Food-People Balance: Proceedings of the Symposium Sponsored by the National Academy of Engineering at the Sixth Annual Meeting (1970)

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THE FOOD-PEOPLE BALANCE

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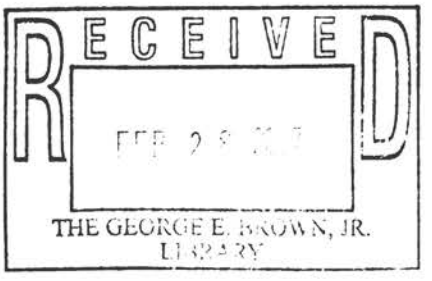
Sixth Annual Meeting



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FOREWORD

Richard D. DeLauer

Technology can be a key to solving the problems of our crowded, hungry world. The engineer has risen to this challenge but his effectiveness has been seriously limited by more fundamental, complex problems. These are the social, political, and economic conditions that exist in the world today.

Three panels of experts met under the auspices of the National Academy of Engineering on April 27 and 28, 1970 to review the barriers to fuller application of existing technology in balancing world population and nutritional resources. These barriers will never be eliminated until they are adequately understood. This must be done before action can be taken on a global scale to forestall a possible worldwide population and food crisis.

On April 29, 1970, the panelists presented their findings at a symposium held in connection with the Sixth Annual Meeting of the National Academy of Engineering.

It is anticipated that these proceedings will give impetus to the mobilization of needed resources from the engineering, corporate, and academic worlds.

The format of the symposium was something of an experiment, at least to those of us who are used to attending the typical meeting and listening to a series of prepared technical papers. It was the thought of our program committee that it might be worthwhile to design a different type of meeting format in order to present various aspects of this important problem to the members of our Academy and to our invited guests. Our intention was essentially to become educated--to learn more about the barriers and constraints that are preventing us in the engineering community from applying our existing technological talents and capabilities (much less our future capabilities) to the solution of the pressing problems of rapidly increasing world population and potentially serious shortages of world nutritional resources.

The approach taken was to convene three panels of distinguished authorities in the three fields of interest: world population, world nutritional resources, and the interactions between world population and world nutritional resources. These panels met for two days in Columbia, Maryland, and then convened to present the results of their discussions and deliberations. We did not expect to hear all of the solutions to the problems of world population and nutrition; rather we hoped to learn more about how we in the engineering profession could start to bring our talents to bear more effectively on these grave problems.

There may be some disagreements as to just how imminent and how critical are the problems of world population and nutritional resources; it is not our purpose here to argue that point or to place dimensions on the specifics of the problem. Whether you view the world situation with alarm or complacency, I think you will agree that the world must strive for the achievement of an acceptable balance between the number of people who populate our earth and the supplies of nutritional resources that can be made available to sustain that population.

As senior members of the engineering profession, and as influential policy-makers in government, industry, and academic circles, we must wake up to our responsibility, on a global scale, to ensure that we are contributing the most we can to these very pressing problems that face us today. We must obtain a better understanding of all the dimensions of these problems--not from a narrowly technological point of view, but from a broadly humanitarian standpoint--and we must recognize that today's planning will very likely determine the quality of life that our grandchildren will experience.

We must understand the total system involved in the food-people balance--ecological, sociological, biological, etc. --as well as technological. We want to grab the ball and run with it; but with the engineer's thoroughness and appreciation for order, we first want to understand the constraints and barriers to our most effective involvement.

As a result of what we learn from these proceedings, we should, as a first step, undertake a critical examination and analysis of the findings and recommendations that are presented by the distinguished panels of experts. To this end, I recommend that the National Academy of Engineering undertake a strong follow-up effort in this area.

ASPECTS OF THE FOOD-PEOPLE BALANCE

Roger Revelle

The world is passing through an incredible transition, as we all know, and this is finding expression in many different ways. One of the most startling and worrisome transitions is the increase in the human population, which has been growing more and more rapidly for the last 350 years, until finally at the present time the world population is increasing at a rate of about 2 percent a year. This is not very much when we think of a bank account, particularly with interest rates of 8 percent, but it is still an unprecedentedly rapid increase that can be most easily understood if we say that the doubling time of the earth's population at the present is about 35 years. That is, we could expect that at the present rate of growth of about 2 percent the world population would be around 7 billion people shortly after the beginning of the twenty-first century.

Contrast this with the situation that existed throughout about 99.9 percent of the lifetime of our species on the earth, when the doubling times were of the order of thousands to tens of thousands of years. A doubling time of 35 years is clearly a remarkable phenomenon, and it is probably true that it cannot persist. Particularly what cannot persist is the ever-increasing rate of increase in the population group.

The second remarkable thing about our time, as we all know, is that there is a gap between peoples that is far greater than any that has ever existed in the history of mankind. We have some 1 billion people who are prosperous and well fed. They have many problems of their own, but getting enough to eat is not one of them. We have a second group of about 2.5 billion people, who are usually called the people of the less developed or the underdeveloped countries, in which food supplies are a major problem. Many of these people do not get enough to eat, and nearly all of them have a worry about whether they will wake up tomorrow or a year from tomorrow or ten years from tomorrow and be able to survive.

So this question of food, which has bothered mankind throughout history, and particularly food in the future, is now one of immense size. (Throughout history some people have been hungry all of the time, and most people have been hungry at least some of the time.)

To give you some statistics, in 1970, the world's population is about 3.5 billion people. By 1985, it will be about 5 billion. By the year 2000 or thereabouts, it will be nearly 7 billion. Of that total number, at the present time about 2.5 billion live in the less developed countries. About 3.7 billion will be inhabitants of those countries 15 years from now, and about 5.4 billion will be living in those countries 30 years from now.

The total world food production at the present time is about 1.5 billion tons. Of this total amount, more than half is eaten by the 1 billion people in the developed countries: about 800 million tons. About 700 million tons, less than half, is used by the far larger proportion of the world's population who live in the less developed countries. Now, why is this? Why should a smaller number of people consume so much more food?

There are two reasons. One is that the people are bigger. Their physical size is much larger on the average, not only because the individual adult man or woman weighs 30 or 40 kilograms more than the individual adult man or woman in the less developed countries, but because the proportion of children is very much smaller in the developed countries than in the less developed countries, and children require only about two-thirds as much food as adults.

The second reason is because of the nature of the diets. In the developed countries, about a third of the diet is in the form of animal products; that is, a third of the total number of calories is in the form of animal products while about two-thirds is in the form of plant products. Every pound or kilogram of animal products requires about 7 or 8 pounds of plant products in order to be produced. That is, a cow or a chicken or a hog or a sheep eats about seven times as much as it produces in terms of milk or meat or butter or eggs and other animal products. Because of the very much larger fraction of these animal products in the diets of the developed countries, the total food required is very much larger than it would be if we simply thought of it in terms of the number of calories per person. By the developed countries, of course, we are talking about the Soviet Union; the countries of western and eastern Europe; the countries of northern America; the United States

and Canada; and Japan; and more or less of the countries in the temperate zone of South America: Argentina, Chile, and Uruguay; and of course also Australia and New Zealand. The less developed countries are the countries of Asia, except for Japan and parts of the Soviet Union that are in Asia, all of the countries of Africa and most of the countries of South and Central America, including the countries of the Caribbean.

The people of these countries probably obtain as food supplies at the present time about 2,600 calories per day, not at the household level, but at the level of production, and probably around 2,200 or 2,300 at the household level. Most of this, 90 to 95 percent of it, is in the form of vegetable products, and a very small percent is in the form of animal products. The result is that their total consumption, as I said, is actually less than the consumption in the developed countries.

Now, if we extrapolate purely on the basis of population growth, we find that since the less developed countries will go from about 2.5 billion to 3.7 billion people during the next 15 years, which is about a 50 percent increase in population, their food, if they continue to eat the same diet, should also increase by about 50 percent, and then another 50 percent during the next 15 years, or somewhat more. It would be 50 percent of the 1985 food supply that would be required by the year 2000 just on the basis of population growth.

However, there are at least four reasons why in fact the food supply should be increased more rapidly than this. The first is that if people obtain a better diet, they will grow bigger. The children will grow faster and become larger. Therefore they will need more food.

The second reason is that if fertility control measures are at all successful, the proportion of children in the populations of the less developed countries will diminish. Therefore the proportion of adults correspondingly will increase, and adults require more food than children.

The third reason is that although the average food supplies in the less developed countries now are adequate for the population on the average, that very statement means that the diet is inadequate for a large fraction of the people--people who are below average in income and below average in availability to them of supplies of food.

The fourth reason is one that the economists usually use, quite apart from these physiological reasons that I have just been stating. As incomes increase in the less developed countries, particularly as per capita incomes increase, the demand for food will go up at a rate that is about 70 percent of the rate of increase of income. This is what the economists call the income elasticity for food, which is about 70 percent with the very low incomes that are characteristic of these countries. That is not true in the developed countries. Our income elasticity for food is only about 20 percent. That is, if the average person in the United States has an income increase of about $100 a year, he won't spend more than $20 of that $100 for food, and he won't spend any of it for more calories. He will spend it for fancier packaging, a more varied diet, perhaps more restaurant meals, and that sort of thing. In the less developed countries, most of the incomes go for food at the present time, and that could be expected to continue for some time in the future.

As a result, we can expect that about a 4.5 percent annual increase in food demand in the less developed countries will occur, which would mean that by the year 1985, 15 years from now, food supplies should be just about double what they are now, and by the year 2000, they should double again, or perhaps not quite double by the year 2000. In the less developed countries, about 670 million tons are now available. By the year 1985, this should be about 1.3 billion tons, and by the year 2000 around 2.5 billion tons, just for the less developed countries.

For the world as a whole, about 1.5 billion tons are produced at the present time. It would be about 2.4 billion by the year 1985, and about 4 billion by the year 2000. Particularly for an engineering audience, we might compare this tonnage of food with some other tonnages. At the present time, about half as much tonnage of food is consumed in the world as of fuels: petroleum, natural gas, and coal. The energy content of the petroleum, natural gas, and coal per ton, however, is about three times that of the food, so that the total primary energy available to people in the form of fuel is some six to eight times that available in their food.

Of course, in the United States, the position is very much more extreme than this. We consume about 1.5 billion tons of fossil fuels in the United States, as opposed to about 150 million tons of food, so it is about a factor of 10 greater in the United States.

The second major food problem is the problem of protein. So far I have been dealing with total tonnage, which can be translated into total calories. One simple number to remember is that 3,500 calories of food are equal to 1 kilogram, or about 3.5 billion calories per ton. Another simple rule is if people eat 2,300 calories per person, this means about 230 kilograms per person per year, or in our case about 8,000 calories and this means about 800 kilograms per person per year.

Now, coming to protein, the protein problem is very tricky. It is by no means clear that there is a protein problem in the world as a whole. If it does exist, it exists for certain groups within the world's population, first for those some hundred million people whose primary calories come from root crops like kasava, yams, and potatoes. In general these people tend to suffer from protein deficiency, and the word for the syndrome, the group of symptoms that indicate overt and severe protein deficiency, is in fact an African word. It is a word developed in those countries that do have as their primary source of calories root crops. The word is "kwashiorkor," which means the sickness of the displaced or the weaned child, the child taken from his mother's breast.

A second group of people who probably do suffer from protein deficiency are pregnant and lactating or nursing women and children just after they have been weaned, the reason being very largely the lack of nutrition knowledge in the poor countries, but also the lack of sufficient protein for the children. It is quite possible to live on a vegetable diet if you eat enough, but children are unable to take in the typical adult foods of those countries in sufficient quantities to obtain enough protein.

In general, however, again on the average, the world's population in all countries does obtain enough protein. This is protein of what the nutritionists call rather low quality. That is, the balance of amino acids in this protein tends to be different from the balance of amino acids in, let us say, egg albumin or milk. The result is that much more total protein intake is required than would be required if the protein were in forms that have the right balance of amino acids. This is an important fact when we think about what we can do about the protein problem.

We should perhaps change the subject and talk not about demand, but about supply. What are the chances for producing future food supplies that will be sufficient to meet the needs of the world's population, and particularly the populations of the less developed countries?

We might say that there is really no problem in the next 30 years of meeting food demands in the developed countries--in the rich countries--except in this sense: our demands are increasing as our diets improve. This is particularly true of Japan and of Eastern Europe and the Soviet Union and, to a lesser extent, of Western Europe. Because our demands are increasing, the availability of surplus food in the rich countries that might be used to feed the poor countries is becoming less and less with the passage of time. So, basically, the poor countries need somehow to produce enough food to feed their own peoples.

This does not mean that each country needs to be self-sufficient in food. It simply means that, overall, the poor countries need somehow to find the means to produce food to meet the future demands of their people, one reason for this being that at least for the time being they have very little to export to pay for food from the rich countries.

The prospects at the present time look very good that the poor countries can, from a technical point of view, feed themselves and will be able to achieve a doubling of food supplies by 1985 and again a doubling by the year 2000. The problem is not really a technical one; it is an economic and social and political one.

Just to give you some idea of the technical possibilities, at the present time in India, about 300 million acres are cultivated for a population of around 530 million people. The new varieties of wheat and rice, which have nothing miraculous about them, but which are simply highly responsive to fertilizers, are so productive, about four to five times as productive as the varieties used in the past, that in India, at least, the total amount of cultivated land could be reduced to about 100 million acres from the present 300 million acres, in other words, reduced by two-thirds. This would be sufficient to feed a population of 1.2 billion people, which is about the population expected in India by the turn of the century unless something drastic happens by way of fertility control. This would be sufficient to feed a population of 1.2 billion people at a level of diet twice as good as it is now, that is, with a diet of about 4,500 calories per day as opposed to the 2,200 that is now available per person in India.

This means, however, growing three crops on each acre, which calls for a lot of irrigation development. It is quite possible to develop 100 million acres of good irrigation land in India to grow three crops. It means a very large requirement for chemical fertilizers, nitrates, and phosphates, and it means, of course, a continuing development of higher-yielding, more fertilizer-responsive, and more water-responsive crop varieties.

But if one looks into this a little more critically, one sees that what it really requires is a social revolution, because the new agriculture is primarily market agriculture and not subsistence agriculture. Farmers cannot grow large quantities of food unless they can purchase what the economists again call the factors of production, which are off-farm inputs such as fertilizer, irrigation water, the new seed varieties, pesticides, farm tools and farm machinery, and knowledge. In order to be able to purchase all these things, they have to be able to sell a considerable fraction of their crops, which means there must be customers available to buy these crops. The customers of course will be people who don't live on farms, but who live in cities or in towns and who do something besides farming.

At the present time, the less developed countries are very highly rural, particularly Asia. East Pakistan, for example, is about 95 percent rural; India is about 80 percent rural. What needs to be done is an enormous development outside of agriculture--in industry, in services, and in transportation: all of the aspects of economic development, just for the purpose of meeting this simple requirement that there be customers who can buy crops that farmers produce. The real food problem is not the simple one of just producing more food. It is the infinitely more complicated problem of changing the whole way of life and the patterns, both social and economic, of the country.

I might say a few more words about protein. There are a great many possibilities for increasing protein supplies. One of the most promising is genetic manipulation of crop varieties, the kind of thing that was done, for example, with corn at Purdue University by Mertz and his colleagues and with wheat in Kansas, which would simply increase the quality of the protein in cereals and get a better balance of amino acids.

Another is the possibility of increasing the world fish catch, provided we don't pollute the ocean sufficiently to destroy its biological potential. At the present time about 65 million tons of fish are caught

annually in the world. There is every reason to believe that by the year 2000 this tonnage can be increased to about 200 million, which will be quite adequate to provide the high-quality protein that is needed by the world's population.

A third good bet, it seems to me, is oil seed proteins: proteins from cottonseed and from other oil seeds.

A fourth possibility, which is being tried now in various countries, would be reinforcing or adding certain special amino acids to cereal grains to improve the amino acid balance.

Perhaps the most promising possibility of all is simply the increased production of livestock and poultry, which will happen if the Green Revolution works, and which probably won't happen if the Green Revolution does not work. I take a very pessimistic view during the next 15 or 20 years of any possibilities from so-called microbiological protein, basically not because it is not possible, and maybe even inexpensive, but because it is just awfully hard to persuade people to eat something that does not look like a chicken or a bowl of rice or something that they are used to eating.

This overview may give you some idea of the magnitude of the problem, which is perhaps in the short run, because of its interactions with economic and social development, at least the second most serious problem facing mankind. I personally think the most serious world problem is the danger of a nuclear holocaust, but the food-people problem is significant for the moment, at least.

THE POPULATION EXPLOSION, IMPLOSION, AND DISPLOSION

Philip Hauser

"Population" recently has been so much a subject in all of the mass media, with so much distortion, that it is desirable to review the situation in sober perspective. I am genuinely concerned about the extent to which hucksterism is now polluting the field as a result of which problems of credibility may be created. In fact, having recently returned from Africa, I am reminded of the story of the lion who stationed himself at a water hole and asked each animal as it came by to take its drink, "Who is the king of the jungle?" The smaller the animal, the quicker it was to respond, "Mr. Lion, there is no question about that. You indeed are the king of the jungle." Toward the end of the day a big lumbering elephant came by and the lion asked the same question. The elephant, being in an ugly mood anyway, wrapped his trunk around the lion and flung him some fifty yards into the bush. The lion came back battered, bruised, and bleeding, and this time remaining at a respectful distance from the elephant, said, "Well, you don't have to get so doggoned mad about it just because you don't know the right answer." That, I think, is where we stand with respect to various aspects of the relationship between population and food and population and the environment.

