PROLOGUE

The battle to feed all of humanity is over. In the 1970s and 1980s hundreds of millions of people will starve to death in spite of any crash programs embarked upon now. At this late date nothing can prevent a substantial increase in the world death rate, although many lives could be saved through dramatic programs to "stretch" the carrying capacity of the earth by increasing food production and providing for more equitable distribution of whatever food is available. But these programs will only provide a stay of execution unless they are accompanied by determined and successful efforts at population control. Population control is the conscious regulation of the numbers of human beings to meet the needs not just of individual families, but of society as a whole.

Nothing could be more misleading to our children than our present affluent society. They will inherit a totally different world, a world in which the standards, politics, and economics of the past decade are dead. As the most influential nation in the world today, and its largest consumer, the United States cannot stand isolated. We are today involved in the events leading to famine and ecocatastrophe; tomorrow we may be destroyed by them.

Our position requires that we take immediate action at home and promote effective action worldwide. We must have population control at home, hopefully through changes in our value system, but by compulsion if voluntary methods fail. Americans must also change their way of living so as to minimize their impact on the world's resources and environment. Programs which combine ecologically sound agricultural development and population control must be established and supported in underdeveloped countries. While this is being done, we must take action to reverse the deterioration of our environment before our planet is permanently ruined. It cannot be overemphasized, however, that no changes in behavior or technology can save us unless we can achieve control over the size of the human population. The birth rate must be brought into balance with the death rate or mankind will breed itself into oblivion. We can no longer afford merely to treat the symptoms of the cancer of population growth; the cancer itself must be cut out.

FOREWORD

Man can undo himself with no other force than his own brutality. It is a new brutality, coming swiftly at a time when, as Loren Eiseley says, "the need is for a gentler race. But the hand that hefted the axe against the ice, the tiger, and the bear now fondles the machine gun as lovingly."

The roots of the new brutality, it will become clear from *The Population Bomb,* are in the lack of population control. There is, we must hope and predict, a chance to exert control in time. We would like to predict that organizations which, like the Sierra Club, have been much too calm about the ultimate threat to mankind, will awaken themselves and others, and awaken them with an urgency that will be necessary to fulfillment of the prediction that mankind will survive.

It was only twelve years ago that we even suggested, in any Sierra Club publication, that uncontrolled population was a menace. We went far enough to write: "People are recognizing that we cannot forever continue to multiply and subdue the earth without losing our standard of life and the natural beauty that must be part of it. . . . These are the years of decision—the decision of men to stay the flood of man."

In the next two years we worried about the battle of man versus his own numbers and were concerned that growth itself was growing and were not joyful about the imminence of California's outstripping New York.

It was Professor Raymond Cowles who shook us loose with a provocative address before a Sierra Club conference, "The Meaning of Wilderness to Science."

What in the late fifties had seemed heretical soon was not so. For the complaints that I had received about mentioning population problems in early speeches, there were more vociferous complaints if I forgot to mention the big problem. In just two or three years it became possible to question growth, to suggest that DNA was greater than GNP, to predict that man had enough genius to require that science and technology be put to good purpose. He could limit his numbers. He could limit his heretofore unslackened appetite for destroying wilderness. He could go back over the nine-tenths or so of the earth that had already felt his touch, sometimes a gentle touch but too often brutal, and do better where he had been. He could start with Manhattan, or Los Angeles.

Whatever resources the wilderness still held would not sustain him in his old habits of growing and reaching without limits. Wilderness could, however, provide answers for questions he had not yet learned how to ask. He could predict that the day of creation was not over, that there would be wiser men, and they would thank him for leaving the source of those answers. Wilderness would remain part of his geography of hope, as Wallace Stegner put it, and could, merely because wilderness endured on the planet, prevent man's world from becoming a cage.

The good predictions could be entertained—the notion of predicting a more and more desirable future, not just a more and more crowded one.

—David Brower

Chapter 1
THE PROBLEM

I have understood the population explosion intellectually for a long time. I came to understand it emotionally one stinking hot night in Delhi a few years ago. My wife and daughter and I were returning to our hotel in an ancient taxi. The seats were hopping with fleas. The only functional gear was third. As we crawled through the city, we entered a crowded slum area. The temperature was well over 100, and the air was a haze of dust and smoke. The streets seemed alive with people. People eating, people washing, people sleeping. People visiting, arguing, and screaming. People thrusting their hands through the taxi window, begging. People defecating and urinating. People clinging to buses. People herding animals. People, people, people, people. As we moved slowly through the mob, hand horn squawking, the dust, noise, heat, and cooking fires gave the scene a hellish aspect. Would we ever get to our hotel? All three of us were, frankly, frightened. It seemed that anything could happen—but, of course, nothing did. Old India hands will laugh at our reaction. We were just some overprivileged tourists, unaccustomed to the sights and sounds of India. Perhaps, but the problems of Delhi and Calcutta are our problems too. Americans have helped to create them; we help to prevent their solution. We must all learn to identify with the plight of our less fortunate fellows on Spaceship Earth if we are to help both them and ourselves to survive.

Too Many People

Americans are beginning to realize that the underdeveloped countries of the world face an inevitable population-food crisis. Each year food production in these countries falls a bit further behind burgeoning population growth, and people go to bed a little bit hungrier. While there are temporary or local reversals of this trend, it now seems inevitable that it will continue to its logical conclusion: mass starvation. The rich may continue to get richer, but the more numerous poor are going to get poorer. Of these poor, a *minimum* of ten million people, most of them children, will starve to death during each year of the 1970s. But this is a mere handful compared to the numbers that will be starving before the end of the century. And it is now too late to take action to save many of those people.

However, most Americans are not aware that the U.S. and other developed countries also have a problem with overpopulation. Rather than suffering from food shortages, these countries show symptoms in the form of environmental deterioration and increased difficulty in obtaining resources to support their affluence.

In a book about population there is a temptation to stun the reader with an avalanche of statistics. I'll spare you most, but not all, of that. After all, no matter how you slice it, population is a numbers game. Perhaps the best way to impress you with numbers is to tell you about the "doubling time"—the time necessary for the population to double in size.

It has been estimated that the human population of 8000 B.C. was about five million people, taking perhaps one million years to get there from two and a half million. The population did not reach 500 million until almost 10,000 years later—about 1650 A.D. This means it doubled roughly once every thousand years or so. It reached a billion people around 1850, doubling in some 200 years. It took only 80 years or so for the next doubling, as the population reached two billion around 1930. We have not completed the next doubling to four billion yet, but we now have well over three and a half billion people. The doubling time at present seems to be about 35 years.[1] Quite a reduction in doubling times: 1,000,000 years, 1,000 years, 200 years, 80 years, 35 years. Perhaps the meaning of a doubling time of around 35 years is best brought home by a theoretical exercise. Let's examine what might happen on the absurd assumption that the population continued to double every 35 years into the indefinite future.

If growth continued at that rate for about 900 years, there would be some 60,000,000,000,000,000 people on the face of the earth. Sixty million billion people. This is about 100 persons for each square yard of the Earth's surface, land and sea. A British physicist, J. H. Fremlin,[2] guessed that such a multitude might be housed in a continuous 2,000-story building covering our entire planet. The upper 1,000 stories would contain only the apparatus for running this gigantic warren. Ducts, pipes, wires, elevator shafts, etc., would occupy about half of the space in the bottom 1,000 stories. This would leave three or four yards of floor space for each person. I will leave to your imagination the physical details of existence in this ant heap, except to point out that all would not be black. Probably each person would be limited in

his travel. Perhaps he could take elevators through all 1,000 residential stories but could travel only within a circle of a few hundred yards' radius on any floor. This would permit, however, each person to choose his friends from among some ten million people! And, as Fremlin points out, entertainment on the worldwide TV should be excellent, for at any time "one could expect some ten million Shakespeares and rather more Beatles to be alive."

Could growth of the human population of the Earth continue beyond that point? Not according to Fremlin. We would have reached a "heat limit." People themselves, as well as their activities, convert other forms of energy into heat which must be dissipated. In order to permit this excess heat to radiate directly from the top of the "world building" directly into space, the atmosphere would have been pumped into flasks under the sea well before the limiting population size was reached. The precise limit would depend on the technology of the day. At a population size of one billion billion people, the temperature of the "world roof" would be kept around the melting point of iron to radiate away the human heat generated.

