

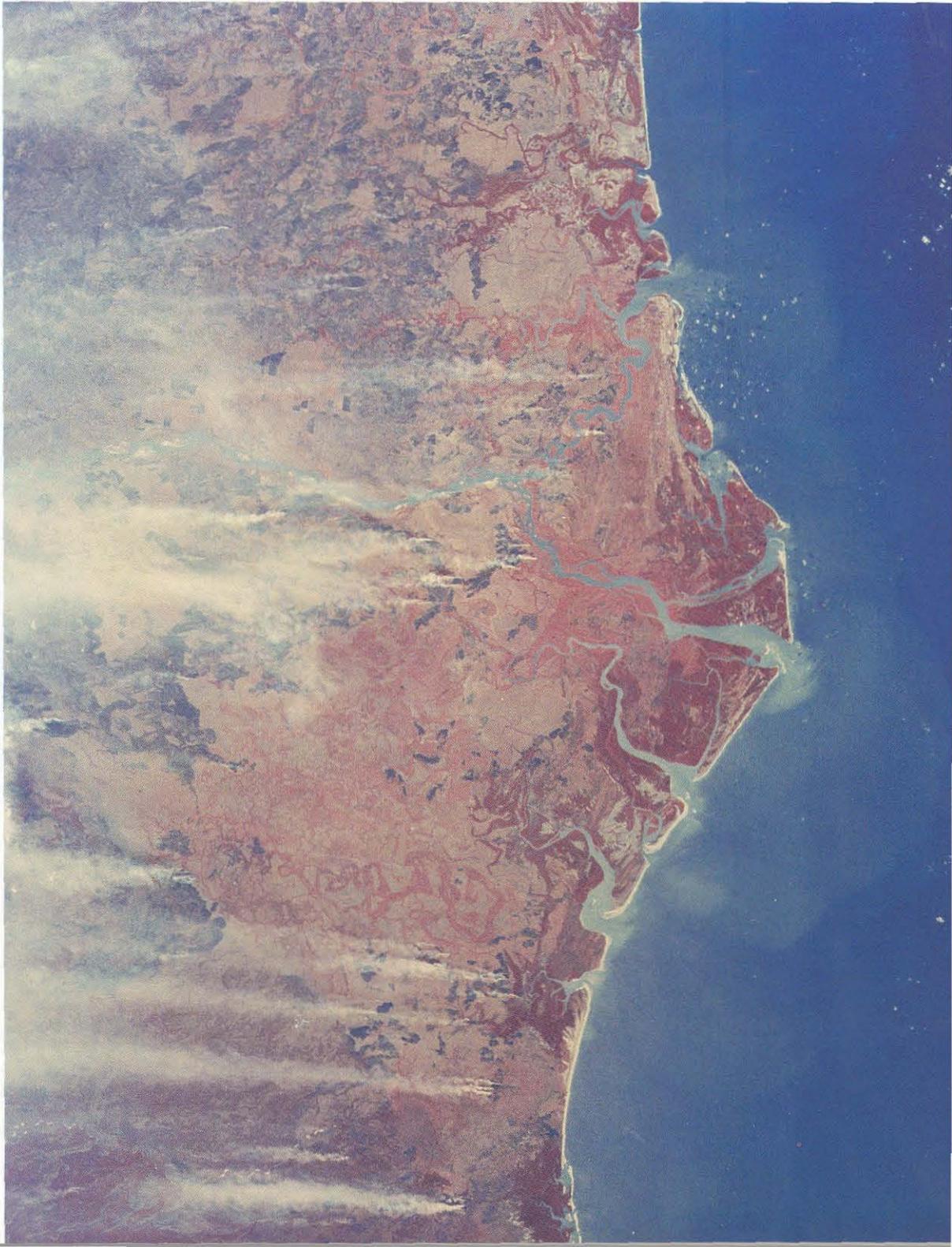
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In this issue

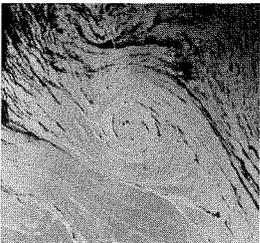
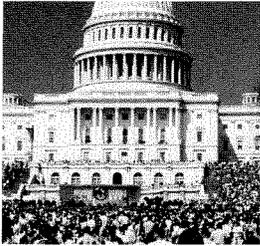
*Visions of a
Sustainable
World*





This view from the space shuttle *Discovery*, taken between April 28 and May 6, 1991, shows smoke from Kuwaiti oil wells burning out of control in the aftermath of the Iraqi occupation. Kuwait City can be seen on the peninsula in the center of the photo, while the island of Faylakah is barely visible through the smoke.

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On the cover: Fires near the east coast of Mozambique, as seen from the space shuttle *Challenger* in October 1984. This photograph, made with near-infrared light, shows many parallel plumes of white smoke from slash-and-burn agricultural fires. Toward the left of the image, the plumes begin to merge into a single pall of dense haze. The erosion resulting from the cleared land can also be seen in the tendrils of silt that extend out into the Indian Ocean from the mouths of the rivers.

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Foreword

*Dedicated to
the memory of
Harrison Brown
(1917–1986)*

The mouth of the Betsiboka River, on Madagascar's west coast, runs reddish brown from its cargo of Madagascar mud. Extensive deforestation has left many hills denuded. Without the network of tree roots to hold the topsoil in place, it washes out to sea with every rainfall. This photo was taken from the space shuttle *Discovery*.

The *Visions of a Sustainable World* symposium, held October 27–30, 1991 in Caltech's Beckman Auditorium, was dedicated to the memory of Harrison Brown (1917–1986), professor of geochemistry and professor of science and government. As symposium co-organizer Murray Gell-Mann, Millikan Professor of Theoretical Physics and Nobel laureate, reminded the audience, Brown "was a pioneer in trying to organize efforts, especially in the world scientific community, to do something about the interlinked problems of poverty, environmental degradation, rapid population growth, and threats to world peace. In 1957, he and two Caltech colleagues, James Bonner and John Weir, organized a workshop on 'The Next Hundred Years.' Tonight, Bonner, now emeritus professor of biology, is with us as one of the organizers of this meeting."

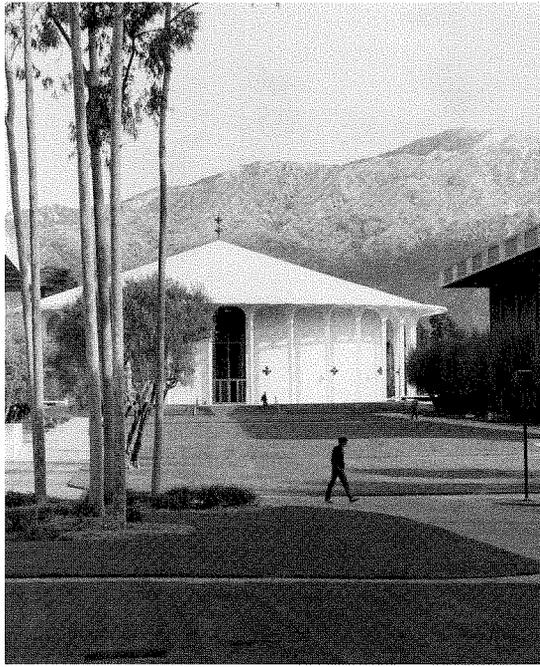
The organizers—Bonner (PhD '34); Norman Brooks (PhD '54), Irvine Professor of Environmental and Civil Engineering; Sunney Chan, Hoag Professor of biophysical chemistry; Gell-Mann; Paul MacCready (MS '48, PhD '52), president of AeroVironment, Inc.; and Bruce Murray, professor of planetary science—divided the conference up into eleven sessions. The first day's sessions dealt with the intertwined problems of development, technology, population control, economics, and managing the "global commons"—those parts of the globe (the atmosphere, the ocean, and Antarctica) that belong to everyone and thus to no one. The second day covered what might be called "people problems"—the roles of culture and ideology, how global government might work, and from what quarters

unexpected developments might come that could throw the other sessions' prognostications into a cocked hat. The third day was devoted to California and its problems. Ever the trend-setter, California's experiences—be they with smog or property taxes—are often relived elsewhere in the years that follow. Thus California, with its burgeoning population and the world's seventh largest economy (as of 1984), is not only a microcosm of the world but a window on its future. (Excerpts from the California sessions will appear in a future edition of *Engineering & Science*.)

The symposium's program notes stated, "Our objective is to stimulate broad thinking and intuition regarding how the Earth's rapidly growing and changing human population and its diverse cultures can, over the next one hundred years, approach an equilibrium with Earth's finite environment and resources within a comparatively peaceful world order [in which] major catastrophes, including disastrous environmental degradation, world conflicts, and widespread tyranny would become unlikely.

"The future, of course, cannot be predicted, and often not even anticipated. Nevertheless, it is useful to try to identify key transitions that appear to be required for an approach to sustainability. An obvious one is a demographic transition to a relatively stable global population. Another is a technological transition to a situation in which there is a great reduction in the environmental impact per person necessary to maintain a given standard of living. That in turn seems to depend on an economic transition to a market system in which prices of goods and services bet-

The Visions of a Sustainable World symposium was held in Caltech's Beckman Auditorium.



"I've noticed that there are two kinds of future. There's the kind that gets confidently forecast, and the kind that actually happens."

ter reflect their true cost to society—present and future. Sustainability will probably require a transition to large-scale patterns of human relationships that foster comparative political stability, as well as ideological transitions to value systems that are conducive to sustainability. Finally, there would have to be a governance transition to a world with adequate arrangements to deal with major global problems, including those arising from enduring ethnic conflicts."

The idea, Gell-Mann instructed the participants, was not "to *forecast* the events or trends of the next 50 to 100 years, but rather to ask whether there is any prospect of the world's history turning in certain directions, vaguely described by the very approximate term 'sustainability,' and, if so, how such changes could come about." Harlan Cleveland, professor of public affairs and planning, emeritus, of the University of Minnesota, applauded this. "I've noticed that there are two kinds of future. There's the kind that gets confidently forecast, and the kind that actually happens. Extrapolations using the original statistical sin of mistaking current trends for human destiny have the great virtue of selling books. *The Limits to Growth* sold 3 million copies in 16 languages, despite the fact that it was wrong on most counts and failed to notice, in trying to project the availability of resources, that information and knowledge were likely to become the main resource as they now are. So naturally the authors thought we were running out of resources. And I'm glad that [Gell-Mann] threw a certain amount of dust in the eyes of the word 'sustainable,' because I came here partly to suggest

that maybe we should find some other word. I don't know quite what the other word is yet, but 'sustainable' is much too status-quoing a word for my taste. There's too much implication that if we can just keep things, particularly the physical environment, about the way they are and not let them degrade any further, that it will be an enormous victory. I don't think that's good enough."

Most conferencegoers were conscious of the irony, pointed out by Robert Gillespie of Population Communications, that "having a conference on sustainability in the United States is somewhat like tribal chiefs, each with 40 children, talking about achieving the one-child family. I don't live a sustainable life. I doubt seriously whether anybody in this room lives a sustainable life." The organizers did their best to run a sustainable conference—even going to great lengths to find a caterer who'd recycle the coffee cups—although, as National Public Radio's Daniel Schorr observed at the wrap-up session, "it was interesting at lunch yesterday to go wandering around and see the beautifully arranged receptacles for drink cans and for Styrofoam. And interesting also how much Styrofoam I saw in the can compartments and how many cans I saw where the Styrofoam should have been." There may be a metaphor here for the gap between good intentions and making people become aware of their actions to the point of changing their habits.