We should all be grateful that the consideration of population problems has definitely entered national and, for that matter, world consciousness. But I think it is important to head off possible boomeranging effects of the Cassandra-like projections of what may happen on the food and environmental fronts during the seventies. Many of the startling predictions will not come to pass and, as a result, there may be unwarranted public relaxation--as if there were no problem about population or food shortages or environmental pollution. Let us proceed to set the facts straight.

Man has been on this globe for some 4 million years. During his occupation of this globe, man has generated four developments that have profoundly affected his values, his behaviorisms, his social

institutions, and his environment. These are the population explosion, the population implosion, the population displosion, and the accelerated tempo of technological change. Permit me to define these terms with apologies for the neologisms involved.

The population explosion is pretty well known and understood today. It refers, of course, to the remarkable acceleration in the rate of world population growth, particularly during the modern era. The population implosion refers to the increasing concentration of the world's peoples on a relatively small portion of the earth's surface, a phenomenon perhaps better known as urbanization or metropolitanization. By the population displosion, I have taken an archaic term out of the dictionary to refer to the increasing heterogeneity of peoples who share not only the same geographic locale, but increasingly the same life space and the same social, political, and economic activities. By heterogeneity I am referring to diversity of population sharing a common locale and life space, diverse by culture, language, religion, value systems, ethnicity, and race. It is not necessary, particularly to this audience, to say more about the accelerated tempo of technological change.

By reason of these developments, man has created a twentieth-century demographic and technological world. This new world has precipitated many unprecedented problems, most of which are reaching crisis stage during this last third of the twentieth-century.

The problems generated include physical problems--air and water pollution, surface and air congestion, and the many other physical problems that afflict this nation as well as the world at large. They include personal and social problems--delinquency, crime, drug addiction; the phenomenon of the revolt of youth characterized by hippies who cannot cope and who, therefore, adopt some form of retreatism at one end of the scale, and by the activists who in their frenzy are now beginning to blow themselves up with dynamite, happily or unhappily, as the case may be; the revolt of the blacks; and the two new revolts that I think will reach crisis proportions during the seventies--the revolt of women and the revolt of the consumer.

The four developments have also generated economic problems and problems of governance. The economic problems include poverty, unemployment, underemployment, consumer exploitation, and others such as that of adequate nutrition. The problems of governance include the interrelations of federal, state, and local governments, apportionment and gerrymandering, the fragmentation of local government, and financing of required public services.

Now, if one were to summarize the highlights of the population explosion, it might be well to think of the two population explosions that mankind has experienced up to this point in history. The first was that which was experienced by the economically advanced nations. It was largely the product of three centuries of social, economic, and technological change during the modern era. It reached its apex during the nineteenth century, largely by reason of the tremendous decline in mortality, particularly in the century between 1850 and 1950. During that period the western world experienced a decrease in death rates of greater magnitude than had occurred in the previous 2,000 years.

This first population explosion was produced by declining mortality in the west, creating a great gap between the death rate and the birth rate, which lagged in its decline. Thus, natural increase--the excess of births over deaths--is what produced the first population explosion. During this first population explosion, confined largely to the economically advanced world, at no time did natural increase result in rates of population growth of nations in excess of 1 to 1 1/2 percent per year. We in the United States during the nineteenth century grew at a greater rate, but by reason of immigration.

Now, the second population explosion is that which has beset the other two-thirds of mankind, but only since the end of World War II. Up to World War II, mortality rates in the developing regions of the world were about at the level of what they were in the western world during the medieval period. Post-World War II developments, however, greatly accelerated the decline of death rates in the developing regions: in Asia, Latin America, and Africa; and since their birth rates were still at premodern levels, rates of natural increase, or total population growth in the developing regions, reached, by standards of the past, astronomical proportions. All of Latin America, for example, is now increasing on an average of about 3 percent per year, a rate that would double the population in 23 years. Virtually no developing region of the world of any size is increasing at a rate below 2.5 percent per year, and some of them, particularly some of the island areas--the Philippines, for example--are increasing at rates in excess of 3 percent per year (3.5 percent per year for the Philippines).

This means that the developing regions of the world, or more than two-thirds of mankind, are confronted with unprecedented problems of adjustment, made more difficult by the post-World War II revolution of rising expectations. These nations are faced with the problem

of inducing economic development, raising standards of living, and increasing food consumption, both in quantity and quality. They are faced with problems of much greater magnitude than any that have confronted the western world. This is the perspective against which I should like to make two observations.

First, mankind as a whole has no alternative, in the long run, but to achieve a zero rate of population growth. (I want to say more about this zero population growth that has become a kind of huckster slogan that might produce, as I have said earlier, adverse boomerang effects before the seventies are over.) That is, contemporary rates of world growth cannot possibly have been sustained for long periods in the past, nor can they possibly persist for very long into the future.

Second, the present 2 percent world population rate of increase is an outrageously rapid rate of growth. This can be documented quickly both retrospectively and prospectively with considerations of this kind: A mere dozen people could have generated a population of 3 billion in 976 years. That was the world population in 1960, and yet we know homo sapiens was in prolific numbers 50,000 years ago. Or the same dozen people since the beginning of the Christian era could have generated 400 million persons for every one now on the face of the earth. Our parking problems would be even more severe, I suspect, than they now are. Or if you want the champion of projections, consider what would happen if you took the average rate at which world population has grown since the end of World War II, 1.7 percent per year, and projected it ahead for 6,200 years. This would be looking ahead not much farther than we look backwards at archeological finds in any good museum. The answer is that the mass of human flesh generated would have a radius expanding outward more rapidly than the speed of light, and about 34 years after that there would be another glob of human flesh the size of the first one.

What is the purpose of these kinds of arithmetical exercises other than perhaps to indicate that the demographers are among those who know how to use compound interest tables? Three incontestable conclusions flow from these considerations.

One is that contemporary rates of population growth could not possibly have been sustained for very long in the past. Second, they cannot possibly persist for very far into the future. Third, mankind has no alternative to a zero rate of growth because in the long run,

given a finite globe--and this is a finite globe, with only 200 million square miles of total surface and only 50 million square miles of land surface--any rate of growth would, in the long run, produce saturation.

Now, a few quick observations about the implosion and the displosion. Why are they relevant to the food situation to which I shall repair before I finish? Because the implosion has compressed the world's peoples into increasingly large urban and metropolitan areas. As recently as 1800, less than 2 percent of the world's peoples lived in urban places. By 1950, that proportion had increased to about 20 percent; in 1960, it was perhaps 30 percent. Utilizing projections of the United Nations, by the end of this century, which is only 30 years hence, perhaps half of the world's population will be living in urban areas.

The population implosion has significance for the problem that brings us together, population and food. To the extent that a large proportion of the world's peoples remain undernourished during the remainder of this century, to that extent the concentration of population in urban areas is going to have quite different political consequences than if peoples were to remain distributed over the rural landscape. In the urban setting hunger generates more social unrest, political instability, and threats to peace; and hunger in the urban setting poses threats also to existent social, economic, and political structures.

Why is the population displosion relevant? There are many frictions being generated and visible in the increasing conflict between diverse peoples in various parts of the world--Catholics and Protestants in Northern Ireland; Israelis and Arabs in Western Asia; Hindus and Muslims in India; Chinese and Malays in Malaysia; and blacks and whites in the Union of South Africa, Rhodesia, and the United States of America. The population displosion, peoples of diverse backgrounds sharing the same locale and life space and attempting to live on an egalitarian basis in a pluralistic society, is a very recent phenomenon. Mankind has not yet learned how to do it.

The population displosion is also relevant to the food problem, because it turns out that if one looks at the distribution of food, whether one considers the quantity or the quality of consumption, it is generally the minority peoples throughout the world who are the most underprivileged with respect to food, as well as with respect to other goods and

services. And it is the minority peoples who may be expected to trigger increasing social unrest and political instability.

May I say that I have brought the population implosion and displosion and their consequences to your attention because I am deliberately trying to get the National Academy of Engineering to set its sights two, three, or four decades ahead of the present. After more than a half century of effort, we demographers, I think, have finally gotten the world, as well as the United States, to be concerned about that part of the population problem involving the birth rate and the total growth rate. But neither the world nor this nation is yet very much aware of the problems relating to the population implosion and displosion. In fact, in my judgment, there will be more human misery generated between now and the end of the century by reason of the population implosion and displosion than by reason of the high birth rate or the high growth rate. This is a perspective yet to be achieved by the world or by the United States, and I think also by the National Academy of Engineering.

In effect, what I am saying is that we must not let concern about the birth rate and the growth rate, or for that matter potential food shortages or environmental pollution, become a smoke screen for obscuring the many other problems that probably should have even higher prioity in world and national attention.

Now let me provide some quick perspectives on food. There is probably no area of population problems that is as confused at the moment as that of the relation of population to food. The reason for this is quite clear. Everything that was written before 1966 about the food prospects of the world tended to be quite pessimistic. But writings since that time have, on the whole, a much more optimistic outlook--for perfectly understandable reasons. One can take the same author and contrast his writings before 1966 and after 1966 and find quite different conclusions, and understandably so. The literature written both before 1966 and after 1966 is still in circulation, and many people are therefore confused by what seem to be complete contradictions in the outlook with respect to the food supply.

The answer for this confusion is to be found in the Green Revolution--the great increase after 1966 in the productivity of grains, specifically rice and wheat, by reason of the "miracle rice" developed in the Philippines and "miracle wheat" developed in Mexico.

The Green Revolution has changed, at least technologically speaking, the outlook for food. All of the dire predictions of mass starvation by millions during the 1970's or by the latest the 1980's should now be relegated to the historical past where they belong. But they are, nevertheless, still confusing the situation on the food outlook over the next two or three decades.

This is not to say that the food problem has been resolved for more than the next two or three decades. In India, for example, the miracle grains, although they have greatly increased production, have resulted in a production level not too different from that which India had already experienced before the onset of the severe drouths that produced the potential famine conditions several years ago. Moreover, there are still problems with respect to the miracle grains, and it remains to be seen whether after a few years they can withstand the onslaught of forces of nature that in the past have attacked such new developments--the onslaught of insects, molds, and the like. There are still some uncertainties about that. Also, as Professor Revelle indicated, the new grains require relatively larger amounts of water and huge amounts of fertilizer, which may not be easy to achieve. Furthermore, it remains to be seen whether a distribution system can be developed that is up to the task of getting increased food production to where it is most needed. It remains to be seen whether increased irrigation will result in sustained much larger yields or whether salination of the soils of the type already evident in Pakistan and in western Asia threatens sustained great yields. It remains to be seen whether the great inputs required to grow the new grains--inputs of capital among other things--will result in exacerbated maldistribution of income in these areas; and it remains to be seen how increased maldistribution of income creating an even greater gap between the haves and the have-nots within these nations will affect the stability of nations between now and the end of the century in the developing regions.

The major limit to population growth in the long run will be space. Food is at the most a short-run consideration. Should they work beyond or up to expectations, the miracle grains can at best give mankind only three or four additional decades in which to attempt to control excessive population growth. This, I think, is the most important perspective about the food situation. In the long run, space will be the limiting factor.

This leads me now to my concluding observations, including that which I promised with respect to zero population growth. The slogan "zero population growth," in which many people now say they believe, is the equivalent of believing in the law of gravitation. It is not a bad thing; it is an inevitable thing. The question is not do we want zero population growth. The question is how soon should it be brought about, and by what methods. I am convinced that there will be population limitation--the growth rate will come down, and the birth rate will come down. There is no question about that because, I repeat, space is the limiting factor. The only question is whether the zero growth rate will be achieved by forces of nature or by man, and if by man, whether the methods will be relatively rational and desirable, or relatively irrational and undesirable.

If zero growth is to be achieved by nature, it will come about by pestilence and famine, disease and starvation in the same sense discussed by Malthus. If zero growth is to be achieved by man by relatively undesirable and irrational methods, then, if I might draw upon human experiences without advocating or elaborating upon them, such methods would include war, homosexuality, and cannibalism. May I say with respect to war that up to this point in human history, the military has been quite inept and quite unable to exercise very much influence on the rate of total world population growth. Even during World War II, the bloodiest of all our wars, the fact is that world population increased by several hundred million. But now there is new hope for the military as an instrument of population control. The advent of the hydrogen bomb makes the military one way to achieve zero population growth (and I don't think this is just a laughing matter, although it is probably a good idea to try to maintain a sense of humor about it so that we don't go stark raving mad).

Well, these are undesirable methods. What would be desirable methods? Let me list them, but first let me mention three terms that are generally used interchangeably as if they were the same thing--conception control, birth control, and population control.

Conception control refers to all of the means whereby conception may be prevented--behavioral, mechanical, chemical, physiological, surgical. This is the method in the main still relied upon by family planning movements throughout the world.

Birth control includes conception control plus abortion, and like it or not, abortion is still the most widely used method of limiting births throughout the world, with estimates ranging from 40 million to 60 million a year. Incidentally, another kind of consideration about which there is confusion is the relationship between conception control and abortion. Were there adequate conception control, there would be no need for abortion. The world will continue to have abortion as long as there is inadequate conception control.

Population control refers to the relationships among fertility, mortality, and migration. It refers also to social and economic policies as they may affect these components of growth. A number of countries in the world now have conception control or some combination of conception control and abortion. No country yet has population control in the sense of trying to fix policy with respect to the total picture as I have just described it. This nation conceivably may move in that direction with the pending Presidential Population Commission, but I am not sure what direction it will take.

Zero population growth, then, is an inevitable thing. To be in favor of it, I repeat, is the equivalent of being in favor of gravitation. The whole question is how soon and by what methods.

I will make my final observation on the relation between population and environmental pollution, which, for the time being, is obscuring the problem of the relation of population and food. Much that is being said in that realm is utterly distorted. We could have no population growth from now on in the United States or in the world and we would still experience increasing pollution. Population in the western world particularly is a minor factor in pollution compared with such things as increased per capita consumption and the absence of agencies with the power or the funds to control the common property resources: air, land, and water. The absence of such agencies is much more significant in explaining pollution than are rates of population growth.

May I say also that pollution is not necessarily a product of the free enterprise capitalistic system, which is among the distortions that are now being uttered. There is just as much pollution in the socialist economies, and for the same reasons. Even the socialist economies have not set up adequate agencies concerned with common property resources, such as air, water, and land. So, both kinds of economies can be faulted on this ground--both have socialized and deferred payment of the costs of pollution.

The other interesting aspect of the current situation is the extent to which youth has picked up the slogans about the relation between population and environmental pollution. Youth has come to advocate zero population growth. But the quicker we achieve it, may I point out to youth, the quicker we solve what some of us oldsters regard as "the youth problem." Zero population growth would generate in this country a population with an average age of 40 years. It would generate a population in which youngsters under 15 became something like 19 percent of the population instead of something over 40 percent in the developing regions of the world. Persons over 60 would increase to about 24 percent from a level of about 15 percent.

The rate at which we are to achieve zero population growth is one that requires reflection. Should it be achieved very quickly? This could be done only with considerable effort, if at all, and at the expense of human values that neither we nor the peoples in the developing areas may be prepared to pay. In any case, we must avoid being mislead by false prophecies and the mouthing of empty slogans. Most of all, we must avoid the disillusionment that may follow the failure of the dire consequences predicted for the short run, which are almost certain to follow. Population problems are both chronic and acute. So are problems of food quantity and quality; so are problems of environmental pollution. But it will avail us little to be misled by distorted versions of either the problems or their interrelationships, and it may harm us to relax in our efforts to deal with these problems after present doomsday predictions fail to materialize. What is needed is not a repetition of cathartic Earth Days but a great effort to arrive at consensus on desirable goals in respect of population, food, and the environment followed by persistent, uninterrupted inputs to accomplish those goals. The achievement of such goals need not be dependent on distortions of the facts, half-truths, and alarmist predictions.

PANEL ON WORLD POPULATION

Stephen Enke, Chairman

Continuing from what Philip Hauser was saying, I would like to give one or two numbers by way of context. Even if the incredible happened and gross reproduction rates were halved in the underdeveloped world today, so that we had something like a net reproduction rate of unity, population would continue to grow for about three-quarters or two-thirds of a century. In other words, you would not obtain zero population growth for another 75 years or so, even if by some inconceivable means you were able to achieve a net reproduction ratio of 1 today--the reasons being that these countries have very young age distributions, young people have high age specific fertility rates, and it would take you three-quarters of a century for the age distribution to get to the point where the population ceased to grow. So, even if you had net reproduction rates of unity today, you would have about a 50 percent increase in the population of the underdeveloped countries before you get zero population growth. The so-called miracle crops, which are very fertile in terms of water and fertilizer, certainly are a blessing. But we need those miracle crops just to take care of the increase that we will have even if we did have net reproduction rates of unity today. The problem is a very serious one.

It was pointed out by Roger Revelle that there was a contrast between the experience in western Europe and North America during the period from 1840 to 1940, and the so-called developing or underdeveloped world of today since the last war. In Europe and North America, as was pointed out, the birth rate and death rate tended to fall very slowly together, with the birth rate enough above the death rate so that populations increased about 1 percent a year.

What has happened in the underdeveloped world since World War I, and even more since World War II, is that the birth rates have tended to remain about the same, around 40 or 45 per thousand per year of population, and the death rates have come down very drastically indeed, down to crude death rates as low as the crude death rates of our own country (the reason again being the young age distribution of those lands).

I would like to point out that it is the engineers who in many ways are responsible for this decline in death rates, and therefore responsible for the population explosion as it is sometimes called, because it was not solely the public health people with their innoculations and quarantines who eliminated cholera, smallpox, and so on. Much of the decline in the death rate is due to improvements in the water supplies--more sanitary water supplies particularly in some of the excolonial countries. So the engineers, and particularly the civil engineers, are implicated, and therefore I am very glad to see that through these sessions they are accepting responsibility, as it were, for part of what they have brought about.

