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## "Food and Population"

Harrison Scott Brown

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Harrison Scott Brown, "Food and Population"  
Portland State University  
June 28, 1979

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[program begins with introduction in background, off microphone]

HARRISON SCOTT BROWN: Thank you. I would like to... wow. [responding to high volume of microphone] I'll tone down now; I'll whisper. I would like to spend the first part of the afternoon talking about the the evolution of the present global food situation. As you know, people have certain minimum needs for food. They need a certain number of calories; a certain quantity of protein which has the right amino acid distribution and so forth. For the most part, the people in the world just barely get that amount. Quite a few get less than that amount, and therefore they lead less than optimum lives. But as people get richer, they like to eat richer diets. And what that usually means is that they eat more animal products, eat more steaks, more chicken; they drink more milk, milk products, cheese, and what have you. And the basic figure that we have to keep in mind is very rough, but animals eat vegetation, just as people eat vegetation, in the form of rice, wheat, and so forth.

But the animal has to live, keep warm, and so forth. And so the animal gives a net return of just a few percent of what has gone into the animal. So the caloric content of a piece of beef is only about 10% of the caloric content of the food that went into the cow in the first place. The cow has frittered away the rest just keeping warm and walking around and staying alive. So it's a very wasteful process. It varies a great deal; chickens are more efficient than cattle. And certain animals eat things that human beings can't eat anyway. But on the whole it is a wasteful process, and we do feed animals food which in countries which have very little protein intake, animal protein intake, is consumed directly by the people themselves.

As a result, the per capita cereal consumption in the United States is very, very high. But only a part of that cereal is consumed directly. The rest of it is fed to animals. And indeed, we feed more cereal to animals than we eat directly ourselves. So when we talk about food needs, we have to define what we mean by need. Just like when we talk about material needs, at one time the automobile was a luxury, and now it's a necessity. At one time a beefsteak was a luxury, and in the United States, a beefsteak has taken on the appearance of a necessity; you feel deprived if you can't have it.

So as time has gone on in the world, food needs have increased in part because population has increased and in part because people have become richer. And they can afford more expensive food. They can afford to let the cows fritter away as much energy as they do. That's the first basic element of what has been happening, and of these two effects, they've been about equal. Population growth has been very important. But the growth of affluence in North America and Europe and Japan has been equally important in determining the total level of food consumption in the world. And indeed, although we are the highest food consumers per capita in the world today total, the Japanese and the Americans and the Europeans are catching up with us. It comes as quite a cultural shock. I go to Japan fairly often, but it really still hits me right in the forehead here when I walk out of a building and I see a Colonel Sanders Kentucky Fried Chicken right across the street, or a McDonald's hamburger restaurant. And these are very popular in Japan, and the popularity is growing, even with steak selling at \$10 a pound.

Now, there is a certain amount of flexibility in all of this. I was quite interested—and all of this depends upon cultural values—I was quite interested, when I was asking a European economist, how did the Europeans adjust to the very large increase in the price of gasoline, which was occasioned by the very large increase in the price of crude oil in 1973-74? Are they driving less? He said Oh, no. They're eating less meat. And this is true; the love affair between the Italian and his automobile is so passionate, that they're willing to eat less meat and more spaghetti, I guess, in return for not depriving themselves and driving their cars. And this of course depends upon one's individual values.

I don't know what the situation would be in the United States if we suddenly increased the price of gasoline to two dollars a gallon. How would we adjust? Would we eat less meat, or would we drive less, or would we overthrow the government? I suspect the latter. Now, the second basic kind of situation that has developed has involved agricultural productivity. We in the United States encountered these vast areas which could easily be put into agricultural production. And we applied scientific methods to agriculture. And we mechanized, and we produced huge quantities of cereals: wheat, corn, and now rice and sorghum, for which there is an export market. Indeed, it has been the export of agricultural products which has enabled the United States to accumulate capital as rapidly as we did, and has traditionally been our largest single export. The same thing has been true in Canada; the

same thing as been true in Australia; with the result that North America is by far the largest single exporter of foodstuffs in the world. Right behind that we find Australia and New Zealand.

