Society and Science

Can science aid in the search for sophistication in dealing with order and disorder in human affairs?

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How can science contribute to the betterment of the human condition?

This is the dominant question that must be asked in any discussion of society and science. For years it has been assumed that the answer to this question is obvious and that it can be answered in terms of increased material well-being for mankind (*1*).

In addition, science has been considered to be an organizing force in society. A large proportion of the human race is psychologically incapable of coping with large doses of disorganization and uncertainty. Mankind has an inborn desire to have some degree of organization in life, and this leads many to gravitate in the direction of religion or of science, both of which are identified as mechanisms for bringing order out of disorder.

The battle between organization and disorganization is a never-ending one and deserves to be examined with all the intelligence we can muster. We have to understand when to fight disorder and when to encourage it; when to stand fast for order and when to give ground. Science has contributed to society as an organizing force in the management of raw data and in the manipulation of nature, but it has produced "dangerous knowledge" and disorganization as well. It is important to look at some of the manifestations of order and disorder and to realize that disorder is the raw material from which order is conceived and selected. Attempts to establish societies based on order will always fail unless they incorporate some *disorder* (*2*). The most important contribution science can make to society is to increase the degree of sophistication with which mankind perceives "order" and "disorder."

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The Quest for Order

Man has long been aware that his world has a tendency to fall apart. Tools wear out, fishing nets need repair, roofs leak, iron rusts, wood decays, loved ones sicken and die, relatives quarrel, and nations make war. One of the important functions of even the most primitive religions has been to establish order and meaning in mankind's way of life, to provide explanations for sickness and death, to rationalize suffering, to circumvent death and make it bearable (*3*). We instinctively resent the decay of orderly systems such as the living organism and work to restore such systems to their former or even a higher level of organization. As viewed in the context of order and disorder, both religion and science have been processes "of maximizing the quantity of organization in the matrix of perceived human experience," in the words of the anthropologist A. F. C. Wallace (*3*). Most religions offer some kind of "solution which assures the believer that life and organization will win, that death and disorganization will lose, in their struggle to become the characteristic condition of self and cosmos" (*3*). Science meanwhile attempted to provide ground rules for the organization of the universe and more recently of man himself. Knowledge led to power, and the power to alter the environment led to new dimensions of order and disorder.

Starting with essentially religious motivations, men like Copernicus, Galileo, Newton, Bacon, Descartes, Hobbes, Locke, Hume, and Kant began to develop an understanding of science and to feel that all the facts of the universe could be sufficiently explained by the existence and nature of matter (*4*). It was felt that there were no problems too big for man to solve, and the concept of natural order in the world probably reached its highest point among philosophers. Many felt that the universe was a mighty clock that had been wound for all time, and that each individual was born to suffer and die to serve a cosmic purpose (*4*).

By the middle of the 19th century we find Charles Darwin developing a comprehensive theory of evolution, based on the survival of the fittest. The phrase "nature red in fang and claw" was coined by Tennyson to dramatize the struggle for survival. Darwin felt that the struggle was difficult to rationalize except as a means to progress, which he believed was the inevitable result from the process of natural selection (*5*). The survival of the fittest was a brutal process for using the raw material of disorder to achieve order, but it served a noble purpose in selecting new and better species, which were now widely understood to arise on a continuing basis. Until quite recently most educated people in both the sciences and the humanities accepted Darwin's idea of natural evolution as a mechanism for progress and found no discrepancy between Darwinism and the idea of a master plan or the concept of purpose in the natural world. But today a great uneasiness pervades the intellectual world, for a variety of reasons. In the field of biology a few individuals have begun to emphasize the view that natural evolution selects on the basis of relatively short-time decisions (*5*) and that most species become extinct. The process is unable to foretell the future, hence today the inevitability of progress and the existence of a master plan must be questioned.

Belief in the comprehensibility of all knowledge and implicit faith in human progress did not fade throughout the 19th century. In this period Rudolf Virchow, a German contemporary of Darwin, studied the ravages of disease, and he is known today as the father of pathology. An outspoken mechanist and an ardent believer in the power of the scientific method, he proclaimed that "knowledge has no boundary other than ignorance," and he plainly felt that this boundary could be pushed back indefinitely (*6*). In these times scientists were still considered the instruments of truth and order, and were able to see the consequence of their work and call it good. The concept of human progress was a materialistic concept of more and better, and men like Louis Pasteur were proving that, in terms of taking the guesswork out of man's biological problems, science could pay for itself a thousand-fold.