It was pointed out that countries with population increases of 2.5 percent per year are doubling their populations in about 28 years. What is the consequence of that for economic development? It depends on what you mean by economic development. Usually people mean a higher standard of living and more consumption per head of population, which is to say, more gross national product per capita.

Doubling the population of a country in itself is not the problem. The problem is how rapidly it happens. If the population doubles in 28 years, if income per capita is not to fall (ignoring technology for the moment), it would be necessary for the land and natural resource supply to double in 28 years, for the stock of capital to double in 28 years, and for the employed labor force to double in 28 years. Unless all of the three principal factors of production can double at the same rate as the population, ignoring technology for a while, we are going to have a decline, not an increase, in per capita income.

Unfortunately, by definition land and natural resources of the useable kind cannot increase in supply at all, so that takes us to the next two factors of production. Employed labor, as distinct from the labor force, depends in part on the amount of capital available. If capital does not grow rapidly enough, you may have a larger labor force, but you may also have unemployment, too. So, even though doubling the population may double the labor force, it will not double the employed labor, unless you have something like a doubling of associated capital.

That brings us back again to capital. Most countries in this world are going to have to supply their own extra investment through their own annual savings. The amount of capital that can be accumulated in underdeveloped countries through transfers from the advanced

countries is really very slight. So we are talking about domestic savings as the main source of capital accumulation in these nations.

It will be necessary for them to save at least 5 to 7 1/2 percent a year of their gross national product and invest it domestically if they are ever going to get a rapid enough capital accumulation to match the increase in labor force to employ enough workers and to enable them to double their gross national product and therefore maintain the same per capita income.

If you read the official documents of the United Nations, and some of these countries, it sounds as though they expected to improve their per capita incomes by 5 or 10 percent a year. These goals are seldom attained. If they are going to increase their per capita incomes at all, it is going to be because of technology: technology that improves state of the art; that permits the same relative amounts of land, capital, and employed labor to produce more because they are being used more effectively in more modern ways.

So, once again, the problem is not that population may increase; it is how fast it increases. Even countries that have an apparently large amount of open land that is unused--the whole Amazon Basin in Brazil, for instance--cannot handle a rapidly growing population. If the population is growing rapidly, it won't be able to accumulate enough capital to make use of presently unused land.

Staying with economics for the moment, if it were possible to reduce age specific fertility rates drastically in these countries, the main economic benefit would come from a change in the age distribution; specifically, the fraction of children under 15 years of age would decline. Today, in many of these less developed countries, 40 percent or more, as Philip Hauser said, of the population is under 15 years of age. These people certainly consume, but they really do not count as producers. If you can reduce the fertility rates, you will reduce the proportion of the population that is under 15, and you increase proportionately the work age population. It is this dynamic that provides the means of increasing output per capita and increasing savings.

The Panel on World Population considered a number of issues about which there is disagreement, and one of the issues that always arises is why it is that women, so many women, 80 percent or more or the fertile age women in these less developed countries, apparently do not practice contraception.

Some people feel that it is lack of knowledge. Of course, some methods, such as abstinence and withdrawal, and certainly abortion, have been well known for millennia. It is true that the more modern techniques--intrauterine devices, vasectomies, and some of the pills--are not so well known in the hinterlands of these countries.

Another possible reason why these women do not practice contraception is the unavailability of some of these methods, and in the rural areas, the more modern methods are not, in my opinion, really available. In many countries the pill is still not on sale or it requires a doctor's prescription. There are no doctors in the rural areas of these countries. The IUD usually requires insertion by a doctor or, at least, a fairly well-trained paramedic. They are often not available. Even village stores do not necessarily sell condoms. So I think availability is a problem.

The Population Council, of course, very often writes as though if you only made enough contraceptives available to enough women in enough parts of every country, there would be no problem remaining. There are others, however, who say the availability of contraceptives, although very necessary, is insufficient in itself unless you can change the motivation of women so that they will use them. Here we encounter many social problems.

In these countries, the barren woman has a rather miserable life if she is married. Women have very few alternatives to being mothers. There are very few job opportunities. They cannot travel alone to cities and start lives and careers on their own.

Old age insurance does not exist, free of inflation, in these countries. Increasing social services, such as education, make extra children no more costly. It may be that we will have to innovate, and offer new rewards for not having children. Let us be sordid; I mean money, bonuses, or if you like, bribes. It may be that governments may have to give money bonuses to women who, say, delay having their first child until they are 25 or have no more than two children before thay are 35. Some governments already give bonuses to men who volunteer for vasectomies. These bonuses are, in my opinion, ridiculously inadequate. We don't know what a really large bonus would produce in the way of volunteers, but we never will know unless we try.

It may be that we will have to give large bonuses to doctors for inserting IUD's, to encourage them to go out into the rural areas. Governments may have to distribute condoms and pills to small stores in rural areas free to the retailer, so that whatever price he sells them at becomes his full retail margin, to give him an incentive to carry and sell them.

In most small villages we have midwives, who occasionally double as abortionists, and in these villages the midwife-abortionist is very often listened to by the other women in the village. She has a certain amount of status. Contraception, so far as she is concerned, threatens her livelihood in both cases. Somehow these women must be brought into the birth control system. They must be made part of it, and it probably is going to require a financial inducement.

One of the other issues that concerned us was how governments should be spending their so-called birth control budgets. As you probably know, for example, the Agency for International Development has $75 million earmarked for population programs in fiscal year 1970, and I think $100 million earmarked probably for fiscal 1971. How should this money be spent? There is a roaring debate. Many of the doctors would like to establish maternal health and child care clinics in more places and staff them more adequately. On the other hand, there are many people who are out and out birth control proponents, who feel that the money for maternal health and child care is being diverted. They say the average doctor has more interest in health and life than in preventing birth. A woman may come to the clinic with her young child, but the doctor will be so busy looking after the child or the mother that he will almost forget to incidentally mention contraceptives.

A doctor who has spent years qualifying as an MD does not find much professional reward in inserting IUD's all day, and he won't do so unless there is a good financial reason. He would much rather be doing something else. You may have to develop a new type of paramedic--a rather modestly trained person who can advise on contraception and who can insert IUD's. In some countries this means that the medical association has to change its attitude toward paramedics.

Then lastly, some people wonder whether there is not a superficial incompatibility in having medical programs in which doctors during part of the day are trying to reduce infant mortality, and the other part of the day are trying to reduce fertility. In some deeper sense are these compatible objectives, or are they not?

DR. RAVENHOLT:

The United States has long manifested its active interest in the improvement of well-being throughout the world. Since the beginning of the Marshall Plan in 1947, the United States has provided more than $50 billion of its resources to augment the resources of needy countries, and this transfer of resources had a very visible impact on the recovery of Europe and also a substantial impact on the less developed countries.

There was, however, a difference. The recovery of Europe occurred rapidly, and there was not a large increase in the population growth rate as a consequence of this application of United States resources. On the other hand, in the developing countries there were a rapid response to the transfer of resources, a drop in the death rate, and a rapid increase in population growth.

Therewith, the United States became more fully aware that it could not simply be concerned with the numerator; that there is a developmental equation; resources divided by people equals well-being; and that we could no longer simply augment resources and let the denominator take care of itself. In Europe the people had long been in the habit of practicing contraception. In the developing countries this was not true.

In the fifties there was increasing concern with the inefficiency of the application of foreign assistance resources solely for numerator expansion, which obtained initial expression in the Draper Report in 1959--calling attention to the fact that the United States must do something about the denominator as well as the numerator.

In the early sixties this was hastened by the work of the chairman of this panel, Dr. Enke, who called attention to the much greater developmental gain from an investment of resources for constraint of the denominator as opposed to application for enlargement of the numerator. This concept--that per dollar invested a much greater improvement would occur in the welfare of people if at least part of it were invested in family planning, although it has been resisted in many places in the world--has nevertheless gained wide acceptance and has been a very persuasive element in the argument that the United States should make resources available for population and family planning. It is

perhaps no coincidence that in 1965 President Johnson called for application of United States resources for solution of the world population crisis.

Since then, during the last five years, the Agency for International Development has developed a population/family planning assistance program. It took some years to convert high rhetoric into an actual program, and it did not actually come into full stride until after the passage of the Title X amendment to the Foreign Assistance Act, on January 2, 1968. But during the past two and a half years this program has moved rapidly. In fiscal 1967, AID used about $4 million for its population program. In fiscal 1968, this jumped to $35 million. In fiscal 1969, it was $45 million. In the current year we have $75 million appropriated for this program, and $100 million is authorized for fiscal 1971.

At the same time, a number of the developing countries have been establishing population programs, which have gone more or less well. As we look around the world, we see that perhaps the region of the world where the action has gone forward the best and the most rapidly is East Asia. There, in certain places such as Hongkong and Singapore (small city states), the job is virtually done--with the birth rate now down to the low twenties, 21 or 22 per thousand population. In other countries, such as Korea and Taiwan, the work is well advanced. The birth rates are still in the upper twenties, but the problem is clearly coming under control. Malaysia has done well. Most notably in the last several years, Thailand and the Philippines have made rapid strides. The progress there has been remarkably swift, much faster than we had thought possible three years ago. Now even Indonesia is moving.

Latin America is perhaps the next most promising region of the world. Rapid changes have occurred in the countries of Central America and the practice of fertility control is extending rather rapidly through Latin America, especially as a consequence of the work of the International Planned Parenthood Federation (IPPF) and the Family Planning Associations. In many of the Latin American countries there are no official programs yet, but there are nevertheless in most of these countries substantial birth control programs operated under private auspices, with nonofficial support from governments and with support from governments and with support from AID. We have provided large support to the IPPF, as well as to other organizations such as the Population Council, the Pathfinder Fund, and universities, to augment their capabilities.

Africa of course has a long way to go, but it is beginning to move. Some of the countries, such as Kenya, Tunisia, Morocco, and Ghana, are making satisfactory progress. On the other hand, because the death rate remains high, the population growth rate is less than it has been in Latin America.

The biggest problem of course is in South Asia: India particularly; Pakistan to some extent. The program in Pakistan has moved rather well in the last five years because of good leadership and the application of substantial resources. Now, because of political changes, the program is moving less satisfactorily, and we cannot quite foresee what will happen.

Unfortunately in India the program has not moved well, mainly because of the scarcity of resources. India's national budget this year is only $2.5 billion equivalent for all purposes, and this means, then, only the quivalent of $5 per capita for a half-billion people. The United States budget, as you know all too well lately, is about $200 billion for 200 million people, or $1,000 per capita. In other words, our national budget is about 200 times as great on a per capita basis as India's budget. Hence, India has very limited flexibility in meeting even high-priority needs.

India's family planning budget within that $2.5 billion is of the order of $50 or $60 million equivalent, which is not very much for approximately 100 million women of reproductive age. A great deal of work remains to be done there.

Because of some of these difficulties we have turned to research. There has been a particular emphasis on the development of new technology--technology that might be more efficient. I am happy to report that on the research front the work is going more rapidly than we had anticipated two years ago, or even one year ago. We see a number of breakthroughs. We see some new improvements in the intrauterine devices (IUD's). Some of these are of particular interest to engineers as they relate to shape and substance of IUD's. Most important in the last several months has been the advent of a new post-conception means of fertility control, the prostaglandins, which give promise that for the first time we will have an effective and remarkably safe abortifacient, one that ultimately a woman may be able to apply herself. Therewith we may indeed be able to move forward with greater efficiency.

MISS DIXON:

I would like to begin on a note of controversy. We don't want you to think that we are in any sense a united front here, so, taking off from what Dr. Ravenholt has just said, I will begin with this point: one of the areas of disagreement in the population field is whether the United States government should be involved in population control at all, at least in the less developed countries. Dr. Ravenholt talked about the large role that AID is playing in this field, and perhaps this would be a good time to suggest that considering the economic and the military position of the United States in the world today, it may be that tying population policies very closely to government agencies is doing more harm than good in the long run. In fact, to borrow a phrase, perhaps the consequences may be counterproductive, considering the suspicion with which some of the suggestions from the United States government are received in politically sensitive developing nations. Perhaps we would do better to work more inconspicuously (a number of people think this) through international agencies that are less closely tied to American foreign policy.

On that note, let me move on and ask what will happen if the family planning programs of the type suggested by AID and a number of other international and local agencies and foundations are successful in the goals that they have set for themselves. This would mean, of course, that contraceptive services, backup abortions, and so on, will be readily available to everyone who wants them. It would assume that birth control is efficiently practiced, that the knowledge is available to everyone, and that couples in the less developed countries have only the number of children that they want to have. It is the old planned parenthood slogan of "every child a wanted child."

If we could achieve this perfection, what would happen to population growth rates? I think this is something that we have to look at very closely. The answer seems to be that although perfect planning would of course reduce the excess fertility that most couples now experience--the extra one or two children that they are having beyond those that they would really like to have--birth rates, and therefore growth rates, will remain high. The reason is, of course, that most couples in the countries that we are talking about <u>want</u> to have large families. The mere provision of family planning services is not going to affect this high fertility motivation.

In fact, we might better ask: why the low level of professed knowledge about birth control techniques in the first place? If people feel a real need for birth control knowledge, they will seek it out, and the fact that they have not--the fact that very few couples in the less developed countries are now practicing or have ever practiced contraception (and some studies show that it may be as low as 5 to 10 percent of married couples who ever practice contraception at all)--suggests that even though methods such as periodic abstinence or abortion or withdrawal are certainly available, the problem of high fertility is definitely one of lack of motivation to reduce fertility, more than of the lack of means. The means are there, and I might point out that the decline in marital fertility in nineteenth-century western Europe, and of course the very low birth rates in the depression years, came about long before we had fancy techniques like IUD's and pills to play around with. Certainly the old-fashioned methods were less effective, but practiced consistently enough and by enough couples, their effect was definitely felt in the birth rate.

A number of studies from Latin America and Asia and Africa suggest that couples in these countries desire or consider ideal anywhere from four to as many as eight children on the average, depending on the area and depending on the group of people being studied. This leaves out those--and in some cases the number is considerable--who really can't understand at all the idea of a hypothetical desired family size in the first place. Where family planning clinics are operating, the experience has usually been that the women who come are in the late years of their reproductive period. They come after they have had more than enough children. They come when they really feel the pressure to do something about it. This is after their six or eight children have been born, and in effect all that is happening is that they are closing the barn door after the cow has escaped.

What we are faced with, then, is the simple fact that high fertility is still valued in traditional societies, and in the absence of social security systems, men and women need sons to support them in sickness and in old age. If a couple wants to ensure that at least one son survives to adulthood, they have to have five or six children to achieve this.

A man's status in the community often increases with the size of his family. He is assured of heirs carrying on the family line, and in many countries, he is assured of religious salvation as well through his offspring. A woman's main obligation in traditional societies is

often to provide sons for her husband. If she succeeds, she is praised, but if she fails--if she is barren or if her babies die when they are infants, or if she does not marry--then she is totally without worth and virtually a social outcast.

In village societies where social and economic activities are built primarily around kinship structures, the whole family is under heavy moral and material pressure to marry off their children to ensure an extension of kinship down through the lines of descent and in cross-affiliations with other families.

It is for these kinds of reasons, because of this built-in pressure toward high fertility, that proposals have been suggested that go beyond family planning to the heart of the motivational problem itself. This is where I think the real work needs to be done.

Dr. Perlman will be discussing some economic incentives, and others were mentioned earlier, so I would like to confine myself to one subject that particularly interests me: the status of women.

As long as the role of women is defined purely as a familistic one, then fertility is going to remain high, and it is only when real alternatives to marriage and childbearing as sources of both economic and social support are made available to women that we can expect any significant change in the birth rates of the less developed countries. This means concentrating very heavily on raising the status of women in education and employment; insisting at least on the equal representation of women at all levels, even when resources are limited. If it means giving up to a woman a job that a man would otherwise have, I think the demographic payoff is increased in this kind of situation.

We might consider setting aside a quota of jobs for childless women in order to encourage delayed marriage, nonmarriage, or delayed childbearing within marriage. Most studies have shown that when employment for women is available--employment that takes them outside the home and is inconsistent with child rearing--then both their desired fertility and their actual fertility decline. A necessary precondition, then, for a fall in the birth rate appears to be offering women a much greater range of choices and greater rewards for nonfamilial activities.

Of course, this kind of argument applies to other groups as well, and as long as you have a minority or even a majority of the population that feels that they are so disadvantaged that there is no chance of improvement in their lives, no matter what they do, then obviously the inducements for fertility control are not there. It is only when the needs that are currently met by having large numbers of children can be met in other ways that birth control will make sense to those we are asking to practice it. At the moment we are asking them to control their fertility without offering anything in its place.

"Birth control" may of course require quite drastic social and political transformations in some countries. In the meantime, the provision of efficient family planning services is perhaps a necessary precondition for a drop in fertility, but it is by no means a sufficient one.

DR. GARCIA:

In agreement with Miss Dixon, a high level of motivation of the couple is the sine qua non of effective contraception. Furthermore, to achieve this, among other things, more universally available increases in newer effective methods are essential. At this point, however, I disagree somewhat, perhaps not entirely, but at least from the point of view of practicability. There are no new methods from a really practical point of view that are going to be available in the foreseeable future, despite the fact that many are on the drawing boards. It will take many years before they will come into actual being, even the ones that are mentioned.

Modifications will be made of the presently available ones, but newer methods attacking different areas of the reproductive system to diminish the number of births are a long time away. It will be quite a while before we have something that is practically available from the point of view of usage to create a dent in the population problem.

