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The following excerpts are taken from the ITEST October 1994 Proceedings on The Science and Poliitics of Food. They are scientifically a bit out of date, but the sweep of the argument has still to be seriously taken into account both by "environmentalists" and by "industry." The first excerpt includes remarks by Drs. Robert Collier and Brendan Niemira. At the time Dr. Collier was with Monsanto and Brendan Niemira was pursuing his doctorate in plant pathology at Michigan State University. Currently, Dr. Collier is teaching at the University of Arizona and Dr. Niemira is with United States Department of Agriculture.

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R. COLLIER Last week I was on a panel speaking to a county public health organization in Wisconsin about biotechnology in general and bovine somatotropin in particular. One of the speakers had an overlay I wish I could use tonight. It showed Moses coming down from Mount Sinai with the tablets. He was explaining the Ten Commandments to the Israelites. Someone in the crowd asked: "Is there anything about technology in there?"

It isn't easy to find comments about biology and biotechnology in the Old or New Testaments. I did find a section in the Book of Wisdom which the author might have used to discuss biotechnology, had it been an issue in Old Testament times. It mentions the miracles God worked for the Israelites so that they would survive their 40 year journey to the promised land. The author (starting in Chapter 19:6) wrote: "All creation in its several kinds was being made over anew." In other words, creation was being made new for the survival of the Israelites. "Serving its natural laws that your children might be preserved unharmed." "Serving its natural laws" is important; biotechnology does observe the natural laws of biology.

Verse 18 reads: "Where the elements in variable harmony among themselves, like strings of the harp, produce new melodies while the flow of music steadily persists." This, it seems to me, is an allegory of life. Life constantly changes, though it has been evolving over time; the melody plays on even as the harmony is changing. We can perceive this change from verse 19: "land creatures were changed into water creatures and those that swam went onto the land." Wisdom continues: "where every way, O Lord, You magnified and glorified Your people. Unfailing You stood by them in every time and circumstance."

When we look at the need to feed the world population during the next 50 years, when we understand that we have virtually maximized our ability to mechanize the use of fertilizers and our traditional breeding techniques, then we realize that, without tools like biotechnology, we will be severely hampered. We'll be caught in a terrible choice of using draconian measures to control the reproduction of people living on earth (to flatten population growth) or of enacting fairly tough environmental measures. We are already debating this in our society. We are considering the proper role of society in controlling reproduction and in stabilizing the world environment as it exists today. Can we freeze the environment as it exists? Or should we not realize that the environment has been changing continuously over time as the world has evolved? Should we even attempt to stabilize our environment?

It's not my purpose to discuss agricultural policy or how that's related to biotechnology. If you are interested in reading about this, I would recommend *Sacred Cows and Hot Potatoes: Agrarian Myths and Agricultural Policies*. It discusses how agrarian myths in our culture get us into trouble when we are setting agricultural policy. These myths also trap farmers into situations where they cannot maximize their ability to make income. This is another burden for a sector of our society that's largely forgotten simply because it has been so successful in providing us with inexpensive food. On the average, Americans pay about 9 cents of their dollar for food; in Europe it's around 20 cents; in Africa it is approximately 75 cents of each dollar. So, we're blessed with our agricultural system. Unfortunately, however, most of us, or at least many of us, no longer remember how that food is produced. Consequently, many of us are easily frightened by scare tactics. A classic example of such tactics was the Alar scare. Nonetheless, in a society that doesn't understand how its food is produced, people are easily frightened when someone says that our food is changed and we have no control over it.

Most of my paper deals with the techniques that will be available in the animal science area for improving productivity of domestic animals. Biotechnology is involved in several places, first in the form of new metabolic enhancers that allow us to improve the efficiency of food production. I emphasized that most agricultural animal science research has been oriented towards reducing the inputs required to produce a given pound of meat or fiber. I want to re-emphasize this because farmers in general cannot control the prices they receive at the marketplace. Prices fluctuate wildly, depending on the world economy. Farmers have little control over their input costs which have risen dramatically over the last 50 years. Yet, the price farmers get for their produce has hardly risen. In fact, milk sells today for about the same relative price that it did in 1950. When farmers face a financial squeeze like that, the only thing they can try to control is the cost of production. When it comes to raising animals, the greatest single cost is for food. Therefore, improving the efficiency of the domestic animal improves a farmer's ability to compete. Let me give a clear example.

