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Documentation: What's Around the Corner for Humanity in the Life Sciences?

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DOCUMENTATION

"What's Around the Corner for Humanity in the Life Sciences?"

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EDITORIAL NOTE: *The author is professor in the field of biological science at the University of North Carolina at Greensboro. This article was first presented as an address to a Theological Conference on Church and Society, held at the Lutheran School of Theology in Chicago, Jan. 8—9, 1970, and sponsored by the Lutheran Council in the U.S.A. It is reprinted here as "documentation" to indicate current trends in scientific thought and speculation. Though providing no theological answers to the problems it raises, the article helps to write an agenda of issues that churchmen and theologians will have to address seriously in the latter third of this century. The editorial staff of this journal hopes that the article will stimulate vigorous discussions as well as an earnest probing of our theological resources as we confront the concerns delineated here.*

The middle third of the 20th century has been called the space age, the atomic age, and the age of computers, to mention a few names. But perhaps the broadest, most accurate description would be the age of science. Science is involved in most of, if not all, our daily activities. Each of the sciences has experienced its own period of relative superiority and resurgence; both chemistry and physics have enjoyed a prestigious position among the sciences during this century.

About 25 years ago, biology began to make giant discoveries that were to initiate a biological renaissance. First there were breakthroughs in the fields of developmental biology, microbiology, genetics, biochemistry, and ecology. These were shortly followed by even larger and more significant developments in almost every subdivision of biology. The trickle of knowledge in biology soon became a current, and the current has now become a raging torrent of data about life processes and living things. The accumulated knowledge about certain areas is doubling every five or six years. There is every reason to believe that the pace of gathering information about biological systems will not slacken in the foreseeable future; probably the rate will even accelerate in the next several decades. Today we truly live in the golden age of biology.

Laymen to the life sciences marvel at new discoveries about DNA, enzyme systems, molecular biology, energetics of food chains, and the like. But, using the vernacular, "You ain't seen nothin' yet!" The sky can be the limit if we permit it. Knowing generally that significant and dramatic breakthroughs will eventually occur is one thing, but trying to predict specifically what the nature of these discoveries will be and when they will occur is much more difficult. Some events are pretty much inevitable, while others are more speculative in nature. It is also difficult to divorce one's predictions about the future from one's personal crusade for or against specific concerns.

My comments here are restricted to those biological breakthroughs that will have some theological or moralistic implications. You must, therefore, understand that this restriction eliminates an enormous number of small and some very large advances in the area of basic biological research. Detailed research, for example, on mitochondrial DNA, mechanisms for hydrogenation in photosynthesis, insect photoperiodism, bacterial taxonomy, and phosphorus metabolism by planktonic desmids will all be very exciting and will significantly advance those areas. But there are few if any direct theological, ethical, or philosophical conceptual spin-offs from such studies.

My remarks are structured in three basic areas of the life sciences according to levels of biological organization. These organizational levels are as follows: The Cell, The Organism, and The Environment. Some concerns to which I will refer do not conveniently fall into only one category, but these difficulties will be obvious.

I. The Cell

Many varied research programs and investigations are currently under way at the cellular or molecular level. There have been fantastic developments in this area in the last 25 years, and most assuredly they will continue in the future.

One of the most dramatic and eventful experiments to occur within the next few years will be the creation of life in the laboratory. Using simple substances thought to occur in the primeval seas three or four billion years ago, and simulating environmental conditions of that time, scientists will cause to occur the spontaneous initiation of living protoplasm. This random, chance meshing of the right combinations of the right materials under the right conditions will produce a living entity. What it will look like or how long it will exist no one knows. But the artificial creation of life in a test tube will probably be a reality within a year or two, certainly by the end of the 1970s. About five years ago Dr. Charles C. Price of the University of Pennsylvania and then the president of the American Chemical Society urged that the United States make the creation of life in the laboratory a national goal. The impact of this soon-to-be-accomplished event on the church and on theology will be enormous.