For this reason I feel that a reappraisal of the present situation is essential from the viewpoints of cost, effectiveness, and medical management. Unfortunately the cost of supplying and maintaining contraceptive modalities really is inversely related to the effectiveness of a certain method. I think that governments are only too painfully aware of this particular aspect.

The do-it-yourself techniques--those of withdrawal, periodic continence, or abstinence--in the main are relatively ineffective from the point of view of motivation. Condoms are relatively effective. From the point of view of cost, they are probably relatively inexpensive. They are quoted to be about $2.50 per gross, and they merely require distribution in the main. Diaphragms, which require the initial fitting, are intermediate in effectiveness. The pill, or hormonal contraception, which costs as little as 15 to 20 cents per cycle or approximately $2 a year per person, and the IUD, which of itself is exceedingly inexpensive but which requires trained medical personnel, are among the really effective techniques.

The backup for medical complications is actually more visible and more visibly obvious with the use of the IUD. However, there is an increasing awareness of the sweeping statements and directives made by the regulatory agencies of large countries regarding the potential hazards of hormonal contraception, albeit of rare occurrence, and in most instances without proof of a causal relationship.

Conclusions about the safety of the IUD and also of the pill are achieved under pressures of prudence and are accepted as fact not only by the nationals of these countries, but also by the leaders of smaller and less developed countries, who are attempting to initiate and carry out broad contraceptive programs. Overemphasis of these possible hazards through emphatic restrictive recommendations without weighing them in relation to the toll of daily living nor in the light of no contraception, which may lead to the far greater hazards of unwanted pregnancy, is not to be condoned. This can only be visualized as being irresponsible to society. The need for paramedical and medical help is even greater for the surgical contraceptive approaches. Vasectomy and tubule ligation, while effective and performed with increasing simplicity, still require skilled personnel. They actually carry with them a slow acceptance rate.

Governments are becoming more realistically aware of the presence of illegal abortions in all nations, among all classes of people. Significant reductions have been achieved through implementation of hormonal contraceptive and IUD programs. There now appears to be an increased awareness of the need to permit more liberal attitudes toward termination of unwanted pregnancies, particularly in women experiencing contraceptive failures. Should not abortions be done under the best circumstances in all countries, since they even now are being done under adverse, illicit, and illegal conditions, with a substantial death toll?

Attempts to stamp out these illegal modalities have failed. There is an apparent attempt to accomplish the liberalization of the laws that favor elimination of clandestine or illegal abortions. However, such laws are being put into effect without having prepared for the increases in the facilities and the numbers of trained persons that such programs will require, as well as the backup for the management of the complications that unfortunately occur occasionally with such procedures.

Of some significance is the fact that the population growth has been stabilized only in countries where abortion is available on demand. Governments must not be circumspect and restrictive, but must weigh all of the facts and adopt all measures that can help society in its battle with the press of population.

DR. GOTAAS:

One of the problems apparently facing the family planning and population programs on an international basis in the various countries is one of the leadership and the organization to accomplish this very important activity most effectively and efficiently. Just as sanitation and environmental engineering programs of the past, which accomplished so much in improving health and reducing disease, had problems in developing greatest efficiency and effectiveness associated with public health organizations, the nongovernmental family planning and population control organizations that have led and spearheaded the development of programs and clinics in 63 countries are questioning whether family planning can be most effectively developed under the control of public health organizations or as independent operations.

These organizations that have spearheaded family planning all over the world welcome the interest and activity of public health organizations. In fact, I think they find it most essential and necessary. But they do question whether the necessarily broad programs with many aspects, varying from stocks of materials in the corner drugstore, trained people, social welfare, educational activities, to clinics and hospitals, can best be handled entirely under organized public health programs.

There are a number of reasons for the belief that some family planning programs should to a degree be separated from the usual maternal and child health, general medical services, or hospital outpatient clinics, and instead be under independent leadership. Some reasons are:

(1) Generally, physicians have been educated to conserve and perpetuate life and will usually exert primary effort in this direction.

(2) In the less developed countries, the few available physicians should not be diverted from more professional work into family planning, because as you have heard earlier, paramedical people can handle many of the activities very satisfactorily.

(3) Many physicians often find that birth control efforts are professionally unstimulating.

(4) Physicians who have been working with the child and maternal health problems during the morning will not have an interest in shifting gears and discussing contraception in the afternoon and in attempting to convince the people who come to their clinic that they should be having less of a family.

(5) Maternal and child hygiene and general medical clinics usually reach primarily the women, and the family planning program, as you have heard earlier, should reach the men as well as the women.

(6) Family planning and population control programs are extremely broad, dealing with education and social and economic problems, as well as the strictly contraceptive and medical measures.

On the other hand, the World Health Organization has taken a somewhat opposite position and considers that family planning activities should be associated entirely with public health or general medical services. Certainly it is desirable to have family planning efforts associated with all maternal and child health programs and all types of health programs and clinics with which they can be associated, but this is probably not sufficient.

The public health organizations have more of the people who are basically trained for work in fertility clinics. The medical clinics more readily attract women, and these are the people who should receive family planning and contraception assistance. Also, people are sometimes afraid to go to a separate family planning clinic for

fear they may be identified with this activity by some of their neighbors and friends, and hence may prefer to use the family planning service of a general medical clinic.

Since information as to the most effective and efficient approaches for conducting family planning programs is not yet available and since the need for maximum progress is so pressing, present child and maternal hygiene and general medical clinics should certainly have active family planning programs. Where no clinics exist, it is certainly desirable to start family planning through mobile or other clinics and centers rather than wait until general medical or health clinics can be established.

Family planning programs, which are relatively new in most countries, are similar to the problems that confronted environmental sanitation in the early years of organized efforts in this field. Sanitation was actively associated with organized public health, but fortunately was also in many cases an independent activity. It would not have been as successful had it been entirely associated with public health organizations, and conversely, it would have been as successful had it been entirely independent and separated from organized public health.

The same is no doubt true of family planning activities today. The World Health Organization, who would associate it almost entirely with medical activities, will probably not provide the optimum arrangement for maximum progress, nor would the best arrangement be to have the endeavors carried on entirely by independent agencies. There must be independent leadership within the private family planning agencies as well as in health organizations.

DR. PERLMAN:

As I understand the record of the development of populations, where we have pretty good data, we have essentially three stages in the development of population controls. Before discussing the third stage in detail, I will briefly identify the first two.

The first stage started early in the nineteenth century, particularly in France where there was land redistribution after the French Revolution and a leveling upwards of individual family wealth. In other countries, especially the United States, there was an extension

of free public education on a very widespread basis. There were, with the development of industrialization, first in Britain and later in the United States and other countries in western Europe, expanded opportunities for the nonagricultural labor force, particularly for young girls. Of course, throughout this period, especially in western Europe, there was a tremendous opportunity for immigration to the new world, and later to Australasia. All of these changes caused antinatal forces to dominate, and they served to provide sufficient incentive for people to practice forms of fertility control that quite materially lowered completed fertility rates of women.

The second stage began after World War II, when the United States went into the foreign aid program on a large scale. We set up very impressive and really monumentally designed public health programs that had the immediate impact of lowering death rates without doing much to birth rates. By the midfifties this growing rate of population in the countries we were assisting, particularly in the less developed countries, had sufficiently frightened the Point IV or what are now the AID officials that they backed off from any attempts to try to influence population growth by public health efforts. They began to cut back their public health appropriations.

With the widespread application of the IUD and the pill in particular and especially with the realization of the advantages of improved communications, the United States government in the last years of the Eisenhower administration and during the Kennedy administration went back into the public health business. It has done, I think, a very important job, even though not always appreciated, in trying to bring the population control concept to countries where that concept has been lacking.

We are now, I would suggest, in the third phase, a phase where we should really bring into play some of our knowledge of community's or individual's responses to economic incentives. Most countries of the world have developed rather advanced social security programs. Many times they are not particularly well-funded programs, but there is hardly an underdeveloped country or less developed country that does not have some perception of a social security program. One of the obvious by-products of a social security program is to provide for people's old age in lieu of having large numbers of children.

We could also probably use a great many incentive systems that we have not used in trying to encourage people to reduce family size. It costs the community very heavily to educate children. It costs the

community very heavily to monitor adolescents, something I think we are just beginning to learn in this country. I would argue that it is entirely reasonable to say to people who do not have children in a given year, "Here is part of the saving that the community realizes because you did not have a child." In other words, for every year you don't have a child, you are given some kind of actual tax benefit, or negative tax so to speak. You are given a subvention.

It is quite imaginable that you could say to a woman who does not have a child before, perhaps, age 25, "We will give you something in the neighborhood of four or five thousand dollars," this being a fraction and not even a large portion of the amount of money that the community will have saved by the slowing down of her family's rate of reproduction.

In India they have tried subventions, that is to say, subsidies for males who have had vasectomies. This program has not been a failure. On the other hand, the subvention has been a very small one. In terms of the actual savings to the community, I think it could be fairly argued that the Indians have been relatively shy about sharing with the individuals who have undergone the surgery the benefits to the community.

I will conclude by pointing out very briefly that we may also be returning to the sort of antediluvian state that existed when I was a college student. When I was a college student, if you got married, you lost your fellowship. I am not sure but what, with our greater appreciation of fertility control techniques, the test in the future will be not marriage but pregnancy, which would cause the school involved to say to the individual that it is not consistent for us to subsidize you at the same time that you are building a family.

In any event, this third level or third stage of control where we have what I would call conscious (as contrasted with the first stage, where it was really unconscious) antinatal programs, is really something worth trying and worth experimenting with in a wide variety of ways.

DISCUSSION

QUESTION: What does the panel think would be the effect in most of the less developed nations if one of the services offered by the family planning clinics was the ability to determine the sex of the child in advance?

MISS DIXON: Studies show not only what the ideal family size is, but what the ideal sex composition of it is: usually two boys and one girl, or three boys and two girls, or four boys and three girls. Girls are consistently the lower figure. There is no doubt that predetermining sex would have a great effect in reducing fertility, but that leaves unanswered the whole question of what it is going to do to a society where you may well end with highly unbalanced sex ratios.

COMMENT: In all African tribes a girl is worth money when she gets married, and if the sex of children could be determined, girls would be preferred over boys. Africans love children, and when a man dies, his brother automatically possesses his wife and his children. There is no man happier than the man who gets a wife he did not have to buy and children that he did not have to produce.

DR. ENKE: Of course, one reason for the bride price or lobola in Africa, as compared with the Victorian dowry that fathers had to pay to get rid of their daughters, is that the African woman is extremely hard-working. She is out there in the fields, she is getting water from the river, etc. She is not really so much a liability as an asset.

Dr. Ravenholt, we have a comment that birth control and family planning are not synonymous. Will you answer yes or no, and explain why they are or are not.

DR. RAVENHOLT: Family planning and population planning are not entirely synonymous, because, of course, population planning may have elements of regulation of mortality and migration. But I think in the broader sense that family planning and birth control are indeed synonymous.

QUESTION: It is easy to see how female liberation and how having females become economic entities would reduce the birth fertility rate in underdeveloped countries. But what are your ideas for the United States, where the ideal family size for the American middle class is somewhere around three children? How would you say we should reduce the motivation to have children in the United States?

MISS DIXON: We agreed to confine our discussion in the panel to less developed countries, but I think very much the same kinds of arguments apply to the United States. I don't want to propagandize here, but it still is the case very obviously that the same opportunities are not there for women, that they are socialized into different roles from the very earliest age, and it is not a case of simply ending discrimination and changing the laws. It is a case of beginning right at the beginning, from the time the child is born and saying to the girl: "You, too, can be an engineer. You, too, can be virtually whatever you want." I think this would have a considerable effect on the birth rate in the United States, too, and that it is a very desirable thing to think about.

QUESTION: In a sense, having a large family in the United States among the middle class is not as much of a burden as having a large family in underdeveloped countries. There seems not to be that many clearcut disincentives, such as starvation, lack of education, and so on, in the United States. What is your opinion?

MISS DIXON: It is a burden if you read Sylvia Porter, who can tell you about how much it costs an upper-middle-class couple to raise a child to age 18 before college. She comes up with something like $36,000. That seems to be a little bit of a burden.

QUESTION: It seems to me that when we are considering limiting the population of the lesser developed countries, I find it hard to discover why we expect them to have the same size families as the industrialized countries when their per capita consumption of resources is much less. In terms of the distribution of the wealth, why should they have smaller families, as small families as we have, when we have much greater consumption per capita?

DR. RAVENHOLT: In watching the evolution of our program around the world and the interest of women and couples in many nations in controlling the size of the family, we are consistently impressed that there is indeed a high motivation for this. Where family planning information services are made available appropriately, attractively, and consistently, I know of no place in the world where there is a lack of takers or use of such services. The advantages to the individual woman from controlling her fertility and the individual family are so compelling and important that she will indeed, when given a choice, ordinarily control her fertility. The economies of these societies will greatly benefit from such advantages.

PANEL ON WORLD NUTRITIONAL RESOURCES

Herbert Pollack, Chairman

One of the things we learned about in our two-day session at Columbia, Maryland, is the problem of interface or communication with other disciplines that are involved in the same problems. The problem of communications comes up. These other disciplines often use a language and a terminology somewhat different from that to which we have been accustomed in the life sciences. It is like the story of the State Department school of languages where various languages are taught and people come from foreign countries to learn English. Once, a Russian group was enrolled, and one of the exercises they went through was to take a typical American expression and translate it into Russian. Then after another group translated it back into English, they compared it with the original expression to see how far they had come.

One expression they used was, "The flesh was weak but the spirit was strong." When it came back through the double Russian-English, it read something like "The meat was pretty poor, but the vodka was excellent."

I am afraid that some of what the economists gave to us or what we gave to them is going to turn out to be a hash of this type.

To attempt to understand the world food-people balance problem requires an analysis of a great many factors, each of which is important to this total study. In addition to the study of the individual factors, there is the very complex situation of the interdependence and interaction of one to another.

The nutrition aspect of the food-people balance problem can best be discussed by considering first man's nutritional requirements and then the means for satisfying these requirements through production, processing, distribution, and consumption of foods. To analyze the overall problem requires a systems engineering approach because of the great variety and diversity of interrelated human, industrial, and

governmental factors. In many of these fields today, we lack the basic information necessary to undertake anything approaching a rigorous analysis. What we ought to try to do is identify the important dimensions of the problem and the areas that require major action and research attention. This is what our panel has tried to do.

The major emphasis in most discussions of the world food problem has been related to the need for improved and increased production of food. In its deliberations, this panel agreed to approach the problem from a somewhat different point of view.

Some of the recent FAO data regarding protein production--I am not talking about consumption or anything, I am talking about production--show that our present total protein production in the world is more than adequate for the current world population and leaves an abundant surplus if it were all distributed and consumed properly.

If we examine the present situation with regard to the production of grain in millions of metric tons per population group, it comes out to well over a pound and a half of grain per person per day, which is more than adequate for more than optimum nutrition to all the world, if it were properly distributed. Production is not the problem.

Our panel took a somewhat different point of view from the conventional approach to the nutritional resources problem. We do not mean to minimize the importance of increased production in the future, but our approach has been to find a practical expedient for immediately improving the means of satisfying human food requirements by improving the utilization of our current worldwide production. There are many leaks in the food pipeline, by which I mean wastages from production to consumption--leaks that can be reduced by the exploitation of engineering techniques.

In addition, one can increase the efficiency of human metabolic utilization by control of parasites and disease. The major emphasis of this discussion will be on those areas in which engineers can make significant contributions. The panel does want it understood that it is also cognizant of many nonengineering problems. In the interest of time, however, we will not enumerate them.

The assessment of the adequacy of food resources depends upon the determinates of individual and population food requirements. Many

of the factors involved in the assessment of food requirements are available for this analysis. If we consider population distribution in various parts of the world, we see that there is a broad base that represents the infant part of the population. The percentage of the population that is children represents about two-thirds of a food unit as compared to a working adult who represents one food unit. The older age group in the western civilization constitutes a good part of the population. I believe the figure is getting to be well over 30 percent in the over 55 to 60 age group as compared to the underdeveloped countries, in which the older age group practically disappears.

The most important factor is the total population involved. This is a figure that can be obtained by direct count or by computation. Second, for the total population, is the necessity of knowing the distribution by age group and sex; nutrient requirements vary for different ages in total calories, protein, and the accessory nutrient factors commonly known as the trace elements and vitamins.

It is important to know the maintenance requirements and those to support normal growth. Height and weight are determinants that influence food requirements for adults after the initial growth increments have been satisfied. The energy for physical work must be derived from food, hence work habits and occupational distribution also must be added to the calorie cost of living, but this work factor may not influence protein requirements.

There is an aspect of this problem that has not received the full attention it deserves. It is an accepted fact that malnutrition lowers resistance to infection and also that classical nutritional deficiencies may be precipitated by episodes of acute infection. The infectious diseases bring about an acceleration of the metabolism in the host.

This is illustrated by considering a nutritional study on a patient who had an infection with a sustained high fever. You are all familiar with hospital fever charts. A chart was kept of the fever and also of the amount of food protein eaten, and it was clear that the amount of nitrogen, which is a protein excretory product, exceeded that which was eaten, even though the intake was quite high--over 2,000 calories--and the protein intake was of the order of 70 grams a day, which is also quite high.

During this period of infection, then, this individual was in what we call negative nitrogen balance. In other words, the protein requirement for an individual during any period of infection episodes is infinitely high. It is impossible to satisfy the protein requirement, because an individual cannot under any circumstances retain this nitrogen for either growth or repair. This is an important factor to remember.