Now, we were able to produce food so cheaply that it paid... well, it became no longer profitable for many parts of the world to to increase their own agricultural production. It was less expensive for them to concentrate on manufacturing things, and then to use the money they made from the manufacturing process to purchase food. And that is what has been happening in Europe. And that is what has been happening in Japan. This is not the first time in history when that process has been undertaken. In ancient Greece, farmers discovered they could make more money by concentrating on the products of the vine and the olive tree, namely making wine and and olive oil and exporting it, than they could make by growing wheat. And as a result, Greece became completely dependent upon imports of food, real food that they could eat. For her survival, and she paid for it, of course by exporting olive oil and grapes. But then the Romans caught on to the same thing in Italy, and the farmers there discovered they could make more money by concentrating on the grape and the olive, and the Romans to became dependent upon imports and to feed their population. They were heavy competitors with the Greeks, and and put the Greeks out of business pretty much in this respect. But their dependence upon food imports led subsequently to grave internal difficulties, because the breadbasket of Rome was North Africa, and tremendous ecological changes took place in North Africa over a period of time. With the result that wheat got very difficult to come by, and as a result the Romans suffered.

The British went through the same process after the Industrial Revolution. They were completely self-sufficient in food production. And then they found it was cheaper to import food from the colonies and primarily from North America than to grow it themselves, and they increasingly became dependent upon imports. They crossed the the boundary in the mid-part of the 19th century, much as we crossed the oil importation boundary around 1948.

So we have this very interesting situation of of a collection of rich nations, three of which are major exporters and count on those exports for their economic well-being: the United States, Canada, and Australia, and New Zealand to a lesser extent. And then a bunch of rich importers which count on the availability of that exported food for their own survival. Here, we're dealing mainly with Western Europe and with Japan primarily, and then to a lesser extent with the more advanced and certain more advanced industrial... more advanced developing countries, Taiwan and Korea.

Now in the meantime, the situation in the rest of the world has been changing, in that population pressures have increased demands for food in the developing countries at a rate

which has been greater since World War Two. The demand has grown at a more rapid rate than the rate of expansion of agricultural production in many of these areas. Superimposed upon that, as I've already mentioned, affluence has been growing, so the demands for exports has been growing. And in a large country like the Soviet Union, the demands have grown more rapidly than the agricultural production there in the following sense: that the people of the Soviet Union have wanted a richer diet for a long time. The government has given them a steadily richer diet. But they haven't been able to produce all of it themselves; the agricultural situation in the Soviet Union is difficult one, in part because they have had to push into the more difficult areas for growing things, of Siberia and so forth, where it is very sensitive to changes of weather, and in part because of organizational problems, internal organizational problems. Their farm collectives don't work all that well; they have difficulty pulling themselves together, so to speak, from the point of view of agricultural production.

So depending upon the the variability of weather, the Soviet Union too comes on the market for cereals, and in difficult times will come on the market for a lot of cereals. And when they have a good year, she's not on the market, and depending upon what the market is like in the producing countries, or depending upon what the crops are like and so forth, that will determine whether we go through a period of glut or famine, or scarcity rather. Indeed, whether the Soviet Union buys or doesn't buy is a major determining factor, because we simply don't have very large buffer stops. The food situation is handled entirely on the open market; it's handled through middlemen and women, I guess, here in the United States, for example, who deal in these things. And it's quite profitable to them, and the ups and downs are not much of a worry to them. They much prefer, I think, to have these instabilities in the system than to have a perfectly steady predictable thing, because that's the way they make their money: speculating.

Now again, I'm just looking at the system of industrialized rich countries of which the Soviet Union is one. This is a system where you have these fluctuations which are basically caused by changing weather. It's caused also by sudden infestations. For example, we were hit not long ago in the United States by a corn blight which which devastated a lot of the crop and produced a very difficult situation. I will add to that the special relationship that exists in the United States between the farmer and the government, because for a very very long time our productive capacity was much greater than the market. And in order to keep things on a relatively even keel, the government had to enter a program of paying farmers to keep land out of use. And it long resorted to a system of subsidized prices and so forth and so on.