In 1954, when Harold Brown wrote *The Challenge of Man's Future* in an attempt to get a grip on the problems inherent in a world of growing population and fixed resources, his was a voice crying in the wilderness. Since then, the wilderness has gotten considerably noisier. Maurice Van Arsdel of USC's Population Laboratory noted, "We can look at what we're involved with this afternoon as part of the life history of a social movement. In the 1950s a good deal of academic concern started to develop about whether or not we lived in a sustainable world. Some of that concern came out of this institution. In the 1960s the environmental movement developed in the U.S. as part of the unrest at that time. Some of you will remember very clearly the first Earth Day in 1970. The environmental movement, however, did not really take hold in the United States. It fizzled during the 1970s, then after governments failed to deal with the problem, the social movement began to reemerge. Perhaps what we are now witnessing is another attempt to jump-start the connection between population and environmental problems, and to make people aware of this connection." To further that attempt, this issue of *Engineering & Science* is devoted to the highlights of the symposium. □

Visions of a Sustainable World

by Murray Gell-Mann

The key concept is probably the achievement of sustainable quality, quality not purchased mainly at the expense of the future.

What do we mean by “sustainable”? In *Through the Looking Glass* Humpty Dumpty explained to Alice how he used words to mean anything he wanted, paying them on Saturday night (the end of the work week) for the privilege. If Mr. Dumpty were in charge today, a great many people would be paying wages to the word “sustainable.” For example, if the World Bank finances some old-fashioned development project destructive of the environment, these days it is sure to be labeled “sustainable development” in the hope of making it more acceptable. So perhaps we, too, can feel free to *assign* a meaning, at least a vague one, to “sustainable” for the purposes of our symposium.

Surely we do not mean stagnation, with no hope of improvement in the lives of hungry or oppressed human beings. But neither do we mean continued growing abuse of the environment as population increases, as the poor try to raise their standard of living, and as the wealthy exert an enormous per-capita environmental impact. Environmental quality, however, is not the only quality about which we are concerned. In negative terms, we need to avoid catastrophic war, widespread tyranny, and the continued prevalence of extreme poverty, as well as disastrous degradation of the biosphere and destruction of biological and ecological diversity.

The literal meaning of the word “sustainable” is not useful here. For example, complete absence of life or of human life might be sustainable for a long time, but it is not what we mean. Universal tyranny might be sustainable, but that is not what we mean either.

The key concept is probably the achievement of sustainable quality, quality not purchased mainly at the expense of the future. It encompasses quality of human life and quality of the biosphere, including survival of many of the organisms with which we share the planet and the ecological systems that they form. Even if a very crowded, highly regimented, extremely violent world with only a few species surviving could be kept going somehow, this is not what we mean by “sustainable.”

Some of us may be technological optimists, believing that we humans do not need to change course very much in order to avoid that kind of future and achieve sustainability through an endless series of technological fixes. And some of us may not believe in the goal of sustainability at all. Nevertheless, we can still discuss the topic, even do research on it. Even if we do not accept “sustainability,” as it is discussed here, as a goal, we can still ask whether there are ways to approach it during the next 50 to 100 years and, if there are, what those ways might be and what the world might look like as a result. The discussion of the questions does not require the sharing of the values of those who asked them.

Historians tend to be impatient with people who claim, “This is a unique period in history.” That has been said about too many eras. Still, our time is special in at least two well-defined and closely related ways: First, the human race has attained the capability of altering the biosphere in a major way. A full-scale thermonuclear war could wipe out a significant fraction of life on the planet, not to mention the trouble that could be





The population of Bangladesh is increasing at an economically unsustainable rate. Although not even among the top 50 nations in land area, its population of 115 million will double in 28 years, approaching that of the U.S. Shown here is the main Friday market in Dhaka.

caused by biological and chemical weapons. And by our procreation and our economic activities, we are altering the global climate and exterminating large numbers of the species that share the biosphere with us. Actually, our destructive effect was greater in the past than is usually admitted—for example, deforestation by the axe and by domesticated goats and sheep, followed by erosion and desiccation. Even the tiny numbers of ice-age people in North America may have contributed to the extinction of the North American ice-age megafauna, such as the woolly mammoth. Nevertheless, today's potential for damage concerns the entire biosphere in ways that are unprecedented. We have a growing multiplicity of environmental problems affecting climate, the oceans, the quality of water and air, to say nothing of the disappearance of species and ecological systems, deforestation, desertification, soil erosion, and so on. Many of the problems are old, but the scale is new.

Second, the rising curves of world population and natural-resource depletion cannot go on rising steeply forever; they must soon pass through inflection points. Will those curves flatten out as a result of human foresight and progress toward a sustainable world? Or will they turn down as a result of the traditional scourges of war, famine, and pestilence? If they do flatten out, will it be at levels that permit a reasonable quality of human life, including a measure of freedom, and the persistence of a large measure of biological diversity? Or will it be at levels that correspond, if there is a sustainable society at all, to a gray world of scarcity, pollu-

tion, and regimentation, with plants and animals restricted to a few species that co-exist with mankind?

We can look at the progressive development of the means and the scale of military competition in a similar way. Will we allow large-scale, thoroughly destructive wars to break out, or will we use intelligence and foresight to limit and redirect competition, to damp down conflict, and to balance competition with cooperation? Will we learn, or have we perhaps already learned, to manage our differences short of catastrophic war?

Gus Speth, president of the World Resources Institute, has suggested that the challenge to the human race over the next few decades is to accomplish a set of interlinked transitions. I have modified his list slightly, incorporating more political, military, and diplomatic considerations in addition to the social, economic, and environmental ones that he emphasized. Much of the discussion that follows is organized around this somewhat crude but useful notion of transitions.

The Demographic Transition

Today, in many parts of the world, there are still high rates of population growth. That is particularly true of tropical, less-developed regions—often in countries that can least afford it. Most authorities estimate that world population will level off some time in the next century, but at a level something like twice the present number of 5-1/2 billion or so. The factors (including improvements in the position of women, availability of safe and effective contraception, and the erosion of traditional incentives

for large families) that are thought to be responsible for the decline in net fertility in many of the developed countries may yet accomplish similar results elsewhere.

If human population will really go through an inflection point and level off in a few decades, both globally and in most regions of the globe, not only is that a historical process of the greatest importance, but the timing of it and the size of the resulting numbers are likely to be of critical importance as well. It seems overwhelmingly probable that population growth encourages environmental degradation, whether through the huge consumption rates of the wealthy or through the desperate struggle of the poor to survive at whatever cost to the future.

The Technological Transition

Many of us pointed out decades ago that it is useful to measure environmental impact, say in a given geographical area, by three numbers multiplied together: population, conventionally defined "prosperity" per person, and environmental impact per person and per unit of "prosperity." The last factor is the one that particularly depends on technology. It is technological change that has permitted today's enormous human population to exist at all, and while there are billions of people who are desperately poor, there are quite a few who live in reasonable comfort. The environmental costs have been huge, but nowhere near as great as they may be in the future if we don't watch out. For a given environmental impact, how much the second factor ("prosperity" per person) can be improved, especially for the very poor, depends to a considerable extent on how much is squandered on the first factor, mere numbers of people. But technology, if properly harnessed, can work to keep the third one as small as possible.

Even simple technological fixes can end up being extremely complex, as in the example of eradicating malaria in human beings: Draining swamps destroys wetlands; DDT sprayed on mosquitoes gets into the food chain; DDT resistance develops; the rural poor in tropical climates can't sit under mosquito nets when they need to work at dawn and dusk; even bioenvironmental controls of mosquitoes or eventual vaccines against malaria might open up for development critical habitats that had hitherto been too dangerous for humans. But ultimately the technological transition has the capacity to lower environmental impact in industrial production, in the extraction of minerals, in food production, in energy generation, and so forth.

The Economic Transition

If the air or the water is treated as a free good in economic transactions, then polluting it—using up its quality—costs nothing, and economic activity is carried on by stealing from the environment, or stealing from the future. There have been attempts for centuries to deal with such problems with prohibitions and fines, but they were often ineffective. Today regulation is attempted on a massive scale in some places, and there are some successes. Presumably the most efficient way to treat such problems is to charge for the cost of restoring the quality. Economists refer to this as internalizing externalities. Regulation, with its fines and other punishments, is a form of charging, but regulators usually require specific actions, whereas internalizing just means paying to restore quality or avoiding the degradation in the first place by whatever means is cheapest. Attempting to charge real costs is a principal element in the economic transition from living in great part on nature's capital to living mainly on nature's income. Charging is *probably* better than regulation, but charging is *certainly* much better than exhortation. For one thing, it reduces ambiguities.

Suppose you are in the business of awarding green seals to products sold in supermarkets for their low environmental impact. After a while you encounter a problem. A particular detergent may be lower in phosphates and produce less eutrophication in lakes, but it requires higher energy use because it needs hotter water in the wash. Soon you find more trade-offs. How do you balance one consideration against another? If there is at least a crude attempt to charge for the eutrophication and if the cost of the energy needed is clearly marked on the product, then a consumer can just use price to make decisions. He or she doesn't need a green seal or even a conscience.

Another topic to mention here is accounting. Do national account systems include the depletion of nature's capital? Usually not. If, as president of a tropical country, I contract to have a large chunk of primary forest cut down for a low price and a small bribe to me, the national accounts show the price as part of the national income (and maybe even the bribe if I spend it at home instead of sending it to a Swiss bank), but the depletion of the forests does not appear as a corresponding loss. And it is not always tropical countries that sell their forests at a loss; look at what is happening to the temperate rainforest in Alaska.

But what most clearly reflects the level of concern over living on nature's capital is the

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discount rate. I understand that the World Bank, in financing projects with large environmental impacts, still applies a discount rate of 10 percent per year to the future. If that is true, it means that the loss of some great natural asset 30 years in the future is discounted by a factor of 20, down to 5 percent, if it is counted at all. The discount rate, used in this way, is a measure of what is called intergenerational equity, which is crucial to the notion of sustainable quality. If we discount the future too steeply, we are stealing from the future. If we generalize the idea of discount rate somewhat, we can say that in many ways it embodies much of what we mean by sustainability.

Economists make much of the possible trade-offs between intergenerational equity and intragenerational equity, that is, the competition between concern for the future and concern for those who are very poor today. Today's poor need to exploit some resources in order to live, even if precious value is lost to the future in the process. In fact, some of the degradation of the biosphere today is carried out by the very poor scabbling for a living, just as some of it comes from the wealthy squandering resources on frills. But a great deal is connected with large projects that are supposed to help the rural poor of a developing country, but in fact often do so rather inefficiently and destructively. Large numbers of smaller efforts, such as microlending, often work better. In this process an institution lends very small amounts to local entrepreneurs, many of them women, to start small enterprises that provide a living locally to a number of people. Many of these offer comparatively nondestructive employment, and contribute to intragenerational equity.

The Social Transition

While we can view the economic transition as accomplishing a gradual transformation from growth in quantity to growth in quality, it is hard to see how we can speak of quality of life if there are still large numbers of people starving, lacking shelter, or dying young of disease, when a more comfortable existence is attained by billions of other people. Clearly, moves in the direction of intragenerational equity are needed for sustainability. And it may be that there is more synergy than conflict between intergenerational and intragenerational equity; the policies that really help the rural poor in developing countries may not be so much in conflict with those that preserve nature. Also, the policies that help the urban poor may not conflict so much with the

avoidance of urban environmental catastrophes, nor with the resolution of environmental and land-tenure problems in the countryside (and problems of domestic urban subsidies or foreign agricultural subsidies) that are producing large-scale migration to the cities, many of them already swollen to such proportions as to be almost unmanageable under present conditions. In fact, the social transition must include solutions to some of the problems of the mega-cities.