Rise of Unmanageable Knowledge

But as science grew more complicated, as the amount of relevant knowledge began to double in shorter and shorter time intervals, scientists began to specialize. As scientists began to know more and more about less and less, the individual scientist became less confident of his ability to organize his specialized knowledge in the larger context of science and society. He no longer was able to devote his time to cosmic issues or to worry about ultimate truth. He was convinced that the latter was not attainable and the former were neither important, useful, nor interesting. It was assumed that all new knowledge was basically good, and that it contributed to order in a way that, if not immediately obvious, would become obvious in the fullness of time. If there were no individual scientists able or willing to cope with cosmic issues, neither were there philosophers of the Descartes variety who could hope to comprehend all available knowledge.

With the arrival of the 20th century the divorce of science and letters was virtually complete, but the Louis Pasteur image was firmly planted in the public mind. Knowledge was power, and the key to knowledge was science. Science produced rayon, nylon, orlon, and dacron. Science produced vacuum tubes, transistors, and semiconductors. Science produced phosgene, mustard, and other deadly war gases.

I think that with the development of the war gases in World War I the image of "dangerous knowledge" became a reality. When World War II came along, more war gases were developed, and this led to the concept of biological warfare. Crop-killing chemicals were invented, nerve gases were produced, and germ warfare was contemplated. The atom bomb was built and used. During and after the war, science produced crop killers, weed killers, and insecticides—2-4-D and DDT and others by the thousands (*7*).

By the end of World War II, science the source of material well-being, science the law-giver, science the source of order and understanding could no longer be regarded as an unmixed blessing, or an agent for inevitable improvement in the human condition.

In the field of biological science the counterrevolution reached a peak when a single writer, Rachel Carson, already established as the author of *The Sea Around Us*, wrote a best-seller called *Silent Spring* and outraged the chemical industry with her emphasis on the side effects of insecticides and weed killers (*8*; see *7*). Then a single drug, thalidomide, sold as a sleeping pill and proved to cause deformities in the babies of a large fraction of the pregnant women who were critically exposed, caused the U.S. Senate to pass a drug control bill by unanimous vote, when, except for the thalidomide tragedy, the bill might not have commanded a majority.

The new realization that science could produce chemical substances that had potentially dangerous consequences not intended by their designers, as in the case of thalidomide, led to other repercussions that may influence the established customs and traditions of society. An interesting example is the case of the young married couple who challenged the abortion laws because their unborn baby had been exposed to the effects of thalidomide. Although they were unable to get help in the United States, there were many who sympathized with their decision, and, when they chose to go outside their own country for a legal abortion, the entire American public learned through the daily press that abortions are medically safe and legally and morally accepted in certain countries in the world. In this episode the message was clear that science can produce unforeseen complications in our lives and can challenge our traditional ways of thinking. By no means as widely understood is the fact that science has created tremendous problems for society by eliminating many causes of death and by greatly reducing the death rate without a proportionate lowering of the birth rate. A few individuals have come to believe that the only immediately effective solution to the population explosion is medically supervised abortion. (This is a solution officially sanctioned by the Japanese government.) Medically supervised abortion would undoubtedly become widespread if legalized, and would provide time for the development of more suitable methods of birth control.

Upsurge in Molecular Biology

While the fear inspired by the publication of *Silent Spring* and by the unforeseen thalidomide danger has severely shaken faith in the infallibility of science, that faith was being reinforced on another front. Biological science was proceeding in the Louis Pasteur tradition in a great humanitarian effort to increase the well-being of mankind. The era of greatly expanded medical research began with the March of Dimes, a fund set up to conquer poliomyelitis by means of research. The widespread support of this effort was followed by the American Cancer Society drive for funds, and this in turn was followed by U.S. Public Health Service support on a generous scale.

Just when the funds from the March of Dimes reached unprecedented heights, the Salk vaccine was developed, and dozens of laboratories that had been tooled up for attacking the poliomyelitis problem were free to think about other things. By this time the support for cancer research was at flood tide, and the hopes raised by the successful fight against poliomyelitis were encouraging both the virus approach and the molecular approach to the cancer problem.