The creation of life is but one facet of a very large, active branch of biology called molecular biology. Nature will be giving up more of her secrets very soon to molecular biologists. Many exciting discoveries are forthcoming and include studies on the nature of genetic material. It is now recognized that the genetic material consists of deoxyribonucleic acid (DNA). It is this DNA which contains the code for inherited characteristics. Different genetic characteristics ultimately manifest themselves in organisms by the production of different proteins. In this way DNA determines the sequence of amino acids (building blocks) in the finished proteins. DNA is capable not only of reproducing itself but also can pass the genetic information on to the cell. In this way it directs the formation of all proteins, including enzymes and hormones. DNA produces first a ribonucleic acid (RNA) according to the encoded instructions. This RNA, called messenger RNA, passes out of the nucleus into the cytoplasm and attaches to ribosomes. This complex then is responsible for protein synthesis. Another RNA, somewhat smaller

in size, called transfer RNA, carries the proper amino acid to the messenger RNA, making sure that this amino acid acquires its correct position in the forming protein. There are at least 20 different transfer RNAs, each specific for a particular amino acid. The basic code and details for this process have been elucidated during the last 15 years. It is a three-letter code, each amino acid being represented by triplets of the four different kinds of chemical bases in DNA. Surprisingly, this code may be universal — the same triplet code specifies the same amino acid in all species. It is now clear that all life is directed by DNA.

Scientists are, of course, interested not only in breaking the code but also in finding out the actual structures of DNA and RNA in order to change or to synthesize these molecules. By so doing, life could be controlled. Progress has been made in this area. For instance, several transfer RNAs have been completely characterized, a few years ago the *in vitro* synthesis of an infectious RNA was reported, and about a year ago it was shown that DNA could replicate itself in a test tube.

With the buildup of data on DNA and RNA, molecular biologists will now turn their attention toward controlling man's heredity. In November 1969, a group at Harvard Medical School isolated a single gene. Using this or a similar process, biologists will, within a few years, be able to take out a gene, alter it or substitute another in its place, and replace it. When this technique is successful, we will be able to control and correct hereditary diseases such as hemophilia and diabetes or turn off the proliferation of cancerous cells.

In recent years there has been much talk about the possibility of artificially modifying the human genetic material and thereby changing mankind. While some would disagree, this topic should be discussed openly and rationally. This is certainly one of the most important ideas to arise out of the entire history of man. There are few other concepts that have greater long-range implications for the future of the human species. Now for the first time, a living creature is beginning to understand its own origin and can logically undertake to design its future. Never before has man been able to rise above his nature to chart his destiny. Genetic engineering can be a reality before the end of this century. There is every reason to believe that man's first attempts to modify himself genetically will be small but will occur soon. These small changes will inevitably lead to more dramatic genetic modifications.

It is now generally assumed that the full DNA content is present in every somatic or body cell. For example, the genetic information specifying the structure of insulin is present in all cells of the body (eye, skin, kidney) in addition to the beta cells of the pancreas. Why do the genes for insulin production only function in the cells of the pancreas? Why do only a few genes ever become operational in a given cell? These same instructions present in the other cells are not activated, and their DNA is repressed. In the next few years biologists will understand why some genes in a given cell are repressed while others become functional. Within two decades genetic engineers will be able to supply a cell with the necessary and appropriate regulatory substances. Then we will really be in the business of genetic engineering.

Investigations into the field of virology will be exceedingly fruitful in the next decade. Viruses are basically composed of RNA or DNA, and their virulence is due to these nucleic acids. Once a cell is infected by a virus, the nucleic acids of the virus direct the cell to make viral nucleic acids and viral proteins rather than cell proteins. In this decade we will have vaccines to counteract most virus infections by chemically altering the nucleic acids of the virus. With chemical microsurgery on the DNA of the virus, the virulent segment can be eliminated without influencing the immunizing potential of the remaining DNA. Lifetime protections against most, if not all, viral diseases will be available shortly. Vaccines against German measles, mumps, chicken pox, and certain cold viruses will be available in a year or two. Vaccines against certain malignancies, such as most leukemias and perhaps other carcinomas, will follow. Viral infections that cause most infectious diseases (from the common cold to most cancers) will have all but disappeared by the end of this century.

An alternative approach to the genetic engineering problem will probably be perfected by the end of the 1970s. This will involve the creation of many different strains of viruses, each grown to provide pure, uncontaminated genetic material. Through careful selective breeding, we can alter a strain of virus to contain precisely the DNA desired. The viruses will then be applied to the cells having imperfect DNA sequences or sequences that produce human deficiencies. It should be noted that the viruses are capable of self-replication indefinitely. Therefore, the DNA of the virus will direct the production of proteins of which the cells are incapable throughout the life of the cell. Thus we will harness and utilize the metabolic machinery of an organism we have heretofore despised and tried to eradicate.