The Institutional Transition

The desire to participate actively in the emerging world economy is strongly motivating the actions of governments and businesses in many parts of the world. Taken along with rapid transport, global communications, and global environmental effects, it renders essential a greater degree of global cooperation to deal with the serious and interlocking issues that face us all. That is the institutional or governance transition. Here a great many considerations come together. The need for regional and global cooperation is hardly restricted to environmental matters, or even environmental and economic matters. The maintenance of peace, so-called international security, is at least as important. Recently, with the changes in the former Soviet bloc and a certain lack of opposition from China, it has become possible for the United Nations to function more effectively than in the past. It is even a routine matter now for the UN to sponsor negotiations to end civil wars and to sponsor the monitoring of elections. But there are many other ways in which transnational cooperation is taking place, and indeed the role of the national state is necessarily weakened in a world where so many important phenomena increasingly transcend national boundaries.

In many spheres, we have had for a long time transnational and even universal or nearly universal institutions, formal or informal. Now there are many more. Typically, they channel competition into sustainable patterns and temper it with cooperation. They range from WHO, UNICEF, and the IMF to Interpol, the Convention on Broadcast Frequencies, migratory-bird treaties, ICSU, and PEN. Some are more important than others, but they are all of some significance.

More and more, we are beginning to come to grips on a global basis with some of the problems of management of the biosphere and our activities in it. The recent willingness of Eastern Europe and China to play a role in making world institutions and practices work is extremely encouraging. It results in the probability of near-univer-

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sality for numerous activities for which there was little hope of it before. Negotiations are also beginning on the “global commons”—those aspects of the biosphere that are not recognized as belonging to anyone and that therefore belong to all, and where selfish exploitation without cooperation can only lead to results unfortunate for everyone. Often these negotiations are based on what Harlan Cleveland calls the “planetary bargain,” in which resource transfers from wealthier countries to poorer ones carry an obligation for the poorer ones to make contributions to global sustainability, such as protection of forests or avoiding nuclear proliferation.

But the problem of what we may call generalized tribalism, the sharp and often violent competition among peoples of different language, religion, race, nation, or whatever, has come into even sharper focus than usual in the last few years, with the lifting of some of the lids that had been put on these competitions by authoritarian regimes. The world is experiencing simultaneously trends toward unity and toward fragmentation.

The Informational Transition

The operation of local, national, and transnational mechanisms for tackling environmental, economic, and security issues, and others, as well as the strong interactions among all of these, requires a transition in knowledge and understanding, and in the dissemination of that knowledge and understanding, that we can call the informational transition. Here natural science,

technology, behavioral science, and professions such as law, medicine, teaching, diplomacy, and so on, must play important roles. Only if there is a higher degree of knowledge and understanding, among elite groups and even among ordinary people, of the complex issues facing us do we have any hope of achieving sustainable quality. And it is not sufficient for that knowledge and understanding to be specialized. Of course, specialization is essential today, but so is the integration of specialized understanding to make a coherent whole. Excellence is cultivated and recognized in specialties, yet leaders are expected to make decisions that take into account not only numerous factors but also the complex interactions among them.

It is in the nature of complex, nonlinear systems that one cannot properly predict their behavior by analyzing pieces or aspects of them separately on a predetermined basis and then putting together those pieces in an attempt to try to grasp the whole. It is essential, therefore, that we assign a higher value than we have been accustomed to do to integrative studies that try to study all the features at once, with their interactions, by a kind of rough modeling or simulation. Some early examples of such attempts to take a crude look at the whole have been discredited because the results were released too early and because too much has been made of them. That should not deter us from trying again, but with appropriately tentative and modest descriptions of what will necessarily be very approximate results.

The Ideological Transition

Finally, there is the ideological transition, comprising the transformations of our ways of thinking that may be required if we are to achieve the sustainability of quality. We don't know to what extent some of our attitudes toward other people and toward our fellow organisms are governed by inherited tendencies. It may be that some of our propensity to form groups that don't get along with one another and some of our propensity to wreak unnecessary destruction on the environment have hard-wired origins—biologically evolved tendencies that were perhaps once adaptive but are so no longer in a world of interdependence, destructive weapons, and greatly increased capacity to degrade the biosphere.

Still, we know that cultural evolution, which is much more rapid, can modify biological propensities. Sociobiology teaches us that we must inherit a tendency to protect ourselves and

One of the greatest challenges is to achieve unity in diversity.

our close relatives so that we and they can survive to procreate and pass on some of our genetic patterns. But in human beings that kind of tendency is profoundly transformed by culture. Tribal cultures can treat relatives who are very distant as brothers, mothers, fathers, and so on. Perhaps the tribespeople jump into rivers to save them much as they would their really close relatives. And, in fact, this kind of so-called "altruistic" behavior extends, in some measure, to the whole tribe.

At a level of greater complexity, this sort of altruism can apply under certain conditions to an entire nation. In this way, the concept of "us" has grown and grown. Can it now grow, on a short time scale, to encompass the whole of humanity and also, in some measure, the other organisms and the ecological systems in the biosphere that we all share? Can family consciousness evolve to planetary consciousness fast enough? Let us hope so, because the future depends greatly on it.

Human cultural diversity and the multiplicity of ideologies characterize our ways of thinking across the globe. Some of those ways of looking at the world, ways of viewing the good life, life styles if you like, may be especially conducive to sustainable quality. Can they become more widespread?

One of the greatest challenges is to achieve unity in diversity. Often, when unity has come in the past, it has come in the form of conquest, sometimes including the attempt to wipe out cultural diversity. In today's world, we have the need, if we are to have sustainable quality, for cultural evolution to accommodate unity in diversity, with the diverse traditions evolving so as to permit cooperation and the other transitions we have discussed. Community is essential to human activity, but the communities have to be motivated to work together, or the future is not hopeful. If our long-outdated proclivities toward what I call generalized tribalism are excessively indulged, we will have military competitions,

breeding competitions, competitions for resources, and so forth at a level that will make the sustainability of quality difficult or impossible.

Our distinguished participants will try to give partial answers to some of these questions. How can these transitions toward sustainable quality be accomplished, if at all, during the next 50 to 100 years? How can we hope to understand, even crudely, the complex interactions among the transitions and their delicate relative and absolute timing? Are there other transitions, or other ways of looking at the whole set of issues, that are just as important? These questions concern the middle range of time.

In the longer range, what kind of dynamic global situation might exist in the middle of the next century in which the sustainability of quality would be approached? What are our visions of such an unfolding situation? What would we see and hear and feel if we were there? How would such a sustainable world adapt to opportunities and to threats of disaster?

Let us really try to envision it, especially a world with growth in quality rather than growth in quantity. Let us imagine a world in which the State of the World Report and the World Resources Report do not look worse every year. And let us also ask what kinds of surprises, technological or otherwise, could make that fairly distant future totally different from what we might imagine.

In the short term, what kinds of policies and activities in the immediate future can contribute to the possibility of approaching sustainable quality later on? What kinds of policies can we advocate, and what can we do in our own lives? Here the issue of preaching versus practice necessarily comes up. Are we ourselves working toward an appreciation of more sustainable life styles? Are we ourselves behaving in a more sustainable manner? It is time for us all to pay serious attention to envisioning a sustainable world. □

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Managing Human Behavior in the Global Commons: Space, Atmosphere, Oceans, Antarctica

by Harlan Cleveland

In all four environments the future depends crucially on what we the peoples of the United Nations do, and stop doing, next.

Now that the actions of human beings clearly outweigh the slower evolution of nature in the global scheme of things, we need to think of the global environment not as a market or as a battlefield, but as a commons. The remedies for Earth's newly diagnosed degenerative disease are not only global; they are also behavioral. And the need to manage human impacts on the global commons will now literally require hundreds of millions of people, not just rooms full of experts and political leaders, to do something or to stop doing something.

The core of the global commons is those four enormous environments, still mostly unexplored, which are already treated in international law, custom, and practice as belonging to nobody and therefore to everybody: outer space, the atmosphere, the oceans, and Antarctica. They are geophysically and biochemically related to each other, and are close cousins also in the human psyche. They are for all practical purposes indivisible; they are bounded by each other; they affect each other's behavior. Indeed, in the case of the atmosphere and outer space, it is hard to tell when one stops and the other begins.

In all four environments the future depends crucially on what we the peoples of the United Nations do, and stop doing, next. So, in all four environments we are moving by fits and starts toward a remarkably commonsensical idea: that our inherited wisdom about ownership and property rights and national sovereignty simply does not apply. It's consequently unwise to export into the global commons the laws and customs and practices we've learned to work with on dry land.

The framework for international politics, security, trade, finance, and the movement of peoples is solidly based on who owns what. In such a framework real estate and artifacts are exchanged. Even people—individual hostages, spies, prisoners of war, sometimes whole populations—are exchanged for all the world as if they were property belonging to someone. But the four environments that make up the global economy cannot by their nature be bought and sold, given or received, yielded up, seized, or appropriated. They have to be shared. And for sharing environments we do not yet have either a solid body of law or a settled theory of political economy. That's why conflict and competition, the laws of war, and the traditions of rugged enterprise are simply not very useful in thinking about the sustainability of the global commons. It's the reason why in the shared environments, notions such as commonwealth and community will have to come into vogue, not only for the reordering of the local human relations in our own community, but for deciding what we do or stop doing about the iciest and wettest parts of our planet, about the air we breathe, the sunlight that gives us life, and the heavens through which we hurtle our serious way toward purpose or oblivion.

While we're jettisoning concepts that may inhibit fresh thinking, I suggest, with apologies to the organizers of this wonderful symposium, we take a sharp look at *sustainable*, that buzzword of the 1990s. *Sustainable* is becoming a status quo word—a justification of things as they are. Our purpose in the global commons should not





Earth Day 1990 brought out the largest grass-roots demonstration in history—200 million people in 140 countries. Here a U.S. contingent assembles in front of the Capitol.

be just to keep it from further degradation at human hands, not just to protect it from ourselves. Certainly we have to protect the commons from becoming humanity's littered backyard, its waste-disposal dump. But the real tragedy of this newly perceived commons would be to leave it unexplored, to neglect its many potentials for contributing to human needs and purposes.

Part of the present tragedy of the commons is that we're not yet using what the global commons freely provides. The marvels of space satellites have not yet narrowed the gap between rich and poor. They mostly enable the affluent to work with each other more efficiently and prepare for more efficient sky-based killing fields. We're wasting the beneficent rays of the sun by not converting them into usable energy. We're neglecting the power still locked in the temperature difference between tropical sea surface and the ocean deeps. We're not yet using our biotechnological talent to maximize the riches inherent in the dense biomass and solar radiation available in such abundance in the so-called poor countries. They're not poor in bioresources, but poor in the capacity to use them. The word *sustainability* seems to bid us to hang onto what environment we have left. It's not nearly a dynamic enough word to generate a world-wide push for growth with fairness.

The good news about the global commons is not to be found by looking out to sea or up at the sky. Right here on land, very large crowds of educated people have decided that the global environment is worth shouting about. And very large crowds of educated people waving placards

cannot be ignored. That's the lesson that dictators and democratic leaders alike are learning these days—many by finding themselves suddenly unemployed. Beyond a certain size, enough to overflow a big city plaza, protesting crowds simply can't be subdued even by force. It was instructive in 1989 that Deng Xiaoping didn't move in on the students in Tienanmen Square until most of them had left. The fusion of education with frustration is obviously explosive. The Polish proletariat, Soviet scientists, workers and merchants and intellectuals throughout the world, from Hyundai auto workers to Moscow liberals, have all figured out how to create media events that mortify, in order to modify, established authority.

The biggest crowd so far—200 million people in 140 countries, almost certainly the largest grass-roots demonstration in history—came out on Earth Day 1990. Stay-at-homes could judge as trivial the televised images of local recycling, which were so much easier to photograph than the global atmosphere; they could jibe at the litter left behind by these crowds for someone else to clean up; they could wince at the spectacle here and there of half-naked young people with painted faces having fun in the sun.

