PRENTICE-HALL BIOLOGICAL SCIENCE SERIES
Carl P. Swanson, *editor*

PRENTICE-HALL INTERNATIONAL, INC., *London*
PRENTICE-HALL OF AUSTRALIA, PTY. LTD., *Sydney*
PRENTICE-HALL OF CANADA, LTD, *Toronto*
PRENTICE-HALL OF INDIA PRIVATE LIMITED, *New Delhi*
PRENTICE-HALL OF JAPAN, INC., *Tokyo*

BIOETHICS

BRIDGE TO THE FUTURE

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PRENTICE-HALL, INC., *Englewood Cliffs, New Jersey*

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Current printing (last digit):

10 9 8 7 6 5 4 3 2

C—13-076513-9
P—13-076505-8

Library of Congress Catalog Card Number 72-149060

Printed in the United States of America

This book is dedicated to the memory of

ALDO LEOPOLD,

who anticipated the extension of ethics to Bioethics:

The first ethics dealt with the relation between individuals; the Mosaic Decalogue is an example. Later accretions dealt with the relation between the individual and society. The Golden Rule tries to integrate the individual to society; democracy to integrate social organization to the individual.

There is as yet no ethic dealing with man's relation to land and to the animals and plants which grow upon it. Land, like Odysseus' slavegirls, is still property. The land-relation is still strictly economic, entailing privileges but not obligations.

The extension of ethics to this third element in human environment is, if I read the evidence correctly, an evolutionary possibility and an ecological necessity. It is the third step in a sequence. The first two have already been taken. Individual thinkers since the days of Ezekiel and Isaiah have asserted that the despoliation of land is not only inexpedient but wrong. Society, however, has not yet affirmed their belief. I regard the present conservation movement as the embryo of such an affirmation.

An ethic may be regarded as a mode of guidance for meeting ecological situations so new or intricate, or involving such deferred reactions, that the path of social expediency is not discernible to the average individual. Animal instincts are modes of guidance for the individual in meeting such situations. Ethics are possibly a kind of community instinct in-the-making.

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Preface

The purpose of this book is to contribute to the future of the human species by promoting the formation of a new discipline, the discipline of *Bioethics*. If there are "two cultures" that seem unable to speak to each other—science and the humanities—and if this is part of the reason that the future seems in doubt, then possibly, we might build a "bridge to the future" by building the discipline of Bioethics as a bridge between the two cultures.

This book is not such a bridge; it is merely a plea that such a bridge be built. In the past *ethics* has been considered the special province of the humanities in a liberal arts college curriculum. It has been taught along with logic, esthetics, and metaphysics as a branch of Philosophy. Ethics constitutes the study of human values, the ideal human character, morals, actions, and goals in largely historical terms, but above all *ethics implies action* according to moral standards. What we must now face up to is the fact that human ethics cannot be separated from a realistic understanding of ecology in the broadest sense. *Ethical values* cannot be separated from *biological facts*. We are in great need of a Land Ethic, a Wildlife Ethic, a Population Ethic, a Consumption Ethic, an Urban Ethic, an International Ethic, a Geriatric Ethic, and so on. All of these problems call for actions that are based on values *and* biological facts. All of them involve Bioethics, and survival of the total ecosystem is the test of the value system. In this perspective, the phrase "survival of the fittest" is simplistic and parochial.

This book is a by-product of 30 years of cancer research—years that might be considered successful from the standpoint of career, publications, promotions, awards, and personal day-to-day satisfaction of intellectual curiosity, but years which must be considered to have fallen far short of the goal of eliminating the scourge of cancer from man's horizon. Progress has been made in prevention and cure, but the conviction has grown that we must be content with small victories and not expect the type of breakthrough that was achieved in the case of poliomyelitis.

During these 30 years a growing philosophical concern about the future, about the concept of human progress, and about the fundamental nature of disorder was a constant thread of unity in my extra-curricular activities. The obsession with the cancer problem is an obvious explanation for the digression into these clearly related issues. The motivation to find "ordered disorder" at the cosmic level to explain the "disorder" seen in the practical aspects of the cancer problem must be the subconscious drive that resulted in the various thoughts that led to this small volume.

Certain isolated publications and personal contacts must be credited as milestones in the development of the interwoven themes of this book. These themes are (a) the relation between order and disorder, (b) the concept of dangerous knowledge, (c) human progress and human survival, (d) the obligation to the future, (e) the control of technology, and (f) the need for interdisciplinary effort. Although I have always been interested in philosophy, it was not until I read "Toward More Vivid Utopias" by Margaret Mead (*Science* **126**:957–961, 1957) that I became activated in a well-defined effort outside my discipline. Margaret Mead has written extensively and well, and with impressive bibliographies on the general subject of the present book. In 1957 she issued a call that struck a responsive chord in me: ". . . we need in our universities . . . Chairs of The Future. . . ." I organized a local group of faculty members as the Interdisciplinary Seminar on the Future of Man and soon afterward was asked to help plan a conference for the American Academy of Arts and Sciences (Hudson Hoagland and Ralph W. Burhoe, issue editors, "Evolution and Man's Progress," *Daedalus,* 1961). At that conference

I met and was further impressed by Dr. Mead, as well as by Dr. Hoagland and Dr. Burhoe. Through Ralph Burhoe, I was introduced to the 1961 paper by Anthony F. C. Wallace entitled "Religious Revitalization," later included in his book *Religion: An Anthropological View* (1966). Wallace alerted me to the idea that both religion and science attempt in characteristic ways to distinguish order and disorder through "a process of maximizing the quantity of organization in the matrix of perceived human experience." By 1962 the Interdisciplinary Studies Committee on the Future of Man was an official faculty committee at the University of Wisconsin. We were privileged to meet in dialogue Anthony Wallace, Don Price, John R. Platt, and others. In 1964 an invitation to participate in a symposium on Teilhard de Chardin caused me to examine his work more closely and to see his contribution as an attempt to bridge the gap between science and humanistic religion. Earlier invitations to participate in symposia, to lecture or to write in the broad area of science and society led to the separate publication of nine of the chapters in the present volume. These have now been collected and arranged in what is hoped to be a logical order. They have been supplemented by an introductory chapter, a chapter on order and disorder in human thought and action (Chapter 7), and two closing chapters.

The discussions in this book on the concept of dangerous knowledge, the fallacy of "more and better," and the problem of controlling the technology were published as early as 1962, but they could accomplish little in the hands of a very restricted group of readers. Today, thanks to the efforts of men like Congressman Emilio Daddario and Senator Gaylord Nelson, technology is receiving careful scrutiny and the environment may possibly be reclaimed. The obligation to the future has been recognized, and the need for combining science with the talents of concerned individuals in the humanities is being met with new legislation calling for an Office of Technology Assessment. The National Science Foundation is sponsoring interdisciplinary programs. Thousands of college students have suddenly realized that the future is at stake.