II. The Organism

In this section I shall discuss those factors that affect entire organisms rather than cellular processes. The mechanisms of the specific influences undoubtedly will be cellular or molecular in most cases but will be more grossly manifested as affecting the entire organism. This discussion will deal almost exclusively with the human organism in the future: first, its prenatal existence; then, its lifetime existence; and finally, its period of demise.

Technological progress is now making the traditional concept of the family obsolete. The reasons are many, complex, and interrelated and should be discussed at length by sociologists, scientists, and others. But new and startling advances in reproductive biology and in medicine may be partially responsible for some familial changes.

The idea of eugenics was first proposed by the Englishman Francis Galton in 1883. By the 1920s, eugenics in America had degenerated into a mixture of pseudoscience, Bible-belt religion, extreme reactionary politics, and racism, so that the term and the idea became repulsive. In recent years there has been a revival of interest in positive eugenics by a wide spectrum of biologists.

Eugenics (eutelegenesis or the field of hereditary counseling) is concerned with the frequency and distribution of different types of genetic factors in successive genera-

tions of human populations. Essentially, eugenics seeks to understand and ultimately to direct the forces that control human inheritance through matings, births, and deaths. The two most widely stated goals of eugenics policies are (1) to reduce the incidence of genetic defects and (2) to raise the level of intelligence. This century will see significant changes in the entire field of eugenics, and a wide variety of methods will be developed to improve the genetic endowment of our progeny.

A recent report stated that in excess of 10,000 children a year are engendered in the United States by artificial insemination of women whose husbands are sterile; sperm derived from donors is used. Undoubtedly, many of the couples who have resorted to this procedure would have jumped at the chance of having their child derived from germinal material of unusual promise. To most persons this would be superior to having a child whose genetic composition would be much less predictable. Because of societal pressures there will be continued advances in the development of what are called sperm banks. Sperm from a wide variety of males will be stored for a period of years in a deeply frozen state to provide time for the donors to distinguish themselves in their chosen fields. Perhaps the sperm would be stored until the donor was no longer alive, and posterity could judge his values dispassionately. Probably the sperm from males who had possessed outstanding talents, intelligence, moral fiber, and physical fitness would be most widely sought. It would then be possible for a couple to select the most desired "genetic father." The genetic father would be distinguished from the "love father," the male who rears the child and who demonstrates paternal love.

It is not unreasonable to assume that human eggs, or ova, could likewise be amassed and stored by freezing. With artificial ovulation and implantation as available as artificial insemination and with egg banks as well as sperm banks to draw from, either a genetic mother or father or both could be selected for the prospective child. Men and women could then ignore heredity in their choice of mates. Thus, a barren woman with all hope exhausted for herself to be pregnant could be afforded the fulfilling emotional gratification of childbearing.

Within 20 years it may be possible for a couple to shop in a new kind of commissary for sperm, eggs, or even frozen one-day-old embryos. Each packet would contain vital information about this prefab embryo and would include such things as sex, potential height, prospects as a successful athlete, eye and hair color, relative susceptibility to various hereditary diseases, and approximate intelligence. The future mother would take the packet to her physician to have the embryo implanted within her uterus.

But, at the same time, the mother might elect not to carry her chosen fetus. She might instead hire out another female as a surrogate mother to carry her embryo for the development period. Thus, a female with a serious problem such as diabetes or a heart condition could still have her maternal emotions satisfied.

To carry this one step further, we are almost to the point of perfecting a completely artificial uterus complete with a circulatory supply, placenta, and protective membranes. This is already a reality for certain animals and has been feasibly demonstrated for human embryos up to about three months of development. In several years it will be possible

to remove embryos or eggs, transfer them to the glass and plastic uterus, and grow them *in vitro.*

Regardless of whether the embryo will grow *in vivo* or *in vitro* and irrespective of its genetic or love parents, within a few years a few cells from one of the embryonic membranes will be analyzed specifically for DNA content and generally for chromosomal integrity. In cases where gross chromosomal breaks or abnormal divisions have occurred, such as in Kleinfelter's syndrome or mongoloidism, an abortion can be effected. There is real and substantial hope that the frequency of chromosomal conditions or defects can be prenatally reduced in the immediate future.