But, you say, surely Science (with a capital "S") will find a way for us to occupy the other planets of our solar system and eventually of other stars before we get all that crowded. Skip for a moment the virtual certainty that those planets are uninhabitable. Forget also the insurmountable logistic problems of moving billions of people off the Earth. Fremlin has made some interesting calculations on how much time we could buy by occupying the planets of the solar system. For instance, at any given time it would take only about 50 years to populate Venus, Mercury, Mars, the moon, and the moons of Jupiter and Saturn to the same population density as Earth.[3]

What if the fantastic problems of reaching and colonizing the other planets of the solar system, such as Jupiter and Uranus, can be solved? It would take only about 200 years to fill them "Earth-full." So we could perhaps gain 250 years of time for population growth in the solar system after we had reached an absolute limit on Earth. What then? We can't ship our surplus to the stars. Professor Garrett Hardin[4] of the University of California at Santa Barbara has dealt effectively with this fantasy. Using extremely optimistic assumptions, he has calculated that Americans, by cutting their standard of living down to 18% of its present level, could in *one year* set aside enough capital to finance the exportation to the stars of *one day's* increase in the population of the world.

Interstellar transport for surplus people presents an amusing prospect. Since the ships would take generations to reach most stars, the only people who could be transported would be those willing to exercise strict birth control. Population explosions on space ships would be disastrous. Thus we would have to export our responsible people, leaving the irresponsible at home on Earth to breed.

Enough of fantasy. Hopefully, you are convinced that the population will have to stop growing sooner or later and that the extremely remote possibility of expanding into outer space offers no escape from the laws of population growth. If you still want to hope for the stars, just remember that, at the current growth rate, in a few thousand years everything in the visible universe would be converted into people, and the ball of people would be expanding with the speed of light![5] Unfortunately, even 900 years is much too far in the future for those of us concerned with the population explosion. As you will see, the next *nine* years will probably tell the story.

Of course, population growth is not occurring uniformly over the face of the Earth. Indeed, countries are divided rather neatly into two groups: those with

rapid growth rates, and those with relatively slow growth rates. The first group, making up about two-thirds of the world population, coincides closely with what are known as the "underdeveloped countries" (UDCs). The UDCs are not industrialized, tend to have inefficient agriculture, very small gross national products, high illiteracy rates and related problems. That's what UDCs are technically, but a short definition of underdeveloped is "hungry." Most Latin American, African, and Asian countries fall into this category. The second group consists of the "overdeveloped countries" (ODCs). ODCs are modern industrial nations, such as the United States, Canada, most European countries, Israel, the USSR, Japan, and Australia. They consume a disproportionate amount of the world's resources and are the major polluters. Most, but by no means all,[6] people in these countries are adequately nourished.

Doubling times in the UDCs range around 20 to 35 years. Examples of these times (from the 1970 figures released by the Population Reference Bureau) are: Kenya, 23 years; Nigeria, 27; Turkey, 26; Indonesia, 24; Philippines, 21; Brazil, 25; Costa Rica, 19; and El Salvador, 21. Think of what it means for the population of a country to double in 25 years. In order just to keep living standards at the present inadequate level, the food available for the people must be doubled. Every structure and road must be duplicated. The amount of power must be doubled. The capacity of the transport system must be doubled. The number of trained doctors, nurses, teachers, and administrators must be doubled. This would be a fantastically difficult job in the United States—a rich country with a fine agricultural system, immense industries, and access to abundant resources. Think of what it means to a country with none of these.

Remember also that in virtually all UDCs, people have gotten the word about the better life it is possible to have. They have seen colored pictures in magazines of the miracles of Western technology. They have seen automobiles and airplanes. They have seen American and European movies. Many have seen refrigerators, tractors, and even TV sets. Almost all have heard transistor radios. They *know* that a better life is possible. They have what we like to call "rising expectations." If twice as many people are to be happy, the miracle of doubling what they now have will not be enough. It will only maintain today's standard of living. There will have to be a tripling or better. Needless to say, they are not going to be happy.

Doubling times for the populations of the ODCs tend to be in the 50-to-200-year range. Examples of 1970 doubling times are the United States, 70 years; Austria, 175; Denmark, 88; Norway, 78; United Kingdom, 140; Poland, 78; Russia, 70; Italy, 88; Spain, 70; and Japan, 63. These are industrialized countries that have undergone the so-called demographic transition—a transition from high to low growth rates. As industrialization progressed, children became less important to parents as extra hands to work on the farm and as support in old age. At the same time they became a financial drag—expensive to raise and educate. Presumably these were the reasons for a slowing of population growth after industrialization. They boil down to a simple fact—people just wanted to have fewer children.

It is important to emphasize, however, that the demographic transition does not result in zero population growth, but in a growth rate which in many of the most important ODCs results in populations doubling every seventy years or so. This means, for instance, that even if most UDCs were to undergo a demographic transition (of which there is no sign) the world would still be faced by catastrophic population growth. *No growth rate can be sustained in the long run.*

Saying that the ODCs have undergone a demographic transition thus does not mean that they have no population problems. First of all, most of them are already overpopulated. They are overpopulated by the simple criterion that they are not able to produce enough food to feed their populations. It is true that they have the money to buy food, but when food is no longer available for sale they will find the money rather indigestible. Similarly, ODCs are overpopulated because they do not themselves have the resources to support their affluent societies; they must coopt much more than their fair share of the world's wealth of minerals and energy. And they are overpopulated because they have exceeded the capacity of their environments to dispose of their wastes. Remember, overpopulation does not normally mean too many people for the area of a country, but too many people in relation to the necessities and amenities of life. *Overpopulation occurs when numbers threaten values.*

ODCs also share with the UDCs serious problems of population distribution. Their urban centers are getting more and more crowded relative to the countryside. This problem is not as severe in ODCs as it is in the UDCs (if current trends should continue, which they cannot, Calcutta would have 66 million inhabitants in the year 2000), but they are very serious and speedily worsening. In the United States, one of the more rapidly growing ODCs, we hear constantly of the headaches related to growing cities: not just garbage in our environment, but overcrowded highways, burgeoning slums, deteriorating school systems, rising tax and crime rates, riots, and other social disorders. Indeed, social and environmental problems not only increase with growing population and urbanization, they tend to increase at an even faster rate. Adding more people to an area increases the damage done by each individual. Doubling the population normally much more than doubles environmental deterioration.[7]

Demographically, the whole problem is quite simple. A population will continue to grow as long as the birth rate exceeds the death rate—if immigration and emigration are not occurring. It is, of course, the balance between birth rate and death rate that is critical. The birth rate is the number of births per thousand people per year in the population. The death rate is the number of deaths per thousand people per year.[8] Subtracting the death rate from the birth rate, ignoring migration, gives the rate of increase. If the birth rate is 30 per thousand per year, and the death rate is 10 per thousand per year, then the rate of increase is 20 per thousand per year ($30 - 10 = 20$). Expressed as a percent (rate per hundred people), the rate of 20 per thousand becomes 2%. If the rate of increase is 2%, then the doubling time will be 35 years. Note that if you simply added 20 people per thousand per year to the population, it would take 50 years to add a second thousand people ($20 \times 50 = 1{,}000$). But the doubling time is actually much less because populations grow at compound interest rates. Just as interest dollars themselves earn interest, so people added to population produce more people. It's growing at compound interest that makes populations double so much more rapidly than seems possible. Look at the relationship between the annual percent increase (interest rate) and the doubling time of the population (time for your money to double):

Annual percent increase	*Doubling time*
1.0	70
2.0	35
3.0	24
4.0	17

Those are all the calculations—I promise. If you are interested in more details on how demographic figuring is done, you may enjoy reading Thompson and Lewis's excellent book, *Population Problems,*[9] or my book, *Population, Resources, Environment.*[10]

There are some professional optimists around who like to greet every sign of dropping birth rates with wild pronouncements about the end of the population explosion. They are a little like a person who, after a low temperature of five below zero on December 21, interprets a low of only three below zero on December 22 as a cheery sign of approaching spring. First of all, birth rates, along with all demographic statistics, show short-term fluctuations caused by many factors. For instance, the birth rate depends rather heavily on the number of women at reproductive age. In the United States the low birth rates of the late 1960's are being replaced by higher rates as more post World War II "baby boom" children move into their reproductive years. In Japan, 1966, the Year of the Fire Horse, was a year of very low birth rates. There is widespread belief that girls born in the Year of the Fire Horse make poor wives, and Japanese couples try to avoid giving birth in that year because they are afraid of having daughters.