When I first visualized this volume, I intended to prepare a new chapter entitled "Man's Uncertain Future." In the past six months there have been so many books on various aspects of this subject that an additional projection of statistics into the year 2000 would surely be skipped by most readers. Nevertheless, those who haven't already done so should certainly read *Population, Resources, Environment, Issues in Human Ecology* by Paul R. Ehrlich and Anne

H. Ehrlich and *The Environmental Handbook* by Garrett de Bell. The latter is a collection of over 50 previous articles or excerpts and includes an extensive bibliography organized into about a dozen categories.

Bibliographies and references are important. I have great respect for a writer who includes references, and I dislike the journalistic technique in which the writer seems to disclaim any debt to the sources that in many cases he simply transcribed. The bibliography in the present volume is limited, but I have tried to acknowledge my sources and to give the reader an opportunity to read further in an organized way. No doubt some ideas have been separated from their sources and given without suitable credit, but in no case was this intentional and any instances will be corrected as promptly as possible after they are noted. An interesting final thought has to do with the uniqueness of the human individual, both biologically and culturally. One kind of cultural uniqueness is expressed by the list of books and articles one has read. The narrower the specialization, the more our book list overlaps with other specialists in the same field until the point is reached at which we become so specialized that we read only what we write. But if we begin to read both in science and in the humanities, it is unlikely that anyone else in the world has read the same books that we have. Should we not then try to draw some conclusions from the reading that no one else has done? Or if there are others who have read the same collection, should we not ask whether they derived the same message?

Madison, Wisconsin VAN RENSSELAER POTTER

Acknowledgments

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© The University of Chicago.

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© The Capital Times, Madison, Wisconsin.

CHAPTER ONE

Bioethics, The Science of Survival

Abstract Man's natural environment is not limitless. Education should be designed to help people understand the nature of man and his relation to the world. The subject matter should include both the reductionist view and the holistic view of biology and should be broader than both together. Man is considered as an error-prone cybernetic machine, and 12 categories of relevant knowledge and their corresponding paradigms are presented. Man's survival may depend on ethics based on biological knowledge; hence Bioethics.

Biology and Wisdom in Action

Mankind is urgently in need of new wisdom that will provide the "knowledge of how to use knowledge" for man's survival and for improvement in the quality of life. This concept of wisdom as a guide for action—the knowledge of how to use knowledge for the social good—might be called *Science of Survival*, surely the prerequisite to improvement in the quality of life. I take the position that the science of survival must be built on the science of biology and enlarged beyond the traditional boundaries to include the most essential elements of the social sciences and the humanities with emphasis on philosophy in the strict sense, meaning "love of wisdom." A science of survival must be more than science alone, and I therefore propose the term *Bioethics* in order to emphasize the two most important ingredients in achieving the new wisdom that is so desperately needed: biological knowledge and human values.

In this age of specialization we seem to have lost contact with the daily reminders that must have driven home the truth to our ancestors: man cannot live without harvesting plants or killing animals. If plants wither and die and animals fail to reproduce, man will sicken and die and fail to maintain his kind. As individuals we cannot afford to leave our destiny in the hands of scientists, engineers, technologists, and politicians who have forgotten or who never knew these simple truths. In our modern world we have botanists who study plants and zoologists who study animals, but most of them are specialists who do not deal with the ramifications of their limited knowledge. Today we need biologists who respect the fragile web of life and who can broaden their knowledge to include the nature of man and his relation to the biological and physical worlds. We need biologists who can tell us what we can and must do to survive and what we cannot and must not do if we hope to maintain and improve the quality of life during the next three decades. The fate of the world rests on the integration, preservation, and extension of the knowledge that is possessed by a relatively small number of men who are only just beginning to realize how inadequate their strength, how enormous the task. Every college student owes it to himself and his children to learn as much as possible of what these men have to offer, to challenge them, to meld biological knowledge with whatever additional ingredient they are able to master, and to become, if their talents are adequate, the leaders of tomorrow. From such a pooling of knowledge and values may come a new kind of scholar or statesman who has mastered what I have referred to as Bioethics. No individual could possibly master all of the components of this branch of knowledge, just as no one today knows all of zoology or all of chemistry. What is needed is a new discipline to provide models of life styles for people who can communicate with each other and propose and explain the new public policies that could provide a "bridge to the future." The new disciplines will be forged in the heat of today's crisis problems, all of which require some kind of a mix between basic biology, social sciences, and the humanities.

Biology is more than botany and zoology. It is the foundation on

which we build *ecology*, which is the relation among plants, animals, man, and the physical environment. Biology includes the science of genetics, which has to do with all aspects of heredity, and physiology, which deals with the function of individuals. For thousands of years men have lived on this earth with no generally disseminated knowledge of their chemical nature. Man's dependence upon his natural environment was widely understood, but Nature's bounty was considered to be limitless and Nature's capacity to recover from exploitation was considered to be ample. Eventually it was realized that man was exploiting the earth to an extent that required the use of more and more science and technology as the richest sources of iron and copper, for example, were used up. From the biological standpoint man has progressively taken over the planet's resources by decreasing the numbers and kinds of other species of life and by increasing only those species that were useful to man, such as wheat, beef cattle, and other consumables. As a cancer specialist, I was naturally impressed with Norman Berrill's statement, which has been repeated in various forms by others without citation since his publication of *Man's Emerging Mind* in 1955 (1). He observed that "So far as the rest of nature is concerned, we are like a cancer whose strange cells multiply without restraint, ruthlessly demanding the nourishment that all of the body has need of. The analogy is not far fetched for cancer cells no more than whole organisms know when to stop multiplying, and sooner or later the body of the community is starved of support and dies." In other words, we can ask the question, is it man's fate to be to the living Earth what cancer is to Man?

In 1955 these words could go largely unheeded, despite the fact that Berrill's book is one of the biological classics of our time. It was widely assumed that science could produce "more and better" of everything that man needed and that progress could be equated with growthmanship (see Chapter 3). The end of that era came suddenly and dramatically at a moment that in retrospect is easy to pinpoint. It came with the publication of *Silent Spring* in 1962 by Rachel Carson (2), who was soon to feel the fury of the interests who were stung by her indictment. Now we can see that the issue is no longer whether she overstated the case against pesticides, and she must be credited with starting the tide of questions that have now reached the flood stage. We now are no longer assuming that science can produce the technology to feed man's increasing numbers (3, 4). We have been told that without the pesticides and herbicides the job would be impossible, and now we are beginning to hear that man may be endangered by some of the very chemicals that were said to be his salvation (5). From many uninformed quarters we now hear demands for a moratorium on science, when what we need is more and better science. We need to combine biology with humanistic knowledge from diverse sources and forge a science of survival that will be able to set a system of priorities. We need to start action in the areas where knowledge is already available, and we need to reorient our research effort to get the necessary knowledge if it is not available.

The age-old questions about the nature of man and his relation to the world become increasingly important as we approach the remaining three decades in this century, when political decisions made in ignorance of biological knowledge, or in defiance of it, may jeopardize man's future and indeed the future of earth's biological resources for human needs. As individuals we speak of the "instinct for survival," but the sum total of all our individual instincts for survival is not enough to guarantee the survival of the human race in a form that any of us would willingly accept. An *instinct* for survival is not enough. We must develop the *science* of survival, and it must start with a new kind of ethics—bioethics. The new ethics might be called *interdisciplinary ethics*, defining interdisciplinary in a special way to include both the sciences and the humanities. This term is rejected, however, because the meaning is not self-evident.