A large segment of biologists is now concerned with the determination of forces behind the differentiation of various groups of cells in embryological development. One of the significant problems in differentiation or cell specialization is the manner in which different cells of the body do different things even though they come from a single-celled zygote and therefore carry exactly the same instructional information. For example, cells of the bone marrow produce hemoglobin, not adrenalin, whereas the adrenal cortex cells produce adrenalin, not estrogen. There must be physiological machinery that regulates the activities of different cells and at the same time inhibits the activity of part of the DNA while stimulating another segment to produce the proper proteins.

At some distant point in the future it may be possible to grow an entire organ, or better still an entire organism, from a group of cells in tissue culture. Obviously the questions of differentiation must be answered before this can be a reality.

A great deal of interest has been shown recently not only about differentiation but about the reverse process of dedifferentiation. Cancerous cells, for example, dedifferentiate and begin to divide wildly. If we could control dedifferentiation and then regulate subsequent differentiation in a new direction, new organs such as hearts and kidneys would be grown from single cells that had been permitted to unspecialize, then to respecialize to form the desired new organ. The idea has been advanced that an individual might one day maintain a culture of his own cells so that a complete replica of himself could be grown if he met with an untimely accident or when he died or for whatever the reason might be. Be on the lookout for new discoveries in this large, active area of differentiation and dedifferentiation.

One suggestion has been made that even teleduplication is ultimately possible. This involves creating replicas of a human being across vast distances in space by feeding a computer a person's DNA specifications and having a receiver on another planet reconstruct him instantly. This idea is certainly "not just around the corner" but may be a reality in, say, 200 years. If this is a reality, the enormous range of problems of personal identity will provide a good measure of worry for a number of people, including theologians.

Just around the corner then is an era where children perhaps will be born of geographically separated or even long-dead parents and where virgin births are possible. This will be an era in which women may give birth to other women's children and one

in which a few favored persons may be the parents of thousands of progeny. This era will bring a further separation between romance and genetics. Of course, participation in any one of these alternatives by a person or a couple will be entirely optional. Eugenics will not and must not be forced on anyone. What will be the legal, social, moral, and religious status of such children? Will physicians be adulterers? Can you imagine the plethora of counseling problems with which doctors and ministers will be confronted in a few short years?

Many efforts are now being made to improve the health and welfare of humans during their formative and adult years to provide us with the "more abundant" life. The human life span will continue to be lengthened as a result of continued advances in medicine, hygiene, public health, nutrition, and other biologically related fields.

By the end of this century the major diseases known today will have, for the most part, disappeared. Vaccinations for most or all of the infectious diseases will be perfected by that time. Computers will make possible rapid, accurate diagnoses and remedial actions for most diseases, accidents, or malfunctions. Other technological devices such as the laser beam, neutron gun, and physiological simulators will prove to be important for the future. The process of aging will be better understood with each passing year. Within a decade or two the average life span can be significantly lengthened even more, and there can be more optimal utilization of these additional years by the elimination of senility due to the prevention of degenerative diseases. For the sake of brevity, I want to discuss only three areas where specific advances are clearly indicated; they are drugs, behavior, and organ transplants.

1. A radically new and uneasy world is developing now as a result of the products of active pharmaceutical research. Only in the last two decades has our society turned to drugs, and only within several years have drugs been abusively utilized. Within a few short years drugs will be available to induce almost every conceivable human emotion as well as those that can alter human behavior almost at will. Some drugs will make persons very happpy and even euphoric, while others could induce a state of intense depression. Every basic human drive together with its fulfillments can eventually be artificially produced with drugs. Drugs for love, hate, and even morality are possible. Not far off even now is the perfection of several drugs that will emotionally incapacitate persons and disorganize brain functions to such a degree that physical, armed resistance cannot be maintained. Thus, warfare may, it is hoped, become obsolete. This type of development could have a greater ethical impact on humanity than the atomic or hydrogen bombs. In the future, drugs can be used to manipulate man's brain, his courage, his morals, his ethics. Is man really the master of his own destiny or will he be puppeteered by drugs administered by others? The future of drug research will be limited only by the moral and ethical mores of society.

2. The field of behavior of human psychology will experience new advances in the years to come. We will see the development of large numbers of methods to increase our mental capacities. A wide variety of experiments in hypnosis, drug therapy, elec-

trical stimulation of the brain, and molecular biology will enhance our understanding of the brain and how to make it function more effectively.