This increased support for poliomyelitis and cancer research has permitted and encouraged the expansion of attacks at the fundamental level, which in biological science may be defined as research with no particular disease in mind or research that is directed toward understanding the nature of life processes in general. This support was due mainly to the fact that the cancer problem has proved to be more formidable than the poliomyelitis problem and there is no agreement on which road will provide the quickest answer. Whenever there are no easy answers the fundamental approach is more easily justified. What has emerged is the new science of molecular biology, which is engaged in an attack on the problem of understanding the mechanism of life itself. This attack is a direct link-up between genetics and biochemistry; the techniques include physical methods, electron microscopes, ultracentrifuges, isotope tracers, and many elaborate semiautomatic electronic instruments, most of which were not available 5 years ago.

Molecular biologists have a religion all their own in which Nobel prize winner Francis Crick is the prophet and the DNA molecular model is the icon (*9*). Molecular biologists have a "trinity" of three kinds of molecules—DNA, RNA, and the protein molecules—which correspond to each other on a unit-for-unit informational basis. They have a "dogma" (and they call it a dogma) which says that "information"—that is, molecular pattern—passes from DNA to RNA to protein but does not pass in the reverse direction.

The DNA molecule is the chemical equivalent of the hereditary gene. It is the basis of evolution because of its five basic capabilities of (i) providing information, (ii) replication, (iii) mutation, (iv) recombination, and (v) expression. These five capabilities of the DNA molecule epitomize the relation between order and disorder in the living world. Because the DNA molecules contain information and are capable of expression, protein molecules can be built according to exact specifications. Because the DNA molecules can be replicated in a highly ordered fashion, cellular reproduction along hereditary lines is possible. Because the replication is not completely ordered and copy errors called mutations inevitably creep in to form new DNA molecules containing new information that can be expressed in the form of new protein molecules, evolution through natural selection is possible. Finally, the properties of recombination and of sexual reproduction provide a further element of disorder by guaranteeing a reshuffling of the genetic information.

The ultimate expression of the DNA molecule or gene is the protein molecule, but between DNA and protein is a complicated protein-synthesizing mechanism that "transcribes" the DNA information into a "messenger RNA" and then "translates" the latter into a specific protein structure by reactions that seem logical and almost machine-like. The protein molecules then bring about the myriad chemical and structural changes that occur in living cells.

Perhaps this slight digression will give some idea of the basis for the modern view of man as a machine. But the view given so far is only the beginning. If the basic machine represented by the trinity of DNA, RNA, and protein were to have no properties other than those already outlined, all forms of life would be too stereotyped in their response to their environment.

The Living Machine

The basic machine represented by the trinity DNA, RNA, and protein has another capability, in addition to evolution, that commands our attention. This is adaptation. The process of mutation explains evolution, but further clarification is needed to explain how evolution can lead to mechanisms for adaptation, one of the most exciting features of living cells.

Every living cell in every organism, from the lowest bacterium to man, has to come to terms with its environment. This coming to terms with the environment involves the regulation or control of the most intimate properties of life. The DNA, RNA, protein system does not grind out the gene products in endless succession; instead, the individual genes and protein-generating mechanisms are turned on or off according to a plan that is partly programmed internally and partly regulated by a process called "feedback." The feedback concept describes a process in which the formation of a product is speeded up or slowed down by the product itself. It is a purely mechanistic system that permits a machine or a cell or an organism to measure the gap between its performance and some standard of performance and to take action to close the gap between the standard and the actual performance. In this kind of machine, not only does the product of the activity regulate the activity, but, if enough product arises from some extraneous source in the environment, the machine is frequently able to shut off its own production of the particular substance completely.

Thus, in individual bacterial cells we find that an organism that can make an essential metabolite for its own use, such as an amino acid for protein synthesis, will immediately shut off the synthesis of the essential metabolite the moment the compound is added to the nutrient medium (*10*). In addition, the synthesis of the enzymes needed to make the essential metabolite will be shut off. Thus the bacterial cell seems to behave as if it had a kind of intelligence. It is as if the bacterium doesn't do anything it doesn't have to do—and neither do human beings, unless persuaded by education or tradition to follow a different course.

If man is a machine, what becomes of free will? If man is a machine, how can a machine develop a new idea? If a bacterium is a machine whose "intelligence" can be mechanistically explained, can we be sure that our intelligence is not generated in the same way?