Now, that was a single episode of infection that we just considered. Let us now examine an episode of malaria in an individual. At one time we used to treat certain forms of syphilis by inducing malaria in the patient and one got a nonspecific defense that cured the syphilitic problem. This gave us an excellent opportunity to study repeated infections or repeated fevers, because malaria, as you know, has periodic febrile episodes. In a typical study, we allowed the patient to have a great many fevers up to almost 106 degrees. With every fever episode, he lost protein from his body until he exhausted his protein and he finally became seriously undernourished in spite of a good protein intake. This is what happens in the tropics where malaria remains one of the major disease problems, and its effect on protein requirements is fantastic.

Let us consider the nutritional requirements as defined by the National Academy of Sciences-National Research Council; starting in 1941. For each period of time, and as defined, there have been changes in what the NAS-NRC said were the recommended daily allowances. These are the nutritional requirements.

Such a record shows that even this august body, of which I was a member over much of this period of time, has dropped its requirements from 4,500 calories to 2,800 calories in the course of 20 years. If we were comparing caloric intakes in 1941, we would have people who on paper were severely undernourished according to 1941 standards. We take the same people with the same intake in 1968, and now they are fat and obese. Actually, of course, there is no difference in them, but this is a paper calculation upon which a great deal of the food shortage in this world exists by comparison to these fluctuating yardsticks that are the result of armchair thinking. These are informed people and I am not disallowing their calculations. I am merely pointing out that they served a function, but their function has been

perverted to many others for which they were never intended to be used.

Incidentally, those requirements also show you that protein requirements have dropped about 30 percent on paper, although actually they have not changed one bit.

We talked about the impact of disease. How much disease does exist and what are the episodes in the underdeveloped countries? We did some very quick calculations. Tuberculosis, which is one of the major diseases in the world today, puts a penalty of 20 percent on the food intake by requiring this amount to take care of the increased metabolism from the febrile episodes of tuberculosis. Eliminating the tuberculosis would automatically increase the efficiency of utilization by 20 percent of the total calories consumed, and as far as the protein is concerned, it would be fantastic.

The penalty from malaria increases approximately 10 percent over the course of time, and the dysenteries, while individually penalizing only about 6 percent, make a profound effect on food costs and calorie costs, when we consider the total number of dysenteries in the world.

The calorie cost of disease in the entire world population is estimated to be 192 million calories from tuberculosis and 84 million calories from malaria. These are calculations that are based upon the data I just described. This is important. We talk about dysentery and we talk about the major problems in the developing countries. Surely one of the most important problems is infant and child malnutrition. In diarrheal diseases the peak incidence appears at about six months of age, and goes through about 18 months. The incidence of diarrhea is fantastically high in this age group of children. This is the age group of children who suffer the so-called kwashiorkor, the protein malnutrition disturbances. Which came first, the disease or the protein deficiency? Actually it is more or less of a vicious cycle. Certainly the disease is one of the important factors that prevent its cure, until such time as you can stop the protein wastage precepitated by these diarrheal diseases.

In the case of the febrile diseases, as I just pointed out, each degree of increase in body temperature increases the calorie cost 7 percent, so that a 7-degree increase in fever, as you saw in malaria,

means there is a 49 or 50 percent increase in calorie costs during these episodes.

What is more important, however, is the profound influence on the protein metabolism that we just discussed. In the normal metabolic steady state of the adult, the amount of nitrogen excreted by the body equals the amount ingested. We observe that crossover at the point where chemical convalescence begins.

During growth periods there is the retention of nitrogen associated with this phase of life. During acute and chronic infection states, there is a negative nitrogen balance or, in lay terms, there is the loss of body proteins. Since it is virtually impossible to achieve this nitrogen balance under infection conditions, protein requirements then become infinity. If one accepts the definition of malnutrition as the end result of failure to supply nutritional requirements in acceptable forms--that is, the food must be acceptable to the people for the conditions under which the individual is living--then we must stipulate just exactly what these nutritional requirements are and how they are modified by the environmental conditions.

Numerous attempts to establish dietary allowances and nutritional requirements by equally competent groups in different parts of the world, each approaching the problem with different philosophies, have resulted in a number of different conclusions. Whereas the United States standard may be 60 grams of protein a day, the British standard may be 40 grams. One group may say 65 milligrams of vitamin C, and another will say 20 milligrams of vitamin C. These are equally competent people of the same standing in their own countries.

It is this divergence of opinion--and it is opinion, not fact--that leads to a good deal of the confusion in the assessment of nutritional requirements, because the yardsticks are so difficult to follow. However, even at the best, these yardsticks are predicated upon good health and the absence of disease. The total impact of disease, then, is difficult to estimate accurately from the currently available data, but sufficient is known to make some well-informed estimates. Simple calculations show that respiratory tuberculosis increases basal requirements about 20 percent, and malaria and dysentery over time will increase them by 20 to 40 percent. In addition, there is the penalty of the worm burdens such as in hookworm disease. The prevalence of hookworm in many of these populations is as high as 92 percent of those examined. That is a

fantastic burden. The worm burden takes about a 10 percent toll on the caloric efficiency of the ingested food.

Malaria and other tropical diseases such as yaws have another impact on food besides their penalty on calories and proteins. The peak incidence of certain of the tropical diseases, such as malaria, occurs in the springtime, which is the traditional planting time. A two-week illness during the peak of the planting season then will give rise to a complete loss of the agricultural production for a whole growing season. The attention of health programs must be toward improving health before and during the planting season, in order to have the harvest season mean very much.

As a result of recent breakthroughs (the Green Revolution) in the production of cereals in some Asian countries, there is a tendency to predict optimistically that food production will meet man's needs. Implicit in such assertions are the assumptions that production increases are largely a function of farming technology and that increased production on the farm means more food on consumers' tables. Both of these assumptions are only partially true. Because of the very large capital requirements and other considerations, it is not at all certain that high-yield technology will be widely adopted throughout the developing world. Neither can it be assumed that production potentials will necessarily be translated into better nutrition for the great mass of people in low-income countries.

Increased production will have an impact on satisfaction of world food needs. However, it will take an effective demand to sustain this effort. As was pointed out by Dr. Revelle and Dr. Hauser, it requires a whole marketing system (which we will discuss) but the demand on the part of the consumer must be there or else the agricultural people will not continue the productive efforts.

Thus in turn the demand depends upon adequate employment and income widely distributed. At the same time, if the growers are unable to sell their increased product at prices that reward their efforts, they will be disinclined to adopt the yield-increasing technology and production will again lag.

When farmers produce beyond the subsistence needs of their families, they look to a marketing system to sell their additional product. A farmer who grows 100 bushels of corn and uses 80 for his

family has 20 bushels for the market. When he can grow 120 bushels, he will then have 40 to sell. Thus a 20 percent increase in his production doubles his marketing capability, and marketing facilities and systems will therefore have to grow at a faster rate than production to satisfy the needs of both the producer and the consumer.

In most developing countries, marketing facilities and systems have lagged even more than production. When India's wheat harvest rose in 1967 and 1968, the grain was stored in school houses and the children were taught in the open fields. Even then considerable grain was lost to human consumption through various intermediary factors.

Avoidance of waste, then, is a major problem. A tremendous loss occurs in raw agricultural production. It is estimated that India loses almost 50 percent of her crop to various predators such as microorganisms and pests. The cost of retrieving this loss has not been investigated thoroughly, but probably is cheaper than increasing production. Preservation, storage, and processing of foods have also been overlooked.

Because there are large numbers of poor in the developing countries, the population that might be supported by a given level of food production depends in part on what systems can be devised for low-cost or free food distribution to those in the large urban centers and unable to buy at commercial prices. The rural inhabitant always takes care of himself. There is a truism in nutritional circles that agricultural production is consumed at home and the surplus goes to the urban markets. Some kind of commercial arrangement then is especially important for the most vulnerable groups, that is, the preschoolers, nursing mothers, and the aged and the institutionalized, because they are not able to forage for themselves.

These vulnerable groups are the ones for whom protein deficiency is particularly critical, and hence means of improving their diet is a factor in the level of population that may be sustained.

Another critical factor in the estimates of food production and distribution is the capability in developing countries for formulating needed policies and for administering programs that will realize production potentials and translate them into actual consumption. Some of the policy issues involved are commodity prices and the manner in which they are set for producer and consumer, and import restrictions

on factory inputs such as fertilizer, farm machinery, and food processing machinery. The organization and operation of programs affecting farmer production decisions require considerable capability to involve large numbers in hard-to-reach rural areas.

For example, growing seasons may be lost if the seed or fertilizer does not reach the grower at the right time, just the same as the growing season may be lost if illness hits the farmer at the wrong time. Purchase of such inputs, that is, fertilizer, machinery etc., may not be possible if credit is unavailable. The produce will spoil if it cannot be given the appropriate storage as needed.

A more productive agriculture is dependent upon manufactured inputs, such as fertilizer and farm equipment, and upon the facilities necessary to market these farm products. Hence, the developing countries need to see that agricultural support industries keep pace with farming needs. In a number of Asian countries the supply of new seeds and fertilizer has not kept pace with wheat demands. In other countries where rice production has risen, needed drying equipment has not been available. Port and transportation facilities, packaging materials, and processing have lagged behind the sudden jump in production potentials, and foreign currencies have not been available to import enough of these kinds of agricultural support goods.

The technology of food markets from production to the consumer requires substantial attention in order to utilize the already existing production.

The panel has come up with some specific recommendations, focusing its attention on those areas where engineering skills may be utilized. The order in which the recommendations are listed suggests the emphasis that the panel wanted to put on each phase and could result from the efforts in each of these areas.

Technical innovations in the distribution of food supplies is the first topic. Much attention has been given to the production of foodstuffs, but the distribution process has been largely neglected. This is an area in which engineers could instill tremendous innovations such as the following.

- Designing of better storage facilities for harvested crops to reduce the amount of loss to microorganisms, pests, weather, etc. Some of these storage facilities should probably be mobile.

- Development of relevant processing techniques to aid in the marketing and preservation of foodstuffs.

- Improved preservation techniques.

- Development of an efficient, economical marketing system that would include the dispensation of market and price information to rural areas, improved packaging, etc.

- New techniques in the utilization of presently unused food sources for direct human consumption. For example, the development of edible human food directly from peanut meal, which is now largely lost because the oil is extracted and the meal is discarded. Sunflower meal and rape seed residuals go through the same discarding process.

The second major topic pertains to increasing the efficiency of human utilization. As we pointed out, this is one of the major factors and can be amenable to change rather rapidly.

As was noted previously, much of the world's food production is expended in compensating for the effects of disease. It has been estimated that as much as 10 percent of human food intake in underdeveloped countries is lost through the ravages of febrile and diarrheal diseases. Elimination of such conditions thus represents a major opportunity to reduce the world's nutrient requirements.

Priority must be given to developing better public health systems for underdeveloped countries--this is an engineering problem. Provision of sanitary water supplies can contribute greatly to reducing the nutrient loss due to disease. The reduction in incidence of diarrheal disease by design of effective sewage disposal systems, drainage of swamps for the prevention of malaria, design of housing to eliminate crowding and contact infection can all play important roles in reducing the burden of disease.

The design of systems for prevention of disease deserves equally careful consideration. Programs for primary prevention through vaccination and prevention of disease transmission through identification and treatment of disease carriers also provide opportunities for engineering attention.

To show you some of the complexities of the interactions of the multiplicity of factors involved in our discussions of this total overall problem, consider the fact that we have production, distribution, preservation, calorie requirements, vitamins, proteins, etc., in the nutrition supply system. In each of these categories we have soil, fertilizer, production, management, crop mix, price, credit, distribution, storage, packaging, wholesale, retail, rules and regulations, pricing, and preservation. We can list the whole series of preservation, milling, smoking, drying, fermentation, etc., and then add the requirements of age distribution, sex, anthropological development, work habits, climate, disease, and so on, and we come up with a very complex matrix indeed.

DR. CHICHESTER:

We all had some input to this panel and I represent an area of concern that has not, I think, had very much emphasis in recent times. We are worried about food, food to feed an ever-increasing population. I think we have taken a very simplistic view of this problem. We have decided that the way to solve the problem of supplying everyone with food is to increase production and we have put by far the major amount of our emphasis on increasing production.

We have had great success with it: we have the Green Revolution. We are able to increase the yields of calories and proteins by very significant amounts, and therefore we can perhaps pat ourselves on the back and say we have really solved the problem even for a long period of time, because these products are now available, so food will obviously go to the consumer.

I would suggest that this is really not so, and that we are perhaps pursuing a pie in the sky with this attitude. Yes, we do have higher production. We have a potential for producing more than ever before that could, but does not necessarily, end up as food in the belly of the consumer.

We know that even without the Green Revolution we produce more foodstuffs by factors estimated by some people to be as high as twice our requirements at the present time. Yet many areas of the world

suffer from malnutrition and deprivation. Some people suggest that this can be explained on the basis that the developed countries consume far more than their share, and therefore there is little left for the rest of the world. This is partially but not entirely true, since the actual amount consumed by the developed countries still leaves production available for the rest of the world. The problem is that it does not reach the people. It rots in the fields; the rats eat it; the material is dumped and rots away before it ever gets to market.

One can use the argument (which has been heard before) that even under the worst conditions, India produced enough food in the field to feed all of its population. But all of this production could not get to the people, so the United States, Canada, and other countries contributed food for the Indian people, and in effect the food that was shipped to India went to feed the rats. Then if you made the equation, India fed itself and we fed the rats.

Now, I would suggest, in view of what the population panel has just told us, that this problem will become significantly worse. I think here is where consideration should be given to the implosion effects, the migration of the farmer (and this will be accelerated by the Green Revolution, since the individual farmer can be more productive) from the rural community to the city. We now move a lot of people away from subsistence agriculture in which they produced enough food to feed themselves, and perhaps have a little left over to market. They could exist on incomes of $80 or $100 a year.

Once they move to the city, though, they become part of the labor force. I am not really prepared to discuss this, except that once they move to the city, they then contribute to the logistics problem of taking the food that is produced in the field, transporting it to the city, and offering it to these people at a price that they can afford. We have not looked at this problem adequately. We have not studied ways to reduce the loss in produce going to market. We have not looked at the technology or the systems that are needed to deliver food from the farming community, particularly rural or semisubsistence farms, to an urban population in the less developed countries.

In Europe, the United States, Australia, and other developed countries, we have developed very sophisticated methods for moving food. We have substituted to a very large extent labor in factories

for labor at home. We talk very glibly about things like convenience foods, and if our economist friends want a system that is labor-intensive, the food industry certainly serves part of this and can serve in this capacity.

Nonetheless, having developed a very sophisticated industry (compared to the rest of the world) to supply food to urban centers, we are finding that even in this sophistication we are beginning to have more and more trouble. Compared to the rest of the world, though, we have very little.

Dr. Pollack mentioned the increase in nutritional requirements brought about by diarrheal states. Most of the infectious organisms that cause this disease are transmitted by food, and consequently we are then approaching a phase of evolution of the world population where people are being packed into cities and we have no logistic means of supporting these people, either to give them income or for that matter to supply food to them.

There is a solution, of course. There always is a possibility of a way out of this by developing a technology suitable for the areas in which it is to be employed. Many people have suggested that we can simply transfer our technology to other countries. I submit that this has not worked before and there is no reason to expect it to work in the food situation.

So we have two choices to actually increase the available food, not the available production, at the moment. One is the introduction of a technology suitable for the geographic area--and an improved marketing system obviously goes along with this. The other is a more concerted attack, and technology can supply this--engineers obviously are involved in technology--a more concerted attack on the losses that we experience every day.

DR. KRIESBERG:

I am in substantial agreement with Dr. Chichester and the need for more attention to the problems of food marketing and distribution. I am also in substantial agreement with Dr. Pollack. But let us pause a moment

to try to see what are the available food supplies, and what are the prospects for producing the food needed by burgeoning populations in less developed countries.

In the first place, a number of studies on food balances in different parts of the world do suggest more reason for optimism than we had a few years ago. This optimism is perhaps like the pessimism of a few years ago, exaggerated in terms of what has been achieved and what is likely to be achieved.

There are considerable regional differences in the developing world as to how close they are to growing the amount of food their own population requires at the present time. There is also considerable difference as to what the potentials are in these different regions of the world in terms of present populations and foreseeable population growth rates.

Let me indicate by a few numbers what these ranges are. For example, if we look at the Central America-Carribbean area, we find that current grain usage there runs now about 160 kilograms per year. (Grain is a measure since it represents about 70 percent of the caloric intake of most people in the developing countries.) On the other hand, it goes down to as low as 100 kilograms per year in west Africa and goes up to as high as 242 kilograms per person in southeast Asia. So there is a wide range. But the range is even greater within countries. Hence when we use average food availability, it seems that we can be optimistic--until we begin to examine the nature of some of these averages.

As another example, let us assume that minimum requirements are 2,600 calories per person per day. There are variations among people as to what it really ought to be --based on size of person, amount of work he does, age, and a number of other factors--but let us assume 2,600 because a number of people have used this figure. Let us assume further that there is availability of calories in the country on an average of about 2,500. That is a difference of about 100 calories, and maybe that is not a great deal. We do know that in the United States, for example, the net usage is of the order of 3,000 calories. That may be a little high, but that is about what the going rate is.

But let us pose for a minute what happens when we take this hypothetical country that has an average caloric availability of 2,500, and we say that 40 percent of the population that can afford adequate diets takes its full share of the calories available in that country, perhaps 2,800 or 2,900 calories. If 40 percent of the people take this off the top, what is left for the other 60 percent of the population?