In the dairy industry in the United States today, it takes about 16,000 pounds of milk per cow per year to break even. That's quite close to the national average. Thus, whether a farmer stays in business or not depends on the number of animals the farmer has or on the efficiency with which these animals produce milk. A farmer with an average production of 14,000 pounds per cow per year needs 130 cows to make $25,000, after paying all expenses. If the cows are producing 18,000 pounds of milk per cow, the farmer needs only 75 cows. If the cows are producing 20,000 pounds of milk, the farmer needs only 25 cows to make $25,000 after expenses. An odd thing: who produces the most milk? The farmer with the 130 cows at 14,000 pounds of milk produces the most milk; he (she) needs those extra cows to buy the feed to make the milk so he (she) can try to make $25,000.

Wisconsin is a clear example of the dairy industry under restructuring right now. The average milk production per cow in Wisconsin is 14,000 pounds of milk per year. The average herd size is 55 cows. So one can see at a glance that with 55 low production cows, a farmer cannot service debt and his children cannot buy the farm. The best opportunity that a small dairy producer in the U.S. has is finding ways to improve the milk production per cow in a safe and effective way. That is the basis for genetic selection; it's the basis for milking three times a day instead of twice a day; it's the basis for improved nutritional management of dairy cows by what we call total extraction. Virtually every method that can be employed at the farm to improve the milk production per cow is employed in order to maximize profits.

Biotechnology is focused in the area of reproduction. I reviewed this in my paper on several levels. Take reproductive control. Early on in the animal sciences, it was realized that it was important to control reproduction. The first breakthrough was artificial insemination which allowed the genetics of a single bull to be spread over an entire industry. Today, top artificial insemination bulls can have from 50,000 to 100,000 daughters, not just in the U.S. but across the world. However, on the female side, the average female has only two or three daughters. It's a 50/50 proposition. If a cow has a total of six offspring, half, on average, would be females. By the time one decides whether those offspring are of any value and gets production records from those three females, there will not be many of their daughters to work with.

The next step was to try to find some way to multiply the genetics legacy of females. That step involved superovulation. First, we multiply the number of eggs that can be obtained from a single female. Ways were developed to split embryos to provide identical copies of the same embryo. The earliest method was physically splitting a two-cell embryo to produce identical twins. This is essentially how identical twins occur naturally. At the two-cell level they sometimes split, producing not fraternal but identical twins. This is a limited process because we can do this only a few times and get only a few offspring. We can't do it at the four-cell stage because the cells are no longer totipotent. We cannot take a four-cell embryo and successfully split it into four different cells. Many times those four cells do not go on to develop successfully. They're missing part of the genetic information required for the early development of the embryo.

Scientists developed cloning in which the embryo was allowed to develop to 64 cells. They then fragmented the embryo into 64 individual cells and took out the nucleus, which contains all the genetic information. Then they got 64 eggs from slaughter house ovaries, took the nucleus out of those eggs and put in the nucleus of the embryo they wanted to copy. They then put that "re-nucleated" egg into a recipient female, ending up with 64 copies of the same original animal -- with some exceptions. Even as early as the 64-cell stage, there are some differences which can occur, resulting in variations in these "identical copies." The inner cell mass, the inner cells of this 64-cell embryo, produce animals that are on average 20 percent bigger than their clone mates. At present no one really understands why this occurs.

The mitochondria are only in the egg -- they're not carried by the sperm. Mitochondria have strictly maternal DNA. A certain part of our genetic heritage comes down only through the maternal line. This is one way we've learned to trace back heredity through the maternal side. Mitochondrial DNA, for example, is involved on the human level in the search for "Eve." You've probably heard of some of the studies in which some scientists have tried to determine whether we can trace all females back to one female, through maternal mitochondria. Be that as it may, if we take the nucleus out and put it into an egg, the mitochondria in one egg are different from those in the next egg. So, even with cloning we cannot have identical copies.

Cloning raises many issues; but it's being done. Cattle are produced by cloning and these animals are used in agriculture. Clearly, for someone in the business of selling embryos -- an amazing number of people in the livestock industry around the world market embryos -- this is an attractive proposition.