Clearly, a long time ago, the government recognized that the food situation, the food problems of the United States and our export market, our own needs and so forth, stabilization of food prices internally, could not be handled through the free play of the marketplace, as they began interfering with it, sometimes properly and sometimes

improperly. In any event, as a result of these increasing demands, external demands, we reached the point where we have a market for virtually everything we can sow. And so our stock, our reserves, went down to practically zero. And indeed, our reserves in the form of fallow land also went down to zero; everything that can easily be... that can be called really truly productive land is now in production. And without the buffer stock, and without that buffer of land that can be put into production on relatively short notice. We exist in rather a precarious situation, because any combination of a number of events can result in our decreased ability to export, which means decreased for an exchange for us. And don't forget that the agricultural exports make the difference between red and black. Well, our trade deficit is now so red anyway, but it would be even redder were it not for that that agricultural export, which is essential at the present time to our economic well-being.

These fluctuations can take very serious forms; for example, in 19—I mentioned this this morning—in 1974, I guess it was, the government saw, while there was a bad year for soybeans, the price of soybeans started to go up rather rapidly, the government saw that this could be a destabilizing element and the in the cost of living, and so we declared a soybean embargo, an embargo on the export of soybeans. The main country hit by this with Japan. The Japanese still haven't gotten over that, because soybeans... in addition to the fact that that they like to eat them, it's sort of a security blanket for them. They still refer to that soybean embargo, they literally refer to it to this day is the first Nixon shock. And it really shook up Japanese society. And I think one has to appreciate how important the soybean is in Japanese culture to understand the impact that this had there... to the point when I was in Japan in 1976—I'm sorry, 1977, last year—the president of Brazil went to Japan with his entourage, and they negotiated three billion dollars' worth of major agreements between the two countries, including one huge agreement whereby Japanese are going to show Brazilians how to grow soybeans, and are going to invest in soybean plantations. And with the Japanese guaranteed full access to the products thereof. It's a very large agreement, occasioned by what they perceive to be, and I think correctly, a real need for diversification of supply, rather than just being dependent upon North America.

So what I'm going to say next, then, must be looked within the framework of this backdrop of what the rich nations are doing about food. Now, for many many decades we've been selling food to developing countries who could afford to pay for it. We have sold a lot of rice, soybeans, feed grains of all sorts. But we really weren't giving cereals away. However, our surpluses did get very large. Our stocks built up to quite a high level. And finally Congress passed a remarkable law, which is known as Public Law 480. And this is a law that has many many features connected with it, but it permits the United States government to give as outright gifts, or... well, to give as outright gifts, food to countries which need the food, or to sell it to them on concessional terms, and these concessional terms usually took the form of their being able to pay for the food in their own currency, and that money in

that currency was put in a bank in the country and could be spent by the United States for things like our aid missions and so forth and so on in those countries.

It was a remarkable law, because it did make it possible then to get lots and lots of food shipped to these countries where the food was needed. Now, that doesn't mean that the food necessarily got to the people who needed it; a lot of it did of course, but in retrospect I think it's pretty clear that there was a lot of... a fair amount of hanky-panky going on, and a lot of the food was diverted into regular commercial channels; but the fact remains this law was unprecedented, I think, in history.

And there were many provisions, again, including sending food through private agencies, through international agencies and so forth; and this was all fine and good as long as we had surpluses. It is perhaps significant that once those surpluses disappeared, and the only food left to sell or to send abroad could be purchased, we stopped giving food to the needy. Almost no food now flows under the Public Law 480, but the law is still on the books and I would guess if there's a big surplus again in the future, which I doubt very strongly, that this would be renewed. But at the present time, the developing countries who need food, who need to import food, will get it only through competition on the open market, in the open marketplace.