As a discipline, traditional biology has reached the stage where it can be taught in terms of principles, recognizing that it is impossible for any individual to become familiar with all the available examples that illustrate the principles. Bioethics can serve no useful ends if it is to be merely a watered-down version of contemporary biology. Therefore, I will present in this chapter 12 fundamental biological concepts that seem important to me as a mechanistic biologist, because of my conviction that Bioethics must be based on modern concepts of biology and not on unsupported introspection.

Before presenting the mechanistic concepts it may be desirable to first mention the nature of the scientific revolution and some of the major historical polarizing views of *mechanism versus vitalism* and *reductionism versus holism*, which in my opinion have delayed the development of a broad and unified biologically-oriented value system. Reductionism and mechanism are the aspects of biology that push the dissection of the living organism to the smallest possible units, inquiring at each stage how the units interact. As the dissection has proceeded to the level of atoms and molecules, the new biologists have become chemists, taking the name *molecular* biologists, and have given the impression that they are not concerned with the organism but only with the parts. These biologists frequently present the popular image of *scientist* as opposed to *humanist*, and their contribution to Bioethics is the reductionist knowledge that comes from the laboratory. Meanwhile the biologists concerned with the *whole* organism, the *holists*, tend toward the humanistic side of the balance, but not as far as the *vitalists*, who in most cases today are not professional biologists. The vitalists are frequently people in the humanities or people whose religious convictions affect their introspective attempts to understand biology. Some highly respected biologists of earlier times were vitalists for historical reasons; that is, they were unable to explain their observations without invoking the idea that mysterious or supernatural ("vital") forces guided all living organisms. Hence the concept of *vitalism*. I hope to make clear my own viewpoint that Bioethics should attempt to integrate the reductionistic and mechanistic principles with the holistic principles. Moreover, Bioethics should examine the nature of human knowledge and its limitations because, in my opinion, it is in this area that the only valid residue of vitalism makes its stand. Bioethics should develop a realistic understanding of biological knowledge and its limitations in order to make recommendations in the field of public policy.

The Scientific Revolution

In order to understand where contemporary biology stands, we need to look upon biological science as one of the consequences of the scientific revolution. Biological knowledge is not something that can be gained by introspection alone. The reason for doubting the validity of unsupported introspection is based on cumulative knowledge about human behavior: we all have built-in instincts for self- and ego-preservation, and we have passions, emotions, and irrational moments. Moreover, we are built in such a way that each new idea appears to solve some problem and creates in us a glow of euphoria. We feel that we have the answer to whatever it was that stimulated us, however transient the feeling may be. Each of the great advances in biology, such as Mendelian genetics and Darwinian evolution, was based on years of experimentation and observation. Nevertheless, these advances had to overcome the previous and persisting ideas that had been arrived at by men whose ideas came from within and were reenforced by a euphoria that was personally convincing. Many of the deep-rooted ideas remaining in the world today—not only in science but in all fields—were originated by individual men who were convinced that they knew truth from within (or by a proclaimed revelation from an outside source) and who by strength of personality were able to gain momentum enough to silence their possible critics. Obviously some ideas have been helpful, while others (for example, those of Hitler) have been the source of much trouble in the world.

The chief feature which distinguishes the scientific approach to a problem from the nonscientific approach (whatever that is called) is the realization than an idea is not necessarily valid just because it seems right to its possessor and makes him feel good. When a scientist gets an idea, he, too, has a pleasant reaction, but he starts looking for a way to test the idea, charging with it into his peer group, suggesting an experiment, referring to previous work (called "the literature"), and occasionally crossing the disciplinary boundaries. In suggesting a new discipline called Bioethics and specifying that we look outside the traditional sciences, I am not suggesting that we abandon the traditional treatment for a new idea, but rather that we cross the disciplinary boundaries on a somewhat broader scope and look for ideas that are susceptible to objective verification in terms of the future survival of man and improvement in the quality of life for future generations (6). In general we can only learn by hindsight, but even this is impossible if we do not keep adequate records and if we rely only on our individual impressions. In the humanities the only test of an idea is its acceptance by society, and if society chooses on the basis of conventional but ill-founded wisdom or on individual short-term gratifications, it may perpetuate an idea that might better have been buried. We need to reexamine our premises and look for better ways to reach a consensus among disciplines, based as far as possible on objective verification and adequate monitoring of the trends in environmental quality.

One of the most important aspects of the scientific revolution is the recognition that ideas can no longer be based on introspection or logic alone. Furthermore, as a general proposition, they cannot be based on a single proof, though they can be rejected on the basis of a single experimentally valid disproof (7, 8). Instead of the word *idea* as used above, T. S. Kuhn (9) has employed the term *paradigm* to describe the basic ideas or concepts in what he refers to as "normal science," which in turn appears to mean the research activities of specialists working within accepted disciplines. These paradigms are the ideas, concepts, hypotheses, or models that provide convenient packages or labels for the basic propositions on which the particular field is constructed. They should be clear enough to be understood by the specialists, yet open-ended enough to provide for further effort. Kuhn emphasizes the resistance displayed by scientists toward any threatened change in the paradigms that characterize their specialty. As I understand his message, a paradigm is much more than a widely accepted hypothesis or postulate; it is a statement that *no one among the experts expects to see disproved.* Thus the concepts to be presented later in this chapter are 12 paradigms in the Kuhn sense (9), covering major aspects of biochemistry and molecular biology, on the assumption that these information capsules may be helpful for those who wish to work in the field of Bioethics by gaining some appreciation of working assumptions that contemporary biologists do not expect to see disproved.

Reductionism versus Holism in Biology

In advocating a new branch of biology I am aware of an existing schism in present biology making for more specialization rather than less. The molecular biologists, whose specialty is unquestionably symbolized by the DNA double helix of Watson and Crick (10), are often accused of being ignorant of "real" biology; their discipline is equated with reductionism. "Real" biology is said to be holistic biology—that is, it is concerned with the whole animal and the whole situation. The trouble with the separation into reductionism and holism is that in considering the whole animal and the whole situation we now have to consider the intimate reductionist details of molecular biology, because these are the *targets* of our environmental hazards, as will be noted. This discussion is therefore a defense of reductionism and molecular biology as stages in the evolution of the new holistic biology that I refer to as Bioethics.

The molecular biologists have their own paradigms; the one best known is called the Central Dogma, which has been remarkably productive. It simply states that biological information passes from nucleic acids to protein. In more detail, it holds that the linear sequence of DNA information bits (base pairs) specifies not only the template for its own replication but also the template for the linear sequence of RNA information bits, which in turn specifies the linear sequence of protein building blocks, which in turn determines the 3-dimensional folding. No exceptions have been established up to now, and there is nothing in the Dogma that denies the possibility that the information in one DNA subsection may be modulated by products from some other subsection of DNA. Nor is it implied that DNA molecules replicate themselves or transcribe themselves to RNA as some critics have charged. The replications and transcriptions are brought about by proteins whose structure is specified by a particular subsection of the DNA complement. It is not assumed that these details can be understood without considerable chemical background and preparation.