But, I repeat, it is the relationship between birth rate and death rate that is most critical. Indonesia, Laos, and Haiti all had birth rates around 46 per thousand in 1966. Costa Rica's birth rate was 41 per thousand. Good for Costa Rica? Unfortunately, not very. Costa Rica's death rate was less than nine per thousand, while the other countries all had death rates above 20 per thousand. The population of Costa Rica in 1966 was doubling every 17 years, while the doubling times of Indonesia, Laos, and Haiti were all above 30 years. Ah, but, you say, it was good for Costa Rica—fewer people per thousand were dying each year. Fine for a few years perhaps, but what then? Some 50% of the people in Costa Rica are under 15 years old. As they get older, they will need more and more food in a world with less and less. In 1983 they will have twice as many mouths to feed as they had in 1966, if the 1966 trend continues. Where will the food come from? Today the death rate in Costa Rica is low in part because they have a large number of physicians in proportion to their population. How do you suppose those physicians will keep the death rate down when there's not enough food to keep people alive?

One of the most ominous facts of the current situation is that over 40% of the population of the underveloped world is made up of people *under 15 years old.* As that mass of young people moves into its reproductive years during the next decade, we're going to see the greatest baby boom of all time. Those youngsters are the reason for all the ominous predictions for the year 2000. They are the gunpowder for the population explosion.

How did we get into this bind? It all happened a long time ago, and the story involves the process of natural selection, the development of culture, and man's swollen head. The essence of success in evolution is reproduction. Indeed, natural selection is simply defined as differential reproduction of genetic types. That is, if people with blue eyes have more children on the average than those with brown eyes, natural selection is occurring. More genes for blue eyes will be passed on to the next generation than will genes for brown eyes. Should this continue, the population will have progressively larger and larger proportions of blue-eyed people. This differential reproduction of genetic types is the driving force of evolution; it has been driving evolution for billions of years. Whatever types produced more offspring became the common types. Virtually all populations contain very many different genetic types (for reasons that need not concern us), and some are always outreproducing others. As I said, reproduction is the key to winning the evolutionary game. Any structure, physiological process, or pattern of behavior that leads to greater reproductive success will tend to be perpetuated. The entire process by which man developed involves thousands of millennia of our ancestors being

more successful breeders than their relatives. Facet number one of our bind—the urge to reproduce has been fixed in us by billions of years of evolution.

Of course through all those years of evolution, our ancestors were fighting a continual battle to keep the birth rate ahead of the death rate. That they were successful is attested to by our very existence, for, if the death rate had overtaken the birth rate for any substantial period of time, the evolutionary line leading to man would have gone extinct. Among our apelike ancestors, a few million years ago, it was very difficult for a mother to rear her children successfully. Most of the offspring died before they reached reproductive age. The death rate was near the birth rate. Then another factor entered the picture—cultural evolution was added to biological evolution.

Culture can be loosely defined as the body of nongenetic information which people pass from generation to generation. It is the accumulated knowledge that, in the old days, was passed on entirely by word of mouth, painting, and demonstration. Several thousand years ago the written word was added to the means of cultural transmission. Today culture is passed on in these ways, and also through television, computer tapes, motion pictures, records, blueprints, and other media. Culture is all the information man possesses except for that which is stored in the chemical language of his genes.

The large size of the human brain evolved in response to the development of cultural information. A big brain is an advantage when dealing with such information. Big-brained individuals were able to deal more successfully with the culture of their group. They were thus more successful reproductively than their smaller-brained relatives. They passed on their genes for big brains to their numerous offspring. They also added to the accumulating store of cultural information, increasing slightly the premium placed on brain size in the next generation. A self-reinforcing selective trend developed—a trend toward increased brain size.[11]

But there was, quite literally, a rub. Babies had bigger and bigger heads. There were limits to how large a woman's pelvis could conveniently become. To make a long story short, the strategy of evolution was not to make a woman bell-shaped and relatively immobile, but to accept the problem of having babies who were helpless for a long period while their brains grew after birth.[12] How could the mother defend and care for her infant during its unusually long period of helplessness? She couldn't, unless Papa hung around. The girls are still working on that problem, but an essential step was to get rid of the short, well-defined breeding season characteristic of most mammals. The year-round sexuality of the human female, the long period of infant dependence on the female, the evolution of the family group, all are at the roots of our present problem. They are essential ingredients in the vast social phenomenon that we call sex. Sex is not simply an act leading to the production of offspring. It is a varied and complex cultural phenomenon penetrating into all aspects of our lives—one involving our self-esteem, our choice of friends, cars, and leaders. It is tightly interwoven with our mythologies and history. Sex in human beings is necessary for the production of young, but it also evolved to ensure their successful rearing. Facet number two of our bind—our urge to reproduce is hopelessly entwined with most of our other urges.

Of course, in the early days the whole system did not prevent a very high mortality among the young, as well as among the older members of the group. Hunting and food-gathering is a risky business. Cavemen had to throw very impressive cave bears out of their caves before people could move in. Witch doctors and shamans had a less than perfect record at treating wounds and curing disease. Life was short, if not sweet. Man's total population size doubtless increased slowly but steadily as human populations expanded out of the African cradle of our species.

Then about 10,000 years ago a major change occurred—the agricultural revolution. People began to give up hunting food and settled down to grow it. Suddenly some of the risk was removed from life. The chances of dying of starvation diminished greatly in some human groups. Other threats associated with the nomadic life were also reduced, perhaps balanced by new threats of disease and large-scale warfare associated with the development of cities. But the overall result was a more secure existence than before, and the human population grew more rapidly. Around 1800, when the standard of living in what are today the ODCs was dramatically increasing due to industrialization, population growth really began to accelerate. The development of medical science was the straw that broke the camel's back. While lowering death rates in the ODCs was due in part to other factors, there is no question that "instant death control," exported by the ODCs, has been responsible for the drastic lowering of death rates in the UDCs. Medical science, with its efficient public health programs, has been able to depress the death rate with astonishing rapidity and at the same time drastically increase the birth rate; healthier people have more babies.

The power of exported death control can best be seen by an examination of the classic case of Ceylon's assault on malaria after World War II. Between 1933 and 1942 the death rate due directly to malaria was *reported* as almost two per thousand. This rate, however, represented only a portion of the malaria deaths, as many were reported as being due to "pyrexia."[13] Indeed, in 1934–1935 a malaria epidemic may have been directly responsible for fully half of the deaths on the island. In addition, malaria, which infected a large portion of the population, made people susceptible to many other diseases. It thus contributed to the death rate indirectly as well as directly.

The introduction of DDT in 1946 brought rapid control over the mosquitoes which carry malaria. As a result, the death rate on the island was halved in less than a decade. The death rate in Ceylon in 1945 was 22. It dropped 34% between 1946 and 1947 and moved down to ten in 1954. Since the sharp postwar drop it has continued to decline and now stands at eight. Although part of the drop is doubtless due to the killing of other insects which carry disease and to other public health measures, most of it can be accounted for by the control of malaria.

Victory over malaria, yellow fever, smallpox, cholera, and other infectious diseases has been responsible for similar plunges in death rate throughout most of the UDCs. In the decade 1940–1950 the death rate declined 46% in Puerto Rico, 43% in Formosa, and 23% in Jamaica. In a sample of 18 undeveloped areas the average decline in death rate between 1945 and 1950 was 24%.

It is, of course, socially very acceptable to reduce the death rate. Billions of years of evolution have given us all a powerful will to live. Intervening in the birth rate goes against our evolutionary values. During all those centuries of our evolutionary past, the individuals who had the most children passed on their genetic endowment in greater quantities than those who reproduced less. Their genes dominate our heredity today. All our biological urges are for more reproduction, and they are all too often reinforced by our culture. In brief, death control goes with the grain, birth control against it.