Some even warned that Earth Day might do actual harm, by persuading folks that everything will be fine if we clean up our individual acts. But it *is* the acts of individuals and couples and households that produce the pervasive threat to the global environment. The poor and the rich are cooperating to destroy in different but mutually reinforcing ways the environment we share: innocent peasants cutting down trees; innocent couples having more babies than they can raise to be healthy and productive; innocent citizens thinking that government regulation and corporate responsibility are someone else's problem.

The policy shifts required to manage human behavior in the global commons, then, will mean wrenching change in government rule-making and corporate strategy. But established leaders of large organizations, public or private, will simply stand there until they feel the heat from people they care about—constituents, customers, employees, and their own educated children. The health of the global environment is the product of behavior by billions of individuals. And that's why it's good news that the crowds for environment have become just as large and demanding as the crowds for democracy have recently been—and even more global.

What should the crowds for environment be trying to get done? The problem is not to

manage the global commons. That would be an act of almost ridiculous presumption, as though with our limited knowledge, primitive models, and fuzzy horizons, we could rationalize the ocean's currents, modify the world's weather, and reorder the Newtonian logic of gravitation in outer space. No, the problem is to manage *human behavior* in the global commons, and this is where new forms of international cooperation could come in.

Should we impose our values on a mostly vacant commons? It's true that wherever we touch it, we affect what millions of years have wrought. The wilderness approach, driven by a paralyzing sense of our own ignorance, would say, "Don't touch!" But as a practical matter the commons won't be left alone, so the problem is to organize world consensus on regulating human behavior in ways that balance our appetite for adventure and our ambitions of expanding human civilization's physical frontiers with a healthy respect for the foul-up factor in every human enterprise.

Commons environments and the dangers of degradation and conflict that arise from them require that someone establish universal norms and standards. What actually happens, of course, will be up to hundreds of government agencies, thousands of companies, regulators, science academies, universities, laboratories, and advocacy groups, and ultimately up to millions of schoolteachers, hundreds of millions of householders and automobile owners, and billions of people trying to raise their living standards to match their expectations. The rules of governing human impacts on the global system have to appeal to large populations, which means that they have to be openly arrived at and that they have to seem as fair as any universal rule can be. That means that setting standards cannot be left only to the technologically strong—those with the prowess to despoil Antarctica, foul the world's seas, exploit the ocean's resources, damage the ozone shield, spew out global-warming gases, and sprinkle debris in outer space. The standard-setters will have to be agreed-upon surrogates for everyone who holds the global commons in trust for posterity.

Trust—there's a suggestive word. The United Nations originally set up a Trusteeship Council in parallel with the General Assembly and the Security Council. The Trusteeship Council presided over the decolonization of more than a billion people. Its success has now made it unemployed. It doesn't have the right membership or the right kind of staff for what I'm proposing, but it has the right name, and the

rest, I believe, can be fixed without amending the charter. Let's not open the charter itself for rewriting: We probably wouldn't do nearly as well in the nineties as the founders did in the forties.

The simplest way, after a negotiation rich in complexity, would be for the Trusteeship Council to form a special commission on the global commons to act as the trustee for our four great surrounding environments. The commission should be extra-national, that is, a collective executive appointed by regional groups of governments for terms of years, say five to seven. The commissioners would themselves act by consensus, not by voting; voting procedures are useful only for taking snapshots of disagreements. The new UN agency, which might come to be called the Trusteeship Commission, would negotiate norms and standards for exploring and exploiting the global commons and would keep the health of the commons environments under open and continuous review. Its guidelines could not be mandatory, but that's what would keep them from being arbitrary.

Much of the needed analytical and monitoring work could then be farmed out to other UN agencies and to nongovernmental corporations, environmental groups, universities, research labs, scientific academies, and international associations. Ultimately the success of any universal standards will rest on our educated behavior—on us, the peoples of the United Nations. This means that all the participants in this complex choreography will also have an inherent mandate to be educators, teaching about the kinds of human conduct that are compatible with life in shared environments. Children in every culture will need to grow up with a feel for what our planet and its environs, explored and exploited with care and concern, can do for human needs and purposes before Caltech is 200 years old. □

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Sustainable Global Commons

Participants in the panel discussion included Sylvia Earle, chief scientist of the National Oceanic and Atmospheric Administration; Joshua Epstein, senior fellow in foreign policy studies at The Brookings Institution; Robert White, president of the National Academy of Engineering; and Edward O. Wilson, Baird Professor of Science and Mellon Professor of the Sciences, Harvard University.

In opening the session on the “Sustainable Global Commons,” Robert White defined “global commons” for purposes of the meeting as “not only those areas of the global environment that are beyond national jurisdiction, in which each nation has a stake and contributes to their deterioration or their enhancement, but also those activities in which there is a global interest—what Harlan Cleveland has referred to as ‘common treasures.’”

Biological diversity was chief among the “common treasures” discussed in the session. E. O. Wilson stated that although diversity of life has always been a dominant theme in biology, “a new urgency now drives the study of biodiversity for its own sake, because at the very time that the importance of all life forms for human welfare becomes distinctly clear, we see with equal clarity that the extinction of wild species and ecosystems is accelerating through human action.”

Although about 1.4 million species of organisms have been given scientific names, Wilson said that “biologists do not know the amount of diversity in the total world of flora and fauna, even to the nearest order of magnitude.” The total number of species on Earth is not 1.4 million, Wilson suggested, but closer to 100 million, with more than 10 million species of arthropods (mainly insects) in tropical forests alone. Only about 4,000 species of bacteria have been officially described, but the actual number could be a hundred or a thousand times that, he continued. “In terms of bacterial diversity on Earth and its potential for scientific knowledge and usefulness to humankind, we are on the edge,

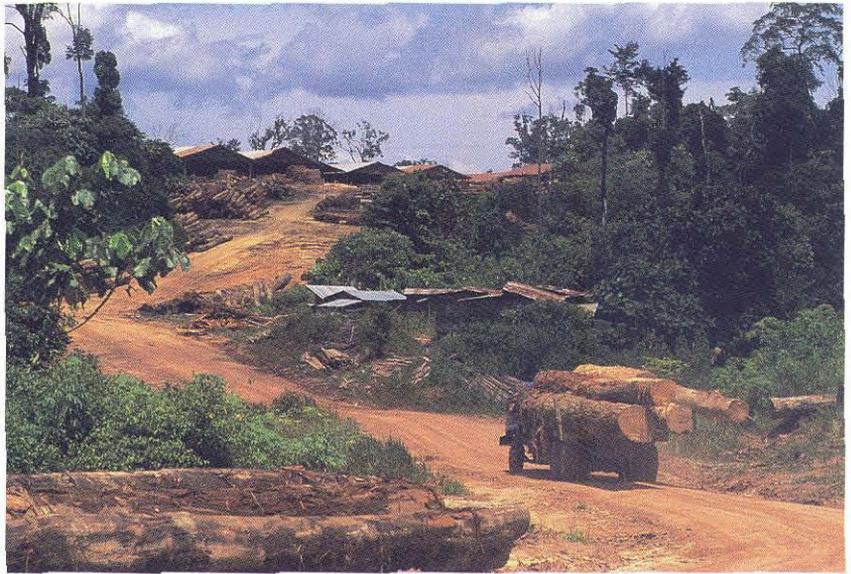
literally, of an unexplored world.”

Despite the fact that “the fossil record suggests that biodiversity is currently near its all-time high at every taxonomic (at least to the family) level,” Wilson warned that we are now in the midst of a “sixth extinction spasm, the greatest since the one that closed the age of the dinosaurs 66 million years ago.” The other extinctions were caused by climatic cooling, by reduction of the continental shelves, and possibly by a hit from a giant meteorite, each one requiring between 10 and 100 million years for evolution to catch up again. This one, however, is due to human behavior. But, some ask, isn’t humanity a part of nature, and extinction a natural process? “The answer, of course,” said Wilson, “is that we are not in this sense part of nature. There has never been anything like the human species before in relation to the remainder of the world’s biodiversity.”

Wilson does not believe it’s too late. “We are certainly going to lose a lot of biological diversity because so much of the natural habitat has been diminished already, but we can still slow and eventually stop the hemorrhaging. Our goal, and this I think must be done by regarding biological diversity of the globe as a common treasure, should be to carry as much of this biodiversity as possible with us through the bottleneck of the next 50 years of overpopulation and environmental degradation. Common treasure it is for all of humanity. Along with our culture itself, that inheritance is going to be—if we save it—the most precious gift we can give to future generations.”

Along with our culture itself, that inheritance {biodiversity} is going to be—if we can save it—the most precious gift we can give to future generations.

Right: Loggers cut a swath through the rainforest in Borneo. Left: A 1988 shot from the space shuttle of Brazil's Rio San Francisco Basin shows the light-colored rectangles of commercial agricultural fields cleared from the forest. Estimates suggest a 25-30 percent increase in land clearing since 1984.



While Wilson's remarks concentrated on the vanishing rain forests, Sylvia Earle was concerned with biodiversity in the oceans. "About 90 percent, by sheer mass, of life on Earth occurs in the sea. And with all due respect to Ed Wilson and to the splintery ends of biodiversity known as species, if you think about the genetic makeup of creatures in terms of the big, broad categories of life from one end of the plant and animal realm to the other, the greatest diversity is in the sea. The sea is not just salty water and rocks. It's a living minestrone. Virtually every spoonful contains something alive, mostly small or microscopic variations on the theme of life on Earth. The history of life on Earth is written in the lives of organisms still present, from microbes to sponges, jellyfish to mammals.

Earle focused on the atmosphere as well as the oceans: "When we speak of one we necessarily touch the other. Heretofore, both have seemed to be infinite, perhaps immutable by the action of puny human beings. And both, heretofore (until the last few decades) have been regarded as free, as have their contents." Earle was optimistic that measures would be taken to put to rights the consequences of human misbehavior in the atmospheric global commons. "It seems so reasonable, so obvious, because we are terrestrial, air-breathing creatures." But she was less sanguine about "our ability to get fired up about the ocean as a vital system that also relates to climate and weather and the atmosphere we breathe."

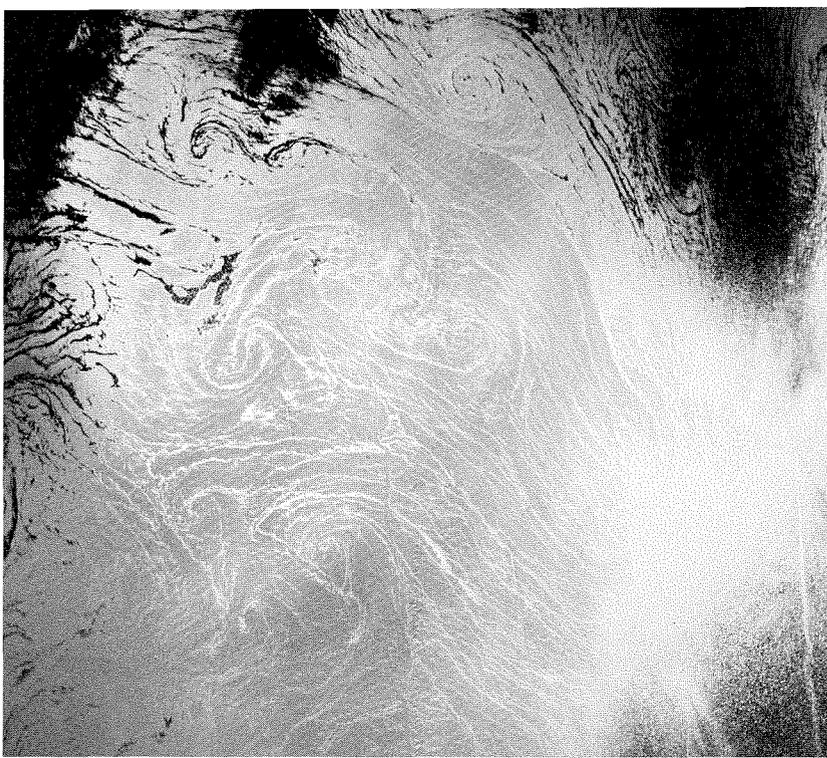
Sustaining biodiversity in the oceans is more difficult than on land. Earle noted in particular

that about 300 species of cephalopods (the squids and the octopuses) remain, as well as 300 species of sharks, all of them vulnerable to changes initiated by humankind, including recent unprecedented high catches and overall environmental modifications. They, and countless other marine organisms, are "residents, not of territory that can be protected with a fence, but of the global commons, the oceans." She also stressed the interrelationship between the atmosphere and the oceans. "The good health of the atmosphere leads to the good health of the oceans, and the good health of the oceans to that of the atmosphere."