But these details of the Central Dogma do not exhaust the possibilities for its continued articulation by molecular biologists. The Central Dogma has been paralleled by another paradigm that has been described by Platt as epitomizing the approach of the molecular biologists. This is the method of strong inference and multiple alternative hypotheses (7). According to this approach even the Central Dogma cannot be proved; it can only survive by failing to be disproved, and like the whole of science in this era, conclusions must be considered as tentative and subject to disproof. What is meant is that a theory can only encompass the available facts, and the possible dimensions of future experiments cannot be foreseen. A theory is not necessarily disproved but frequently may be enlarged or modified to accomodate new knowledge. The acceptance of this new paradigm of the uncertainty of human knowledge has led to a new breed of scientists who enjoy science as a game of wits in which parry and thrust are the order of the day. Students are conditioned to challenge their mentors and to be able to relinquish their fondest beliefs. While it is conceivable that a whole generation could be misled into accepting the Central Dogma as a universal truth rather than as an expedient operating premise, there are enough rewards for dissent to insure that minority views will be heard.

Of all the dissenting views elicited by molecular biology one of the most frequent is the complaint that the new biologists are reductionists who believe that cells can be explained solely in terms of molecules, that animals and man can be explained solely in terms of cells, and so on. But the people who voice the complaints are usually leaping to the conclusion that the enthusiasm and brashness of the new biologists means that they believe that cells can be explained in terms of molecules *and nothing else.* It would be more accurate to say that they believe that cells must be explained in terms of molecules, and men in terms of cells, and that principles of higher organization will emerge as the lower levels become understood. Indeed, these principles are now emerging in terms of feedback loops between the component molecules. The idea that all of biology can be explained in terms of chemistry and physics *and nothing else that is not available to the minds of men* is a proposition that can be acted upon even if it remains to be proved, and its chief drawback has been the lack of humility and ordinary prudence that it has encouraged in the application of limited biological knowledge to environmental problems of heroic proportions. While it is perfectly conceivable that eventually all of biology, including ecology and environmental hazards, can be explained and predicted in terms that are available to the minds of men, I for one do not believe that the information can ever be contained in the mind of a single man, and I have serious doubts as to whether it can be computerized or otherwise managed so as to be available to a single man or group of men for purposes of infallible prediction of side-effects. Although earlier in this chapter I defined wisdom as the knowledge of how to use knowledge, that is, how to balance science with other knowledge for social good (see also Chapter 3) I am here reminded of the ancient psalmist who said "The fear of the Lord is the beginning of wisdom." In contemporary terms this can be taken to mean that the forces of Nature cannot easily be manipulated to man's short-range demands without society's incurring many long-range consequences that cannot always be foreseen. Thus in many cases we learn by hindsight, but what is more tragic is our frequent *failure* to learn by hindsight. The beginning of wisdom in the sense of the psalmist and in contemporary terms may invoke in us a decent respect for the far-flung web of life and a humility as to our limited ability to comprehend all of the repercussions of our technological arrogance. I think that it is one thing to accumulate knowledge at the molecular level and to proceed on the assumption that it will be manageable, and it is quite another to operate at the management level and to deal with the application of knowledge that is always incomplete. Yet this is the predicament of the Federal Food and Drug Administration and many other government agencies, who can scarcely avoid a charge of under-reaction or over-reaction in many instances that are judged with the benefit of hindsight. There can be no doubt that neither our medical experts nor the administrative officers with whom they must cooperate can possibly have as much information and insight as they need for decisions on any given occasion, or as much public understanding of their predicament as they deserve.

It is clear that in the face of our actual needs, the arguments of reductionism versus holism become absurd. The intact organism is more than a simple sum of its parts, but the organism arises by virtue of the communication between cells. This communication is in terms of molecules and is best understood by the reductionists, but at the same time it forms the feedback network and structural integration that makes holistic mechanisms a reality. Thus each hierarchical level is formed by the feedback connections that link its subunits into a higher organization. We must combine biological reductionism and holism and then proceed to an ecological and ethical holism if man is to survive and prosper. But this integration may be impeded by a tendency to equate reductionism with the mechanistic view of life and holism with the vitalistic view of life; this tendency will now be discussed.

Mechanism versus Vitalism

A number of years ago I made the statement that man is a machine, and I took the position that this was no longer a debatable point, noting that we should direct our attention to the question "What kind of a machine is man?" (Chapter 4). More recently I had the opportunity to review (11) the book by Reiner, *The Organism As An Adaptive Control System*, (12) and to observe that his description is a more meaningful description of life than the simple term *machine*, which is immediately alienating to some and is misunderstood by many others. Nonetheless the concept of life as an adaptive control system is still on the side of mechanism in the old argument between the mechanistic and vitalistic concepts of life and of man. From time to time we see statements that the mechanistic concept of man is outmoded, no longer held, invalidated by new knowledge, and so on, but these statements mean nothing as unsupported opinions. We really are obliged to ask what mechanists believe, what vitalists believe, and if man is a machine, what kind of a machine is man?

Here I must identify myself as a mechanist and place myself in opposition to all who wish to challenge that view. As a matter of opinion, I would go along with the words of Nobel prizewinner Francis Crick who said " . . . And so to those of you who may be vitalists I would make this prophecy: What everyone believed yesterday and you believe today, only cranks will believe tomorrow" (13).

If we examine the opposing views more closely, we find that they

are really matters of belief, i.e., of opposing kinds of faith. In essence the mechanist says "life is explainable in terms of chemistry and physics and nothing more that is not available to the minds of men" while the vitalist says "life is not explainable in terms of chemistry and physics alone, and the added ingredients transcend the realm of knowledge that is available to the minds of men." The mechanist has faith that even if all the facts are not known today, some day they will be known. I suspect that the vitalist fears the advent of such a day, and probably hopes (perhaps rightly) that it will never arrive. Meanwhile the world is in danger of going down the drain while we argue the question "to tamper or not to tamper" because in many respects this is what the argument between mechanists and vitalists is all about. There is ample evidence that much of the opposition to science and to environmental planning comes from people who believe that the world operates according to an already established plan and that any attempts to dissect, understand mechanistically, or manipulate are simply getting off on the wrong foot and certain to fail in the long run. My own view as a pragmatic mechanist is that the question of success or failure still hangs in the balance, but the question to tamper or not to tamper has already been answered. Cultural evolution has decided that man *will* tamper with his environment and with his own biology. Man has tampered on a colossal scale, and we cannot revert to a hands-off policy at this point in history. Henceforth we can only plead for more intelligent, more conservative, and more responsible tampering. We must plead not for a moratorium on new knowledge but for a coupling of biological knowledge and human values, i.e., an interdisciplinary or biologically-based ethics.