In summary, the world's population will continue to grow as long as the birth rate exceeds the death rate; it's as simple as that. When it stops growing or starts to shrink, it will mean that either the birth rate has gone down or the death rate has gone up or a combination of

the two. Basically, then, there are only two kinds of solutions to the population problem. One is a "birth rate solution," in which we find ways to lower the birth rate. The other is a "death rate solution," in which ways to raise the death rate—war, famine, pestilence—*find us.* The problem could have been avoided by *population control,* in which mankind consciously adjusted the birth rate so that a "death rate solution" did not have to occur.

Too Little Food

Why did I pick on the next nine years instead of the next 900 for finding a solution to the population crisis? One answer is that the world is rapidly running out of food. And famine, of course, could be one way to reach a death rate solution to the population problem. In fact, the battle to feed humanity is already lost, in the sense that we will not be able to prevent large-scale famines in the next decade or so. It is difficult to guess what the exact scale and consequences of the famines will be. But there *will be* famines. Let's look at the situation today.

At least half of the people of the world are now undernourished (have too little food) or malnourished (have serious imbalances in their diet). The number of deaths attributable to starvation is open to considerable debate. The reason is threefold. First, demographic statistics are often incomplete or unreliable. Second, starving people usually don't die of starvation. They often fall victim to some disease as they weaken. When good medical care is available, starvation can be a long, drawn-out process indeed. Third, and perhaps most important, starvation is undramatic. Deaths from starvation go unnoticed, even when they occur as close as Mississippi. Many Americans are under the delusion that an Asian can live happily "on a bowl of rice a day." Such a diet means slow starvation for an Asian, just as it would for

an American. A *New Republic* article[14] estimated that five million Indian children die each year of malnutrition. Dumont and Rosier in their book *The Hungry Future*[15] estimate that 10 to 20 million people will starve to death this year, mostly children. Senator George McGovern[16] has called hunger "the chief killer of man."

Through the first decade following World War II, food production per person in the UDCs kept up with population growth. Then, sometime around 1958, "the stork passed the plow."[17] Serious transfers of food began from the ODCs to the UDCs. As food got scarcer, economic laws of supply and demand began to take effect in the UDCs. Food prices began to rise. Marginal land began to be brought into production—as evidenced by reduced yields per acre. In short, all the signs of an approaching food crisis began to appear. Then in 1965–1966 came the first dramatic blow.

In 1965–1966 mankind suffered a shocking defeat in what is now popularly called the "war on hunger." In 1966, while the population of the world increased by some 70 million people, there was *no* compensatory increase in food production. According to the United Nations Food and Agriculture Organization (FAO), advances in food production made in developing nations between 1955 and 1965 were wiped out by agricultural disasters in 1965 and 1966. In 1966 each person on Earth had 2% less to eat, the reduction, of course, not being uniformly distributed. Only ten countries grew more food than they consumed: the United States, Canada, Australia, Argentina, France, New Zealand, Burma, Thailand, Rumania, and South Africa. The United States produced more than half of the surplus, with Canada and Australia contributing most of the balance. All other countries, including the giants of China, India, and Russia, imported more than they exported. In 1966 the United States shipped *one quarter* of its wheat crop, nine million tons, to India. In the process we helped change the distribution of people in the country. Thousands migrated into port cities so as to be close to the centers of wheat distribution. We also, in the opinion of some, hindered India's own agricultural development. Perhaps we gave too many Indians the impression that we have an unlimited capacity to ship them food. Unhappily, we do not.

In 1967 we were extremely fortunate in having a fine growing year almost worldwide; harvests almost reached the per capita level of 1964. This partial recovery, due largely to good weather, shifted some agriculturists (especially in the U.S. Department of Agriculture) from pessimism to limited optimism about the world food situation. Some hopeful signs, especially in the form of new wheat and rice varieties (the Green Revolution), encouraged even more optimism. But even those most concerned with the Green Revolution say it can at the very best buy us only a decade or two in which to try to stop population growth. It's too soon to evaluate its true potential. But it clearly cannot be assigned the panacea role so devoutly wished for by many.

Even with the Green Revolution well established in some areas, there was again *no* increase in world food production during 1969 according to the FAO, while the population inexorably rose by 2%. Much of the lack of increase was due to deliberately lower production in ODCs, which in 1968 had produced great grain surpluses that they were unable to sell. These were economic surpluses, food that destitute, hungry people in other countries could not buy. The possibility that such "surpluses" can exist is in itself a commentary on the moral conscience and economic system of the world.

Large segments of the populations of many UDCs (and many people in some ODCs) simply do not receive enough to eat. If the world's food were equitably distributed (which it certainly isn't today),[18] there would be enough calories—just barely—for everyone. Some optimists maintain that there is plenty of food and that food will not be a problem in the future. Usually, these people are only counting calories. Unfortunately, human beings need much more than calories to stay alive and healthy; they need protein, fats, vitamins, and minerals. Malnutrition—a lack of one or more of these essential elements in the diet—is even more widespread than a shortage of calories. The most common deficiency is in protein. Without enough high-quality protein (protein which is properly constituted to meet human nutritional requirements) in a mother's diet during pregnancy and in a child's diet during the first few years, the child may suffer permanent brain impairment and be mentally retarded. Permanent dwarfing, crippling, and blindness (as well as illness and death) can also result from various nutritional deficiencies.

So the food problem is not simply one of providing more food. The *quality* of food provided is also very important. Protein is the key to the world food problem —it is high-quality protein which is most expensive to obtain, both in economic terms and in terms of the ecological cost of getting it. The highest quality and highest concentrations of protein are found in meat, seafood, poultry, and animal products such as milk and eggs. Poor people must subsist mainly on plant foods—grains, fruits, and vegetables—thus their diets may have inadequate protein, both in amount and quality.

Some of the most depressing situations are found in Latin America. There, politicians have generally been far behind those of Asia in recognizing overpopulation as a major source of their problems. As noted earlier, doubling times in many Latin American countries are truly spectacular. And the poverty, hunger, and misery of the people are equally spectacular. The hideous conditions in the urban slums—*favelas* in Brazil, *barriadas* in Peru, *tugurios* in Colombia, *ranchos* in Venezuela—have received wide publicity in the press and popular commercial empire and to protect our access to the resources we "need" for our affluent society, the United States has supported an unhappy status quo throughout the "Third World." We have backed a series of dictators and oligarchs in numerous countries under a phoney banner of "anti-Communism." By open and covert action we have often prevented land reform and other socio-political changes which are needed before reasonable agricultural development can occur.[21] There is no question that changing this pattern of behavior will be essential to the survival of both UDCs and ODCs; the world can no longer afford to support and tolerate such inequities.

Soon food production in the UDCs will fall catastrophically behind population growth. Many of these countries now rely heavily on imports. As the crisis deepens, where will the imports come from? Not from Russia—she herself will probably need to import food. Not from Canada, Argentina, or Australia. They need money and will be busy selling to food-short countries, such as Russia, which can afford to buy. From the United States then?

They will get some, perhaps, but not anywhere near enough. Our vast agricultural surpluses are long gone. Indeed, if we were to suffer a large-scale crop failure, we would be in serious trouble. We have less than one year's supply of stored crops. Our agriculture is already highly efficient, so the prospects of massively increasing our production are dim. And the problems of food transport are vast. No knowledgeable person thinks that the United States can save the world from famine with food exports, although we might be of considerable help in temporary or local situations which may precede a general collapse.

All of this can be easily summarized. There is not enough food today. How much there will be tomorrow is open to debate. If the optimists are correct, today's level

of misery will be perpetuated for perhaps two decades into the future. If the pessimists are correct, massive famines will occur soon, possibly in the 1970s, certainly by the early 1980s. So far most of the evidence seems to be on the side of the pessimists, and we should plan on the assumption that they are correct. After all, some two billion people aren't being properly fed in 1971!

A Dying Planet

Our problems would be much simpler if we needed only to consider the balance between food and population. But in the long view the progressive deterioration of our environment may cause more death and misery than the food-population gap. And it is just this factor, environmental deterioration, that is almost universally ignored by those most concerned with closing the food gap.