It will become a particularly powerful method when it is capable of identifying a superior embryo at the one-cell stage, if we can do it that early. Then we shall have a method for weeding out the less desirable embryos even before we place them into recipient females. This will wipe out the generation interval. We won't have to wait three years to find out what that cow's milk production will be. We shall know just by taking the genetic markers that are involved and looking for them in the early embryo. If we had a 64-cell embryo, for example, it would just take one cell to determine that animal's DNA pattern, because we have another technique in which we can multiply the genetic message in one cell and look for all the different markers.

In my paper I mentioned one example of a marker we discovered at Monsanto; namely, the growth hormone gene marker. Let me give you some idea of how rapidly this type of work occurs around the world today. We published those results in about 1992. The work was based on the fact that there are four different forms of somatotropin, a growth hormone produced by the cow's pituitary. Two of those are due to a genetic mutation, a single base-pair switch, guanine to cytosine. Using restriction enzymes to cut the DNA, we can determine which cows have which variant. We screened the major dairy breeds across the U.S. and found that in the Holstein breed one variant was favored. That variant was worth about a thousand pounds of milk a year. Since we've published that paper, it's been verified by four or five laboratories in Japan, Germany and in the U.S. Just this week I received a paper in which a research group demonstrated that the cows that have this one specific genetic marker have more growth hormone concentrations; that's why these cows have a superior level of milk production. That marker -- within a two year period, remember -- has already been licensed by a firm in England to begin screening all the bull embryos and all the cow embryos that go through their artificial insemination embryo practice. This kind of technique will be utilized more and more as we learn what genes control these various traits.

Working with domestic animals is complex because a trait like milk production is not due to a single gene. It's due to probably more than 100 genes. We are dealing with what are called quantitative traits, those due to more than one gene. This makes it more difficult. Nonetheless, researchers have every intention of finding each of those genes, of mapping the genetic markers and of using the knowledge gained on developing embryos.

These same techniques can be used in humans. It's the very same biology. As with artificial insemination, the technology is relatively rapidly transferred once the technique is developed. I'm not going to get into the ethics or morality of that beyond noting that it poses a question for society.

The last things I'll mention are transgenics and biodiversity. Let's start with transgenics. Once we can excise segments of DNA, we can selectively put it into animals either to produce proteins or to overcome disease states. Consider a defect like cystic fibrosis -- to give an example in humans. If we can find the gene factor and the defect, we can possibly correct it.

As I said, these techniques will be used two ways in domestic animals. First, we can genetically engineer the mammary glands of dairy cows to produce milk containing human proteins. Why would we want to do that? Well, we could produce an infant formula more like human milk, containing the growth factors and the antimicrobial agents present in human milk. Infant formula constitutes an approximately $4 or 5 billion industry. With that kind of money at stake, people will be quite willing to do this. In fact, GenFarm, a Dutch genetic engineering company, has already produced bulls and cows that can carry human genes for milk for infant formula production down the road. There is also a company in Scotland producing sheep and goats with human factor IX for clotting and some other peptides highly valuable to human medicine.

A second reason for putting such material in animals instead of using *E. coli*, a bacterium, is that certain proteins in humans are glycosylated, that is, they have sugars on them that bacteria cannot put there. It can be done only by other yeasts or an animal production process, an animal cell. So, these proteins made in animals can more closely resemble what the protein looks like in humans. There will be -- there are already today -- transgenic companies, transgenic biology, oriented around human health. There will also be transgenics to improve growth rate, transgenics to add traits, improve quality.

Let me give another example. Today, dairy farmers in the U.S. produce milk, but this is the only country in the world where milk is legally defined by Congress. In fact, milk, in order to be sold, has to be at least 11.5 to 12 percent solids. That means it has to have a relatively high fat content. In order to get value for the milk a farmer sells, it has to have about 3 percent fat. Eighty-five percent of the milk that's sold to stores is 2 percent; most people I know drink less than 2 percent. As people get older, they tend to drink lower fat milk. But the farmer is paid to produce high fat milk. Of course, this gets into the agricultural policy area, but it is feasible -- and in fact it's what the consumer is asking for -- to produce milk higher in protein and lower in fat. We can use transgenic technology to genetically engineer cows to produce low fat, high protein milk. That milk would be of greater value to the dairy industry and more desirable to the consumers. That's another way we could use transgenic technology.

There's very little regulation of transgenic biology at present, except where one intends to insert something into the human food supply or to release something into the environment. Both of these situations are heavily regulated but, in fact, at universities there's very little oversight. We'll find regulations becoming stricter as the process of transgenic biology grows and develops.