By the year 2,000 it may be possible to join one's nervous system to a computer. By appropriately programing the computer, we might, for example, experience the audio, visual, emotional, and religious experiences of a visit to St. Peter's Basilica, the Church of the Holy Nativity, or the Wittenberg Cathedral without ever leaving our living rooms. Or we could experience a spring sunrise over a campfire in the Maine woods with all the attendant sensual feelings. The computer could simulate the stimulations of all of our senses as though we were there in person.

Psychologists say that in the not-too-distant future, psychological assistance for everyone will be a reality. Persons with varying degrees of competence and expertise will be available to every community for counseling people and helping them alleviate some of their anxieties. Social or behavioral engineering on a mass basis will be a major breakthrough in community health services in the near future.

3. Organ transplants have certainly excited both scientists and laymen in recent years. There are to be future advances in this area. The big hurdle to overcome in tissue or organ transplantation is the immune barrier that rejects foreign proteins. It is this same mechanism that enables our immunological system to combat various infections and inflammations. Future attempts in suppressing the immune response may be rather dramatic. New techniques will be developed to destroy or incapacitate the antigen groups of donated tissues.

The man of the future will carry a medical identification card that will include his vital medical data as well as his tissue compatibility parameters. This card will also carry access numbers to a computer where his complete medical history is stored. The computer will rapidly assist the physician in determining the tissue compatibilities between the recipient and donated organs or tissues stored in biological banks.

Organ transplants will continue to be made only on the most severely critical patients and on a very limited basis. The chief limitation will be the source of donated organs, whether from dying persons or from closely related animals. Look for technology to produce a wide variety of gadgetry or hardware in lieu of transplanted organs. Hearts, stomachs, kidneys, and spleens will be replaced by teflon, dacron, metallic, or electronic devices that will function in place of diseased, worn-out organs.

The definition of death has always bothered both physician and clergyman. Most physicians now hold that there are three different levels of death. One is cellular death, which may occur as much as three weeks after interment. Cells producing hair and nails, for example, continue to live for days and weeks. The second level of death is physiological death — the cessation of all vital processes such as heartbeat, breathing, and brain waves. Our current working definition of death is at this level, physiological death. A third level of death has been called being, brain, or reality death. This occurs when some circumstance causes the termination of the existence of our psyche or meaningful being. Our definition of death should be at this level in a few years. When brain death or irreversible coma occurs, a person ought to be pronounced dead. Why prolong this

existence hopelessly and artificially when a person's being is no more? This is not mercy killing or euthanasia, because death has already occurred. The church should define death at the mental or reality level as final death, as medicine is now doing.

III. The Environment

In this last section I shall limit my discussion to two extremely important problems facing mankind today and in the immediate future: pollution and the population explosion. Both are really environmental problems that are partially related to each other, yet are separate entities in many respects.

1. *Pollution.* Other authors have used vivid descriptive titles for their remarks about pollution; some of these are "Our Hostile Environment," "Is There Intelligent Life on Earth?" "Can the World Be Saved?" and "Environmental Decay." Pollution is one of the most pressing problems that society faces in the next few decades. This ecological crisis is a result of man's abuse of his surroundings with garbage, chemicals, sewage, gases, and other forms of pollution.

Frustration over the nation's increasingly dirty air, littered highways, filthy streets, and malodorous rivers is rising and spreading. Is this a fit conclusion to "America the Beautiful," our beloved virgin continent? The pollution problem is acute, but it reflects something even worse: a dangerous illusion that our technology can construct bigger and more complex industrial societies with no consideration for the immutable laws of nature.

Problems of pollution are not confined to the United States. The entire industrial world is becoming polluted. The fantastic effluence of affluence is far outstripping the rate of natural decay. Huge quantities of diverse and novel materials are now being added to the air we breathe, to the water we drink, and to the land we inhabit. These pollutants are either unwanted by-products of our technology or spent substances that have served their intended purpose. These extraneous substances impair our economy and our quality of life. They threaten the health, longevity, livelihood, recreation, cleanliness, and happiness of the citizens who cannot escape their influence.

To early man nature was harsh and hostile and something he deeply respected and worshiped. His technology was unable to harm the environment. The technology of modern man, however, is capable of destroying the environment. Yet, because he is so aware of his technological strength, he has been almost oblivious to the limitations of his environment. In the last few decades man has put undue pressures on the environment to absorb his insults. Many scholars of ecology are fearful that human pollution may trigger some ecological disaster that would rudely upset the delicate balance of nature. This would probably lead to the elimination of most life on this planet.