It is fair to say that the environment of every organism, human and nonhuman, on the face of the Earth has been influenced by the population explosion of *Homo sapiens*. As direct or indirect results of this explosion, some organisms, such as the passenger pigeon, are now extinct. Many others, such as the larger wild animals of all continents, have been greatly reduced in numbers. Still others, such as sewer rats and house flies, enjoy much enlarged populations. But these are obvious results and probably less important than more subtle changes in the complex web of life and in delicately balanced natural chemical cycles. Ecologists—those biologists who study the relationships of plants and animals with their environments—are especially concerned about these changes. They realize how easily disrupted are ecological systems (called ecosystems), and they are afraid of both

the short- and long-range consequences for these ecosystems of many of mankind's activities.

Environmental changes connected with agriculture are often striking. For instance, in the United States we are paying a price for maintaining our high level of food production. Professor LaMonte Cole has written,[22] ". . . even our own young country is not immune to deterioration. We have lost many thousands of acres to erosion and gullying, and many thousands more to strip mining. It has been estimated that the agricultural value of Iowa farmland, which is about as good land as we have, is declining by 1% per year. In our irrigated lands of the West there is the constant danger of salinization from rising water tables, while, elsewhere, from Long Island to Southern California, we have lowered water tables so greatly that in coastal regions salt water is seeping into the aquifers. Meanwhile, an estimated two thousand irrigation dams in the United States are now useless impoundments of silt, sand, and gravel."

The history of similar deterioration in other parts of the world is clear for those who know how to read it. It stretches back to the cradles of civilization in the Middle East, where in many places deserts now occupy what were once rich and productive farmlands. In this area the process of destruction goes on today as in the past, still having ecologically incompetent use of water resources as a major feature. A good example is the building of dams on the Nile, preventing the deposit of nutrient-rich silt that used to accompany annual floods of the river. As almost anyone who remembers his high-school geography could have predicted, the result has been a continuing decrease in the productivity of soils in the Nile Delta. As Cole put it, "The new Aswan high dam is designed to bring another million acres of land under irrigation, and it may well prove to be the ultimate disaster for Egypt." The proposed damming of the Mekong could produce the same results for Vietnam and her neighbors.

The present growth of the world population commits us irrevocably to a policy of increasing annual food production for at least the next two or three generations. If this is to be successful, we must learn to do it in the most efficient, least damaging way. If we want the most food produced per acre, we must for the most part eat the plants. The reason is quite simple: the Second Law of Thermodynamics. The law says, in part, that when energy is transferred, some of it becomes unusable at each transfer. Each time energy is transferred in an ecosystem, some of it is converted into heat energy which is not usable by the organisms in the system.

Consider a simple example of what ecologists call a "food chain." A plant is eaten by an insect which is eaten by a trout which in turn is eaten by you. The plant has bound some of the energy of the sun in the chemical bonds of its molecules. The insect extracts that energy and uses some of it to make insect tissues. The trout, in turn, extracts some of the energy in the insect and uses some of it to make trout. Finally, you extract some of the energy in the trout and make it into *Homo sapiens*. In transfers of this type only 10–20% of the energy present in what was eaten at stage one turns up as usable energy at stage two. To put it another way (using the lower efficiency figure), 1,000 calories of plant makes 100 calories of insect which makes ten calories of trout which makes one calorie of person. By skipping the insect and trout links in the food chain, we could get 1,000 calories input simply by eating the plant ourselves, rather than settling for ten calories of trout. Similarly, 100 calories of grain suitable for human consumption but fed to cattle produce at most 10 to 20 calories worth of beef.

For this reason, as the world gets hungrier, we will feed lower and lower on the food chains, meat will get more and more expensive, and most of us will become

vegetarians. Meat will not disappear entirely, however. Many semi-arid areas which cannot be irrigated and farmed will support grazing. Similarly, for the foreseeable future, most of the nourishment we extract from the sea will be in the form of meat.

Plans for increasing food production, such as the Green Revolution, invariably involve large-scale efforts at environmental modification. These plans involve the "inputs" so beloved of the agricultural propagandist—especially inorganic fertilizers to enrich soils and synthetic pesticides to discourage our competitors. The new strains of wheat and rice require large amounts of fertilizer and more irrigation water than traditional ones do in order to produce their high yields. Their resistance to pests is unknown; they may also need higher inputs of pesticides for protection. Growing more food also may involve the clearing of forests from additional land and the provision of irrigation water. There seems to be little hope that we will suddenly have an upsurge in the level of responsibility or ecological sophistication of persons concerned with increasing agricultural output. I predict that the rate of soil deterioration will accelerate as the food crisis intensifies. Ecology will be ignored more and more as things get tough. It is safe to assume that our use of synthetic pesticides, already massive, will continue to increase, especially in UDCs. In spite of much publicity, the intimate relationship between pesticides on the one hand and environmental deterioration on the other is not often recognized. This relationship is well worth a close look.

One of the basic facts of population biology—that branch of biology that deals with groups of organisms—is that the simpler an ecosystem is, the more unstable it is. A complex forest, consisting of a great variety of plants and animals, will persist year in and year out (with no interference from man). The system contains many elements, and changes in different elements often cancel each other out. Suppose one kind of predator eating mice and rabbits suffers a population decline. For instance, suppose most of the foxes in the forest die of disease? The role of that predator will probably be assumed by another, perhaps weasels or owls. There is no population explosion of mice or rabbits. Such compensation may not be possible in a simpler ecosystem. Similarly, no plant-eating animal (herbivore) feeds on all kinds of plants. So the chance of one kind of herbivore, in a population explosion, completely devouring all the leaves in a mixed woodland is virtually nil.

Man, however, is a simplifier of complex ecosystems and a creator of simple ecosystems. Synthetic pesticides, for instance, are one of man's most potent tools for reducing the complexity of ecosystems. Insects which we consider to be pests are most often herbivores: corn earworms, potato beetles, boll weevils, cabbage butterflies, etc. Herbivores ordinarily have larger populations than the meat-eaters (carnivores) which feed on them. There are many more deer than there are mountain lions. Those animals with the largest populations are also those most likely to become genetically resistant to assault with pesticides. The reason is not complicated. The original large populations are just more likely to contain the relatively rare genetic varieties which are already resistant. Individuals of these varieties will survive and breed, and their offspring will be resistant.

There is a second reason why herbivores are more likely to become genetically resistant to pesticides. For millions of years the plants have been fighting them with their own pesticides. Many of the sharp flavors of spices come from chemicals that plants have evolved to poison or repel the insects which are eating them. The insects in turn, have evolved ways of protecting themselves from the poisons. So the herbivorous insects have been fighting the pesticide war for many millions of years—no wonder they're so good at it.

What happens when a complex ecosystem is treated with a synthetic pesticide? Some of the carnivorous species are exterminated, and the pests become resistant. The ecosystem is simplified by the removal of the carnivores and becomes less stable. Since carnivores can no longer help control the size of the pest population, the pesticide treatments must be escalated to more and more dangerous levels. Ads for insecticides sometimes imply that there is some absolute number of pests—that if we could just eliminate all the "public enemies" things would be dandy. In fact, pesticides often *create* pests. Careless overuse of DDT has promoted to "pest" category many species of mites, little insectlike relatives of spiders. The insects which ate the mites were killed by the DDT, and the mites were resistant to DDT. There you have it—instant pests, and more profits for the agricultural chemical industry in fighting these Frankensteins of their own creation. What's more, some of the more potent miticides the chemists have developed with which to do battle seem to be powerful carcinogens—cancer-producing substances.

When man creates simple ecosystems, he automatically creates ecological problems for himself. For instance, he often plants stands of a single grass—wheat fields and corn fields are familiar examples. These lack the complexity necessary for stability and so are subject to almost instant ruination when not guarded constantly. They are particularly vulnerable because very often the natural anti-insect chemicals have been selected out of the crop plant by plant breeders (these chemicals often don't taste good to us, either!).

Pesticides, of course, also reduce the diversity of life in the soil. Remember, soil is not just crushed rock and decaying organic matter. It contains myriads of tiny plants, animals, and microbes, which are essential to its fertility. Damage from pesticides must be added to all of the other sources of soil deterioration active today.