Another method of inserting genes into animals uses oncogenes -- genes that cause cancer. But these genes also do other things. The ski oncogene is the example I used in my essay. It can be inserted into muscle to get a more muscular animal. There's a dairy breed in Belgium called the Belgium Blue. It's a double muscled animal. Although they look pretty bizarre, they're quite popular in Belgium. That's an example of a naturally produced animal. We've all seen transgenes. If you've seen a mule, you've seen a transgene. It's a horse crossed with a donkey. That was done on a very crude level before. Now it's going to be done with very specific ends in mind.

The last thing I want to mention is biodiversity. We have a lot of nearly extinct major breeds. There are 241 distinct breeds of cattle in the world and yet in the U.S., for example, 95 percent of the dairy cows are Holsteins. Many minor dairy breeds will soon be extinct if we don't freeze the embryos and store the genetic information for future generations. We don't know how that information might be used in the future or what genes may be of value.

Because of my experience in this area, I look at genes as treasure houses of information stored up over millennia of evolution. We don't know how many of these genes might be used in the future to improve food production capability or possibly to adapt to a change in our environment. It may be a change that's not man-induced, produced by some factor we can't control - maybe a tilt of the earth which has a major impact on the environment. If there is a change in the earth's tilt - this is related to glaciation - if the earth swings the other way, we'll have a major environmental change.

The ocean flounder has an "antifreeze gene" that allows it to stay alive in cold environments. Specifically, the lipids usually become fragile as the temperature drops; this is a change in the degree of saturation or chain link with which the lipid becomes more fluid, allowing the animal or plant to stay functional in colder situations. Inserting that into strawberries results in "frost-free" strawberries. These were produced in California. There was a hue and cry over biotechnology during which, if I recall correctly, fields were destroyed by environmental activists. I doubt that they ever marketed the frost-free strawberry.

Brendan Niemira will talk about plants. I'd just like to say that we will see an integration of the plant and animal biotechnologies. We will genetically engineer plants to make them better for animals. Plants have a lot of things in them that animals cannot use. One of them is lignin, a component of the cell wall that not even ruminants can break down. They can break down cellulose but not lignin. If we can find ways to make plants more usable, if we can develop plants that fix nitrogen better or produce more high quality protein in their cells, then the food source will become more valuable for animals and for farmers. The latter could get better growth rates and greater milk production from their animals.

These things are in the future. We're just at the dawn of the age of biotechnology. But even now it raises many issues because of its power and because it means we're starting to control evolution in many ways, certainly the evolution of domestic animals, maybe not so much wild animals. We have exerted a degree of control over animals since they've been domesticated, and we certainly will exert a much greater degree of control than we have in the past.

B. NIEMIRA A couple of things in my essay are related to some of the things that Bob Collier mentioned -- the maximization of the productivity of some of the agricultural systems that have traditionally been used. Dr. Collier's much more familiar with it from an animal standpoint. I'm more familiar with it from a plant productivity standpoint. But some of the themes are very similar: plants, as they have existed or plants as they have been produced through traditional breeding, can be pushed to do only so far. Some of those limits have been reached with fertilizer applications in plant productivity and feed maximization in animal systems.

As noted in my essay, a couple of ways are used to try to modify this situation and to increase productivity over what we might ordinarily see. That includes changing the plant's growing environment or changing the plants themselves. In my essay I list a number of different ways that environments in which plants were grown have traditionally been modified. These modifications are coming more into vogue with a rediscovery of sustainable agriculture systems. This is a mindset focused on trying not to turn the plant into a machine or to treat the plant as a machine. Rather, it looks to incorporating the plant with its needs and requirements into the environment in which it growing. I touched on intercropping, cover cropping, crop rotations in my essay so I'll not repeat that here.

We're interested in modifying the plant through biotechnology. Biotechnology accelerates the results we would see with traditional breeding; results are achieved in a much shorter time. We may be able to produce a final marketable hybrid seed in perhaps 1/1000th of the time that it might have taken before we could apply some of the modern technological methods to the breeding.

