call attention in this paper to something I did not have in mind at the symposium: the fact that both Bronowski's notion of progression of evolution through successive strata of stability or the naturally preferred configurations existent in the universe and my notion that this is equivalent to natural selection in the biological and cultural stages of evolution have also been suggested by Herbert A. Simon. I am in debt to William Wimsatt for calling my attention to Simon's "The Architecture of Complexity," first published in the *Proceedings of the American Philosophical Society* in 1962 and in 1969 by the M.I.T. Press as chapter 4 of Simon's *The Sciences of the Artificial*. Simon pointed out there that "the complex forms can arise from simple ones by purely random processes. . . . Direction is provided to the scheme by the stability of the complex forms, once these come into existence. But this is nothing more than survival of the fittest—that is, of the stable" (M.I.T. ed., p. 93). Simon even presents an interpretation similar to mine in the above paragraph about the close relation between selection and replication. He points out that "atoms of high atomic weight and complex inorganic molecules are witnesses to the fact that the evolution of complexity does not imply self-reproduction. If evolution of complexity from simplicity is sufficiently probable, it will occur repeatedly; the statistical equilibrium of the system will find a large fraction of the elementary particles participating in complex systems. If, however, the existence of a particular complex form increased the probability of the creation of another form just like it, the equilibrium between complexes and components could be greatly altered in favor of the former" (M.I.T. ed., p. 113). He then goes on to describe his view of the dual role of nucleic acid and protein in providing the "blueprints" and "recipes" necessary for the reproduction of complex systems of life. Katchalsky, in his paper in this issue of *Zygon*, also points out the role of the remembered "blueprint" for reproduction as the key to understanding stability of new levels of complexity of open systems or dissipative structures that we call life: "Living cells are therefore not only loose dissipative structures . . . , but a *dynamic pattern* superimposed on a *fixed network*, the organization of which is dictated by the genetic code" (in first paragraph under his "Concluding Remarks"). One could say that genetic and cultural blueprints for replication operate to hold the shape (maintain stability) of patterns in living species and men in ways that are functionally equivalent to electrostatic bonds for molecules.