I have already indicated that I am not convinced of the validity of the mechanistic view in its extreme form that all knowledge is theoretically available, and I have a lurking suspicion that the minds of men may not achieve the societal wisdom that is needed. But as a professional biochemist trying to "solve" the cancer problem, and having become interested in the dilemma of science and technology —to tamper or not to tamper—I have concluded that we have to proceed on the basis of the mechanistic premise, but we must bring in greater emphasis on human values and ethics. We have to proceed *as if* we believed that the solution to man's major problems includes nothing that isn't "available to the minds of men," with just the added ingredient of humility ("fear of the Lord") that admits the possibility that natural forces may elude our attempts to build the kind of Utopia we can imagine. Whether a belief in a Deity is required or not is less important to me than the question of whether we proceed with humility or with arrogance, whether we respect the forces of Nature or whether we assume that science can do anything, whether we look at our ethical heritage or whether we ignore it.

It seems to me we have no choice other than to try to deal with dangerous knowledge by seeking more knowledge (Chapter 5). We have already decided to tamper with the system, now we can do no less than to proceed with humility, respect the forces of Nature, and with respect to our ethical heritage, "prove all things; hold fast that which is good." The situation is urgent. In the opinion of many some aspects of our ecological problem may already have reached a point of "no return" as far as man's purposes are concerned. We need to rather quickly discover the weakest links in our environmental complex and begin to correct our past mistakes.

Man as an Error-Prone Cybernetic Machine

The concept of life as a cybernetic machine has been admirably discussed by Reiner in the publication (12) referred to earlier, and if this is a correct image, the humanistic biologist will have to adjust to it. I have only to add one more ingredient that was not stressed by Reiner, namely, the quality of disorder (Chapter 7). I would agree with Reiner that man can be described as an adaptive control system, but I would insist that it is not enough to assume that the quality of disorder is implicit in that definition. I would insist that it be explicit. Thus I would postulate that *man is an adaptive control system with elements of disorder built into every hierarchial level.* Reiner has emphasized the description of machines or control devices in terms of the "mode of operation" and the "mode of control," each of which may be *fixed* or *variable*. By this approach we come up with the following categories and my own modification:

Device	*Mode of Operation*	*Mode of Control*	*Reference*
Simple machine	Fixed	Fixed	Reiner (12)
Simple control system	Variable	Fixed	Reiner (12)
Adaptive control system	Variable	Variable	Reiner (12)
Living system	Variable + disorder	Variable + disorder	Potter (11)

The modification that I have proposed can be illustrated by Reiner's description (12) of the variable modes of operation and control typified by a man running toward the trajectory of a ball that he is trying to catch, when he suddenly discovers that it is not what he had assumed but something dangerous (Reiner mentioned a concrete block or a rattlesnake), whereupon the man rationally changes his attitude from wanting-to-catch to not-wanting-to-catch (as any good adaptive control mechanism should). I pointed out (11) that we all know of situations where the human machine for inexplicable reasons changes back from the rational move (not-wanting to catch) to the irrational move (wanting to catch the rattlesnake) in a split second, and sometimes gets away with it and thereby establishes a new behavioral pattern (cf. Chapter 7).

It is not possible to discuss details of living systems as adaptive systems with built-in disorder without looking into the molecular levels of life. I have rather arbitrarily set up 12 categories of biological knowledge which can be used to organize the detailed knowledge in the field, and I will follow each category with a brief statement which will be an accepted postulate, or paradigm in the sense employed by Kuhn (9), that is, an accepted postulate that is not doubted by experts in the field.

Twelve Categories and Paradigms in Mechanistic Biology

1. Molecular Structure, Interconversion, and Interaction

Paradigm *Every living system is a community of molecules, maintained in organized configurations and relationships by undergoing continual syntheses and degradations through successive small changes that take up or give off energy in the form of heat or work (14, 15).*

There are no texts, references, or encyclopedias that attempt to list the total number of kinds of molecules required for even the simplest form of life, probably because the task has been considered impossible to fulfill. It is possible to hazard a guess that the number is not less than 1000 but whether it is 3000 or 10,000 or greater is anyone's guess. It was formerly thought that cells with simple nutritive requirements (so-called autotrophs) were simple cells; but with the discovery that these cells contained all the compounds most characteristic of higher forms of life, it was realized that all cells have a long list of substances that are required for their on-going life processes, called *essential metabolites*. Some cells make these substances themselves and do not need them as nutrients. Other cells are unable to make some of the compounds, and for such cells we can draw up a list of *essential nutrients*. For man the list of essential nutrients is fairly long and includes a number of vitamins, amino acids, minerals, and additional substances (see reference 16).

2. Catalysis, More Specifically, the Chemistry of Enzyme Action

Paradigm *The majority of chemical reactions in living cells are too slow and too improbable to occur in the absence of a catalyst, and the cells have mechanisms for increasing or decreasing the amount and the activity of the proteinaceous catalysts (enzymes) that make the necessary reactions occur at an appropriate rate. All specialized functions and all general organismic functions depend on catalysis.*

Chemical reactions cannot be catalyzed unless they are energetically possible, and it is often said that an enzyme cannot bring about a conversion that would not occur spontaneously at a slower rate. This statement is true, but it sometimes gives the misleading impression that life without enzymes would be possible though sluggish. This does not follow, for reasons that will become apparent below (also see reference 17).

3. Energy-Coupling Mechanisms

Paradigm *Life is maintained by a continual input of energy which must be available to convert building blocks to more complicated essential metabolites, to provide heat, and to do electrical, mechanical, and chemical work. The essential trick of using energy-yielding reactions to drive energy-requiring reactions is called energy-coupling, and without it life would be impossible.*

The energy is obtained by the combustion of fuel that can be obtained from the environment and oxidized with atmospheric oxygen or by means of cleavages and reactions with other electron acceptors. A compound frequently mentioned as an energy coupler is ATP (adenosine triphosphate) because it is frequently a common denominator, being formed by energy-yielding reactions and dissipated by energy-requiring reactions (18).

4. Alternative Metabolic Pathways

Paradigm *Individual molecules of nearly every essential nutrient and essential metabolite and most intermediary metabolites are not predestined to be used either as fuel or as building blocks for energy-requiring reactions but collectively may be used in varying proportions for alternative divergent pathways, the balance of which is determined by the amount and activity of the several enzymes that compete with each other for any given molecule (16). Similarly, alternative converging pathways provide for multiple routes of synthesis for many essential metabolites.*

It is the existence of alternative pathways and competing enzyme systems that makes the possibility of "sluggish" life without enzymes completely impossible. Thus the idea of enzymes doing nothing but speeding up reactions is absurd. If a metabolite A can go to either B or C, and these in turn can go to D or E and F or G, respectively, the proportion of A that ends up as D, E, F, and G will in fact be determined by the amount and activity of the six competing enzymes (catalyzing A to B, A to C, B to D, B to E, C to F, and C to G, respectively), and the proportions will vary widely in different cells at the same time and in the same cells at different times. It is the competition between alternative divergent and convergent pathways that determines the course and duration of life (and, I might add, the presence or absence of cancer, and the difficulties of cancer chemotherapy). See Fig 1.1.