We see some results now and will see more in the future. More radically altered plants -- transgenically altered plants with genes from other plants, genes from fungi, bacteria or from animals -- are of greater interest and greater concern. These things can be immensely profitable and immensely useful; nonetheless, there is a major concern with doing some of them. I'm not a Jeremy Rifkin saying we shouldn't do them. I strongly feel that we should. But most surprises are bad. Surprises can be very bad. We might have unexpected results. I don't know what percentage will be interesting and harmless. It takes only one really nasty surprise to destroy the potential benefits that we might have derived from an entire system of inquiry. Plants that produce 20 times as much grain, plants that fill their seed heads in one-tenth of the time, double muscled cows, cows that produce 16,000, 18,000 or 22,000 pounds of milk per year -- those will not be remembered if a gene escapes and we have some kind of a catastrophic situation on our hands. We have to remember, as we do these studies and projects and create the organisms we're working on, that Mother Nature always bats last.

As recently as 10 years ago, there was a feeling among microbiologists and geneticists that, if we could modify a single cell and if we could control the activity of that one single cell or that one gene, we would be able to do whatever we wanted to the plant or animal. We know now that it's not that simple. This brings me to a theme I saw through all the essays: that is that the reductionist worldview is falling by the wayside in favor of a more global holistic worldview. This reflects the fact that the problems we're trying to solve can't be solved by addressing one little subset of the concern.

We can't make a better plant by making a better gene, because, when we create that new gene and change that plant, we will take that plant out of the test tube in a sterile laboratory and put it in the field. The plant will interact with a lot of different things we have not accounted for in the laboratory. We can't possibly account for all of them in a laboratory. There's not a lab in the world, not a greenhouse in the world, not a field trial plot in the world, that will see all of the changes and all of the different interactions that these plants and animals will see as they will go through their lives and are used during the next five or ten or 100 years. We have to integrate what we're doing with the big picture.

I touched on some of these issues toward the end of my essay. There are major questions we must be aware of. After we have created these new plants and animals, these new organisms we're working on, how will they interact with other things in the environment? How will they interact with their symbiotic organisms, with the mycorrhizal fungi that live in the soil and without which many plants can't grow. How will they interact with the symbiotic bacteria that allow lichens to fix their nitrogen. How will they interact with wildlife that we didn't think of in the lab? What will happen to animals that come along and eat our high lysine corn? Say we have a spillage of the milk with human protein in it. How will that affect the soil microbiota? These are questions we can't answer unless we take the time and trouble to try to think of everything. Nobody can do that. But we can think of many things or even, maybe, most things.

When we create these organisms and release them into the environment, we must remember that we're not fitting them into a sterile field. We are not going to be putting them into an environment isolated from everything else out there. These organisms will interact. In my essay I gave an example of a recent research study done at Michigan State University. They demonstrated that there are certain types of plant pathogenic viruses that actually lift DNA from their host plant, incorporate it into their own genome and then carry it to a different plant, to a different species of plant. In the past that hasn't been very much of a problem, because the only kind of DNA in plants is plant DNA.

But consider the introduction of a plant -- it may very well be growing in the field now -- carrying the BT (Bacillus thuringiensis) gene. I know there are a number of kinds of crops that are going to be using the BT gene, the BT toxin. That toxin is quite effective against a number of insects. The potato beetle is the one that I'm most familiar with. This is a natural toxin and scientists have found this gene in a soil bacillus and decided that it was a marvelous toxin. It's a natural pesticide. Science lifted the gene out of the bacteria and put it into plants -- into potatoes, corn and, I believe, rye. There are a number of other plants that are planned for use with the BT toxin gene.

This is the kind of situation in which we need to consider what will happen to those genes. We must look at what will happen to that DNA. DNA does not stay in one place; it travels. If it hasn't been made clear, in the ongoing debates in the popular press and in this forum, that DNA is mobile. Be aware of that fact. It's perhaps more mobile in plant systems than it is in animal systems. But I feel that it won't be very long before we do start to see some modifications in animals incorporating rather radical transgenic fixes. I can't predict what those will be. In fact, I have no idea what they'll be. During the next 10 to 20 years, we'll see some strange things coming about, a lot of mixtures of plants, animals, fungi, bacteria. Some we'll be familiar with, others, not. All of these can be tremendously useful and tremendously productive, but they have to be fitted into what already exists.

The environment is out there. All of the organisms that live in the soil, float through the air, live in the trees, everywhere, will interact with our construct. If that construct does just fine in the laboratory, we have to make sure that it will do fine in the environment, because the environment is boss. That is the main message I'd like to communicate in talking about plant biotechnology. Clearly, there's a lot of potential for good in new or re-designed plants. Nonetheless, there is a real danger associated with biotechnology that I think we need to consider very carefully before we start moving full bore into modifying all of these organisms.