The prestigious Environmental Pollution Panel of the President's Science Advisory Committee reported the following: "Pollutants have altered on the global scale the carbon dioxide content of the air and the lead concentration in ocean water and in human populations. Pollutants have reduced the productivity of some of our finest agricultural soils and have impaired the quality and safety of crops raised on other lands. Pollutants

have produced massive mortalities of fishes in rivers, lakes and estuaries and have damaged or destroyed commercial shellfish and shrimp fisheries. Pollutants have reduced valuable populations of pollinating and predatory insects, and have appeared in alarming amounts in migratory birds. Pollutants threaten the estuarine breeding grounds of valuable ocean fishes; even Antarctic penguins and Arctic snowy owls carry pesticides in their bodies."

There are many, many questions regarding pollution that beg for answers. Where do we go from here? Can the world be saved? What will be our strategy for a livable environment? Can we find effective antidotes for our ecological poisons? Is our environment destined to become even more hostile? The simplest solution is to stop pollution or, better yet, to revert to a romanticized past that is totally free of pollution. The latter is, of course, impossible. The past is gone with the wind. We live in today's world, which is industrialized, overpopulated, motorized, and rapidly becoming polluted. We cannot take nature back to its pristine purity. We must deal with the problems within our current perspectives.

Ecologists will assume a much more prominent role in science and in our society in the last 30 percent of this century as prophets of doom and destruction unless we can rehabilitate the environment. One immediately draws a parallel between modern ecologists and the Old Testament prophets, who saw desolation in the future unless men turned from their evil ways. Society will be abruptly shaken into an outrage about environmental decay. Within 20 years societal pressures will demand: (1) the total cessation of the detonation of atmospheric nuclear weapons; (2) the treatment of sewage independent of streams or rivers; (3) the abolition of internal combustion engines; (4) precise and absolute air and water control on all industrial plants; (5) the elimination of coal, wood, or fossil fuels as a source of interior heating; (6) the elimination of all industrial plants that use water as a heat exchanger (which causes thermal pollution); (7) careful conservation controls on land erosion and on land runoffs from mining and smelting areas; and (8) the total abolition of the use of insecticides, herbicides, pesticides, and all biologically lethal sprays.

I am confident that these and other goals will be national or worldwide goals in the 1970s and 1980s. Presidential campaigns will be won or lost not over the validity of these goals but over the methods to be used to achieve them. By 1990 as much as 40 percent of our national revenues will be spent specifically on restoring the quality of our environment. These goals must be accomplished if we are to survive.

2. *Population Explosion.* Perhaps it is significant and fitting that this topic be discussed last. It is urgently important that solutions to this problem be found. All the preceding futuristic predictions about developments in the life sciences cannot be completely fulfilled unless the rate of population growth can be significantly reduced.

The population of the world is now growing at an unparalleled rate of 2 percent per annum. This may not seem inordinately high or unusual. But this rate means that about 130 persons are now being added per minute to the present population, and this figure will increase in magnitude in the future. A mere dozen people a thousand years

ago could have produced the present world population at this rate of growth, or in another thousand years each of us could have 300 million living descendants. This cannot happen. Something must be done *now*.

One has to look at the history of the rapidity with which the world's population has grown to appreciate fully the urgency of the problem. It took at least a million years, that is, from the emergence of man from his primate stock until 1830, for the population to reach 1 billion persons. In 1930, just 100 years later, there were 2 billion persons. By 1973, just 43 years later, the human population will have doubled again and there will be 4 billion. At this rate by the year 2,000, there will be an excess of 7½ billion persons, a doubling of the present population.

The problems are not due primarily to increased birthrates, since they have remained essentially the same. The problem is that people are not dying as fast as they formerly did. The relationship is quite simple: only live people have children. The more people science saves from death due to typhoid, cholera, diphtheria, smallpox, malaria, polio, and cancer, the more people will be around to reproduce. Obviously if natality continues to exceed mortality, any finite space will eventually fill up and overflow. The Reverend Thomas Malthus in 1798 first pointed out that populations tend to increase geometrically while other needs such as food and subsistence increase only arithmetically.