Earle introduced two ideas for sustaining the oceanic part of the global commons:

1. Reevaluating allowable take: "Whose fish or krill or squid are these? If a population of desirable species can be determined that would maintain a sustained take of x number or tons of individuals, this allowable portion could, in theory, be skimmed off in a sustainable way. But is it necessary that the whole 'take' be taken? And is it necessary that one nation or several nations be favored in terms of the take? Or might the allotment be divided among many interested nations, or maybe all nations? Some could opt to put their part back in the system. For example, if it were agreed that 3,000 minke whales could be taken on a sustainable basis from Antarctica, some nations could say, 'Well, this is my portion, but I opt to keep mine in the bank.'"

2. Protected areas: "This is like an insurance policy—an ecosystem approach to protection in the global commons that would guard against loss of biodiversity, a hedge against the unknown.



Spiral eddies in the Mediterranean Sea photographed from the space shuttle.

There are precedents in the U.S. for protection of areas in the global commons. In deep-sea mining legislation, there is a provision for stable reference zones—protected zones—to be established as a standard to monitor change. Large biosphere reserves have been suggested for terrestrial habitats, and now this concept is extending into the sea. Some of the prime candidates for protection include scientific research areas, places known to be vital for fisheries, and sites that can be identified as critical habitats or essential areas for vital processes, locally, regionally, or globally. These are obvious targets, but most important is reaching an understanding of what must be done to ensure the health of the system as a whole. And then doing it.”

The health of the atmosphere was the first transnational environmental issue to seize the world’s attention. “Global warming has been the issue that crystallized this great international political drive to try to confront problems of global change,” according to Robert White. “The problems of the global environmental commons, those which all nations have a stake in solving, such as climate warming, destruction of stratospheric ozone, and pollution of the coastal oceans, render all nations environmentally interdependent. These are problems that can be addressed effectively only by concerted international action.”

Joshua Epstein discussed global warming and biodiversity in terms of complex systems. “Even the most isolated ecosystems are complex, nonlinear systems, whose overall response to small perturbations is often very difficult to foresee.” He presented several examples of what he called

“nonlinear cascade effects” that can result from those small disruptions. He described the counterintuitive system-wide repercussions of removing a single predator from the top of a food chain. And he explained that even adding species can cause a chain reaction of ecological disaster. Drawing on the work of biologist J. D. Murray, Epstein recounted the disastrous 1960 introduction of the Nile perch into Lake Victoria, the largest lake in East Africa. This virtually wiped out several hundred smaller fish species important to the local economy. Some of these species, in turn, had helped control the population of a particular snail that forms an essential link in transmitting bilharzia, a disease fatal to humans. The “complexity of the problem” is what Epstein kept emphasizing. His current work on sustainability concerns the nonlinear interaction of large-scale processes such as population growth, climate change, species extinction, weapons proliferation, declining equity, and economic evolution.

Epstein explained his analysis, published recently with Raj Gupta, on control of the greenhouse-gas emissions that lead to atmospheric warming. He proposed a tradable-permit scheme (also applicable to global catch quotas for, say, fish, or to permits that could be earned by reforestation), which he described as efficient, equitable, and fostering risk-taking and technological transitions. “Suppose someone is making an investment in a risky clean-air technology, T . Let’s imagine that the investor buys carbon permits as he makes this investment. If the technology fails, then the carbon permit price should rise, as hopes of supplanting fossil-fuel energy sources with T are dashed. If the permit prices are higher, losses on the investment can be partially offset. Because of this negative correlation between the permit price and the project’s success, the variance of returns to the investor, the risk, is reduced.”

By emitting greenhouse gases without restraint, Epstein said, “we’re toying with basic parameters of a complex system, whose sensitivities we do not understand very well. But if we wait for complete certainty that intolerable damage is being done, that damage may be difficult to reverse.” □

Development for a Sustainable Future

The session was chaired by J. Gustave Speth, president of the World Resources Institute. Panelists included Russell Mittermeier, president of Conservation International; Al Binger of the Rockefeller Foundation; Jared Diamond, professor of physiology at UCLA Medical School; and Alvaro Umaña, former Minister of Natural Resources, Energy, and Mines, Costa Rica.

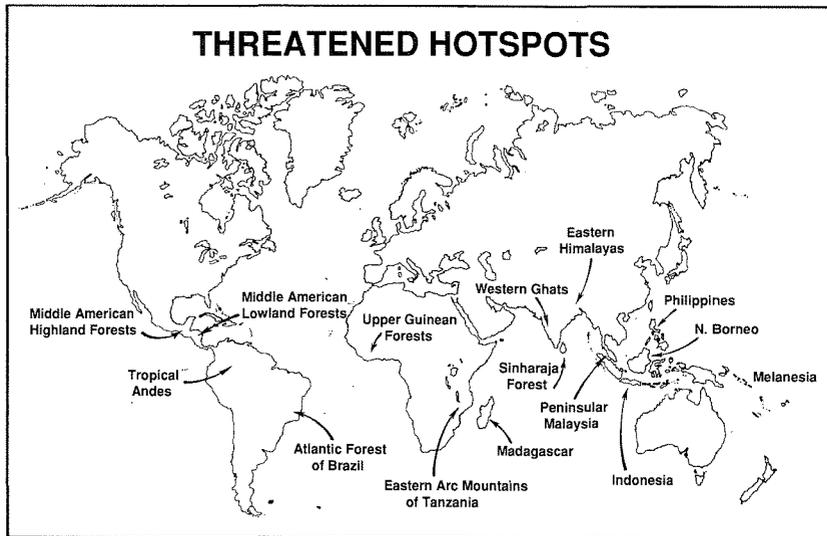
In the main, the panel agreed with Gustave Speth's opening summation: "The battle for the planet will be won or lost in the developing world. Sustainable development is going to require a much stronger commitment to equity and social justice than we now are able to muster. A sustainable society requires a social transition to a more equitable sharing of environmental and economic benefits, both within countries and among countries. The wealthy consume inordinate quantities of the world's natural resources, while the poor have little choice but to overtax the resource base." Jared Diamond dissented: "'Sustainable development' is an oxymoron, like 'full-length bikini.' My own vision of a sustainable world is one in which the notion of 'sustainable development' is recognized to be a fiction, and in which the human population and its impact on the environment are no longer increasing."

Russell Mittermeier spoke of "ecosecurity" as the complex relationship between geopolitical stability, environment, and development. "With the end of the Cold War, I hope we will shift our attention to the temperate-tropical dilemma. Very soon more than 80 percent of the world's population and 18 of the 21 largest cities will be found in the tropics. The most environmentally degraded countries in the world—places like Haiti, El Salvador, and Ethiopia—are often the most unstable." Remarked Al Binger, "In 1962, Haiti had 65 percent forest cover. Today you need a good statistician and a *very* good economist to come up with even 2 percent, because you have to manipulate the numbers so immensely. Haiti's ability to develop from its natural resource

base is gone forever."

Several panelists called for new money dedicated to sustainable development, accompanied by a reordering of spending priorities for existing aid. Education came high on the list. Binger noted that the developing countries have 75 percent of the world's population and around 15 percent of the scientists and engineers, and observed, "I find it ironic that the generation given the responsibility of solving problems that our generation and many before have created, is receiving substantially less education than most previous generations." Providing environmentally sustainable jobs for burgeoning populations, raising women's status, reforming land tenure, strengthening non-governmental organizations, nurturing emerging democracies, promoting demilitarization, and stemming corruption all made the wish list. Several speakers noted that hundreds of billions of dollars have been spent to little avail. Binger faulted the development agencies. "The World Bank in particular invests in quantity instead of quality. If a loan officer comes to my country and identifies two portfolios of energy aid, one for 500 million dollars for two years with an internal rate of return of 20 percent, and another for 200 million with a return of 80 percent, he'd be penalized for proposing the latter because he's supposed to be moving money. But everybody keeps telling me that there's no money, so how can the system reward moving money when there's no money to be moved? These institutions were created to close the gap between the haves and the have-nots. I would figure that the have-nots would be in charge, because they're

"In 1962, Haiti had 65 percent forest cover. Today you need a good statistician and a very good economist to come up with even 2 percent, because you have to manipulate the numbers so immensely."



These 15 tropical areas cover just 0.64 percent of Earth's land area, yet are thought to contain 30 to 40 percent of the world's biological diversity. Without dramatic changes in mankind's behavior, 90 percent of these habitats—and the species within them—could be destroyed by the year 2000. (Modified from Myers, 1988.)

supposed to benefit. Instead, the haves run things. How do they know what the have-nots really need?"

Mittermeier provided a scorecard of international aid's successes and failures since World War II, then suggested that there are three areas requiring fundamental change. First: "Development has economic growth as one of its inherent assumptions. But planet Earth is a closed system with finite resources. We need to redefine development as enhanced quality of life instead." Alvaro Umaña added, "It is only after people have reached a certain basic standard of living that population tends to stabilize." Second: "Development has not provided economic pluralism—the distribution of economic and other benefits to all sectors of society. Most of the benefits accrue to the bureaucracies and technocracies that handle the loans, and relatively little actually reaches the poor." Third: "Development has not taken environmental issues into account. We act as if resolving the health, literacy, and other developmental issues would remove us from environmental constraints." Aid generally consists of technology or short-term donations that don't take into account local knowledge, which is usually much more appropriate to the ecosystems in which the poor live, Mittermeier averred. Loss of traditional culture and dependence on imported technology often follows. Many biodiversity problems result from inappropriate energy technology such as burning forests for charcoal, or the huge hydroelectric power schemes in the Amazon, as well as from the timber cutting, cattle ranching, and slash-and-burn agriculture usually invoked.

Environmental considerations have to become the foundation for all future development programs.

Mittermeier singled out conserving biological diversity as the key to sustainable development. "This is our biological capital in the global bank, and though we almost invariably take it for granted, it is absolutely critical to our own survival. Earth is still the only place in the universe where we know with certainty that life exists." Added Binger, "If biodiversity is our Fort Knox, I would draw the comparison that the soldiers guarding the real Fort Knox are well fed and well educated. The people guarding our biodiversity are usually barefooted, poverty-stricken, and their children seldom go to school." Diamond noted that the extinction rate is worst in the tropics, especially for insects and plants, up to 90 percent of which have yet to be described and named and whose extinction would thus pass unnoticed.

"I estimate that about half of the world's species will be extinct or doomed by the time my sons reach my present age. Even if all humans on Earth dropped dead tomorrow, current high extinction rates would persist for centuries" as the last survivors die off, and other species dependent on them vanish in turn. "Species are connected together like dominoes," Diamond continued. "Exterminating 50 percent of the world's species is like removing 50 percent of the parts of an airplane and then trying to fly it, with the difference that we know which parts of an airplane are essential."