[The next excerpt is taken from Session IV of the same set of Proceedings. It represents an intervention made by Dr. Thomas Sheahen, a physicist from the Washington, DC area. Dr. Sheahen is currently acting as a consultant in the same area.]

SHEAHEN I have two things to talk about briefly. One is electricity, the other is chaos. The connection between them is the matter of capital. This morning we talked about responsibility and accountability, but, when it comes to building things, we need capital. We heard about the need for roads, infrastructure and pipes to carry clean water. All that is capital equipment.

I've learned from various people recently that the following is true. The curve of almost anything you want, economic activity, or whatever, tends to increase as our use of electricity increases. It may interest you to know that the average American, each one of us, our children, our spouses, everybody we know, uses a kilowatt all the time -- the national budget of electricity divided by the national population.

A few years ago at ITEST's Workshop, *The External Environment*, I produced some charts from various projections of energy resources in the world. Americans were at about a kilowatt, Western Europe and Japan were at about 500 watts and the Third World was well under 100 watts. This meant that most people used zero watts, because there is no electricity in big fractions of the world. My point at that conference was our need to provide electricity to these people, if we're ever going to let them come up to a higher standard of living.

Bob Morris' paper mentioned the problem of storing food and how it spoils on the way to market. Jack Kinney's paper talked about not being able to get out of the mud when one is only 100 miles away from a huge food supply and about people starving because of lack of infrastructure. Bob Morris mentioned that when he was a child the family had an ice box and later a refrigerator. People in undeveloped countries haven't got the refrigerator yet. Electricity is needed for these things. They have to have capital investment if they're going to have electricity. Whether we're talking about a coal burning plant, a nuclear plant, a hydroelectric power dam, they're not going to have electricity without capital investment -- that's very important. Capital investment implies banks and investors -- it implies profit. That's what that world is all about.

In the area of forming capital, a huge mistake was thrust upon the world, upon governments and planners; that mistake has persisted for about 20 years. That great error had and has to do with the idea that capital is incompatible with a sustainable economy, a sustainable world. Back in the very early 1970s, the Club of Rome -- a group of important world planners -- got together and concluded that it was necessary then to restrict capital formation in order to avert catastrophe later. They came to that conclusion on the basis of a big computer model. We have found out since about 1982, when the branch of mathematics called chaos was developed, that that whole computer model is total nonsense. I want to just take a brief minute to tell you why.

When we work with coupled nonlinear equations and solve the equation for the present moment, the next moment, the moment after that and the moment after that, we can propagate the equations forward and get a numerical solution from the computer. If we do this for today, tomorrow, and next week, it is probably okay. But if we keep going with these equations, sooner or later, no matter what we are computing this way, our solutions diverge into chaos.

Weather systems are a good example of this. Weather experts have big computational models which involve coupled nonlinear equations. They work very well if we know the today's weather and are trying to predict tomorrow's weather. On the TV at night they have a seven day forecast which is so-so. But if we look at the National Oceanic and Atmospheric Administration booklet [given to each participant at the Workshop], we find on pages 21 and 22 that we can forecast a season ahead. If we know what this year's weather was like, we can do a halfway decent job of computationally predicting next year's El Niño or lack thereof. But if we try to do it long term, it's terrible. The biggest thing, and I'm sure Ben Abell can confirm this, is when we get a bigger and better computer and propagate further and further forward, we get weird situations. We can grind our computer forever, but, because of this problem of coupled nonlinear equations, we can't get a good solution over a long period of time.

Somewhere in the early '60s when big computer mainframes were coming into use, James Forrester at MIT worked out a science called "industrial dynamics." He started with coupled equations of industrial inputs, computed them and predicted what was going to happen. This was pretty good. He'd carry it forward five years or something like that. Pursuant to his work, the Meadowses and others took the basic structure of the computer program and put in world type variables like pollution, population, food, and so forth. They computed that forward. Sure enough, their computer actually gave them numerical values. Food, resources, population, industrial output per capita and pollution were noted. The Meadowses would cut off the calculation and carry it no further when something went to zero. Negative population, for instance, would make no sense. But they predicted from this type of computer modeling -- nothing but a mathematical artifact -- that there were going to be catastrophes like a huge collapse in world population. They had many of these scenarios. One scenario came up nice, the one in which they restricted capital.