If my arithmetic serves me correctly, it would be just barely over 2,000 calories on an average for the 60 percent with lower incomes. Then if you want to take the lowest 30 percent by incomes, the amount of calories they could buy at market prices would be much less. Thus, one finds that there is a very large proportion of the population of developing countries that certainly do not have anything close to the average amount of food or calories available.

So, while there is room for optimism, we cannot be complacent about the food-population balance. There are so many things that yet need to be done if the higher production rates are to be sustained, and of course the translation of that production into consumption.

Estimates by the FAO and by the President's Science Advisory Council, a few years ago, that production rates of growth in food would need to go up about 4 percent per year in order to keep barely ahead of the estimate of growth in population and the increased requirements based on some increases in income that might be anticipated with increased development in these countries; 4 percent annual growth rate is greater than that which has been historically the case in just about every country in the world.

The estimates are that it would take a tremendous amount of resources, much larger than those now being made available, in these countries on a bilateral or multilateral assistance basis to assure that kind of growth rate.

So, some optimism on the production side, yes; but I would urge that we do not equate production with consumption.

Let me make an additional comment on the subject of food distribution. There are two problems of distribution that we need to be concerned with in terms of satisfying consumer needs. One has to do with the physical movement of commodities, and that involves the transportation, storage, handling, and aggregate cost and mechanism for moving

the increased tonnage from the places where it is grown to the large urban areas where most of it is consumed.

The other is the economic side of distribution, and that is making it possible for people to afford, or more nearly afford, a more adequate diet. For this, we need to turn to overall economic development on the one hand, and on the other hand to devising new delivery systems. Such systems need to reckon with the likelihood that large proportions of the population of these countries cannot afford the kind of diets or the kind of nutrition that they need.

Engineers can do a great deal to develop the physical properties and the components of a more efficient food marketing system. Working with economists and nutritionists, engineers can also contribute to a better working socioeconomic system for food distribution.

Among specific engineering tasks, the following might be suggested:

(1) Developing small low-cost grain storage facilities for on-farm or local village usage.

(2) Designing low-cost refrigeration units for the tens of thousands of small retail stores in low-income countries.

(3) Developing means to reduce the humidity as well as the temperature in warehouses for storing such commodities as potatoes and pulses.

(4) Developing portable low-cost bridges that may be used in conjunction with farm-to-market roads, to facilitate the movement of farm inputs and farm products in seasons when swollen streams have traditionally interfered with such traffic.

On the socioeconomic aspects of delivery systems, I believe that a great deal might be done by systems designers in the engineering professions. I have in mind whole-system analyses concerned with costs and benefits of alternative commodities that might be grown and that might satisfy nutritional needs in a country. There are possibilities for greater rationalization in the use of resources by interregional trade in commodities, using comparative cost advantages more fully. I see possibilities for improving the process of sales transactions to facilitate the expanding commercialization of agriculture in developing

countries. These are some of the things that engineers might undertake--in the interest of translating farm production into food consumption for the people of developing countries.

DR. POLLACK:

Let me just make one supplementary remark using my prerogative as chairman. One hears a difference of, say, 3,200 calories required for the western Caucasian, and 2,500 calories for the Asian Oriental, and these are comparable figures. May I remind you that the "standard man," which is used purely as a reference point, in the Caucasian world is 5 feet 10 inches tall and weighs 170 pounds with a surface area of 1.85 square meters. The standard man in the Orient is 5 feet 4 inches tall and weighs 122 pounds with a surface area of only about 1.4 square meters. The caloric requirement of the standard man in the Orient is actually slightly less than 2,500, and the caloric requirement of the standard Caucasian man is actually about 3,200. The difference is a physiological necessity and requirement. When we discuss averages, please bear in mind that the figures are not comparable except by interpretation of the actual anthropological measurements of these people and their full physiological requirements.

DR. ROCKWELL:

What I will speak in favor of is trying to improve the planning process for meeting the world's nutritional requirements. I suggest that there are great benefits possible from objective consideration of the problem in a couple of ways.

First of all, it seems to me that there is a class of very interesting problems that derive from predicting the nutritional requirements the world will face in the years to come. You have heard subtle differences of opinion as to what these requirements are. We have talked about a number of factors that will affect them: age, sex, height, weight, life style, disease, and so forth. The distribution of these factors can have really profound impacts on the nutritional requirements.

If, for example, you just alter the life style of a given human being--convert him from a sedentary life style to a very active one--you will nearly double his caloric requirement. Over the next decades, great changes are presumably going to take place in nations. People are going to come from farms into the cities and vice versa. I think the consensus of our panel has been that it is very difficult to get a very good fix on what are our caloric requirements, and not only caloric requirements, but also the other nutritional components. So here is a class of intellectual problems that I think engineers and others should find very entertaining and profitable in the years to come--to consider the problems of predicting the nutritional requirements of the world.

There is another class of problems to be considered in the sense of modeling; these grow from the other side of the balance. How do we meet the requirements? Various questions of planning crop mix and land allocation apparently have not been well considered. I believe that is the consensus of our panel. Work on the decision-making process at the level of the individual farmer or the producer of nutrients seems to show promise in the engineering community.

There is the networking class of problems. How do you get the food from the point at which it is grown to the point at which it is consumed without having bottlenecks and wastage? Again, operations research methods have been developed that seem to show promise in improving this process. I believe it is the consensus of our panel that they have not been adequately explored or exploited and that they provide a useful class of endeavor for the engineering community.

There is the general question of resource allocation models. How should a developing country invest its available funds? This again presents a very complex problem in which comparatively little work has been done. Should one dollar be spent on developing a transportation system for every dollar that is invested in the fields per se?

There is the question of rationalizing the development of agricultural processes as part of the developing economy as a whole. Again I think it is the consensus of our panel that many intriguing problems fall in this area.

Then there is the development of planning aids and management aids that may help less developed countries in meeting their own requirements; an example of such aids is the PERT program management technique. It might be modified. It might be useful in helping countries that don't have a large staff of managers to improve the development of their nutrient system.

Let me quickly touch on some of the advantages. First of all, those of you who develop decision models are well aware of these, I think. It is not clear what new data are needed; trying to develop these decision models will help focus on what classes of data ought to be collected.

Secondly, work in this area presumably will force decision-makers to consider a wider range of possibilities, and this in the long run should be good. It will aid in the understanding of the complex interactions. One does not have to think about the problem very long to see the enormous number of interactions and ramifications to trying to improve the nutrient production in a country with a comparatively small number of resources.

We think there is a motivation for the engineering community to devote time and effort to this on two grounds. First, it is an intellectually fascinating class of problems. A lot of graduate students ought to be able to get doctorates by working on various aspects of the decision process. Second, I think it is the consensus of our panel that a profit can be made; that there is a great market particularly in less developed countries for people who are capable of contributing to the planning process and making it more efficient.

The problems seem to be appealing from an intellectual point of view. They show great promise of contributing substantially to solving the food-people problem, and it may be possible to make an economic profit in the process as well.

DISCUSSION

QUESTION: Dr. Kriesberg, Dr. Revelle mentioned the projected increase in harvest of protein from the sea. Given the fact that the most productive areas of the sea are very limited areas, a very small percentage

of the sea in general, and given also the fact that these are the areas that are suffering most from pollution from the continents, do you consider this an overly optimistic prediction?

DR. KRIESBERG: Yes, I do. In general we have been somewhat overly optimistic about the proportion of the food that might be available for human consumption coming from the sea. I am less sure of the proportion specifically concerned with protein possibilities, but even here I suspect that there are alternatives that are more economic and that have wider acceptance than that which would be obtainable from the sea.

QUESTION: Dr. Chichester, I agree with you completely on the tragedy involved in the waste of food, but I am also concerned about the possibility of someone misinterpreting what you said about the food we sent to India. I have had to deal with the question of the allegation that the food we shipped over there under PL 480 was used to feed the rats. Would you please clarify your statement on that.

DR. CHICHESTER: The material that we sent under PL 480 was used to feed the Indian population. The reason we had to send it was because they experienced a drought, and they, like we, also experienced tremendous losses of the product in the field because of rodent infestation, spoilage, and improper storage; the food just dropped on the ground between here and there. So, we shipped the equivalent to them of their normal losses, but the food that we shipped was fed to the Indian people. The point is that what we sent them went largely to replace the losses in what they had in fact produced but could not use.

QUESTION: One of the problems that I can see is that of education, both as to what to do with the food once you get it and how to preserve it. If we have good food, lots of it, good nutrition, that is going to have some impact on the number of women who reach childbearing age, which is also going to have an impact on the population growth. This is a matter of education. Have you considered educating a population that at present believes we have to have six children so that one will reach majority? Do we have to start the educational process before the food process actually is completed so that those children that are born will

not reach childbearing age? Have you considered the educational possibility with respect to nutrition?

DR. CHICHESTER: There is no doubt that if you supply a population with more food and better nutritional balance, the mortality from disease probably is decreased. It does not prevent the individual from becoming diseased, but it probably aids in his survival.

Moreover, if you feed a population better, and this is to a certain extent a supposition, they grow larger and therefore increase their caloric requirements. However, if they are better able to work and be productive, and you can assure them that they will not lose their children in infancy, from a population control standpoint you have a much better chance of convincing the average family to accept a smaller number of children. Traditionally, one reason for having a large number of children is to ensure that at least some of them lived to be able to support you when you could no longer do it. Yes, I think education in nutrition is worthwhile. I am not sure that I know, though, how to attack this problem in underdeveloped or developing countries effectively. There has been quite a bit of effort in this area, and I think we have not found the best solution by any means.

DR. POLLACK: We need to utilize the anthropological disciplines to learn how to make effective educational programs. We have spent a great deal of money in nutritional education over the course of many, many years. I have been personally involved in a good deal of this and to date I think our success is just about nil. Part of the problem has been our inability to understand the real problems of the recipient of the education. We need better sociological understanding or anthropological understanding of the people we are trying to reach. What are the things that we can do to identify or make them identify themselves with the programs to improve general health conditions and food utilization?

QUESTION: Several years ago when the government of India was being inundated with estimates from various agencies as to how much of India's crop was lost at various points along the way, various international agencies as well as United States and third-country agencies were all making estimates. Since some of these studies overlapped, some

related to loss in the field, some during harvest, some in transport and so on, they unreasonably added the figures together and came to the startling conclusion that India loses 112 percent of her crop every year.

One has to be realistic in estimating food losses. Obviously the losses are regrettable, but I think they are probably exaggerated.

Are there not levels of loss that are not only acceptable but also economically sensible? In other words, has there been any level at which we can say it costs more to eliminate the loss than to grow the food?

DR. CHICHESTER: I agree with you. Obviously one may be able to talk about zero population growth, but one cannot talk about zero loss from an agricultural commodity. Your question is what is the level that is acceptable economically? I would submit that in many places, even in the United States, we experience considerable losses. We happen to be able to afford it because we are a large producer. But that does not mean we are able to afford it economically, and therefore over the years we have reduced our losses. We make a major effort, but we never eliminate them.

However, in the developing countries, these losses exceed ours by a very large factor, perhaps two or two and a half times. This is not only because of not possessing the technological equipment, but also because the know-how to develop an efficient marketing system does not exist. I am suggesting that this is one place where the engineers can make a very significant contribution. I am not suggesting that we immediately abandon any efforts to increase production, but I think this is an area in which the marketing of foods, particularly in an urban situation, has been sadly neglected in the less developed countries. From a program standpoint, however, it is rather difficult to handle. It requires both research and the development of technology. It requires education of people to handle whatever technology is developed, and of course it requires an investment in both money and time. Again my suggestion is that this is an area in which one can increase food on the table at moderate cost. The way our statistics are set up, food availability is figured on what is grown. This increases the supply of food, but not necessarily the supply of nutrients. We have to be a little careful about whether we talk about nutrients or food, but reducing

production losses increases the supply of food getting to the consumer, and this is the point.

DR. POLLACK: There is also another factor to this problem. In this country and in the developing countries we process our wheats and mill them to a high degree of white flour. One of the main purposes of this originally was to extend its shelf life, because unmilled flours turn rancid and get full of weevils and other insects. A few years ago, during the war particularly, we heard the hue and cry that in processing flour, we were removing all the vitamins, so we then had to develop the technology of putting the vitamins back into the flour before it came to the table. Any preservation of food over a period of time will always lead to a degradation or definite loss of the micronutrients, by which I mean vitamins particularly, so that we have to guard against or replace or replenish these vitamin losses that occur in the protection of the staples.

QUESTION: I am worried about the price of the Green Revolution. I would like to ask whether the panelists have information on the projected world supplies of fertilizers and water, which are very important components in the Green Revolution, and also whether they have any information about the effects of this revolution on the soil as a result of the intense irrigation.

DR. OLD: We have recently looked at the fertilizer balance in southeast Asia going from roughly the Philippines to India, and it is currently projected that fertilizer and the fertilizer picture will be in balance by about 1974 to supply the Green Revolution types of crops.

QUESTION: Do you mean crops on the presently arable land or does the estimate contain projections of bringing in crops on marginal land?

DR. OLD: It covers the arable land that will be required for the food production, which goes down as you use the intensified crops.

DR. POLLACK: With respect to the water and irrigation effects, the use of tube wells and other types of deep-water release in this Green Revolution leads to a potentially dangerous situation, at least one which is thought-provoking. There was a drop of 17 feet in the water table in one area of India that was reported to us at the panel meeting. Just what the significance of this will be over the period of time and what will happen to other groundwater supplies we do not know, but we must be alert to these as potential problems of the Green Revolution. It is not without its mixed benefits and probable risks. What the good is and what the bad is will have to be examined very carefully.

QUESTION: Dr. Old answered the question on fertilizer availability, but failed to answer the question on whether fertilizers were going to affect soil productivity. Dr. Chichester emphasized this whole question of getting the food to the people and emphasized the loss to rats and to vermin. In both of these areas we have the suggestion that engineers should solve this problem. I would like to ask you, Dr. Pollack, whether you see any problem in having engineers solve what are basically ecological problems?

DR. POLLACK: The engineer in this case is a tool, in that engineering techniques are tools to be used in the structure of the total approach to the problem. It is not intended to say that we are going to use engineers to solve our ecological problems. But many aspects do require the help and use of engineering techniques. Whether or not fertilizers are going to affect fertility of the soil is something else and we will have to wait in the course of time to see. Certainly the experiences in this country over the period of many years that we have been using fertilizer have not been to indicate such deteriorations.

DR. CHICHESTER: Perhaps I put too much emphasis in my discussion on pest control in particular, which is certainly one aspect, but, you see, to deliver food to the people you have to preserve it. In many cases, you have to process it to give it stability. You have to build silos. You have to build farm-to-market roads. You have to develop packages that will protect it from disease organisms. You have to learn how to do this and do it on a commercial scale. This I believe is within the province of the engineer, and it is not necessarily--except peripherally, in the actual handling of the raw material--something that reflects on the ecological problem.

QUESTION: Earlier we discussed the loss of foods through waste, but nothing was mentioned about potential losses that come from paying United States farmers not to grow food. Would a panelist comment on that topic?

DR. KRIESBERG: When the American farmers are "paid not to produce," what we are doing as a matter of public policy is helping them plan their production in line with our domestic needs, our likely sales overseas, and our food aid commitments to food-short countries. Farmers expect to have a right to get paid for what they produce, yet as citizens or taxpayers we would want to bear the burden of paying our farmers to feed the world. Hence, our policies help farmers produce amounts that are in line with what the market will take, both the United States domestic market and the foreign markets.

When India required much larger PL 480 shipments--food aid--it was our policy to encourage American farmers to produce more and that helped to meet India's needs. With India's production increasing, and India therefore requiring less food aid (I am using India as a case in point, because it was a large user of PL 480 foods), United States policy sought to reduce production so as not to rebuild unnecessary resources. We put some land back into the bank, so to speak, for future needs as might be required. It is a matter of making use of our productive resources, but also helping the other countries to develop their own resources to handle their own needs, rather than to remain dependent upon United States charity.

PANEL ON INTERACTIONS BETWEEN WORLD POPULATION AND WORLD NUTRITIONAL RESOURCES

Erik Thorbecke, Chairman

The first point our panel has made is that if it were possible to construct a complete quantitative model of the world economy, which contained all of the important relationships on the production side, on the demand side, and on the technological side, as well as the institutional and behavioral relationships and constraints, it would be possible to follow through in a quantitative way explicitly the interactions between world food production and world population growth. One could trace time paths of these variables that would be interesting in terms of really finding out explicitly the extent to which there is interaction between these two variables.

Now, it is of course clear that given the present state of knowledge, it is Utopian to try to do this kind of work. So, we will try to examine each side somewhat independently of the other, and then try to bring them all together.

First, I would like to present the status of the food-population balance. Second, I would like to discuss briefly the future prospects for food production and population control. Finally I will list some recommendations that our panel felt might be relevant from the standpoint of what the engineering community might want to consider doing as a follow-up to this symposium.

Looking at the food-population balance, the first statement to be made is that the quality of the statistical data upon which many of the existing analyses are based is extremely low. It is low both on the food production side and on the population side. It is well to remember that a great deal of the production in the developing countries takes place in traditional agriculture, in the subsistence sector. Much of this production is for self-consumption, and it is clear that any estimate aimed at measuring the size of the total production is bound to

have a fairly large degree of error. On the population side we have the same problem when it comes to measuring the sizes of populations in those areas that are somewhat removed from large urban centers.

So, at this stage, we ought to keep in mind that the measurement problem is a serious one. Notwithstanding this, I think that everything that has been said so far in these proceedings would be consistent with our belief that there is in fact a significant world food problem. It is not a problem from a total global standpoint--from the standpoint of taking the total production of foodstuffs and simply dividing it by the number of people on the face of this earth--but it is a problem when we look at the distribution of this food among the different countries, and even more importantly, among the people within a particular country.