Now with respect to these countries, that's a very small amount anyway. Only a tiny amount of food goes from North America or Australia to the developing countries. Most exports, the lion's share of the exports, go to the more developed countries and to the rich countries who can afford to pay for it, and to some poor countries who can afford to pay for it in hard currency. For example, China has worked with—the People's Republic of China—has worked for a long time attempting to develop its own agriculture to the point where they reach a level of self-sufficiency. They're doing a remarkable job, I think. But they have their ups and downs, occasioned by ups and downs of weather, and the one politically destabilizing thing that can happen, one of the most important politically destabilizing things that can happen in China, is a food shortage, a real honest-to-god food shortage. And the Chinese leaders are quite aware of this and so when they see anything like this lying ahead, they will themselves go on the market with good hard currency. And so from time to time you see very large purchases emerging from China. They usually buy them from Canada, but sometimes from the United States as well.

And this in itself has a destabilizing influence upon the overall market. There are some countries which we would call poor countries, which import food from us on a regular continuing basis. They do this just consciously spending their their foreign exchange on this in part because they have to. There are some countries which just regularly import food because they simply can't do enough themselves to feed themselves. Sri Lanka is an example there. But for the most part in developing countries food that is imported is

irrelevant. It's what they grow themselves that is of critical importance, and it is how they get their food, how the food becomes distributed, that is of critical importance as well.

In 1975, I had the interesting experience of being tapped to be chairman of a major study on the world food situation, which President Ford had asked the National Academy of Sciences to undertake. The study, which we called the World Food and Nutrition Study, took two years. It involved—it was a massive affair—it took 1500 people altogether that were involved, experts in agriculture and nutrition and the like. And the report was delivered to President Carter just a year ago, and some of our conclusions in that study I think are quite important. Perhaps the most important eye-opener for me, as a non-expert in the field, was that if you're trying to put your finger on the main cause of hunger and malnutrition in the world today, it is not lack of food, it is poverty. That for the most part those 800 million people who live near the edge of starvation in the world don't get enough to eat simply because they don't have access to the food that exists. They either have no land to grow their own food, or they don't have a job to make money to buy food. And that's the major single cause, whether it be a poor person living in the rural areas or whether it be a poor person living in the in the city.

The most important single cause of hunger and malnutrition in the world is poverty, and that if by some miracle the production of food in the world were to be doubled suddenly, that would have very little effect in the short run on the hunger and malnutrition situation. This, to me, was an eye-opener. That if one is really going to do something about the problem of hunger and malnutrition, you have to get right at the poverty issue.

Now that doesn't mean we shouldn't grow more food. That does not mean that the United States should not take more seriously the problem of of giving food where it seems desirable, where there's a famine or where there is some kind of a circumstance like a pestilence that is disturbing the the overall picture. But it does mean that unless we get at the problem of poverty in the world, no matter what else we do is of little avail.

Now beyond that, it's terribly interesting to examine the tremendous variations with which the people of developing countries come to grips with this problem. Some come to grips with it effectively. Some don't come to grips with it at all. We can get sort of a clue when we look at certain indicators of well-being in the world, and one tends to use statistics that are sort of readily available through the United Nations and elsewhere. One useful one is infant mortality. Nutritionists for the most part pretty much agree that that the greatest single contributing factor to a high infant mortality is lack of adequate nutrition. That the child might actually die of some disease, but will die of that disease because he or she is malnourished. A second statistic that's interesting to look at is just life expectancy at birth, because this sort of gives an integrated view of not only the level of nutrition in the very early years, but also some integrated picture of how well the individual is fed, and what the



infrastructure is for for public health over a full lifetime. A third indicator of well-being is literacy, and it's been pointed out that that one cannot divorce literacy with some of the other factors of life expectancy and infant mortality.

But the important thing is that one looks at at these qualities, which are are not obviously connected with such things as per capita income and the like. Because per capita income can give a grossly distorted picture of what really is going on in most of the developing world today. As an obvious example there, you can see many African countries where most people have an annual income of, let's say, most families have an annual income of let's say seventy to a hundred dollars a year. And where a handful of plantation owners can have very, very large per capita incomes in the average, the average looks pretty respectable. And again, it's a little like the old example of you have one foot in dry ice and the other foot in boiling water, and you can say that the average is very comfortable.