Of all the synthetic organic pesticides, we probably know the most about DDT. It is the oldest and most widely used chlorinated hydrocarbon insecticide. It is not found only where it has been applied. Virtually all populations of animals the world over are contaminated with it. DDT tends to accumulate in fatty tissues. Concentrations in the fat deposits of Americans average 11 parts per million (ppm), and Israelis have been found to have as much as 19.2 ppm. More significant in some ways has been the discovery of DDT residues in such unlikely places as the fat deposits of Eskimos, Antarctic penguins, and Antarctic seals. Seals from the east coast of Scotland have been found with concentrations as high as 23 ppm in their blubber. Pesticide pollution is truly a worldwide problem.

In nature DDT breaks down very slowly. It will last for decades in soils. A study of a Long Island marsh that had been sprayed for 20 years for mosquito control revealed up to 32 pounds per acre of DDT in the upper layer of mud.[23] Unhappily, the way DDT circulates in ecosystems leads to a concentration in carnivores; it is concentrated as it is passed along a food chain. While most of the food energy is lost at each transfer up the food chain, most of the DDT is retained. The danger to life and the reproductive capacity of some meat-eating birds is approaching a critical stage now, and the outlook for man if current trends continue does not seem healthy. The day may come when the obese people of the world must give up diets, since metabolizing their fat deposits will lead to DDT poisoning. But, on the bright side, it is clear that fewer and fewer people in the future will be obese! We must remember that DDT has been in use for only about a quarter of a century. It is difficult to predict the results of another 25 years of application of DDT and similar compounds, especially if those years are to be filled with frantic attempts to feed more and more

people, but the harm seems likely to outweigh the benefits more and more as time goes on.

Concern about the effects of our ecologically incompetent use of synthetic pesticides has been widespread for years, and many environmental biologists have spoken out in warning. Perhaps the most famous was Rachel Carson, whose splendid *Silent Spring* became a best seller. I would also highly recommend Robert L. Rudd's more technical *Pesticides and the Living Landscape* and Frank Graham's *Since Silent Spring*,[24] which covers more recent events. But those financially involved in the massive production and application of pesticides seem to have only one reaction. They and their hired hands among entomologists heap ridicule and abuse upon the ecologists.

Unfortunately, of course, there are some dietary extremists and the "no-pesticide-ever-for-any-reason" school which provide ammunition to the pesticide industry, but that doesn't change the facts of the case. It is probably true that the direct and immediate threat to human health in present-day use of synthetic pesticides is not extreme. It is also true that many people have led longer, healthier lives because of pesticides—as in Ceylon. The question of long-term effects on health remains open, however. They are difficult to judge until the long term has passed. Recent studies have shown a relationship between deaths due to certain liver diseases and stress diseases and higher than average concentrations of DDT in corpses.[25] Individuals born since 1945, and thus exposed to DDT since before birth, may well have shorter life expectancies than they would if DDT had never existed. We won't know until the first of these reach their forties and fifties. Since the experiment is being run on the entire world, we may never know exactly how much difference it has made.

Present-day practices can be condemned on several other counts. First of all, they are often basically uneconomical, locking the farmer and other users into expensive programs that could be avoided by using ecologically more sophisticated control methods and by reeducating the public. For instance, housewives should be taught to accept certain levels of insect damage in their produce in lieu of the small dose of poison they now get. Secondly, and by far most importantly, there are the simplifying effects on ecosystems discussed above, effects which in many cases may now be irreversible.

One could go on with pesticide horror stories galore. The scientific literature is replete with them. There are stories of dying birds, of mosquito fishes resistant to endrin (a potent insecticide) and excreting so much of the chemical that they kill nonresistant fishes kept in the same aquarium. It is a record of ecological stupidity without parallel.

One specific episode will illustrate how complex and subtle the effects may be. Professor L. B. Slobodkin[26] has described a plan to block the seaward ends of lochs in western Scotland and use them as ponds for raising fishes. One of the problems has been to find ways to raise the young fishes in the laboratory so that they can be "planted" in the ponds. It has been discovered that newly hatched brine shrimp serve as a satisfactory food for the kind of fishes that will be raised. These may be obtained from brine shrimp eggs that are gathered commercially in the United States and sold to tropical fish fanciers for use in feeding young tropical fishes. The American supplies come from two places—the San Francisco Bay Area and the Great Salt Lake Basin in Utah. Sufficient eggs for the project can no longer be obtained from the Bay Area because of the demands of the aquarists, and because large areas of suitable brine shrimp habitat are now subdivisions. Unfortunately, the Utah supply is no use to the British since brine

shrimp hatched from Utah eggs kill their young fishes. The poisonous quality of the Utah shrimp comes from insecticide residues draining from farmlands in the region. So insecticide pollution in Utah is blocking fish production in Scotland!

Finally, pesticides contribute to the serious problems of general environmental pollution. Professor Cole[27] warned, "It is true that 70% or more of the total oxygen production by photosynthesis occurs in the ocean and is largely produced by planktonic diatoms. It is also true that we are dumping into the oceans vast quantities of pollutants consisting, according to one estimate by the U. S. Food and Drug Administration, of as many as a half-million substances. Many of these are biologically active materials, such as pesticides, radioisotopes, and detergents, to which the Earth's living forms have never before had to try to adapt. No more than a minute fraction of these substances and combinations of them has been tested for toxicity to marine diatoms, or, for that matter, to the equally vital forms of life involved in the cycles of nitrogen and other essential elements. I do not think we are in a position to assert right now that we are not poisoning the marine diatoms and thus bringing disaster upon ourselves."

Since Cole wrote these words, an article in *Science* magazine[28] has described reduced photosynthesis in laboratory studies of marine diatoms exposed to DDT. We are, of course, removing many terrestrial areas from oxygen production by paving them. We are also depleting the world's supply of oxygen by burning (oxidizing) vast quantities of fossil fuels and by clearing iron-rich tropical soils in which the iron is then oxidized. When the rate of oxygen consumption exceeds the rate at which it is produced, then the oxygen content of the atmosphere will decrease. As Cole says, "If this [decrease] occurred gradually, its effect would be approximately the same as moving everyone to higher altitudes, a change that might help to alleviate the population crisis by raising death rates."

However, photosynthesis by the present plant population of the Earth produces a yearly quantity of oxygen equivalent to only a tiny fraction of the mass of oxygen already accumulated in the atmosphere. If we drastically reduce photosynthesis, oxygen depletion will occur, but probably very slowly. I suspect that other ecological catastrophes accompanying poisoning of the sea and clearing plants from the land would lead to mankind's extinction long before we have to start worrying about running out of oxygen. For example, DDT affects some kinds of planktonic plants more than others. This could lead to large changes in the plant plankton communities which are the basic source of energy for marine life. The results for our fisheries could be catastrophic. Therefore food depletion probably would be the first and most obvious effect of poisoning the tiny plants of the sea.

If you live in one of our great metropolitan areas, you know very well that pesticides are just one of many factors in the pollution of our planet. The mixture of filth that is dignified with the label "air" in places like Los Angeles, St. Louis, and New York would not have been tolerated by citizens of those cities 50 years ago. But clean air gradually changed to smog, and nobody paid much attention. Sadly, man's evolution did not provide him with a nervous system that readily detects changes that take place slowly, not in minutes, hours, or days, but over decades. It was important for early man and his nonhuman ancestors to be able to detect rather sudden changes in their environments. The caveman who did not immediately notice the appearance of a cave bear did not survive to pass on his genes for a dull-witted nervous system. Large animals charging, rocks falling, children crying, fires starting—these are the sort of short-range changes that our ancestors had to react

to. But the world of 276,824 B.C. was much like that of 276,804 B.C. There was little reason for a creature that only lived an average of perhaps 20 years to learn to deal with environmental changes that occurred over decades. We perceive sudden changes readily, slow changes with difficulty.