In many of the developing countries, we find that the income distribution tends to be extremely uneven, which means that there are large groups within these countries who simply do not have the purchasing power--the income--necessary to obtain the food.

In any discussion of the world food problem, it is essential to relate food production to overall economic development. Dr. Revelle has indicated this, but I would like to make a few additional points.

On the one hand, this relationship is important from the standpoint of being sure that the food that is actually produced can be sold commercially. This means that outside of agriculture there must be a sufficiently high rate of income growth to make possible the purchase of this food.

On the other hand, we know that, particularly as a result of the new technologies that have been well described here, there are requirements within agriculture for all kinds of inputs that come from the industrial sector, such as water, fertilizer, and insecticides. This means that the industrial sector and some of the other sectors of the economy must make their own contributions to agriculture. There is a whole set of relationships between agriculture and the other sectors that are essential in the process of economic development. In the process of growth, it is important to have balance between the growth of these different sectors. If agriculture grows too fast, then of course what is going to happen is that the food actually produced might be sold only at lower prices. This will tend to discourage further production. On the other hand, if there are food scarcities, if the growth rate of production in agriculture tends to be too small, then agricultural

prices will rise and this will discourage consumption. Thus it is quite important to have balanced growth in terms of these various sectors of the economy.

Looking at the Green Revolution, one of its extremely important consequences is that it might make some contributions to what is perhaps the most serious problem that developing countries are facing, namely, that of underemployment and unemployment. I would go as far as to say that in the decade of the 1970's, this problem may be more serious than the food problem.

Now, the problem of unemployment and underemployment is of course caused by many factors, but the principal reason has been the acceleration of the growth rate of population. Some of the symptoms of this problem have been (1) the very large migration from the rural areas to the urban areas in practically every developing country in the world and (2) the fact that in practically all of the large cities of the developing countries we find urban slum areas that cause all kinds of economic, social, and sometimes political problems.

One of the impacts of the Green Revolution is going to be on labor requirements, and here the first rather obvious effect is that it will increase the labor requirements in agriculture per acre because, now with the new technologies, more labor will be required to apply fertilizer. There might be multiple cropping, which will of course require different labor activities. So, on a per-acre basis, the demand for labor will increase. On the other hand, because of the tremendous yield increases, the labor requirements per unit of output are very definitely likely to fall. We foresee the problem that in the next five years or so the net effects of these two forces will be positive in terms of increasing labor absorption within agriculture, but beyond what may be a five- or six-year period, it is quite likely that any further absorption of labor within agriculture as a result of these new technologies will be very difficult. So in the very short run, I think that the Green Revolution may play an important role in terms of mopping up, in a productive sense, part of the labor force that otherwise would go to the cities and be underemployed or unemployed, and create the kinds of problems that I mentioned above.

There is one rather specific point where we felt that the engineering community might be helpful. Even though there is a great deal of underemployment in agriculture, certain bottlenecks exist at harvest

time--at peak harvest time--and these might be greatly alleviated by the design of new and highly selective types of mechanical implements. They might be specialized tractors or other kinds of selective mechanization, which would not substitute for labor during the remainder of the year. This is an engineering problem that should and probably will be faced in the near future.

A second effect of the Green Revolution that has not been discussed is that it seems to indicate that even traditional farmers are responsive to monetary incentives. We have seen small farmers in Pakistan respond to the tremendous increase in the profitability of the new seeds. We have seen them adopt new technologies basically as a response to the availability of profits and the proper relationship between the prices of output and the prices of the inputs.

I would like to say a few words about the function that the sectors outside of agriculture might have to perform in the process of economic development necessary for the food produced to actually be consumed. The report prepared by the President's Science Advisory Committee on the world food problem estimated that the rate of growth of gross national product--the rate of growth of income in the developing countries--would have to be of the order of 5.5 percent per year over the decade of the 1970's. This is a relatively high target. It is lower than the Pearson target of 6 percent, but it is feasible. However, one of the obstacles to the achievement of this growth rate is that in a number of the developing countries, there is a tendency to substitute capital for labor (despite widespread unemployment), rather than to employ techniques that would be more labor-intensive and that would fit much better the resource endowments existing in these countries.

There are at least two reasons, I think, for the adoption of relatively capital-intensive techniques in these countries. The first reason is the many policies in these countries that make the price of labor higher than its contribution to output. Minimum wage rates exist. The employer has to pay all kinds of fringe benefits. And union pressures make the price of labor higher than its equilibrium value, that is, its total output.

On the other hand, some policies discriminate in favor of capital. The use of overvalued exchange rates makes capital imports cheaper than they really should be. The presence of various tax schemes, tax exemptions, and exonerations, as well as the use of subsidized interest

rates has had the impact of making capital relatively cheap in many developing countries. Every rational businessman reacts by using more of the relatively cheap factor and less of the relatively expensive factor, and naturally he will choose a technique that is relatively capital-intensive.

This, of course, has contributed very greatly to the unemployment problem in these countries and our feeling was that it would be extremely desirable to see what the engineering community could do in terms of either rejuvenating existing techniques that could be adapted to the requirements of these countries, or secondly, perhaps, to designing entirely new technologies, which again would be better suited and better tailored to the conditions existing in these developing countries.

Finally, a third area where we felt that the engineering community might have a contribution to make, again dealing with the production side, is in helping economists in the construction of qualitative models of various economies and regions. These quantitative models are usually of a multisectoral nature in the developing countries. They contain a number of sectors, such as agriculture, manufacturing, and services. They contain information on the production relationships among and within these sectors, and some of these models have become relatively sophisticated, being of a linear or sometimes quadratic programming type. We felt that a very fruitful cooperation could be started here between economists and engineers in this general area.

Whereas our panel's examination of the food prospects warranted guarded optimism, when we started looking at world population, we became very pessimistic. There is no need to repeat what has already been mentioned, but let me emphasize a few points.

It is interesting to note that if we look at the averages, and if we say that the rate of growth of population in the developing world is now of the order of 2.6 percent per year, this is really the average of a distribution where you have some countries with population growth rates of 3.3 or 3.4 percent in Latin America. It also hides the fact that there are a number of countries way below this average--2 percent or 2.1 percent in Africa, where the growth rate of population is bound to increase in the near future. This because we find in these countries that the mortality rate is still declining rather rapidly as a result of

better sanitation, better health care, and so on. So the problem is indeed not entirely global. It is a problem that must be looked at from the standpoint of different countries and different regions.

From an economic standpoint, the implications of a very high rate of growth of population are of course that the level of aggregate income has to grow at least as fast as the population to maintain the standard of living at the same level. If you have a rate of growth of population of 3 percent, it means that you need at least a 3 percent rate of growth of gross national product to maintain the same standard of living. In other words, you almost have to run in order to stand still. I think this is something that has not been sufficiently appreciated.

In order to achieve any increase in the standard of living, in order to achieve any increase in per capita income, the order of magnitude of the necessary increase in income is probably about 6 percent. If there is a 6 percent rate of growth of gross national product with a 3 percent rate of growth of population, it means somewhat less than a 3 percent increase in per capita income.

Now, what does this mean? It means that a country like India, which today has a per capita income of about $100 a year, would take about 27 years to get to a level of per capita income of $200 a year. This is not very encouraging. You start at extremely low levels of per capita income, and even on the expectation of being successful in achieving relatively high income growth rates, the absolute increase in income that results is fairly small. I am sure that $200 per capita is much better than $100, but it is a far cry from the $4,000 average income that we have in this country.

I will conclude now with the recommendations that the panel has made, and I have already indicated two such recommendations dealing with the desirability of the engineering community looking at what can be done in terms of designing selective mechanization processes for the type of agriculture that we find in the developing countries. I also mentioned the fact that the adaptation of all of the techniques that would be less capital-intensive than they are in the developed countries might contribute substantially to the further income growth and output growth of the developing countries.

Our next recommendation is that the continuing diffusion of the new technologies in agriculture will necessitate large investments in water, and here, as Dr. Revelle mentioned, it is clear that the engineers can play an important role.

I have also mentioned the contribution that engineers might make in collaborating with economists on the construction of models of developing countries. Such models could be used for policy purposes, to arrive at a determination of the kinds of policies to be used at the macroeconomic level--that is, at the level of the government--as well as at the level of the individual business.

Another recommendation was that a number of younger engineers should be encouraged to become more interested in training in international economic development. It is conceivable that some of them might move from outer space to "inner space," and look at some of the countries outside of the United States in a somewhat more intensive way than they have done in the past. Here it is possible that more attention to the teaching of basic economic tools and the teaching of tools useful to engineers might be encouraged. There are a number of engineering economics schools (Stanford has such a school), and it is possible that this kind of interaction might indeed be fruitful.

The panel also recommended that the National Academy of Engineering take the leadership in sponsoring workshops and seminars to facilitate the interchange of ideas among economists, engineers, demographers, sociologists, and other professionals who are interested in economic development and who have already made some contributions to an understanding of the process of economic development.

Our last recommendation was that the Academy might consider establishing more intensive links of either formal or informal nature with a number of the international agencies, such as the World Bank, and also some of the bilateral agencies such as AID--agencies working in the area of international development--who need a great deal of engineering skills and engineering information. This kind of interaction, which might be formal or informal, might indeed make possible the provision of the required engineering talents to these agencies (which might further the process of economic development) and also would provide the Academy and the engineering community with a better understanding of the kinds of problems and the kinds of questions that are faced by these agencies.

DR. YUDELMAN:

It occurred to me that perhaps some of the audience doesn't really know what the Green Revolution is. In developing countries agricultural output was traditionally expanded through expanding acreage. Agriculture pushed ahead with the fringes of cultivation. However, the systems that we used were very land wasteful. As population pressure increased and as demand for food increased, it was found that this system or method was not meeting the requirements or the demands of the people and population.

So it became necessary to think in terms of increasing yields per acre, and basically the Green Revolution is all about increasing yields per acre. In increasing yields per acre, the techniques of production that we used when land was plentiful were not applicable. We had to develop a new technology; something had to be different. The method of shifting cultivation, crop rotation, planting in straight lines, and so forth, which increased output as you used an increasing amount of land, did not apply when you had a fixed land acreage.

Now, the technology that was developed came out of research conducted by the Rockefeller Foundation over a 20-year period. This technology is basically the production of new varieties of seeds. The main feature of these seeds was that they gave very high yields when used with fertilizer on experimental plots. This initiated the Green Revolution, starting in Mexico.

In order to spread the Green Revolution, it was necessary to go through the whole process of agricultural development. Some of the requirements of agricultural development have been mentioned here. You have to have seeds, you have to have fertilizer, you have to have credit, you have to have roads, you have to have markets, and all the rest of it. But there are two significant things about the Green Revolution. One, that the new seed varieties changed a very important component of the system, which in turn had a series of effects on the rest of the system.

Secondly, it was found that our concept of the peasants as people who really did not respond to economic incentives was incorrect. The Green Revolution has indicated that where farming is profitable, and farming becomes profitable when yields rise substantially and there is

a satisfactory ratio of prices between inputs and outputs, then people respond.

These are the two things that have happened. The Green Revolution experiments indicated that yields could be increased, and in recent years there has been a substantial spread of the new technology. Now we are interested in such questions as who have been the new farmers, what are the limits of the Green Revolution, and what can be done about it.

First of all, who have been the people who have responded? As I said, the peasants have responded in many countries. Let me cite the case of Mexico, where there are two kinds of cereals that are part of the Green Revolution, wheat and corn. The wheat production that has risen fantastically has been produced on larger farms. The corn production is produced on small nonirrigated farms to a large extent. Wheat production has gone up enormously. Corn production has increased, but relatively much less than wheat.

What are we to infer from this? One inference is, of course, that the larger-scale farmers had access to the other inputs, because they were commercial producers. They could get credit. They could pay for the water. They were already tied into the fertilizer production system. They could satisfy their requirements. In some respects the economy was geared to serving them. The smaller-scale farmers had to face all of the imperfections of the market. This is a matter of tremendous concern to the government of Mexico because it feels that the income distribution in the rural areas of Mexico is worsening even though production has been increasing greatly.

One of the problems of the Green Revolution is how to devise a system of institutions to take care of the more disadvantaged sections of the population, that is, the rural producing population.

Studies done in India show that the small-scale producers were very quick in their acceptance of change. They are probably better off than they were, but the income gap is probably growing.

As I said, the spread of the Green Revolution has been remarkable. It has been in effect for only five or six years since the Mexican experience, and we are still gathering data and trying to find out what has been happening. But we are beginning to see some of the obstacles that are arising. Some of these have been mentioned here.

One of the things that we have certainly become concerned with is the need for improved water use because although seed and fertilizer are the main inputs, we are finding that water control is tremendously important. Of course, this is an area of great concern to engineers. It seems as though this may be one of the major physical barriers on the inputs side.

The Green Revolution has been confined largely to wheat, corn, and rice, but in many parts of the world those are not necessarily the main foods. Looking ahead at the kind of population increase we are anticipating, it is obvious that we have to think about other crops as well. People are now wondering if the same thing can be duplicated with these other crops. There are very active moves afoot to establish a whole series of international research institutes working on the pulses and other crops and livestock. These institutions will be international in character, financed by international agencies, and located in different areas of the world. It is our hope that the new knowledge generated by these institutions will help overcome some of the problems that we would otherwise have with food production lagging tremendously behind population growth.

My personal experience in some of this work leads me to reinforce some of the statements that were made earlier. One of these is that the data problems are really considerable. One hears about lagging production in Country A, Country B, Country C, based on statistics produced by this organization or that organization. When you visit these countries and try to find out how the statistics are produced, you really wonder about the validity of many of the things that are said.

I would like to reinforce and repeat the need for caution in the interpretation of a great deal of these data. Certainly when you get the two variables, population growth and food production, it means that you have got to be doubly careful about interpreting output per capita.

DR. PACK:

The first thing we should understand is that as agricultural production goes up in the less developed countries, labor will eventually be released from the agricultural sector. This has happened already,

but the process will be slowed up somewhat by the Green Revolution, which is labor-intensive if we define this as the amount of labor used per acre of land. However, it does not use a lot of labor per unit of output, because the new seeds are very productive. What will happen eventually is that labor is going to be released at a fairly rapid rate from the agricultural sector. There is already considerable migration from rural sectors into the urban sector. So, in five or ten years, the urban sector is going to have to take up a large portion of the job creation that will have to go on in these economies if people are to be employed. It is also going to have to generate income with which people in the economy who are not directly engaged in farming can obtain the wherewithal to purchase the agricultural products.

One of the paradoxical things that has been happening in many underdeveloped countries is that industrial output has been going up rather rapidly. We see in recent years rates of growth of industrial output of 6, 7, and 8 percent per year. But at the same time that industrial output is growing so rapidly, we also observe virtually no increase in employment. Associated with approximately 6 percent rate of growth of industrial output, we may find only 1 percent increase in industrial employment per annum.

By way of comparison, if the rate of industrial output were to grow at 4 percent in the United States, it would generate typically something like a 1.5 percent rate of growth of employment. For some reason the underdeveloped countries are not generating the same growth rate of employment relative to output as the western countries do.

The question is, why is this occurring? There are two reasons. First, many of these countries have followed policies that bias the entire process against the use of what economists call labor-intensive techniques. By labor-intensive, we mean techniques that use a large amount of labor relative to the amount of capital. We do not mean that one should go back to the cottage industry--to the very inefficient types of very old-fashioned production. Within the range of economically efficient techniques of production one usually has the choice in many industries of adopting the techniques that substitute labor for capital. One problem is minimum wage legislation that exists, a whole host of government subsidies to the industrial sector, which in one way or another reduces the price of new equipment to industrial firms.

The second reason is that new countries have the possibility of immediately going to the most modern, most advanced techniques available in the West. That is, everybody talks about the advantages of relative backwardness, the concept that when a country begins to industrialize quite late in terms of western history, it can benefit from the previous development of new techniques. It does not have to go through the process of reinventing the entire industrial revolution for itself.

But this is a double-edged sword, because most of the advances in the western countries in the last fifty years have been designed to meet the conditions of the western countries that have typically been those of scarce labor and the desire of people to reduce the number of hours they work, rather than work 60 hours a week as was occurring at the time of World War I.

This has meant that engineers in the western countries have essentially been designing techniques that will save on the scarce labor. These techniques should not be used in the underdeveloped countries. Nevertheless these are the ones that are produced in the countries that are currently exporting capital equipment to these countries.

What this means for these countries is that they typically are adopting United States or German or British techniques and putting them into use despite the fact that their conditions are completely dissimilar from those in the countries in which the techniques are being created. A not unusual urban unemployment rate would be 20 percent, which is roughly what we had during the Depression. If you go to many of the major cities of the world--Rio de Janeiro, Nairobi, any of those--we find an unemployment rate that is really spectacularly high. Moreover, people who are engaged in services such as buying a package of cigarettes and selling them two at a time, which is called retailing, are not in fact employed in any significant sense. There is a lot of what economists call disguised unemployment.

The question then becomes what can be done about the employment problem within the industrial sector. I think some things have to be done in the agricultural sector also.

One of the things that can be done is to try to resuscitate techniques that were abandoned in the western countries 20 or 25 years ago. Many of them are economically efficient at the prices of the factors of production, which may be made to prevail in the underdeveloped countries. That is, if you take the price of skilled labor, even in a relatively advanced country such as Argentina, it may well be a sixth of the price of United States skilled labor, and there is no reason to believe that it is so much less productive that it cannot be used efficiently.