So the other indicators, other than money, have been put together in sort of a simple-minded index; this was done by the overseas Development Council in New York and Washington. And it's called the the Physical Quality of Life Index, and it's rather interesting to look at the relationships there because clearly they are nutrition-related; they are food-related to a very major degree. If you turn on the light, please, I'll come back to that one.

There we are. The people who drafted this didn't do a very good job. Ignore these two squares or rectangles. But this shows the per capita gross national product. And this is the physical quality of life index, which is put on a scale of zero to a hundred. And these areas all are developing areas of developing countries. North America, the USSR, and so forth all have very high per capita gross national products and a high physical quality of life index. These all should be over here; the drafters of these, I'm sorry, couldn't read I guess, heh. This should be reversed. So forget about these, just forget about them entirely... but they're all very high. But you'll notice how very low... you'll notice how these fall into cultural fields. Where the black African countries are all very low in physical quality of life index, very low in per capita GNP, but there's a range. You notice that for the most part, Asian countries have low per capita income. But relatively high physical quality of life index. What that really means is that they've learned how to take care of each other in some way. And indeed there is one which falls way off scale up in here, which is Sri Lanka. Sri Lanka has a physical quality of life index which is extremely high. It's about 80. And indeed, their infant mortality rate is lower than in Washington, DC. Their literacy rate is higher than in Washington DC, their life expectancy at birth is higher than in Washington DC, and they accomplished this on a mean per capita income of about a hundred and fifty dollars a year.

It's a fantastic achievement, a fantastic example of people taking care of themselves, learning how to take care of themselves. The same situation is true in the state of Kerala, in India. K-E-R-E-L-A. Or K-E-R-A-L-A, I can't remember. It's rather an interesting part of India. It

doesn't differ from the rest of India in per capita income, but they too have a very high physical quality of life index that is well over 70, 75. They somehow have learned how to take care of each other and provide services that are necessary. I mention quickly that in the case of Kerala, it's a matriarchy. I don't know if that has any significance or not, but it is a matriarchy.

But what all of this demonstrates when you look at the fantastic per capita income, average per capita income in Washington, DC, you suddenly realize that because of the large underprivileged Black population in the city, that it has such a fantastically high illiteracy rate, such a fantastically low life expectancy at birth, such a very high infant mortality rate, where people are more malnourished than they are in parts of Asia. It makes one really believe that we've got to come to grips with this whole problem of income distribution, with this whole problem of how do we take care of the maximum number of people adequately? Clearly, one can do it.

It's interesting to look at some of these other countries. The physical quality of life index of the OPEC Arab countries is about the same as that of the other Arab countries, in spite of a much higher income. One can say they just haven't had enough time yet. But it's about the same. You will notice that up here in Africa, very high income, but still a low physical quality of life index; and this is almost entirely due to the maldistribution of income, a few very wealthy people. If you look at Latin America, their physical quality of life index goes up higher. And that's mainly the southern countries of Argentina, Uruguay, and the like; Chile with the mining. But their incomes are much higher than corresponding PQLIs in Asia; and of course in Latin America, Latin America is notorious for maldistribution of income. You find wealth there that pales the wealthiest people in the United States into insignificance. One can seldom see the level of personal wealth that exists in Latin America even in a place like the United States or Europe. And so maldistribution of income clearly plays a substantial role.

And indeed, it's terribly interesting the influence that the physical quality of life index seems to have upon birth rate. Somehow, for reasons not understood, as the physical quality of life index increases, the birth rate decreases. When it gets up to be about 70, wham! it decreases very very rapidly; and one would guess in part this is because of the fact that a high physical quality of life index is associated with a workable infrastructure, an educational system, and a communication system and the like. I don't mean to say that there is a proven cause and effect relationship here. But the correlation is certainly a very high one, and I suspect that on the basis of what we think we know about birth control programs and the like, that the relationship is an important one.