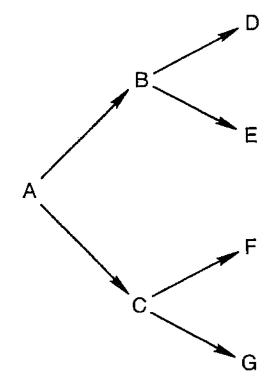

Fig. 1.1 Alternative pathways of metabolism illustrating competition between enzymes. See text.

5. Energy Storage, Gauging, and Replenishment

Paradigm *Every cell and every hierarchy of cells has a limited amount of reserve energy in the form of compounds immediately available and in the form of back-up reservoirs that can be used to replenish the working reserves. In addition the inventory of reserves must be constantly known and warning signals must be activated to demand replenishment of the energy reserves from outside sources, whenever the internal reserves are threatened.*

This is probably the key piece of information that vitalists seem not to have understood. Vitalists usually emphasize the idea of a guiding purposeful drive in living organisms, sometimes referred to as the *élan vital*. In the absence of detailed understanding of the built-in mechanisms by which even the simplest organism can judge the status of its energy reserves and mechanistically take action when these reserves are threatened, it is easy to imagine some mysterious vitalistic principle as the explanation. But obviously a rather simple machine could be devised to do the job of sensing energy status and acting appropriately. The point is that any cell that could not perform in this way never survived to be observed by us, so all successful living organisms behave purposefully in terms of their own or their species' survival.

6. Information Storage

Paradigm *All living organisms at all hierarchical levels must cope with their environment and, having survived, be able to store and retrieve the vital know-how, using relatively stable molecules like DNA (deoxyribonucleic acid) (19) or relatively stable associations of communicating cells, as in brain and nerve networks, or organs that communicate by means of special chemicals via blood and body fluids. The stored information is part of the machinery that provides for both the formation of the catalysts (enzymes) and their structural and humoral organization.*

I have estimated the number of DNA molecules in a human cell at 450,000 based on actual analyses and assuming a molecular weight and the possible number of informational bits (base pairs) at about 5.8 billion. The sum total of the information in the DNA molecules in an

organism constitutes the *genotype*, and biological scientists are eager to learn whether DNA molecules are the only form of biological information storage. Four nucleotides in a sequence of 2 can be arranged in 4^2 or 16 different ways, and a sequence of 10 can be arranged in 4^{10} or about a million different ways. Thus, the possible total of sequences for 5.8 billion base pairs is for practical purposes infinite (20).

Similarly, if the number of central neurons in the brain system is 10 billion (Chapter 8), the number of possible connections is practically infinite. It is inconceivable that we will ever have all the possible details of the stored information mastered, and we have to ask ourselves the practical question of how much to tamper? when? and how? As indicated earlier, we have already tampered with Nature a great deal, and to do nothing at this time is also a form of tampering with the system.

7. Information Replication

Paradigm *A cell or a hierarchy of cells that has the ability to cope with its environment must pass this information on to its progeny if life is to persist, and it does so by replicating the necessary information in ultramicro-packages, apportioning the duplicated material to progeny cells partly by Mendelian genetics (21) and partly by other mechanisms.*

When the basic structure of the DNA double helix (cf. model, reference 22) was first proposed by Watson and Crick (10), they stated at once, "It has not escaped our notice that the specific pairing we have postulated immediately suggests a possible copying mechanism for the genetic material." Whether all of the nontransient information in a fertilized egg is contained in its nuclear and extranuclear DNA molecules is still not known, but the process of differentiation and development that leads to an adult in organisms with or without brains is in any case encoded. The information that is thus programmed is not a fixed program but a program of unfolding capacities for physiological and psychological adaptation. We are programmed to respond in a variable way to a certain range of environmental contingencies. As men we are not built to respond in the best possible way to any possible environment, but to respond in a satisfactory way to the environment in which we evolved to *Homo sapiens*. It is my contention that this response included the preservation of a built-in tendency toward irrational or erratic behavior, if the unplanned or irrational behavior led to desirable results. Man would then *learn* to repeat this behavior (Chapter 7). Thus, we are not robots but are capable of learning by unplanned experience (i.e., by hindsight) in addition to learning by planned experience (e.g., from traditions in the cultural heritage). Information gathering capacity in single cells can be passed to the progeny by means of DNA and possibly unknown mechanisms. Information gathering capacity in man is replicated and passed through the germ line in a similar way. In addition information is replicated in the culture by word of mouth, by recorded language and symbols, and by example.

8. Imperfection in the Information System

Paradigm *There is a finite probability of error in the course of information replication. Novelty may be introduced by a built-in tendency toward spontaneous copy-error or by increased copy-error from environmental hazards. The errors may then be replicated and subjected to the test of survival. This paradigm is the basis for Darwinian evolution by natural selection (23), which of course acts on the whole animal.*

If the first DNA molecule had been replicated without error and novelty had depended on the spontaneous formation of additional and different molecules, evolution probably never would have occurred. But with a tendency in the molecule toward a nearly but not quite perfect replication ability, novelty (mutation: copy-errors) was guaranteed while gains were conservatively maintained. Similarly, cultural evolution would have been very slow were it not for the tendency of man to introduce novelty by sheer inability to learn exactly what he is taught. This is not to say that the trick of creativity cannot be accomplished deliberately once we get the significance of it. Man undoubtedly has a higher capacity for storing abstract information than any other form of life, but this fact is inevitably accompanied by the fact that man has a greater tendency to introduce error or deliberate variance into his memory bank than any other form of life and hence the greatest opportunity to introduce novelty into his life. This set of opinions is highly relevant to the ancient problem of determinism versus free will. Because man can make mistakes or deliberately introduce novelty into his life and in either case learn by hindsight, his behavior can never be automated; he is less determined by fate and

has more opportunity to depart from the established norm. To this extent he has more opportunity for the exercise of individual free will than other life forms.

9. Feedback Mechanisms

Paradigm *Every form of life has built-in mechanisms by which it constantly reads its own performance in relation to its environment and automatically regulates its physiological and psychological behavior within the limits set by its inherited and genetically established feedback components (12).*

The product of a chemical reaction catalyzed by an enzyme constitutes information that can be used to decide whether the immediate reaction or some other reaction should be speeded up or slowed down. This product not only provides information, but it may actually be the effector and thereby directly regulate enzyme synthesis or enzyme activity. The feedback concept is probably the most important biological idea to be introduced into biology since the concept of the gene and Mendelian heredity. Whereas Mendel's work was done in the 1860's and the gene was rediscovered in the early 1900's (21), the feedback concept at the level of enzyme activity and enzyme synthesis was not clearly enunciated until 1956 and the years that followed the papers by Umbarger, Pardee, and Vogel. The process of physiological adaptation has as one of its principal ingredients feedback from enzyme products on enzyme activity or synthesis (cf. references in Chapter 9).