Therefore, one of the things that engineers can do is try to rediscover, or resuscitate, the old techniques that were abandoned earlier and make some improvements on them. Many of the techniques--when they were abandoned--did not incorporate some types of design changes and did not allow for some types of quality improvements that may well be available now. But these quality improvements may well be capable of being added onto the older equipment. This is a place where I think engineers can make crucial contributions.

In the steel industry, for example, it is well known that until the oxygen blast furnaces came into use, most of the increases in productivity were generated by relatively small design changes rather than by any major new technological breakthroughs. The same thing can be done with the older techniques. You do not need a major design breakthrough. Rather, you need some small changes, and this is something where engineers clearly have the comparative advantage, to use the economist's phrase, in carrying out.

MR. CLAXTON:

A number of the points that I have in mind in connection with interactions have been made by some of the speakers who have preceded me. Let me refer to some of those points, nevertheless, in terms of their interrelations as they have appeared to me in the time that I have been working on this subject matter here in the State Department.

I have in mind about seven interrelationships that I would like to mention, each very briefly.

The first is that population growth is inexorable. Even if we could slow the growth of world populations during the rest of this century by some 30 percent, there would still be a drop in the world's potential population of about 7.5 billion down only to the level of about 6 billion. In the developing countries if present rates of population growth continue, there will be something like 6 billion people by the end of this century. Even if by a remarkable effort, growth can be slowed about 30 percent, which will be quite an achievement, there would still be something over 4 billion people in the developing countries of the world.

Another element that is sometimes not considered is that even if those reductions should be achieved, world population growth is going to continue very considerably into the next century. For example, if it were possible to achieve the level of a two-child family some time in the reasonably near future, population growth would still continue for about 65 or 70 years, and by the time it stabilized it would be at a very much higher level of numbers of people in the world than at the time the two-child family was attained.

For example, if by the year 1980 we are able to achieve a so-called net reproduction rate of one, that is, the two-child family, the world population growth would not stabilize until the year 2050, and by that time there would be 5.6 billion people or so in the world. If a net reproduction rate of unity is not achieved until the year 2000, world population growth will continue until the year 2070, by which time the total population would be 7.4 billion. And if the unity reproduction rate is not realized until 2050, stabilization will not occur until 2120, by which time the world population will be about 14.5 billion people! So, world population growth is inexorable. No matter what we and other nations and individuals try to do to slow it down, it is going to be very considerable. Therefore, we must realize that the more manageable, hopefully more manageable, variable in this situation is our ability to increase the production and distribution of food, and we really must focus on this with the greatest seriousness.

The second point is that it is dangerous to think only in terms of the whole world in averages of food production and population growth. Many of us have been dropping statistics about 2 percent, 3 percent population growth, 1.5 billion tons of food, etc., and if we distributed it all out everything would be fine. I am reminded of President Lincoln's story about the man who was told that the river had an average depth of

4 feet, so he started to walk across it and drowned in the 7-feet section in the middle. The same is true of the world situation. There are great variations in population growth, great variations in the potential of increase in gross national product per capita, and great variations in local food production. I emphasize local food production because, generally speaking, the problem of feeding people is going to have to be addressed essentially at the local level. It does not really do to talk about the fact that the world's food production, including that of the United States and Europe, could feed X numbers of people in the whole world for Y period of time, because the problem of the people in the developing areas of the world with regard to their ability to buy the food from the developed areas of the world is essentially insoluble any time in the near future. For such a distribution of food to occur would require very substantial grant programs from the developed countries of the world. The thing that we tend to focus on, and rightly, is to help the developing countries themselves increase their food production locally.

This is what the Green Revolution has been trying to do, and we have been hearing about it, but let us realize that in the last decade only one section of the world, the Far East has actually increased its food production per capita. The other three major regions of the world reported by the FAO, Latin America, Africa, and the Near East, have not increased their food production per capita during the last ten years, despite the very considerable effort that has been made to help them do so. The problems of translating and transferring the Green Revolution from the Far East to different economies in different climates in Africa and Latin America are very considerable.

Just because we have begun to attack the food production problem successfully in one area of the world does not mean it will be easy or immediate in other areas of the world. I emphasize immediate because population growths are going to continue while we are trying to transfer the technology that has been successful in one area or that is beginning to be successful in one area to other areas of the world. We must consider not only regions of the world, but also the possibilities of the relationship of populations to food and to potential food, the ability to purchase food in individual countries within regions, as well as among regions. I emphasize the ability to purchase food because even if the capacity to produce and distribute food were solved in many areas of the world, it would not enable people who are hungry to buy the food unless they have the jobs to make the money to turn their

internal demand of hunger into the effective demand of being able to buy from the farmer. This has been referred to on several occasions earlier.

The third point is that we must think in terms of more rapid general economic development. We cannot think only in terms of increasing food production or slowing population growth when we are thinking of the food-population equation. It is essential for us to think in terms of increasing general economic development, jobs in industry, jobs in agriculture, to employ the people, to give them the money to buy the food that can be produced and that they need. I suggest that here is a role in which engineers may very well have a very large opportunity, the opportunity of helping to develop industries that may be antiquated by American standards, but that would be appropriate in developing countries, labor-intensive, to provide jobs at low capital and high employment, to help do the kind of thing we have just been discussing.

The fourth point is that although the Green Revolution has now happily pushed back the time when according to earlier predictions there might have been widespread famines in the world, we are still warned by experts that it will at best give us only a few decades until the population and food production lines in all probability will cross again. We are warned that we must begin serious programs of reducing population growth in the many developing countries of the world right now.

The President's Science Advisory Committee on the World Food Problem put it very trenchantly this way: To avoid a continued worsening of the population-food situation during the years beyond 1985 that may even reach an economically or ecologically irreversible state of imbalance, it is imperative to institute intensive programs of family planning now.

The fifth point is that to achieve the latter, we must have not only improvements in biological services--research in human reproduction and contraception, the provision of biological services of the kind that Dr. Ravenholt quite properly pointed to--but we must also do some of the things that Miss Dixon pointed to. We must help the developing countries find improved ways for bringing to the people in those countries an understanding of the importance to them of lowered fertility and to persuade them indeed to undertake programs to accept measures that will enable them to space their children and to have a smaller family size.

As a sixth point, there may be an important relationship between the provision of good nutrition and helping to slow down population growth. For example, we do not know yet, because we have not tried experimentally in enough cases, to relate child feeding nutrition programs to family planning programs. Thus a mother who comes with her child to a child feeding place, a nutrition place where supplementary nutrition is supplied, could find at that same place information and encouragement to space her next child or, if she has more than a certain number or all that she wishes, to limit her fertility.

Along the same lines, I am thinking of what Dr. Pollack mentioned, the importance of increased health care as a matter of improving nutrition by lowering the disease that uses up nutrition in a wasteful fashion, by associating such care and nutritional services and family planning services at the same place, in the same environment, with the same kind of offering and presentation to the women and indeed the men of the community.

Finally, we should consider some effects of lowering birth rates. There is a great range from pessimism to euphoria among demographers and others in this field. Some feel that the problem is essentially solved because the techniques exist. Others feel that it will be very difficult indeed, and perhaps impossible, to solve it before there are considerable upheavals or social collapses in many of the countries of the world.

We should realize that whatever the actual event will be in this case, lowering birth rates can have an immediate value of many kinds. The most obvious thing is that lowering the population or lowering the rate of population growth in relation to increased food production will in itself allow a higher ratio of food per person in the world, in a region, or in a country. But perhaps even more important, it will have the effect of reducing expenditures for immediate consumption and will free funds that can be put into the kinds of economic development we mentioned earlier. This is essential both for making it possible for people to buy the things they need and for helping them slow population growth. Even though the effect of a birth control program may not be immediate in terms of making job opportunities or making it possible to employ the children who have been born during the last 20 years and who will be coming into the job market now and for the next 20 years, it can help rather immediately in a number of other ways.

For example, India's program of population planning intends to achieve a reduction of the present 20.5 million births per year by about 9 million births during a 10-year period from 1968 to 1978. If it is able to achieve this, the economic effect would be that of reducing the total demand by something like 18 million child-years of consumption. In a country like India, which is always on the margin of production and availability of food, this could perhaps make the difference between a situation of no famines or of minor failures or inadequacies of food on the one hand, and a very substantial famine or a great lack of food on the other hand. The same would be true, of course, in other countries by analogy.

DR. LOGAN:

My participation on this panel and my interaction with the other two panels was essentially of value to me in knowing more about how social scientists and medical scientists think. However, I would like to emphasize certain points that I think have been made, and that I believe are of particular importance to engineers.

In the first place, we seemed to agree that there was no significant role that engineering could play in population control unless it might be a personal attitude, but as there are only an insignificant number of engineers in the world, I believe this would probably not affect the total world population to any great extent.

However, the engineer is directly involved in food production and in the more effective distribution and utilization of food. There is, of course, a vitally important role that the engineers play in association with the problem of employment, and underemployment industrialization, and in general in improving the quality of life, which is certainly an important by-product of the whole situation we are discussing.

The points I would like to emphasize are first of all the point made by Dr. Rockwell: the role that the engineer can play in planning, analysis, and design of the systems that might be of use either in population control or in the field of food production.

In the field of increased production and more effective utilization of food, there is of course the very important matter of health and

sanitation and, perhaps most important, the field of water supply, including the areas of sewage and sewage disposal, of insect control, including malaria control, and the control of schistosomiasis.

Of course, it is obvious, also, that the engineer can and does play a vitally important role in the design and implementation of irrigation and drainage systems. This involves his interest in the construction of dams, reservoirs, wells, and drainage works, in land preparation for irrigation, and in flood control.

Other fields in which engineers can make contributions include transportation and storage, the design and construction of railroads, the design and construction and operation of waterways, the design of market roads and other roads, the construction of granaries and storage devices, and the important field of pest control.

Finally, in the field of industrial engineering, the engineer is the person most responsible for the development and operation of drying facilities, packaging facilities, and the manufacture and production of fertilizer.

These are the obvious points; they have all been made before. I think they need reemphasis because of the importance the engineer has in these fields and the role he must play if we are going to produce the important changes that have been contemplated in world food production.

DR. HOELSCHER:

My own interests are in the process of industrialization, and I have been involved in southern Asia and southeastern Asia for many years on that problem. It has become obvious to me that the factors that are important in the process of industrialization of a nation or of a region and the complex array of problems that arise during and as a part of that process of industrialization, and indeed the constraints that limit the success of such efforts, turn out to be the same in nearly every respect as those factors and problems and constraints that this panel discussed and examined during its working sessions.

Stated somewhat differently, consideration of the interactions of the world food problem and the world population problem leads one to the analysis of an array of problems and factors that are the same as those that engineers have regularly had to face during concern for the growth of industry or the diversification of industries in the developing world and indeed in our own country. These include the array that we know so well, the necessity for the appropriate technology, mineral resources, land resources, water resources, transportation, communications, labor availability and indeed labor reliability, power systems and the reliability of power marketing systems, and educational systems as well. Education is certainly one of the important problems throughout the world. It is necessary to educate the people in the developing nations to their own problems to enable them to make use of their own choice of solutions to their own problems, and then indeed to manage, and I repeat, to manage their systems that are intended to be of assistance in the amelioration of their problems.

I am not talking about engineering education. I am talking about village levels of education, much earlier levels than polytechnics, which are of course vital. It seems to me that engineers do have a base from which to become involved in this food-population problem. Indeed, there is a rapidly emerging interest within the engineering schools of the United States in such matters as industrialization within the developing nations, in devising methods for developing sound technical educational systems to be supportive of industries, and perhaps most importantly in establishing effective interactions between and among the schools in the developing nations that are devoted to technical education, and in the industries or between the engineering instructors in those schools and the engineers in industry.

Indeed, this is happening. There is a growing number of young engineering faculty throughout the country who are very much interested in, and who have had some experience with, problems of the developing world. I call your attention to the new division of the American Society for Engineering Education, which is an organizational element of education, devoted entirely to this array of problems. As one who was involved in bringing the international division of that into being, I can express very strongly the hope of all ASEE members for opportunities to work with the Foreign Secretary of the National Academy of Engineering and the NAE Commission on Engineering Education on problems of this kind, problems of mutual interest.

Let me turn very briefly to another question for a moment--the question of appropriate technology for industrial development in the developing world. To clarify it I would like to suggest to you that you allow me to oversimplify for just a moment and group industries in two kinds. Let us think in terms of two kinds of industries. Type A includes those that must operate at world levels of technology; it is impossible to imagine building a jet aircraft in a developing country with anything like the same techniques that are used in Europe, the United States, or Russia, and similarly for antibiotics. On the other hand, there are industries, which I will call Type B for the moment, that can and frequently do operate at much less than world levels of technology: dye manufacture, leather tanning; a whole array of these going all the way down, if I may, in their degree of technological sophistication to the hand crafts.

I think it is feckless for us to suggest that the Type A industries need not, cannot, or should not grow or increase in number within the developing world. There are many reasons why this kind of development does take place, will take place, will continue to take place, and indeed, in my opinion, should take place.

The kind of industries for which we can imagine a less sophisticated level of technology are those that fall in the Type B group. Here I suggest to you that by and large new technologies are not necessary. These technologies presently exist throughout the engineering literature of the world, not only in the United States. What is needed here for this kind of industry (the Type B industries), if you will, is the resurrection and updating of these by people in the developing nation itself.

The problem as I see it is that we cannot very well help them do that kind of industry from here. This is something that they must do, that indeed they do do, and that is going on in increasing numbers of cases throughout that part of the world. For example, in Madras, there is a small company with two engineers and something on the order of fifty workers. They purchase bunker fuel oil residue from the harbor and by a series of processing steps including a partial oxidation, mix it with some wood tar to convert it into a synthetic pine tar oil, actually a synthetic additive, which they sell to the local tire manufacturers, and chug out rupees in substantial numbers. It is a very low technology industry. That is one of six or seven that I could describe to you in that particular area near that large city.

I am sure these types of industries will grow. At the moment in India if you involve yourself with a development that requires less than 7.5 lakhs of capitalization (about $100,000), the central government does not become involved. So one of the things that is going to be a matter of great concern within the country is a policy of some kind that will speak to the kinds of support given to these less than 7.5-lakh capitalization industries versus the kind of support, permission, and policy structure that will apply to those that are larger.

To talk about denying or advising the developing countries away from the Type A industries is a very bad thing to do in my opinion. Indeed, I suggest to you that it will be feckless.

DISCUSSION

QUESTION: I have not heard anyone deal seriously with the problem of ecological imbalance induced by widespread high-level use of fertilizers and pesticides, and the possibility that the Green Revolution may be quite limited because of the ecological consequences. In thinking about this point, I know of four areas that have not been mentioned. One is the eutrophication and toxification of the water supply systems; second is the elimination of natural checks on pest populations and the consequent instability of the crop output; third is the genetic and/or lethal effects of pesticide accumulations in all higher trophic levels, including man; and fourth are modifications of the environment--for example, irrigation projects in Egypt and the spread of parasites that nobody knows how to deal with yet.

DR. YUDELMAN: The levels of fertilizer use are extremely low in the developing countries, and the kind of problems that are emerging in the developed countries, the kind that you have mentioned, are not yet present, especially with the eutrophication problem and some of the pollution problems. It is true that with the concern for food production perhaps not enough attention has been paid to the long-range effects of these changes, but governments have to make choices, and given the choice between food and other things, they are prepared to discount the future rather heavily. No doubt with the great deal of present concern for the environment, these factors will be given more attention in the future. Dr. Logan can talk about the Bilharzia question.

DR. LOGAN: Of course, Bilharzia has been called the civil engineering disease, and as you have indicated, it is often associated with irrigation projects. Unfortunately we don't have any satisfactory way of dealing with schistosomiasis. It is still a very serious disease in Egypt and other parts of the world where the snail exists. So it is true, this is a cost of irrigation in many parts of the world.

The fact that we are so concerned now in large parts of the world about the future of the planet is going to cause us to move ahead with caution, whereas I think before we were moving ahead blindly. So, the only point is that now we are much more cautious than we were five years ago, or even a year ago.

QUESTION: It has been suggested that economic development is the ultimate goal. I would like to raise the point that this has led to a false impression about economic development and food development. The increase in gross national product per capita has been suggested as being the key, and this has to be gotten by investment of savings. No one has discussed savings as yet or sources of savings. We know that funds flow from foreign countries to countries such as Taiwan and Korea for military reasons. We have not talked about whether the government is going to enforce savings or whether the private economy is going to furnish the savings. If it does not have to be enforced, does this mean that the people are not going to get the food, as for example it did in Russia during Russia's economic development?

DR. PACK: I think the availability of savings is certainly a necessary condition for development in many countries, but it is very far from a sufficient condition. One can illustrate in some very simple ways by taking countries that have had relatively limited savings and yet have been able to translate this into fairly rapid development, whereas other countries, such as Norway, with extremely high savings rates, have not been able to develop very rapidly. Although they are at a high level, their growth rate is not very high.

I think in any case that savings alone is not a sufficient condition. It is certainly necessary, but a lot of other factors are involved, particularly the social commitment of the leaders to development rather than to favoring one sector vis-a-vis another.

When we get to the question of generating savings, undoubtedly there are three sources of savings in any economy. One is by private households, essentially; one is the corporate sector; and one is the possibility of the government sector having surpluses. In most countries it is going to be exceedingly difficult to get the private sector--the households--to save a lot unless you can have a substantial redistribution of income, and it is very hard for them to save. Certainly savings are going to have to be increased in many of these countries, but my suspicion is that at current savings rates, which are on the order of 18 or 20 percent gross savings rates according to UN data, there will be sufficient to generate development if a whole host of other conditions are available. So I don't think the savings questions is the crucial question now. What is very important is the question of opening up the world markets to the products of underdeveloped countries.

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