As a result pollution went up in a finite way, food per capita dropped a little, population was okay, and we lived happily ever after. What they never realized in all of it was it was totally a computational exercise in chaos. It was an accident. Rather than having capital dropping down, they might have had strikes by baseball players falling off. Any screwball variable at all could have given them this completely fortuitous result. Unhappily, this kind of thing was seized upon by The Club of Rome, big world planners. They went off and started making world policy based on the idea of restricting capital now. So this is some of the stuff that we're up against when we wonder why people in other nations aren't doing things right. Part of it is because they have extremely poor judgment about what science can and can't do for them.

[A final excerpt is taken from Session 2. It involves Mr. Robert Morris, a chemist and then Corporate Vice President of Technical Affairs and Product Integrity at Continental Baking Company, a subsidiary of Ralston Purina Company. He is currently President of Managing Technologies in Williamsburg Virginia. Mr. Jack Kinney, now deceased, at the time (1994) was a self-employed environmental engineering consultant. He was very active in Africa, especially Uganda. Dr. Helen Mandeville is Prof. Emeritus of English at Saint Louis University and Pastor Daniel Jungkuntz is a Lutheran Pastor in Newport News, Virginia.]

MORRIS I'd like to comment on three things. First I'll mention bureaucracy. I thought Steve Kuhl's comment last night and again this morning about industry or agribusiness being another form of bureaucracy is right on target. I do not disagree with that. There's very little difference, as Jean-Robert Leguey-Feilleux points out, between the control of the bureaucracy of a large corporation -- I've worked in some of the largest -- and the control exercised by federal regulators or the activities of various UN organizations. There is a significant difference, however, over the controls which limit the activities of these bureaucracies: the UN bureaucracies can go on *ad infinitum* because they appear to get their money from only two sources; namely, begging among the community of nations or extracting it from the dues structure of the United Nations through its budget. The federal and state regulatory bureaucracies get their money by taxation and, consequently, they have almost unilateral control over what those taxes are at any given point in time. We can see that from the tax structures in the United States over the last 15 years. The industrial bureaucracy, however, gets its money from only one place; namely, selling a product or a service to the community. They are the ones most immediately responsible to the community of customers and clients. If they do something wrong, they pay for it very quickly, whether it is trying to introduce a frost-proof strawberry or a genetically controlled tomato that ripens very slowly during distribution. If the "federal regulator of the household" doesn't want to buy them, the producers and distributors get that message very quickly. I would rather live with a bureaucracy that the people can control with relatively quick response time than with a bureaucracy that I never expect to have any control over.

Whether France, Italy or the United Nations would be better off with or without bureaucracy, or whether France and Italy would have survived, raises an issue for me. Those bureaucracies cannot take credit for progress, if, in actual fact, the rate of progress was unchanged or impeded by their presence. If we looked at the development in those countries over that time frame, I expect that we would come up with clear statistical evidence that, when the bureaucracies of the French and the Italian government, and even the United States government, control something, things change more slowly. That may be good in some people's minds. I just happen to disagree with it.

That leads me to my second point, the definition of democracy. Democracy as I understand it is the rule of the majority acting on factual information. It is not controlled by minorities, whether those minorities depend on and extract politically correct behavior from the majority of people in an organization or whether they are the minorities of federal or state regulators. Until we have informed majority rule, we don't have a democracy. Informed majority rule means that up to 49.9 percent of the population will be disappointed at times. My only argument with that state of affairs is that I've been disappointed too many times and I'd like to have a shot at the other side. I would have that shot if I were able to operate on a basis of facts and without the control of minority regulators.

My last comment is about technology changed by society. If you read my paper, you would see that the revolution that took place in agriculture in the United States between 1900 and 1994 was unbelievable, really unbelievable. There is nothing in the literature where anyone at any time during those 94 years ever predicted properly what was going to happen in the next ten years. Now all of a sudden we're afraid of it. We think it's out of control. We think that it's going to gobble us up in some way, in a science-fiction-film kind of operation. The really big change since 1975 is that we no longer as a nation will control the rate of that technological change.