Mittermeier recommended a very strong emphasis on setting priorities, focusing today's limited resources on the "hot spots" where only three to five years remain before an ecosystem vanishes. Umaña added that soil, energy, and nutrient-cycling management—biomass management—are going to become critical. "The surface of the earth is going to look a lot different in 50 to 100 years, and we will have to learn to revegetate the planet, and to manage that surface, in a very different way than we do today." Both agreed on the need for protecting core areas of biodiversity. Less than five percent of the globe's land surface is protected today. An integrated worldwide system of protected areas will have to be developed in the near term, followed by restoration of the degraded land surrounding them in the long term. This, of course, means aid designed to make self-sufficient those countries within whose territories these protected areas lie, so that they no longer have to draw down their biological capital to survive.

Umaña added another dimension. "We must recognize the rights of indigenous peoples wherever nation-states took their land from them—all



The tropics' economic salvation may be in its plant life.

Above: Methanol extracted from sugarcane could be the motor-vehicle fuel of the future.

Below: A Malagasy pharmacy. Who knows what wonder drugs lie undiscovered in these roots?



“Madagascar’s rosy periwinkle led to a very powerful and useful drug against leukemia, primarily in children. Western companies reaped big profits, but not a single cent went back to Madagascar.”

over the American continent and in many areas of Asia and Africa as well. The knowledge that indigenous people have is absolutely critical to understanding how to use natural ecosystems.”

Proposing solutions is easier than paying for them. Mittermeier pointed out that biodiversity conservation can be good business. Harvesting nontimber forest products pays better than clear-cutting the forest for pasture or timber extraction. Ecotourism—going into natural areas and looking at wildlife—is on the rise. And debt-for-nature swaps—arrangements in which a third-world country is allowed to write off some part of its foreign debt in exchange for agreeing to preserve, undeveloped, some parcel of land—make a very large contribution to conservation without costing much. Umaña agreed. “There has to be a recycling of debt through debt-for-nature swaps, because we cannot continue the present trend where the developing countries are net exporters of capital to the developed world. Latin America exports more capital each year than it spends on education.

“We have to recognize the economic value of carbon storage,” Umaña continued, referring to the need to counterbalance mankind’s growing emissions of carbon dioxide—primarily from burning fuels—into the atmosphere. (Carbon dioxide traps heat, potentially making parts of the planet unlivable through a runaway “greenhouse effect.”) “The industrial countries will have to pay for it. Carbon-dioxide abatement policies should be based on present emission rates, but responsibility has to be based on cumulative emissions, because CO₂ stays in the atmo-

sphere for a very long time. And unless the developed countries recognize that when I plant a tree and store several tons of carbon in it, I’m providing a service to the global environment, there’s very little chance that revegetation will take place in sufficient quantities to make a difference. When an economist walks into a forest all he sees is the timber and the land. Everything else is valued at zero. That’s the most prominent force behind the destruction of the forests.”

Umaña pointed out that “the developing countries see biodiversity preservation as a burden, not as an opportunity for development. The wealth isn’t quantified, or else it’s appropriated. Madagascar’s rosy periwinkle led to a very powerful and useful drug against leukemia, primarily in children. Western companies reaped big profits, but not a single cent went back to Madagascar. We have to strike a bargain between the biodiverse countries and the biodiversity users. As an example, the National Biodiversity Institute of Costa Rica recently signed an agreement with Merck & Co., Inc., the world’s largest pharmaceutical company, which paid \$1 million for the right to explore Costa Rica’s biodiversity more systematically. And if any products of this exploration lead to commercially useful drugs, the royalties would be divided.

Binger and Umaña blasted agricultural subsidies as enormously destructive to the environment, and called for their immediate end. Binger was blunt: “There’s no reason why Japan should be allowed to pay its farmers 76 cents a pound in subsidies and keep the Filipino, Indonesian, or Thai rice farmer out. I don’t care if Japanese rice has spirits associated with it. It is ethically wrong.” Said Umaña: “According to the International Monetary Fund, agricultural subsidies cost the developing world \$50 billion a year in foregone foreign exchange—more than the sum of the industrial nations’ aid programs to the developing nations.” Binger, recalling his Jamaican upbringing, remarked, “about 15 years ago, my little village produced sugarcane. We had a decent quality of life. But in the early 1970s, the U.S. and the other OECD [Organization for Economic Cooperation and Development] countries started agricultural subsidies—about 250 billion dollars a year paid to farmers who use unsound technologies (the French and Germans use 700 pounds of fertilizer per acre) to provide products that their own society doesn’t need. This surplus goes on the world market, where it further depresses prices paid to tropical farmers, and what can’t be gotten rid of that way is distributed as humanitarian aid. In short, the North has effectively displaced the southern farmer—about half

of the world's population. When you lose your market you can't transform man-hours into production, and you have no choice but to withdraw capital from the natural-resource base to survive. In my village, we've withdrawn so much capital that there are no timber species left. They've all gone to the sawmill. The little creeks we used to swim in are now rivers which run dry most of the year, then flood. Three major floods in Jamaica over the last five years have cost over 260 billion dollars in damage. The fisheries are choked with silt from the denuded mountains, so our fishing industry is in collapse.

"The Jamaican economy is now the most indebted in the world per capita—1.3 million people with an average income of less than \$800 a year owing in excess of 4.5 billion dollars," Binger continued. "We pay 50 cents on every dollar for debt service, and then by the time we pay for petroleum, the Ministry of Finance has three cents of every dollar left in disposable income. Three cents to protect the environment, to educate the young, to provide transportation, to provide work. Without development that returns more than three cents on the dollar, we cannot invest in environmental problems."

Binger laid much of the blame on sectorial planning, wherein "the agricultural people make a plan—Chapter 1. The energy people make a plan—Chapter 2. The housing people make a plan—Chapter 3. And the only thing that goes from beginning to end is the binder. This isn't planning—it's compilation. The Agricultural Commissioner came to our village and said, 'I'm here to talk about agriculture. I don't want to talk about water. I don't want to talk about transport. You're going to close your sugar industry and plant root crops instead.' So we pulled out the sugarcane, which is a perennial that carpets the hillsides—holding the erosion rate to perhaps five tons of soil per acre per year—and we replaced it with yams and casaba. Now our erosion rate is 50 to 100 tons per acre per year. For every pound of yams that we sell in New York, we put 50 tons of soil into the Atlantic Ocean. We'll lose six feet of topsoil in 60 years. I asked the farmers, 'Why don't you farm over there?' They said, 'Only rocks grow on that part.' They don't make the connection that the soil is eroding, just that the rocks are becoming more prominent."

The developing countries will have to create hundreds of millions of jobs in the next century or face even worse unemployment than already exists, Binger reminded the audience. "My vision is that the majority of those jobs will be in rural areas, based on renewable natural resources—

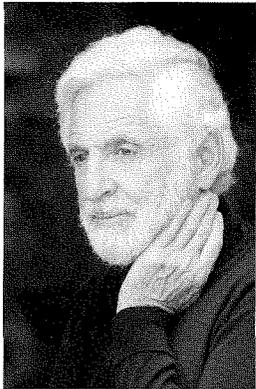
what some of you affectionately call biomass." An energy-from-biomass economy would generate those jobs in sufficient numbers, and provide the economic incentive necessary for sound resource management. Binger recommended redirecting aid programs toward developing the technology to extract energy from sugarcane—the chief renewable resource of many tropical countries like his own Jamaica—and away from systematically dismantling the tropics' sugar industry. "We would have the best of all worlds. We would have a way for farmers to earn a living without destroying the environment, we would have sources of energy that would have no net carbon dioxide contribution, and we would have technology-driven development that could absorb our excess labor force. One might argue that sugar was a slavery crop, that sugar is hard work. I can't think of any developing-country person spending his day under a tree who wouldn't prefer a hard day's work to no day's work."

All the panelists were guardedly optimistic that the problems could be solved. Even Diamond thought things—at least in Indonesia, where he does his field work—were "difficult but not hopeless." Umaña offered this summary: "I think the human population will stabilize, more or less, in 50 to 80 years. We're going to pass through a very difficult period during the next few decades. We'll see some nasty stresses and some disasters, especially in places like sub-Saharan Africa. We're starting to see them already. But if we can fight a holding action, using whatever arguments work, we can make sure that a significant portion of biological diversity, and human cultural diversity with its attached knowledge, will survive." Binger summarized the developing countries' plight. "The poor don't need high-volume consumer goods—what they need are the basic necessities of life: food, shelter, clothing. [I think we can deliver those] if we understand how to focus aid, and commit ourselves to technology development that isn't market-driven, but people-driven." And Mittermeier invoked the memory of Konstantinos Doxiadis, who hypothesized that by the latter part of the next century we would have an ecumenopolis—a global human settlement linked by many different communication and transportation networks. "The real challenge will be to integrate core areas for conservation of biodiversity and maintenance of cultural diversity, and land for agriculture, forestry, and fisheries, into this scenario so that we don't wind up with a horror like some gigantic Mexico City, São Paulo, or Calcutta, but rather with something that's actually better than what we have today." □

"I asked the farmers, 'Why don't you farm over there?' They said, 'Only rocks grow on that part.' They don't make the connection that the soil is eroding, just that the rocks are becoming more prominent."

The Need for Birth Control: Why and What Kind?

by Carl Djerassi



The world population will reach 10 billion—perhaps even 15 billion—by the middle of the next century, according to the World Bank. We can make a difference between 10 billion essentially unavoidable births (most of whose future parents are already born) and an additional 5 billion possibly preventable ones through some form of family planning. Russell Mittermeier described the developed and the less developed nations as the temperate and the tropical worlds. I would rather divide them into geriatric and pediatric countries. In the pediatric nations, nearly half the population is below the age of 15; in the geriatric ones, like Japan and the U.S., up to one-fourth of the population is above age 60. The geriatric countries have all the money, all the technology, and most of the trained manpower; they apply most of it to solving geriatric problems—geriatric diseases, like cancer, for example. There is little left to solve the problems of pediatric societies, and that, I think, is our real dilemma.

Just 12 nations contain two-thirds of the world's population, as shown in the table on page 22. Only four of these countries—the ex-Soviet Union, the U.S., Japan, and Germany—are “developed” countries, and one of them—the former Soviet Union—may soon lose that distinction. Germany will remain on the list for a few more years and will then disappear permanently, because its population takes 7,000 years to double, compared, for example, to 24 years for Pakistan or Nigeria. Egypt is not on the list yet, but, with a population of around 55 million, and a doubling time of about 24 years, it soon will be.

At present, the world population is doubling every 39 years—a growth rate of about 1.8 percent per annum, which is a poor return on one's bank account, but a spectacular one in terms of people.

Japan will probably drop from the list within a couple of decades.

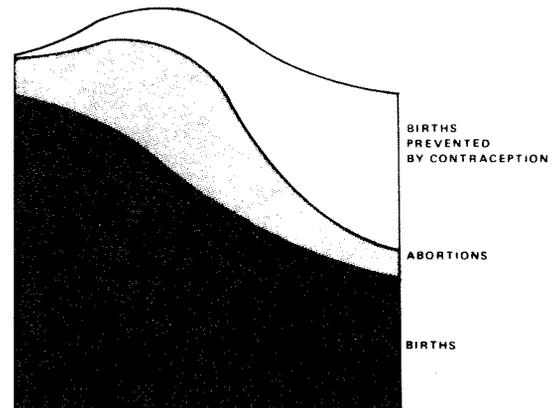
At present, the world population is doubling every 39 years—a growth rate of about 1.8 percent per annum, which is a poor return on one's bank account but a spectacular one in terms of people. This growth is not evenly distributed, and the only reason that the world situation does not appear to be as bad as it really is is because of China's massive population-control efforts. (China has one-fifth of the world's population.) For a good look at the problem, take Bangladesh—an economic basket case whose population continues to increase at an unsustainable rate. In 25 years, Bangladesh's population may approach that of the U.S. today, yet Bangladesh isn't even among the top 50 countries in land area.