I believe the dilemma is solved for man by a highly sophisticated combination of order and disorder. The problem of biological evolution is solved by a built-in "copy-error mechanism" for introducing novelty in DNA molecules in the form of mutations. My theory is that creativity in man is the result of a built-in "copy-error mechanism" in the reproduction of ideas. Our minds operate with a certain built-in amount of disorganization. Our minds are always reshuffling facts and racking them up in new combinations. If the new combinations come too slowly we call a person stupid, and if they come too fast we call him a schizophrenic. Most new ideas do not turn out as expected, but we can weigh them—sometimes subconsciously—in terms of our past experience, rejecting many of them without further test and predicting success for others. A person who does this skillfully is said to have common sense. The scientific method is simply a way of testing our common sense under a rigid set of rules that makes us reject the idea when the facts go against us. It is an acceptance of the fact that the correctness of an idea is not determined by how good the idea makes us feel at the moment of illumination.

If the theory is correct, inventive computers would be feasible (see *11*). Instead of for a fixed program, the machine would be built to let its mind wander a bit. If the theory is correct, the problem of free will is solved, because we can never be completely programmed like a computer with fixed responses. Because of the built-in disorder in our minds we will always be able to come up with new combinations and put them to a test (see *11*).

Chemical Control of Life Processes

While learning about the ways in which cells control their own activity, scientists are learning how to control life by adding chemical substances to the environment, but in learning how to control life we are forging a two-edged sword. The knowledge of how to kill cancer cells, poliomyelitis viruses, insects, lampreys, dandelions, crabgrass, and, eventually, any form of life may be what the public is paying for, but such knowledge can lead to undesirable applications as well as to intended results. No matter what phase of life control is studied, there will be unintended by-products. Insecticides and weed killers will affect life other than the insects and weeds. Cancer killers will prove to be effective in producing abortions—in fact, they already have been. Compounds that prevent conception produce an increase in fertility when their use is discontinued. Even when insecticides or weed killers prove highly specific, the elimination of one form of life may have unanticipated consequences for other forms. Knowledge of how to control life is dangerous knowledge, since it is difficult to manage, and such knowledge is not just around the corner, it is here. Dangerous knowledge can never be put back into the laboratories from which it came. Dangerous knowledge is a major problem of society, and the only solution to dangerous knowledge is more knowledge. From the disorder of unevenly developed branches of knowledge we must achieve some new kind of equilibrium.

The new knowledge on how to manipulate life processes involves not only the killing of various insects, weeds, pests, viruses, and cancer cells but also the development of chemicals that affect the emotional and psychological attitudes of human beings, and again we are dealing with dangerous knowledge. The new tranquilizers and energizers are certain to have unanticipated side effects and consequences that cannot be appraised by any means other than actual experience.

In describing knowledge of biological control as dangerous knowledge I am really discussing science as a force in cultural evolution. While in the past science could be seen as a source of material well-being and as the organizer and source of new knowledge, it is now realized by many that science is in fact a source of considerable disorder and of knowledge that society is by no means prepared to manage (*12*).

Perhaps science should make a more conscious effort to determine the impact of new knowledge on society. One of the roles of science in society should be to clarify the meaning of *order* and *disorder* as they relate to both biological evolution and cultural evolution. I believe that the processes of natural selection and survival of ideas in cultural evolution are analogous to the natural selection and survival of DNA molecules in biological evolution, and that ideas are the key to understanding cultural evolution just as DNA molecules are the key to understanding biological evolution. Earlier I remarked on the five basic capabilities of DNA molecules. I noted that mutation and recombination represent elements of disorder without which the system could not evolve, while information, expression, and replication represent elements of order. I believe that ideas or concepts possess the same five capabilities, and that, without the elements of disorder represented by mutations and recombinations of existing ideas, cultural evolution could not occur. At present it appears that science is to cultural evolution what a mutagenic mutation is to biological evolution. That is, science is a new idea that generates more new ideas at an ever-increasing pace. Many of the new ideas have had consequences that have not been foreseen.

Earlier I noted that biological evolution proceeds on the basis of short-range decisions arrived at by natural selection, with the result that many species become extinct. Is it possible that civilizations become extinct because they proceed on the basis of short-time decisions and are unable to estimate their future needs in relation to their future environments?

If we accept the idea that science is flooding society with new and dangerous knowledge, that the knowledge of the consequences of biological control is incomplete and inadequate, that more knowledge is needed, what long-range policies should be advocated?