If the smog had appeared in Los Angeles overnight, people would have fled gibbering into the hills. But it came on gradually, and man, adaptable organism that he is, learned to live with it. We first paid serious attention to smog when it presented itself as a direct health hazard. Smog disasters years ago in Donora, Pennsylvania, and London, England, produced dead bodies and thus attracted attention. Corpses usually are required to attract the attention of those who pooh-pooh environmental threats—indeed many of my colleagues feel that only a pesticide disaster of large magnitude will produce a real measure of rational control over these substances. The 1952 London incident was blamed for 4,000 deaths, the current record. Since then a clear link between air pollution and respiratory disease has been established. For instance, doctors compared cigarette smokers from smoggy St. Louis with cigarette smokers from relatively smog-free Winnipeg, Canada. There was roughly four times as much emphysema—an extremely unpleasant disease that suffocates its victims—among the group from St. Louis. Death rates from both emphysema and lung cancer have risen spectacularly over the last decade, especially among urban populations. Pollution also may be linked with certain kinds of heart disease and tuberculosis, not as a cause but as a contributor to higher death rates. In addition to this disease threat there is also the strong suspicion that occurrence of certain cancers is associated with specific pollutants in the air. People now are generally aware of the air pollution problem, at least as far as its direct challenges to health and beauty are concerned. But, once again, the subtle and much more important ecological threats usually remain unrecognized.

One such threat, of course, comes from the killing of plants, many of which have little resistance to smog. Remember, every plant that goes is one less contributor to our food and oxygen supplies. But even more important is the potential for changing the climate of the Earth. All of the junk we dump into the atmosphere, all of the dust, all of the carbon dioxide, have effects on the temperature balance of the Earth. Air pollution affects how much of the sun's heat reaches the surface of the Earth and how much is radiated back into space. And it is just this temperature balance that causes the changes in the atmosphere that we call "the weather."

Concern about this problem has been greatly increased by the prospect of supersonic transports. Most people have been opposing this project on the basis that the "sonic booms" generated will drive half the people in the country out of their skulls while benefiting almost no one. But ecologists, as usual, have been looking at the less obvious. Supersonic transports will leave contrails high in the stratosphere, where they will break up very slowly. A lid of ice crystals gradually will be deposited high in the atmosphere, which might add to the "greenhouse effect" (prevention of the heat of the Earth from radiating back into space). On the other hand, they may produce a greater cooling than heating effect because of the sun's rays which they reflect back into space. One way or another, you can bet their effect will not be "neutral." The greenhouse effect is being enhanced now by the greatly increased level of carbon dioxide in the atmosphere. In the last one hundred years our burning of fossil fuels raised the level some 15%. The greenhouse effect today is being countered by low-level clouds generated by contrails, dust, and other contaminants that tend to keep the energy of the sun from warming

At the moment we cannot predict what the overall climatic results will be of our using the atmosphere as a garbage dump. We do know that very small changes in either direction in the average temperature of the Earth could be very serious. With a few degrees of cooling, a new ice age might be upon us, with rapid and drastic effects on the agricultural productivity of the temperate regions. With a few degrees of heating, the Greenland and Antarctic ice caps would melt, perhaps raising ocean levels 250 feet. Gondola to the Empire State Building, anyone?

In short, when we pollute, we tamper with the energy balance of the Earth. The results in terms of global climate and in terms of local weather could be catastrophic. Do we want to keep it up and find out what will happen? What do we gain by playing "environmental roulette"?

My first job after I got my doctorate was working as a research associate with Dr. Joseph H. Camin, then of the Chicago Academy of Sciences. That was in 1957–1958. Ten years later, Joe Camin spent a sabbatical leave with me at Stanford. We reminisced over some extremely pleasant times we had had working together on a field problem, studying natural selection in water snakes which lived on islands in the western end of Lake Erie. The problem was fascinating, and we would be very much interested in continuing the research today. But all we can do is reminisce. You see, Lake Erie has died. The lake can no longer support organisms which require clean, oxygen-rich water. Much of this shallow body of water is a stinking mess—more reminiscent of a septic tank than the beautiful lake it once was. The snakes are almost gone, as are the fishes on which they fed. In 1955 the lake supported commercial fishing for high-quality fish. In that year 75 million pounds of fish were taken. No one in his right mind would eat a Lake Erie fish today.

Lake Erie is just one example of a general problem of pollution of lakes, rivers, and streams in the United States and around the world. Lake Michigan will soon follow it in extinction. A recent *New York Times* article described the reduced chances of Russian conservationists to save Lake Baikal and its unique plant and animal life from a fate similar to that of Lake Erie. Many of the world's rivers are quickly approaching the "too thin to plow and too thick to drink" stage—and carrying to the sea those dangerous compounds discussed above.

Finally, let me mention a pollution problem not limited to air or water. We are constantly adding lead to our environment from ethyl gasoline and pesticides, and it is present also in many common substances such as paints and food-can solder. Some scientists are very much concerned with the quantities of lead found in the bodies of Americans. In some instances these are approaching the levels necessary to produce symptoms of chronic lead poisoning—weakness, apathy, lowered fertility, miscarriage, etc. It is a sobering thought that overexposure to lead was a factor in the decline of the Roman Empire. As Dr. S. C. Gilfillian[29] has pointed out, the Romans lined their bronze cooking, eating, and wine storage vessels with lead. They thus avoided the obvious and unpleasant taste and symptoms of copper poisoning. They traded them for the pleasant flavor and more subtle poisoning associated with lead. Lead was also common in Roman life in the form of paints, and lead pipes often were used to carry water. Examination of the bones of upper-class Romans of the classical period shows high concentrations of lead—possibly one cause of the famous decadence of Roman leadership. The lower classes lived more simply, drank less wine from lead-lined containers, and thus may have picked up far less lead. This little horror study should make us all more leery of the "corpses before we recognize the problem" school of thought. Chronic low-level effects can be

critical, too. Recently there have been some moves to reduce the lead intake of Americans by reducing the amount of leaded gasoline used. A virtually complete ban on such gasoline is badly needed.

Other heavy metals are turning up as environmental hazards, notably mercury and cadmium. Both metals are very poisonous and both enter the environment as industrial wastes. The major source of mercury pollution is the process for producing chlorine (large amounts of which are used in the manufacture of plastics). Seed grain is often treated with mercury fungicides, which resulted in the poisoning of an entire family in New Mexico in 1969. Similar accidents have been reported in several countries. Other sources of mercury pollution are pulp mills, hospitals, and laboratories.

Mercury occurs in both inorganic and organic forms, the latter being somewhat more toxic, resulting in brain damage. Exactly how much mercury will produce overt symptoms of poisoning has not been determined. Moreover, as with lead, low-level chronic doses may well have detrimental effects. High concentrations of mercury have been found in numerous kinds of fish and wildlife in and around North American rivers and lakes and in other ODCs where tests have been made. In these heavily polluted waterways, large quantities of mercury have accumulated, which are gradually being converted by microorganisms to the dangerous organic form, methyl mercury. Methyl mercury easily enters food chains. Even if no more mercury is discharged into these waters, enough is stored on the bottom in some areas to keep adding methyl mercury to local food chains for centuries. Mercury is, of course, poisonous to other organisms as well as human beings. It has been found to reduce photosynthesis in planktonic plants,[30] as does DDT. Recently, concentrations well above FDA acceptable levels have been found in tuna fish and swordfish sold for food in the U.S. Both fish come from the open sea; it appears that mercury is another worldwide pollution problem. How serious it is we are only beginning to discover.

Obviously, the use of mercury in industrial processes and in seed preservatives should be stopped wherever possible. In situations where it can't be replaced by something else, it should not be allowed to escape into the environment. If it becomes feasible, every effort should be made to remove or inactivate the accumulated mercury from freshwater systems.

Deterioration of our environment clearly holds threats for our physical well-being, present and future. What about our mental health? Does the deterioration threaten it, too? Are we living in a deteriorating "psychic environment"? Riots, rising crime rates, disaffection of youth, and increased drug usage seem to indicate that we are. Unfortunately, we can't even be sure how much of the reaction of an individual to the deterioration of his environment is hereditarily conditioned, or how much is a product of his culture. At least three biologists, H. H. Iltis, P. Andrews, and O. L. Loucks[81] feel that nature as well as nurture may be very important, that mankind's genetic endowment has been shaped by evolution to require "natural" surroundings for optimum mental health. These biologists write:

"Unique as we may think we are, we are nevertheless as likely to be genetically programed to a natural habitat of clean air and a varied green landscape as any other mammal. To be relaxed and feel healthy usually means simply allowing our bodies to react in the way for which one hundred millions of years of evolution has equipped us. Physically and genetically, we appear best adapted to a tropical savanna, but as a cultural animal we utilize learned adaptations to cities and towns. For thousands of years we have tried in our houses to imitate not only the climate, but the setting of our evolutionary past: warm, humid air, green plants, and even animal companions. Today, if we can afford it, we may even build a greenhouse or swimming pool next to our living room, buy a place in the country, or at least take our children vacationing on the seashore. The specific physiological reactions to natural beauty and diversity, to the shapes and colors of nature (especially to green), to the motions and sounds of other animals, such as birds, we as yet do not comprehend. But it is evident that nature in our daily life should be thought of as a part of the biological need. It cannot be neglected in the discussions of resource policy for man."