One component, though by no means the only one, of the solution is more and better birth control. I would like to divide the latter into “software” and “hardware.” Hardware refers to the actual methods people use—pills, condoms, sterilization, IUDs, abortion, or even nontechnological methods like withdrawal. The software is much more complex—social, political, legal, religious, economic, and cultural factors. The software issue was summarized in 1974 by Bernard Berelson, former president of the Population Council, in a plan to reduce India's growth rate. His key point was that if women enter the work force in appreciable numbers, it will be more difficult to sentence them permanently to the kitchen and the bedroom. (This has actually happened in eastern Europe since World War II, where many women now work outside the

Country	Population (millions)	Population doubling time (yrs.) at 1990 rate	Rank by area (square miles)
China	1,220	49	3
India	853	33	7
ex-U.S.S.R.	291	80	1
U.S.	251	92	4
Indonesia	189	38	15
Brazil	150	36	5
Japan	124	175	>50
Nigeria	119	24	31
Bangladesh	115	28	>50
Pakistan	115	23	35
Mexico	89	29	14
Germany	80	7,000	>50

Above: The 12 most populous nations on Earth, in decreasing order of population, as of 1990. (Data from the Population Reference Bureau, Inc.)

Right: As prosperity—plotted from left to right on this graph—increases, the birth rate decreases and the number of births prevented by contraception increases. At the same time, the abortion rate rises briefly and then declines as people become more sophisticated about birth-control methods.



home.) He also proposed universal education for both sexes, outlawing child labor, cutting infant mortality to below 25 per thousand, and introducing a functional system of social security. That way, one need not depend on one's children for survival in old age, and at the same time one need not have many offspring to overcome high infant mortality. Interestingly, in the early 1970s this was already official policy in the People's Republic of China as part of the Cultural Revolution, even though this was not yet known in the West.

My area of competence is contraceptive hardware issues. We need a contraceptive supermarket, where one can pick and choose from among many different methods, because there is no ideal contraceptive—not for populations, not even for individuals. The proper choice depends on the time of life—on health, on lifestyle, and on professional and family priorities. The table opposite shows contraceptive choices in Europe, which has essentially “solved” its population problem, leveling out at about half a billion people. Of these five large European countries, some, like Italy, don't go in much for technology—57 percent of Italians either use no birth control whatsoever, or use *coitus interruptus*, or the “rhythm” method. But even if we examine the portion of the population that uses technological methods, the preferred method varies from country to country. Essentially no one uses sterilization for birth control in Italy, yet 23 percent do in the U.K.

The only advanced industrialized country that surpasses the U.K. in sterilizations is the U.S. In the last ten years, we have reached the point

where more married couples get sterilized than use reversible methods of contraception. The Pill still predominates in the U.S. among the reversible methods. Pill use went into decline in the mid-1970s because of the public's concern about widely publicized side effects, but is now at an all-time high. It is extremely likely—in fact, it's unavoidable—that the U.S. will continue to depend on these methods for at least the next couple of decades. The shelves of our supermarket are very poorly stocked.

I would now like to discuss a political hot potato—abortion as birth control. If one sums up the number of births, births prevented by contraception, and abortions, and plots them versus standing on the socioeconomic scale, the number of abortions is found to be highest among the poor. As people move up on the socioeconomic-cultural scale, family size drops, as couples presumably start having only the number of children they really want to raise. At first, there is a bulge in abortions, because people need a degree of sophistication before they consider preventive methods for reducing the number of births; only gradually does contraception (i.e., preventive methods) come into play. Eventually the ideal is reached, when contraception predominates and relatively few abortions occur—primarily for health reasons, or because a good contraceptive method failed. The problem is that abortion is the only postcoital birth-control method we have. Every other commonly used method is pre-coital. RU486 is actually a method of abortion. (This is really how one should divide birth-control methods—just as I prefer “pediatric” and “geriatric”

	Italy	Spain	U.K.	France	W. Ger.
No method	30	26	10	33	19
"Natural" methods (rhythm, withdrawal)	27	16	4	3	24
SUBTOTAL	57	42	14	36	43
Pill	6	19	38	31	33
Condom and other barriers	23	23	17	9	7
IUD	14	13	8	19	10
Sterilization	1	3	23	5	7

Contraceptive methods used in western Europe vary from country to country. The figures refer to percentages of sexually active women between ages 15 and 45. (After F. E. Riphagen, 1987.)

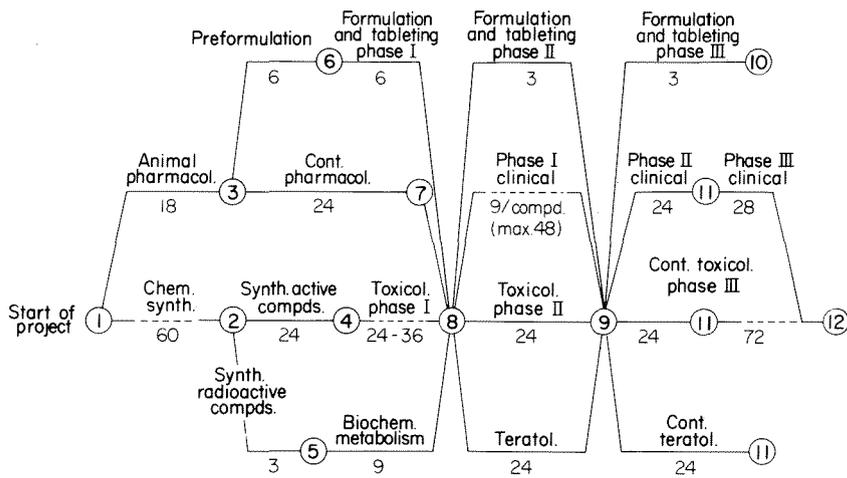
countries, I find "precoital" and "postcoital" more useful.) We need to develop postcoital methods, and yet the U.S. has decided to do nothing at all in this area—not that we are doing much in the others, either.

My desiderata for an ideal contraceptive, if I can have only one, are these: First, I would focus on women, not because I'm a man, but because, by definition, a liberated woman is in charge of her own fertility. And, if one considers the interruptible steps in human reproduction, all the postcoital steps necessarily involve the woman. Hence my emphasis on female contraceptives. Second, birth control has to be separate from coitus to be truly effective—this has been the single most important lesson we have learned from the Pill and IUDs. Third, if it is a systemic agent, it should be something that one need only be exposed to briefly—not like the Pill, which must be taken daily, or for three weeks every month. Fourth, it should need no sophisticated medical backups, so that it can be used anywhere in any country. Fifth, it should be easy for anyone, including teenagers, to understand and use. Finally, for obvious reasons, literacy should not be required.

In 1989, I published a paper in *Science*, entitled "The Bitter Pill," which listed, in order of feasibility, six methods of birth control that could be developed if the will and the support were there. The biggest impact, particularly in the pediatric countries, would be number six on the list—an anti-fertility vaccine. This would represent a fundamental change. An individual—either all men or all women, depending on which sex the

vaccine was developed for; only one would be needed—would get vaccinated at intervals after puberty, and then would have to do something deliberate in order to become fertile—the reverse of what we are doing now. Unfortunately, the chances of that happening within the next two decades are essentially zero, not for scientific but for other reasons, such as potential liability suits in a litigious society and—even more important—the total lack of interest, on the part of pharmaceutical companies, in such methods.

What about more likely methods? First, if one could find a spermicide that is also effective against AIDS under ordinary conditions of human coitus, it would certainly be accepted in the Western world and eventually in other countries. But I think that the single most important advance would be the second on my priority list: a once-a-month menses-inducing pill. A woman would take such a pill only when she expected her period, and had been sexually active during that month. The woman would not know if the egg ejected with the menstrual flow was fertilized or not. Such a pill would fulfill almost all the criteria I listed before. Thus, a woman would only have to take, at most, 12 pills a year, compared to the 250 or more she takes now. While not very attractive economically to pharmaceutical companies, such a postcoital approach would have an enormous impact worldwide. Such a pill could be developed in 10–17 years, which is about par for the course for getting a new pharmaceutical onto the market, and would cost on the order of \$150–200 million. Wide use of such a postcoital pill would make conventional abor-



Timeline for the development of a male contraceptive pill. Times are shown in months.

tion disappear fairly rapidly, assuming, of course, that one's definition of life is not the one that the last two American presidents have held—that life exists the moment the egg is fertilized, and that a five-second fertilized egg is already termed “a baby.” But for the hundreds of millions of people in the world who do not subscribe to such an unprovable assumption—at least as far as the first few days after fertilization are concerned—such a pill would represent an enormous advance.

The third method is a reliable ovulation predictor based on much more convenient home methods than currently available for determining fluctuations in hormone levels associated with ovulation, which would provide a much more reliable indicator of the “safe” period in a woman's cycle. Fourth comes a reliable method of reversible male sterilization. Right now, the millions of men who have vasectomies are usually people who have had their families, and are giving up procreation. For young men to consider vasectomy, it has to be reversible. Option number five, a male contraceptive pill, is essentially impossible in this century. Its development would easily take 20 years, as shown in the figure above. For a male contraceptive pill to be available in the year 2000, the product would have to be in advanced clinical and toxicological trials right now, which, of course, is not the case. How would we otherwise answer a man's question: “What happens if I take my pill for 40 years?” Whether we shall have a male Pill in the first decade of the next century depends very much on what we do now, and we're doing virtually nothing, for a very simple reason. In 1970, when

I first drew that figure—for a talk at Caltech, incidentally—there were 13 major pharmaceutical companies worldwide that had contraceptive-development programs. Nine were American. In the early 1980s, only four large companies were left—one of them American. I suspect that even this number will be smaller by the end of this decade.

In 1980, a British trade organization, in a survey of the pharmaceutical industry's research priorities, found contraception to be absent from among the first 35. Even nose drops ranked higher. That tells you something of how the market has spoken. But without action by the international pharmaceutical industry, there is no way to stock the contraceptive supermarket. Thus all the pediatric countries that have decided to do something about birth control—and most of them have in some way decided to do something—will have to depend on existing hardware. Their emphasis is now on improvement in contraceptive software, most importantly by combining responsible family planning with maternal and child health care.

I would like to conclude with a statement, posed in my 1989 article (when the Ayatollah Khomeini was still alive), that made good dinner conversation: “What do Iran and the U.S. have in common?” The answer was that these were the only two countries in the world that had successfully moved the contraceptive clock backward in the last decade. No other country had done so. Some, like the United Arab Emirates and Saudi Arabia, had done nothing, but most of the others had moved forward. And the U.S. had moved backward on both the hardware and software fronts.

Today, only one country is left—the U.S. Since Khomeini's death, Iran has again started to move forward on the birth-control software front. This is not the case in the U.S. Our obsession to make abortion illegal, which includes a lot of additional baggage that has nothing to do with birth control, is really responsible for our national retrogression. Rather than making abortion illegal, our rallying cry should be, “Make abortion unnecessary!” Such an aim can only be realized by improvements in sex education and in improved and universally accessible contraception—two approaches that are now very much on the national back burner. □

Carl Djerassi, the inventor of the oral female contraceptive popularly known as “the Pill,” is a professor of chemistry at Stanford University.

Rather than making abortion illegal, our rallying cry should be, “Make abortion unnecessary!”

The Demographic Transition and the Technological Transition

The session was chaired by Maurice Van Arsdol, professor of sociology and director of the Population Research Laboratory at USC. Panelists included Carl Djerassi; Robert Gillespie, head of Population Communications; James Bonner, professor of biology, emeritus, Caltech; J. Gustave Speth, president, World Resources Institute; Lance Davis, Harkness Professor of Social Science, Caltech; J. Michael Davis, Assistant Secretary for Conservation and Renewable Energy, U.S. Department of Energy; Robert White, president, National Academy of Engineering; and Robert Williams, senior research scientist, Center for Energy and Environmental Studies, Princeton University.