10. Cellular and Organismic Structure

Paradigm *Three-dimensional structure and compartmentation of cell activities within and among cells and separate from the environment is the basis of morphology and provides the means by which all of the preceding biological categories can be linked to the classical characteristics of life such as reproduction, irritability, motility, and so on.*

The cell remains the most important link between inanimate molecules and all the higher forms of life. Certainly no virus possesses all the qualities of life included above in items 1–10. The compartmentation of cells into nucleus, cytoplasm, membranes, and the organelles within these compartments, has been studied to great advantage by means of the electron microscope as shown by Swanson's book entitled *The Cell* (24). The diversity in form, color, and behavior in multicellular organisms is so great that no biologist is considered an expert on all the available genera. The variety is so great and the "purposefulness" so uniquely displayed in some forms that the late Raymond Nogar, O.P., was led to comment in *The Lord of the Absurd* [(25), p. 143], that "No one can contemplate the beak of the Brazilian caw-caw, the horn of the rhino, or the buck teeth of the wild boar without concluding the Creator is a clown." We are led finally to conclude that any change in the genetic code, any reaction, and any morphological structure will be permitted if the property can pass the hurdles: Will it survive? Will it do a job? Will it confer no disadvantage that will be too great? Will the organism reproduce? Will the organism adapt to its environment or force its environment to adapt to its own needs?

11. Environmental Hazards

Paradigm *The natural as well as the man-made environment contains many small molecules that resemble essential metabolites sufficiently to interact with and damage specific enzymes, information systems, or structures and thereby produce malfunction in the living system. In addition, many nonspecific damaging chemicals and agents such as radiation occur in the environment.*

Although enzymes are highly specific in their interaction with the compounds in living tissue, they are not completley specific, that is, they cannot discriminate between substances Nature patterned them to act upon and substances that are very similar but toxic for them. It is one of the tenets of modern chemotherapy that if an enzyme exists and its specific substrate is known, organic chemists can build a molecule that will inhibit the enzyme, albeit not on the first try as a rule. Various forms of life also produce substances that are toxic to other forms of life, and it is widely accepted that by suitable tests plant extracts and fermentation liquors can be assayed for their ability to kill infectious bacteria or to kill cancer cells. Thus the sulfa drugs were made by organic chemists, while penicillin was isolated from mold cultures. More recently, powerful agents have been synthesized for the purpose of acting as nerve gases, insecticides, pesticides, or herbicides (weed-killers or crop-killers). Just as cancer-killing drugs are not

without action on normal cells, the insecticides and the plant killers are not totally innocuous to other forms of life, and the complete range of their biological activity can obviously never be checked out on every species in advance. Yet they have been deliberately disseminated in the natural environment on the basis of tests on what were felt to be representative species. Especially in cases where agents are toxic in very small quantities, it is axiomatic that they act by combining with a special type of enzyme or with hereditary material. In addition to the environmental hazards that act more or less specifically, there are of course many that act nonspecifically. Among these, the radiations, including X-rays, radioactive fallout, cosmic radiation, and even sunlight, all have the capacity to produce mutations in the hereditary substance and to damage cells in other ways.

12. Physiological Adaptation

Paradigm *Every living organism possesses a genotype that determines its ability to alter its physiological mechanisms in response to changes in the environment, which may include various kinds and amounts of environmental hazards.*

The phenotype was originally defined by geneticists in terms of outward expressions of the genotype such as color of eyes and hair, structural markings or forms, skin color, and other features that are more or less permanent. Later the discovery of "inborn errors of metabolism" led to considerations of metabolic pathways and enzymes that appeared to be present or absent. More recently metabolic pathways and enzyme levels have been shown to vary widely in a matter of hours in normal metabolism as well as in the response to various insults in the form of toxic substances that are environmental hazards (Chapters 9 and 10). Many toxic compounds lead to the formation of enzymes that destroy the compounds, but sometimes the compounds are made more toxic. Little is known about any disadvantages accruing from an adaptive increase in the amount of drug-detoxifying enzymes, but in the case of the peregrine falcon it appears that enzyme changes include increased breakdown of steroid sex hormones, interference in calcium metabolism resulting in weaker eggshells, and resulting failure to produce young birds (5).

The genotype can be shown to determine adaptability to environment in many ways. The genetically-determined property of skin pigmentation permits some humans to tolerate extreme exposure to sunlight while others are simply incapable of developing a protective darkening of the skin in response to sunlight. Some individuals can increase their tolerance to high altitudes, while others cannot. Thus the hereditary apparatus determines not only the more obvious phenotypic characters but also the more subtle variable characters that delimit the range of environmental extremes that can be tolerated. These environmental extremes probably include noise, pyschological pressure, and many other environmental hazards that are still poorly understood. Studies on adaptation are needed not only in connection with environmental hazards but also in connection with the concept of optimal stressor levels that would help human individuals approach the optimum phenotypic expression permitted by their genotype (Chapters 9 and 10).

Physiological Adaptation as the Key to Biology

Of all the things we need to know about biology, adaptation is the phenomenon that we can least afford to ignore. We ought to begin with adaptation and use it to bring into focus all the other facets of biological knowledge, which have been briefly touched upon above. Although we cannot hope to master all the detailed information and interactions that are possible and that actually occur, we can reasonably be expected to know that we as individuals can do something about adaptation. It is the handle on biology, the rudder by which we can steer a course between boredom and weakness on the one hand and information overload and exhaustion on the other.

The genetic basis of life is usually given much more emphasis than adaptation in the teaching of biology, although an individual's heredity is presently fixed by acts beyond his control in contrast to his adaptive level. Heredity sets limits on our powers of adaptation and the special kinds of adaptation that we are best suited for. But few people ever develop their adaptive powers to the fullest, and we still have much to learn about the benefits and costs of adaptation. What we do know is that adaptation can best be understood by combining the inputs from both the reductionist and holistic points of view.

The adaptation that I have been referring to is adaptation by individuals, which is properly called *physiological adaptation*. It involves a variety of hormones and a realignment of many cellular processes in all parts of the body. Physiological adaptation occurs in every one of us every day. The shifts in body chemistry may be

minimal or they may approach the limits of our capacity in response to the stressors that we encounter. Each of us is forced to make some adaptations every time we get out of bed in the morning, and as we proceed through the day we may encounter heat or cold outside the limits that we prefer. We may need to run to catch a bus, we may climb a flight of stairs, breathe some automobile exhaust, take a tranquilizer, smoke a cigarette, drink a cocktail, eat an unusually large meal (or one that is high in protein, carbohydrate, or fat), go hungry, travel to a higher altitude, face darkness or bright lights, shiver in silence or cringe at loud noises, and so on. Most of the stressors are not continuous. They wax and wane, they occur in cycles, they are repetitive in some kind of a daily, weekly, or seasonal rhythm, and we are able to cope with them because they do not all occur at once nor do they occur continuously. We do not know the optimum level and optimum cycle frequency for the various stressors that we are exposed to, and we know too little about the physiological cost of making an adaptation to any given stressor. *Nor do we know enough about the cost of having no adaptational demands.* But it is clear that this is the part of biology that each of us needs to know more about because it affects us personally. As individuals we can do something about adaptation, given a little more knowledge from our school system and accepting the task of acquiring more knowledge as a lifetime process. Moreover, knowledge about adaptation is something that will affect the way we choose to bring our offspring through childhood and adolescence. How much should we shield and how much should we expose our children?