Because we've educated so many people in our graduate schools who have gone back to their home countries and now practice technology the way they were taught to practice it here, the control of agricultural, biological and chemical technology, and even physical technology, is no longer centered in this country. Technological capacity is worldwide and any country can move it along. If we think we can legislate or regulate technological progress out of their lives, we will find out that we cannot. What will happen is that, instead of eating U.S. products, we will be eating foreign products made by technologically advanced systems. We must keep that in the back of our minds. This country's greatest export since 1975 has not been food, minerals or weapons -- it has been PhDs with loyalties to their native countries who are now as good as we can ever expect to be.

KINNEY One of my greatest worries is that we would have an Italian or a French bureaucracy. Any bureaucracy like that would be a disaster. There are other ways of doing things. When Idi Amin was booted out of Uganda, I was invited to set up a program for the redevelopment of Uganda. I collected information from the World Bank and the UN. I found out later that it wasn't worth the paper it was written on -- but they carried it to three decimal places. It looked official -- and it was wrong. I spent two years developing a profile of Uganda.

My idea of the environment is looking at the totality of the human environment. Anything that affects that environment is part of my concern. I put together a profile on Uganda that included their water supply, their sanitation (or lack of it), their agriculture (crops and animals), their transportation, their education and their housing. I spelled out the whole national picture. Then I prepared a regional setup that showed how it fitted into the overall picture. How does one promote that or reduce it to the village level? What kind of leadership is needed? What kind of information is needed. The bureaucracy at the governmental level, at the ministerial level, was really something. They didn't want this information out. They didn't know whether it was right or wrong; they didn't care whether it was right or wrong. This was the best estimate available. They had the support of the prime minister in checking it. This estimate reduced the whole project to the local level -- from the bottom up instead of from the top down.

There are two populations in each African country. Ten percent are the elite. Ninety percent are the rural and urban poor. The two of them do not overlap; they do not mix; they are separate worlds. The UN and our government deal with the 10 percent elite and argue that it is up to them to filter the results down to the rest of the population. I have friends who are ministers making $50 a month whose children are at the Sorbonne or Cambridge. The graft is fantastic. Half the funding (half the money) in Uganda never reaches a bank. I said, “Fine, if the government people don’t trust banks, then team up for yourselves and work from the bottom up. Develop your own unions.” They are doing it. Their standard of living has doubled, in some places tripled in five years. This can be done by guidance, not by dictation. Development can never come through a bureaucracy. It has to come from people who are acquainted with it.

The Ugandan agricultural research station was one of the best in Africa. If one goes there now, one sees musty bookshelves and no periodicals. “How are you aware of what’s going on?” They reply that visitors tell them what’s going on. When I came back here, I contacted the Department of Agriculture. I asked whether they could set up a computer system through their library to that research center so that they would have everything available? I never got an answer. I wrote a second letter and received no answer. Somewhere we must determine if we’re interested in helping people or not. If we are, we must determine the means by which we can do it. I hope that, with the mix in this group, we might have the imagination to determine how we can break that logjam.

MANDEVILLE I’d like to recommend an article by Christopher Hitchens which came out in current issue of Vanity Fair, of all places. Amidst all the underwear and perfume ads, there’s an article that looks like a preview and postscript to what Mr. Kinney has been saying. I can’t remember the exact title because I wasn’t expecting to bring it up. Hitchens made a trip circling Africa and pinpointed almost the same places Jack Kinney mentioned. He came to the same conclusion: Africa is now being run by the United Nations; it’s being financed by the World Bank; neither of them listen to people. As Mr. Kinney was talking, I kept going back to Hitchens’ article. I suggest cutting out the ads and stapling the article together. That will give continuity. It’s a depressing article. But it looks like he wrote it from this conference.

JUNGKUNTZ I think we’re trying to find some wisdom. To do that, we need to distinguish between our feelings and our thinking and arrive at some calm interaction. I see deep feelings in each of the papers, but at this point we have only minimal understanding of each other. I have not heard yet a response to Dr. Leguey-Feilleux’s question to both Jack and Bob. If we’re going to complain about bureaucracies being the problem, with what will we replace them? Bob Morris responded by distinguishing between government bureaucracy and corporate bureaucracy. But with what can we replace governmental bureaucracy? We can’t do away with it. We’ll just replace one bureaucracy with another. The issue seems to be about the wisdom of who will guide that bureaucracy. Does it come down to saying that as long as it’s our bureaucracy, it’s good and as long as it’s somebody else’s bureaucracy, it’s bad?