Okay, could you turn that off now, please? So, the conclusion that we reached in the study was that the world food situation indeed could be improved. But one had to work along

three major fronts. The first is that of the elimination of abject poverty. And I think that this... really, this concept has had an effect, in that our own aid programs have done an about-face. For years and years and years, developers that have... the planning people in many developing countries such as India, for example, and the planning people in AID took the view that you had to go the route of industrialization, have more and more industrialization, use aid money, insofar as possible, for capital in major projects for industrialization. Forget about the rural areas, because from the money, from the profits that were made through industrialization, money would "trickle down." It's called the trickle-down theory. And that would lead eventually to agricultural production, increased agricultural production, and the elimination of poverty. Well, this simply has not worked.

And I think this is one of the more important about-faces that has taken place since World War II in major development policy considerations: that one has to concentrate on the areas of poverty. One has to really look at who isn't getting the food and why aren't they getting the food, and then come to grips with doing something about it. Getting them jobs; dealing with rural development on an elaborate scale; and then in the urban areas, of course, you do have the problems of urban unemployment which are very severe, and there, industrialization can help, but only if it's job-producing industrialization. An oil refinery which is run by a computer and which requires two people watching a bunch of dials and the only reason they need two is because one might drop dead—that doesn't really improve the employment situation very much.

The second line of attack is the increase of food production itself, which is terribly important. And there, the consensus is that—I think this is this is correct—that much more food can be produced in the world today than is now being produced, and the places where it can be produced most easily are the developing countries themselves. And the reason for that is that their productivity now is still very low; that by applying scientific methods of agriculture, that the necessary food can be grown. But as I will come to in a moment, at a cost.

Now, what is the cost? The developing countries indeed can produce much more food. All they have to do, if they grow wheat, is use these new varieties of wheat; tune them genetically for the conditions in the particular locality, and these will give much greater yields if you add enough water. If you add enough fertilizer. Where do they get the water? Well, it rains, but you've got to ensure steady supply of water at the right time. This means getting water out of a river, which means pumping it; or getting water out of a well, which means pumping it. And how do you operate the pump? You use oil or electricity. Then you add fertilizers, nitrogen fertilizers first. Where do you get the fixed nitrogen? Well, you make it. What do you make it from? Natural gas or oil. Or you import it. And what does the person who exports it make it from? Natural gas or oil. So in any event, you're importing natural gas or oil.

And we saw how in the 70s, in the late 60s and early 70s, the green revolution started to spread through India: a miracle. Varieties of wheat developed in Mexico in the Rockefeller Foundation program were transferred to India, and the farmers in the Punjab got fantastic yields. Very clever farmers; they knew how to add what they had at the right time and so forth. But the Indians had to make fertilizers. They imported the oil from Saudi Arabia to make the fertilizers. The price of fertilizers went up by a factor of 4. Or the price of oil went up by a factor of four; the price of fertilizer went up by a factor of 4, and the consumption of fertilizers by the farmers decreased by about a factor of 4. And the yields decreased by about a factor of 4.

And not only were they not making the fertilizers, but buying them was difficult. Because the major exporter of nitrogen fertilizers for Asia is Japan. Japan has a huge fertilizer industry. The Japanese are pretty clever. They were limited on how much oil they had available. They were hit at first by the embargo, but an indication of how politically effective that embargo was is that the Japanese did a 180-degree change of foreign policy in about five microseconds. So the embargo on Japan didn't last very long. She went from pro-Israel to pro-Arab in [snaps fingers] like that. So the Japanese calculated they can make more money by converting imported crude oil into automobiles than they could by converting imported crude oil into fertilizer.

So they cut back on their fertilizer production, so then you couldn't buy it at any price if you had the money. And they sent out high-level delegations in 1974, one to Peking and one to New Delhi, announcing a 15% cut in fertilizer allocations. The problem of growing more food is clearly a soluble one from a purely technological point of view, but you cannot divorce it from the resource component, which means basically the amount of energy that you put into the system. And if you don't have the energy to put into the system, then you're in real trouble. And that's basically the problem in most developing countries today, simply because there are so many of them are energy importers, and are destined to be for a long time. India is one. Thailand is another; the Philippines another. For a while Indonesia was an exporter, but is soon going to go over the hump. Malaysia is self-sufficient; the People's Republic of China is self-sufficient, but Asia, for the most part, they are they are importers, in spite of a certain amount of offshore oil and so forth.