You will note that my discussion of man's environment has not dwelt on the themes that characterize the pleas of conservationists. I haven't discussed the rumor that a giant vinyl redwood tree will be constructed and trucked around the State of California for all to see (permitting all the other "useless" redwoods to be mowed down by our progressive lumbering industry). I've shed no tears here for the passenger pigeons, now extinct, or the California condors, soon to join them. No tears for them, or for the great auk, or the mammoths, or the great herds of bison, or the California grizzly bears, or the Carolina parakeet. I haven't written about them, or of the pleasantness, beauty, indeed glory of many natural areas. Instead I have concentrated on things that seem to bear most directly on man. The reason is simple. In spite of all the efforts of conservationists, all the propaganda, all the eloquent writing, all the beautiful pictures, the conservation battle is presently being lost. In my years of interest in this question I've come to the conclusion that it is being lost for two powerful reasons. The first, of course, is that nothing "undeveloped" can long stand in the face of the population explosion. The second is that most Americans clearly don't give a damn. They've never heard of the California condor and would shed no tears if it became extinct. On the contrary, many Americans would compete for the privilege of shooting the last one. Our population consists of two groups; a comparatively small one dedicated to the preservation of beauty and wildlife, and a vastly larger one dedicated to the destruction of both (or at least apathetic toward them). I am assuming that the first group is with me and that the second cannot be moved to action by an appeal to beauty, or a plea for mercy for what may well be our only living companions in a vast universe.

I have just scratched the surface of the problem of environmental deterioration, but I hope that I have at least convinced you that subtle ecological effects may be much more important than obvious "pollution." The causal chain of the deterioration is easily followed to its source. Too many cars, too many factories, too much detergent, too much pesticide, multiplying contrails, inadequate sewage treatment plants, too little water, too much carbon dioxide—all can be traced easily to too many people.

Of course, a smaller population could eventually destroy the ability of the planet to support sizable numbers of human beings. This could occur through the profligate use of weapons as diverse as chlorinated hydrocarbon insecticides or thermonuclear bombs. But with a human population of, say, one-half billion people, some minor changes in technology and some major changes in the rate of use and equity of distribution of the world's resources, there would clearly be no environmental crisis. Equally, regardless of changes in technology or resource consumption and distribution, current rates of population growth guarantee an environmental crisis which will persist until the final collapse.[32]

Chapter 2

THE ENDS OF THE ROAD

Too many people—that is why we are on the verge of the "death rate solution." Let's look briefly at what form that solution might take. The agencies most likely to result in a drastic rise in the death rate in the next few decades are exactly those most actively operating in pre-explosion human populations. They are three of the four apocalyptic horsemen—war, pestilence, and famine. Rapid improvement in public health, advances in agriculture, and improved transport systems have temporarily reduced the efficacy of pestilence and famine as population regulators. Improved technology has, on the other hand, greatly increased the potential of war as a population control device. Indeed, it has given us the means for self-extermination.

It now seems inevitable that death through starvation will be at least one factor in the coming increase in the death rate. If we succeed in avoiding plague or war, it may be the major factor. It is all too easy, however, for a layman to discount the potential for population control possessed today by plague. It is true that medical science has made tremendous advances against communicable diseases, but that does not mean that these diseases may now be ignored. As population density increases, so does the per capita shortage of medical personnel, so do problems of sanitation, and so do populations of disease-harboring organisms such as rats. In addition, malnutrition makes people weaker and more susceptible to infection. With these changes and with people living cheek by jowl, some of mankind's old enemies, like bubonic plague and cholera, may once again be on the move. As hunger and poverty increase, the resources that nations put into the control of vectors (disease-spreading organisms) may be reduced. Malaria, yellow fever, typhus, and their friends are still around—indeed, malaria is still a major killer and disabler of man. These ancient enemies of *Homo sapiens* are just waiting for the resurgence of mosquitoes, lice, and other vectors, to ride high again.

Viruses present an additional possibility. For reasons that are not entirely understood, virus diseases vary in their seriousness. For instance, viruses may become more potent as they circulate in large populations. It is not inconceivable that we will, one of these days, have a visitation from a "super flu," perhaps much more virulent than the famous killer of 1918–1920. That global epidemic killed some 25 million people. A proportionate mortality in the double 1918 population of the near future would be 50 million people, although modern antibiotics might prevent secondary bacterial infections which presumably killed many in 1918–1920. But what if a much more lethal strain should get going in the starving, more crowded population of a few years from now? This could happen naturally or through the escape of a special strain created for biological warfare. Modern transport systems would guarantee its rapid invasion of the far corners of the globe. It would be impossible for vaccines to be produced and distributed in time to affect the course of the epidemic in most areas. A great strain would be placed on facilities for production and distribution of antibiotics. Incapacitation of people in vital transport and agricultural occupations would add to the horror by worsening famine in many areas. A net result of 1.2 billion deaths—one out of every three people—is not inconceivable. By comparison, during World War II only about one out of 200 human beings then alive died in battle.

We came close to disaster in 1967. A virus disease, never seen before in human beings, transferred from a colony of vervet monkeys to research workers in laboratories in Marburg, Germany, and in Yugoslavia. Of the 32 people who contracted it, seven died, in spite of excellent medical care and the fact that they were all healthy adults. Two weeks before the disease, named Marburgvirus, broke out in the laboratories, the monkeys had been in London Airport. If the disease had appeared then, it could have spread throughout the world literally within hours.

Thermonuclear war could also provide a death rate solution to our problems, if it did not end them altogether by rendering *Homo sapiens* extinct. Politicians and war-games specialists like to postulate recovery programs following such a war, based on different numbers of survivors. However, several very critical factors are omitted from their calculations. Among these is the impact upon the environment of a nuclear exchange. These planners seem to think that survivors would emerge from their shelters, rebuild the cities, and go on as if nothing had happened. But it wouldn't be that simple. Even "clean" nuclear war over the North American continent would burn off vast areas of vegetation in huge fire-storms. This would doubtless produce violent weather changes and unprotected topsoil would be washed into the sea. The silt would have adverse effects on fisheries around our shores, as would oil and other materials flowing into the sea from our ruined civilization. Thus both farmland and fisheries would be damaged at a stroke.

Postwar planners also do not consider the psychological aftermath of such a holocaust. The virtually demolished "post-attack" world would be demoralizing, to say the least. If the physical paraphernalia of industry were destroyed and not quickly restored, industrial civilization would probably permanently disappear, even if large numbers of people survived. The resources are no longer available to start the industrial revolution over again. High-grade iron, copper, and other ores are no longer easily accessible; nor does oil bubble to the surface. Industrial technology itself is essential in order to keep industry going.

Obviously, we cannot discuss all of the possible courses of events as the world crisis deepens. It seems inevitable that world political tensions will increase as the disparity between "haves" and "have-nots" increases and as the penalties of being in a "have-not" nation become more and more severe. The chances of war increase with each addition to the population, intensifying competition for dwindling resources and food. Political events will have powerful influences on exactly how the death rate increases. They will affect how much food is grown and how it is distributed. They will affect the possibilities of plague. They will affect birth rates, especially in ODCs. They will affect the chances of effective international action. The possibilities are infinite; the single course of events that will be realized is unguessable. We can, however, look at a few possibilities, using a device known as a "scenario." Scenarios are hypothetical sequences of events used as an aid in thinking about the future, especially in identifying possible decision points. I'd like to offer three scenarios, giving three possible projections of what the next fifteen years or so could be like. One is in the form of a short story, one a sequence of hypothetical news items, and one a condensed history written in the future.

Remember, these are just possibilities, not predictions. We can be sure that none of them will come true exactly as stated, but they describe the kinds of events that might occur in the next few decades.