Another kind of adaptation is *evolutionary adaptation*. This applies to populations and occurs by mutations (copy errors) in the genetic material. The change in the hereditary material may be an improvement, a disadvantage, or it may be neutral, and the neutral changes may persist until some future generation in which they are helpful or harmful. Thus, the hereditary makeup keeps changing from generation to generation, always being challenged in terms of reproduction and survival in the current environment. One of the characteristics toward which evolutionary adaptation moves is the capability for physiological adaptation, but it also moves toward a closer fit to the environment, a fit which will require less physiological adaptation. Since evolutionary trends are not reversible, a species that is becoming better and better fitted to its environment can become extinct if the environment changes more rapidly than the species can undergo evolutionary adaptation. But the message that I wish to convey is that, from the standpoint of human society, the problems of the next 30 years cannot be solved by attempting to direct human evolution, and by the same token, inattention to human evolution *for this period* can do little harm. Adaptation by evolution is a slow process, it occurs over many generations, and it is inherently difficult to direct in man for many reasons, including our inability to decide on positive goals. On the contrary, physiological adaptation is something that individuals can accomplish and, moreover, they can choose to alter their course from time to time.

A third kind of adaptation is *cultural adaptation*, a process that occurs in both individuals and populations. Cultural adaptation involves psychological and behavioral changes that are affected by the underlying physiological and cellular biology. We are rapidly approaching an era in which it will be impossible to deal with the problems of behavioral change induced by a cultural adaptation to an overwhelming and widespread use of drugs that modify behavior unless we simultaneously learn more about the nature of biological man and the molecular targets of the new drugs. If we can establish which drugs produce dangerous and irreversible changes, for example, we can take firmer steps to prevent their acceptance. A desirable cultural adaptation would be the wider acceptance of the available knowledge in cancer prevention and health improvement. Other types of cultural adaptations with far-reaching consequences would be the decisions to accept population control by encouraging the use of contraceptive measures or by facilitating the ease with which women can secure medically safe and competent abortions. Cultural adaptation seems to impinge on evolutionary adaptation and physiological adaptation in virtually every instance that can be imagined.

Biology, Philosophy and Cultural Adaptation

The idea that disorder is built into biological and cultural systems at all levels came to my attention most forcibly from two different sources at about the time that I was beginning to ask myself, "Why cancer?" One source was Professor A. F. C. Wallace, who is quoted elsewhere in this book (Chapters 4 and 7). Almost simultaneously (1961), *Darwin and the Modern World View* by John C. Greene (23) appeared. Greene quotes many conflicting views on chance versus design in the purposefulness of Nature. I was especially impressed with his citation of a passage by Nogar whose later work (25) has

already been cited above. Nogar observed [(23), p. 66] that philosophers tend to fail to understand that " . . . when the Darwinist asserts openly that chance is the sufficient reason for the organization of the world, and denies outright the existence of intrinsic finality among organisms" or asserts "that organic agents simply do not act for any purpose or end, he is calmly saying what is intrinsic to his biological theory of the evolution of species. This is not an unwarranted extrapolation, an inferential extension of Darwinian theory; it is inherent in the very theory itself and has been all along."

In a curriculum designed around Bioethics, the ideas of Wallace and of Greene ought to be included among readings in *philosophical biology*, and the role of disorder in biological and cultural evolution should be fully explored. Disorder is a force to be utilized, the raw material for creativity. The problem is to harness it and keep it within the bounds of reason, that is, to be rational about irrationality. A thorough study of biological disorder would reveal that it is normal, not pathological, although it can appear in the form of pathology when extreme. The study of the nature and role of disorder in biology and in cultural evolution would do much to help interpret the supposed conflict between "humanism" and "science" as illustrated by the collection of 18 essays entitled *The Scientist vs The Humanist* (26). The editors comment that "Among the classic debates of history, none has more relevance to our age than that between the scientist and the humanist. No debate is more central to society's definition of an educated man; no debate is more important to the student faced with the choice of a career. And no debate more clearly focuses the long-standing antagonism between those who see the meaning of life in terms of material progress and increased knowledge of the natural world and those who see it only in the personal fulfillment of every man's 'humanity'—of his moral, intellectual, and aesthetic capacities." They further ask, as I have asked in this chapter, "How can the advances of science and the heritage of humanities be combined to the benefit of the individual and of society?" I have taken the position that biology is the science that can most fruitfully be combined with the humanities and that both are necessary for our survival.

The assumption that the students who take one semester of biology are automatically able to think in terms of Bioethics because of their other exposures would be a serious mistake, yet they may be closer to that goal than those who specialize in some present phase of biology. It would not be possible to build a suitable interdisciplinary course in biology and humanistic subjects by combining a variety of existing courses unless each of the courses in the curriculum were directed to the purpose of training and inspiring students who could be called properly qualified in Bioethics.

Somehow the idea has to be promulgated that the future of man is not something that we can take for granted (6). Human progress is not guaranteed nor is it a natural consequence of Darwinian evolution. The natural world cannot be depended upon to withstand our insults and support our offspring in limitless numbers. Science cannot substitute for Nature's bounty when Nature's bounty has been raped and despoiled. The idea that man's survival is a problem in economics and political science is a myth that assumes that man is free or could be free from the forces of Nature (27). These disciplines help to tell us what men want, but it may require biology to tell what man can have, i.e., what constraints operate in the relationship between mankind and the natural world. Bioethics would attempt to balance cultural appetites against physiological needs in terms of public policy. A desirable cultural adaptation in our society would be a more widespread knowledge of the nature and limitations of all kinds of adaptation.

Bioethics, as I envision it, would attempt to generate wisdom, the knowledge of how to use knowledge for social good from a realistic knowledge of man's biological nature and of the biological world. To me, a realistic knowledge of man is a knowledge that includes his role as an adaptive control system with built-in error tendencies. This mechanistic view, which combines reductionist and holistic elements, would be totally incapable of generating wisdom unless supplemented with both a humanistic and an ecological outlook (28). The concepts and viewpoints expressed in this chapter may be examined in relation to the books by Teilhard de Chardin, especially *The Phenomenon of Man* and *The Future of Man*, which were written nearly 30 years ago (29). Although he differs in approach, his aim is the same: to combine the science of biology with a preservation of human values and to strive to make man's future come up to what it could conceivably be. The present world is dominated by military policy and by an overemphasis on production of material goods. Neither of these enterprises have given any thought to the basic facts of biology. An urgent task for Bioethics is to seek biological agreements at the international level.

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29. In subsequent chapters we will adopt the viewpoint that a world goal of zero population growth is mandatory for the preservation of human values. If Père Teilhard de Chardin were alive and writing books today, it would be no more unlikely that he would adopt a similar view than it was for him to champion evolution in his day (see Chapter 2).

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