This is basically one of the real problems that confronts us, or confronts them; but in confronting them it confronts us. How can rural development take place and increased crop yields be obtained without relying... without becoming hooked on imported petroleum? The real question is, can these countries improve their agricultural production making use of indigenous supplies, indigenous resources? Whether that power resource be a windmill, or a water wheel, or whether it be an electrical generator using using methane from agricultural waste, what have you. That is really one of the critical problems confronting us,

but the agricultural problem in these countries is not going to be solved in the absence of a solution of the energy problem.

And in that way, these two problems are inextricably tied up together. There are many subsidiary questions, of course, such as problems of rural electrification. Do they try to do it on a massive centralized... using a massive centralized system, or a decentralized system, or what? Now, of course, other resources are needed too, like phosphates. And indeed the Chinese have started something brand new, in that they are now using phosphate deposits on a village level that would not even be looked at twice by any self-respecting large-scale chemical manufacturer, but which are adequate on a village level for fertilizing the fields around that village. And a geologist in the institute which I had has uncovered the fact that throughout much of the developing world, there are many such deposits that could be used. They just haven't been looked at before adequately in this light.

Well, so much for the food problem as such. Let me come to one other complicating feature which, again, involves food and it involves energy. And that is the whole problem of climate. The climate in the world is always changing from natural causes; there has been a ceaseless pulsation of mean temperature of the Earth from the beginning. Some of it on a time scale of millions of years, some of it on a time scale of hundreds of thousands of years, and some of it on a relatively short time scale. Let me... if you'll turn the light on again, please, I'll go back to some earlier slides.

This is a chart of the mean temperature of Iceland over the last millennium or thereabouts, and you see that there have been significant ups and downs. And it's believed that this is typical of the whole Northern Hemisphere. These temperatures are gleaned in ways that we needn't go into here now, but they're probably pretty good. You notice we go through periods of great warmth, and then through periods of relative coldness. This period in here is known as the Little Ice Age, and indeed it was pretty cold. We can see this from historical records, but then you will notice, wham—up we go. And this peak here is about 1940, where it was warmer on the average than it has been in the last millennium.

And yet for some interesting reason, we call this temperature normal temperature. You will notice we're going downhill and we're going downhill pretty rapidly, and I can show you that in the next slide. Here, we give the same data, but going from 1870. And you see the Little Ice Age here; and it's rather interesting to look at paintings that have been made of Swiss glaciers and the like by tourists in the late part of this century, of the last century. Compared with today, you know, they've just receded. Today you can't skate on the canals of Amsterdam. People skated on the Thames River back in this period; it became, you know, they called this normal. And so there has been a major change, a warming trend. And now what is pretty clearly a cooling trend. Yeah?

[audience member asks a question in background]

BROWN: The situation is very complicated, but if you look at the natural causes for changes, first on a long time scale, it's changes in the Earth's orbit. Then on a shorter time scale, apparently there are two major factors involved. One involves actual changes in the amount of energy which the sun puts out, as evidenced by sunspots and the like. The second involves particulate matter in the atmosphere, and this is intimately related to volcanic explosions and the level of volcanic activity. At the time of Krakatoa, the winter after that, they had the last major explosion early in the century. That was known as the year without a summer. When you put particulate matter in the atmosphere, it reflects the sun's rays and so things are cooler. Yeah?

[audience member continues]

At the moment, I don't count them; I'm sorry, I don't. [...] Well, no, your sunspot maximum-minimum, that's an 11-year period. Yeah. [...] But in any event, the combination of these two, which act in opposite directions: particulate matter cools, and if you have an increase of solar activity, then it can neutralize the particulate matter; if you have a decrease then they can add up together.