Our entire society suffers from what I call the "chamber of commerce syndrome"—that bigger automatically means better. This type of thinking permeates all of society from municipalities to universities to local parishes. We inadvertently are encouraging persons toward overpopulation. The institutions of our culture must bear much of the blame for the population explosion.

Passion between the sexes must, of course, remain a basic and fundamental human right. But this basic right cannot include having children at will. Procreation must become a matter of public concern. Man has an acute responsiblity to the next generation of limiting the size of that generation. All of the world's desperate needs such as ample food, permanent peace, good health, and a high level of quality living are unattainable for everyone either now or in the future for one obvious reason: people pollution.

The effect of too many people produces three other effects. First, more people make it increasingly difficult to enjoy the quality of life to which we aspire. Second, larger numbers of persons contribute proportionately more to the problems of air and water pollution and to environmental decay. And last but certainly most important of all, we are rapidly exhausting the resources with which to support more people or even the ones living now.

It is pessimistic but realistic to predict that in the very near future there will be a massive, worldwide famine during which hundreds of millions will die of starvation. The Paddock brothers, authors of the book *Famine—1975!* present a most pessimistic nutritional outlook in only five years. Others forecast that the food disaster will occur in 1980—1985. Even the most optimistic experts say the famine will have occurred by 1990. Enormous numbers of people will certainly starve within 15 years in Asia,

India, Africa, and South America. So vast will be this famine that the Vietnam War, in which more than 40,000 Americans have now died, will pale by comparison and will be all but forgotten by 1980.

By 1980 society and humanity will turn in panic to science and technology for some quick, massive answers or solutions to these problems. It is foolish and irresponsible to think that technology can bail us out of this dilemma. So vast will it be that most people in the "have-not" countries simply won't be around to see the 1990s. Farming the oceans or massive use of fertilizers will, at best, only buy us a year or two of time. Even the prospects of famine are awful and terrifying. But the impending famine will be worldwide, it is inevitable, it cannot be forestalled for long by technology, and it will be the world's greatest catastrophe to date. The moral, ethical, and religious ramifications of this imminent and extraordinary struggle for existence or survival of the fittest are enormous and stunning.

The only hope any nation or segment of humanity has is to minimize as much as possible the crushing and decimating effects of the famine. This can only be done by immediately cutting our rate of population growth to zero. Zero growth can be accomplished either by reducing the birthrate or by increasing the mortality rate. In the next few years society will become acutely aware of the impending crisis. Society will demand that biologists, physicians, and demographers devise ways to either increase mortality or reduce natality. I suspect our egocentric tendencies will lead us way from enhancing the mortality rate, which will directly involve us, the living. Alternately, we will demand more rigid measures of birth control.

By 1980 we will be using every conceivable means to minimize the incidence of births. Watch for widespread, even universally available, uses of various modifications of the Pill, intrauterine devices, vasectomies, antiovulation drugs, antimeiotioc drugs for both males and females, abortions for all who desire them, tax incentives for not having children, mandatory sterilization of both parents of more than one illegitimate child, and mass education about family planning. Research is now under way to perfect chemicals that retard or prevent gamete formation and then can be applied in large-scale dimensions to water supplies. Investigations are now in progress to perfect chemicals that would function as spermicides supplied by massive aerial spraying. Thus, it is possible to reach large masses of people with birth control measures.

Biologists have a unique role to play in society, since by training and research interests they are vitally interested in man as an organism as he attempts to survive in his environment. Biologists will become more political and more active in the conscience of society. Scientists generally will have to direct their thoughts and skills away from problems of their current interest and toward problems of greater social significance. There will be, then, rapid and profound shifts in areas of emphasis in both basic and applied research.

What's around the corner in biology? We face a very paradoxical future. The future on one hand is exhilaratingly optimistic, with the sky as the limit, while on the other hand, it is hopelessly dismal and almost fatalistic. Our only hope and salvation is to

establish an order of priorities of things that biology can or must accomplish first. Certainly at the top of any priority list will be the population explosion, followed closely by the war on pollution. We must begin immediately to resolve these two great dilemmas that face mankind. We must make dramatic and significant financial and materialistic commitments in a dedicated effort to insure some sort of future. Assuming the population explosion can be checked and assuming that we can restore the quality of the environment, then these other advances in the life sciences will occur. What a fantastic and glorious future lies ahead for humanity — maybe?

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