Specific Suggestions

Specifically, I urge that more studies be made on the phenomenon of adaptability, which occurs in man as well as in lower forms. Knowledge of adaptability is important because, if an organism can adapt, by the same token it will "de-adapt." When we carry a heavy load, our ability to carry loads increases, but the corollary is that, when we have no loads to carry, our ability to carry loads decreases. Just how big a load should we be able to carry and what kind of load-carrying program will be best for each individual? How can he be helped to find his way to a load that will make him a useful member of society? When I speak of load-carrying capacity I am thinking of a load in the broadest sense. A load can be physical or it can be intellectual or emotional. Many tasks call for a great expenditure of creative energy, and we know far too little about how to bring out the best in people, about how to determine when an individual reaches a point of no return in his educational or home environment. When I speak of helping an individual find the load that is best for him and that will make him a useful member of society I speak from the conviction that the performance of useful function within the capacity of the individual is the only source of true happiness. In the present context of order and disorder, we assume that some kind of balance between routine and novelty is desirable, and that tasks should stretch the capacity of the individual at some times and not at others.

While emphasizing the importance of a search for more knowledge on man's adaptability, I also urge that more studies on man's individuality be made, in line with the many interesting leads provided by Roger Williams (*13*). If one man's meat is another man's poison, perhaps one man's stimulus may be another man's stress (*14*). In the studies on adaptability and individuality we should try to find methods for helping people discover themselves. We should encourage the development of individual differences and should look upon individual differences in terms of their contribution to society. Above all we should study the phenomenon of stress in all its aspects—physical, mental, and emotional—as well as the sensory channels through which stress is perceived. The concepts of audio stress and visual stress are particularly meaningful in this day and age. But we should not seek to eliminate all forms of stress; rather we should introduce the concept of "optimum stress" and seek to define its parameters and meanings in terms of individuals.

More generally, I urge the establishment of interdisciplinary groups that will study, on the one hand, cultural evolution and adaptation in the light of biological evolution and adaptation and, on the other, the accumulated knowledge and methods of the humanities and social sciences. In advocating such an organization I urge the study of contemporary and long-range problems that arise from the uneven application of scientific knowledge, but we should look for ways not only to avoid pitfalls but also to better the human condition. Science is not wisdom, but we can use the scientific method to seek wisdom. Wisdom is the knowledge of how to use knowledge to better the human condition, and it is the most important knowledge of all. Aristotle distinguishes between philosophic wisdom and practical wisdom. Practical wisdom, he says, concerns personal interests; philosophic wisdom combines scientific knowledge with intuitive reason about "things that are highest by nature" (*15*). If we may equate his philosophic wisdom with a proper balance between the highest good for present and future individuals and for present and future society, it is clear that the wisdom I refer to is close to Aristotle's philosophic wisdom.

In seeking wisdom by consensus of interdisciplinary groups we need to examine all the old ideas by means of the scientific method, and in addition we need to establish a continuing exchange of new ideas between scientists and humanists. We need to develop a new breed of scholars, men who combine a knowledge of new science and old wisdom, men who have the courage of the men of the Renaissance who thought truth was absolute and attainable.

Although the dream of absolute truth has faded, there is today a large group of scholars who are familiar with the concept of the living machine and aware of the philosophic implications of the existence of truly random phenomena (*16*) and the terrible responsibilities these implications place upon individual scholars and groups of scholars. The time is past when individual intuitive reason or revelation can be relied upon to provide all the relevant scientific knowledge; instead there must be continuing group discussion, and conclusions must be continually subject to amendment.

Conclusion

I advocate further research on the concept of "optimum stress" and on the nature of adaptation in human performance and in the human environment. At the same time I advocate further inquiry into the role of random processes in biological evolution and cultural evolution—in other words, a search for a new sophistication concerning the meaning and roles of order and disorder in individual lives and in the long-range problems of society. To accomplish these ends we need a new breed of scholars, with rigorous training for understanding the fundamental nature of man. They should be organized into special groups, with the task of generating wisdom that represents a consensus of many minds. They should be rigorously trained in the humanities and social sciences, and, in particular, in molecular biology (which includes chemistry and physics), because the new scholasticism should not be debating whether man is a machine but, rather, it should ask, "What kind of machine is man?" The aim of the new studies will be to arrive at valid concepts of order in terms of morality, tradition, custom, and law, and to develop further understanding of the role of disorder in arriving at new positions on how to improve the human condition. The results of the new studies should be incorporated into the educational system as rapidly as possible. The ultimate goal should be not only to enrich individual lives but to prolong the survival of the human species in an acceptable form of society.

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