Now, so much for natural causes, which are actually more complicated than what I've indicated. Superimposed upon that, there are man-made complications. Now the man-made complications, we are beginning to believe, can be very serious. One man-made complication is increasing particulate matter in the atmosphere as a result of overgrazing, as a result of desertification. A second man-made complication is our outpouring of carbon dioxide into the atmosphere through the combustion of fossil fuels. A third, and related to the latter, is in deforestation, which in effect decreases the rate at which excess carbon dioxide can be assimilated into the biomass, and it's a complicated mess, that theoretically has not really adequately been come to grips with, except—it so happens, and I'm very proud of this fellow, because he was a postdoctoral fellow of mine. I got him interested in carbon dioxide 25 years ago at Cal Tech, and got him measuring carbon dioxide in the atmosphere and he measured diurnal effects, and what it looks like in rainforests up in the state of Washington, and what it looks like when you go up in a blimp, and so forth and so on. Then he established a very important observatory on Mauna Loa in Hawaii, which has given us now a record of the carbon dioxide content of the atmosphere over ocean, the ocean situation away from industry, for quite a few years now, and it's clearly going up. Carbon dioxide is the only major atmospheric constituent that permeates the whole atmosphere, which absorbs in the infrared. And in so doing, it has a marked effect upon the radiation balance of the atmosphere, and has what we call a greenhouse effect in that it traps infrared radiation. And as a result, the more carbon dioxide you have the greater you will expect the mean temperature to be.

This might seem incongruous, then: we're getting cooling with increasing carbon dioxide. But if you look in the southern hemisphere, there appears really to have been a heating, a warming. And it is suspected that this cooling is in part the result of increasing particulate matter in the northern hemisphere as a result of industrial activity and the like, and the particulate matter doesn't get across the equator, but the carbon dioxide does. The particulate matter stays trapped north of the equator.

Well, I don't want to bore you with going into this in any more detail, except to point out that here is the expected increase of carbon dioxide in the years ahead, which then can be converted into increased mean temperature. And this is two-tenths of a degree centigrade, four-tenths of a degree, six-tenths, eight-tenths, one degree by the year 2010. Now that doesn't sound like much. But it is enough to produce major global changes. Now it might sound comfortable, you know, we're going to melt a lot of snow in the north, we're not going to have to pay so much to heat our houses. But associated with any temperature change of that sort, there's bound to be a change in the circulation pattern of the atmosphere. The atmosphere rotates around the Earth. And that means a change in the pattern of distribution of rainfall. And that's really the critical thing. How is the pattern of rainfall going to change as this whole process takes place?

Now, when you talk about a pattern of rainfall change, that implies it's going to rain where it is not raining now... [laughing] and it's going to not rain where it is raining now, in many places. Of critical importance to us is what's going to happen in the Midwest, in our granaries. Of critical importance is what's going to happen to the monsoon belts. Will they shift? Now, we saw a very interesting phenomenon in the last few years, when there was a terrible drought in what is called the Sahel, which is the region of Africa south of the Sahara Desert. They experienced a tremendous drought, and lots of people died; but one of the most interesting phenomena was how the drought led to huge migrations of people. First, tens of thousands of people jamming into the cities, hoping to find food and water there. Others migrated across the Nigerian border with their cattle, hoping to find water for their cattle. Suppose the monsoon belt in India... should the Indian subcontinent shift, if only by a hundred miles or so. The fact is, people are living where they live now because that's where it rains. That's where they have access to water. And if that moves a hundred miles away, eventually, yes, a steady state sets in; but in the meantime, one has a dislocation which can be devastating.

So it's going to be terribly important to examine these changes in the years ahead. They've got to be monitored very very carefully, and the theoretical base for the meteorological consequences of this are going to have to be explored in far greater depth than they have thus far. Of course, one obvious implication is that we might have to ration the consumption of fossil fuels in order to keep the rate of outpouring of carbon dioxide from getting too

high. But we can't cope with it. The thought of an international conference aimed at rationing fossil fuels and coming to an agreement as to who gets to burn it and who doesn't boggles the mind. And yet, I have friends who are not alarmists who are seriously discussing this, as something that has to be examined very very carefully.

So, here we have the ultimate link-up between energy and food, and that the energy can produce climatic changes which can dramatically affect the food supply. Again, I feel that this is a problem that we can come to grips with. But like any problem, you've got to understand the problem before you can solve it. And we are far from really understanding this problem in all of its fantastic complexity. I think that's a good place to stop.

[applause]

[program ends]