This session covered a lot of ground, starting with population control, proceeding to agriculture, technology, and energy, and finally running up against the brick wall of economics. Robert Gillespie called the population problem “monumental,” saying, “the world had one billion people in 1850. The second came in 1930, the third in 1963, the fourth in 1975, the fifth in 1988, and the sixth will be in the year 2000. In the lifetime of many people in this room, the population will triple. When the last flood hit Bangladesh and took 139,000 lives, they were replaced in three weeks. Half the people in the world haven’t even started having children—they *are* children. Forty-eight percent of the population in Africa is below 15, so for Africa to achieve population stabilization, they’d all have to have one-child families for the next 30 years. Latin America and Asia, with 37 percent of the population below 15, would have to have one-child families for 25 years. Taiwan is constantly used as a model for family planning, with one of the most successful programs in the world, yet its population has doubled since the early 1960s, and will double again because of the momentum factor.”

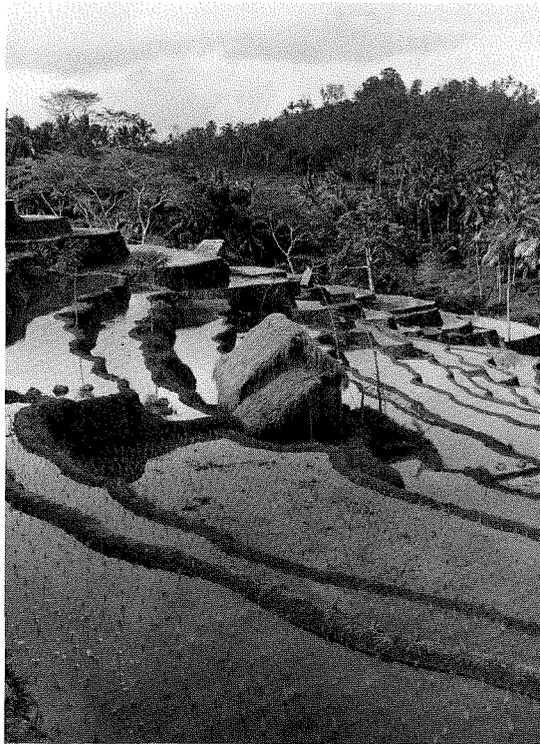
Gillespie explained that “there are a lot of ways that you can change people’s value systems to achieve the small-family goal.” These ways include improving the status of women, increasing the age of marriage, and lengthening the intervals between pregnancies. “In India I’ve mobilized vasectomy carnivals. In Bangladesh we hired 18,000 family-planning field workers. In Thailand we held condom blowing-up contests in the grade schools.” Successful programs,

Gillespie said, establish a set of tangible rewards for people who participate in the program, and establish visible, recognizable symbols of that participation. A pin, for example, worn by Indonesian youth who commit themselves to not marry before a certain age, and to ultimately have small families. Coupon books designed to lengthen the interval between pregnancies—a stamp goes in the book each month, and when the next child is born, the book can be redeemed for goods and services, like Green Stamps. The more stamps in the book, the greater its redemption value. Vasectomy Club cards for discounts at participating restaurants, bowling alleys, department stores, and so on—increasing the merchant’s business as well. But the card must have tangible value, or it won’t work.

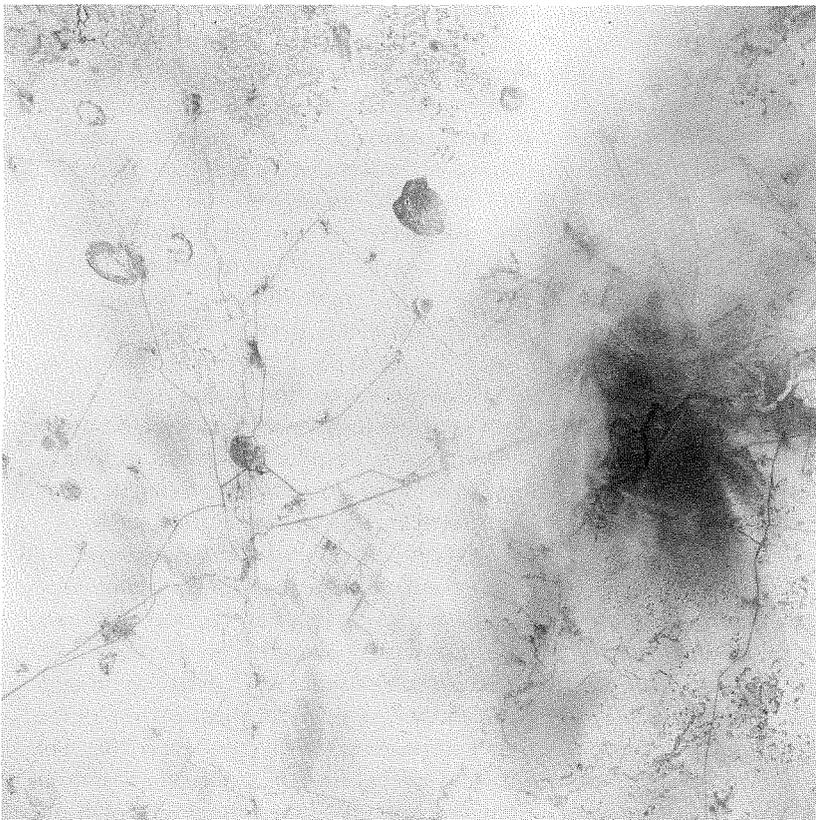
Even if we can stabilize the population at, say, 10 billion, the achievement will be irrelevant if we can’t feed them. James Bonner asserted that “we can operate sustainable, eco-friendly agriculture in perpetuity on the human time scale.” Bonner stated that we know everything necessary to keep our food production stable, including how to breed plants to survive different climates, resist diseases, and bear more fruit, seeds, or whatever we eat; what the soil, nutritional, and water needs are; how to irrigate without poisoning the soil with salts; how to control erosion; and how to rotate crops to control pests and return nutrients to the soil. These techniques were all used together for the first time in the “green revolution” of the 1960s and 70s. The growing use of beneficial insects that eat crop-eating bugs; the potential development of more

“When the last flood hit Bangladesh and took 139,000 lives, they were replaced in three weeks. Half the people in the world haven’t even started having children—they are children.”

**Right: Rice paddies—
an example of
sustainable agricul-
ture in the tropics.**



**Below: This space
shuttle shot shows
sooty snow surround-
ing the Siberian steel
city of Troitsk.**

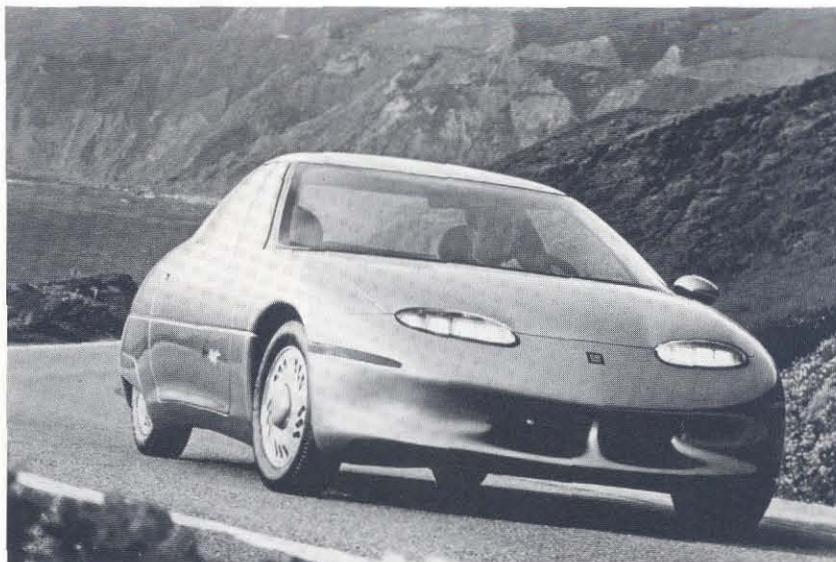


efficient, slow-release fertilizers embedded in ceramic pellets; and advances in biotechnology—incorporating disease-resistance and other genes into plants—hold the promise that food production can keep pace with population growth, but only for a limited increase in human numbers. Said Bonner, “I calculate that if we educate farmers worldwide to use optimal practices, and we don’t grow on marginal land or chop down tropical forests, we can support, as vegetarians, about 15 billion people. If we want to support them on the American diet, in which of the 12,000 calories per person per day we produce, we eat 2,000 calories as plant products—bread, Rice Krispies, pie, and hamburger buns—and feed the remaining 10,000 calories to cows and chickens, getting a 10-percent return (1,000 calories) in animal products, we can support about 3 billion people, a figure less than the present world population. Those calories that are lost to us are supporting cows and chickens in idleness—a gigantic animal-welfare program. How many people the world can grow food for depends in large part on how many cows we want for company.”

Maurice Van Arsdoel pointed out that Europe had achieved prosperity, and the low birth and death rates that go with it, by colonizing much of the rest of the world. The inflow of resources to Europe as it industrialized led some scholars to assume that technological advances would always be able to support growth. “Sociologist William Catton, in *Overshoot, The Ecological Basis of Revolutionary Change*, makes the telling point that advanced societies are again hunters and gatherers—not of plants and animals, but of fossil fuels and minerals. Are we using the fossil fuels and minerals that might be our grandchildren’s birthright? Technology has not until recently turned to dealing with maintaining a sustainable world.”

Gustave Speth predicted that if current trends continue, the world economy in 2050 could easily be five times larger than today’s. He called for a worldwide revolution in technology—the rapid, wholesale abandonment of materials-intensive, high-volume manufacturing processes for ones that use fuels and raw materials efficiently, generate little or no waste, and recycle most of that. Such technology must reduce environmental damage per unit of output fast enough to outpace production increases. “There’s simply no hope of this planet accommodating the expected economic growth unless there’s a thoroughgoing ecological modernization of industry and agriculture—a new industrial revolution focused as much on saving natural capital as on generating

Right: The Impact, built by General Motors, is a prototype of what the electric car of the mid-1990s might look like.



“Environmentalists are instinctively antitechnology, or have deep concerns about technology as a source of solutions, because it has been the source of so many problems.”

Below: When the wind is right, Los Angeles’s smog layer extends all the way out to Santa Catalina Island, 24 miles offshore, as seen in this view from the shuttle Columbia.



man-made wealth. And that means siting and building new plants. We’re becoming a nation proficient at retrofitting, at keeping dirty plants alive.”

Speth’s technological revolution will require revolutions in private attitudes and public policy. “Environmentalists are instinctively antitechnology, or have deep concerns about technology as a source of solutions, because it has been the source of so many problems. I recently wrote an article, saying much the same things I’m saying here, for a magazine published by a prominent environmental organization. The editors rejected it, saying the message would be anathema to the members.” Speth called on environmentalists and industry to let go of one another’s throats and work together, with government, to integrate sustainability into new technologies and products, by design, from their inception. Our national R&D, technology, and competitiveness policies must identify critical environmental technologies, and stimulate the private sector to develop them. “We need to mobilize the resources of the private sector as never before.” Furthermore, we should “reevaluate our approaches to environmental regulation. Current regulations may actually inhibit innovation—they certainly provide no incentive for going beyond standards.” He recommended rethinking the Environmental Protection Agency’s problem-oriented approach—programs for water pollution, air pollution, pesticides, solid waste, and so forth—and reorganizing the EPA in part by economic sectors such as energy, agriculture, manufacturing, housing, and transportation. This

would place environmental concerns at the beginning of the planning process, through better coordination with other government departments and with the economy itself.

The panel agreed that much of the necessary technology exists in nascent form today. Various panelists cited biotechnology to treat effluents, reclaim soils, sequester or recycle carbon dioxide, and put more octane in biofuels such as alcohol from sugar cane; computer-aided design and manufacturing to use raw materials efficiently and reduce waste; the use of satellites and computers for environmental management; and such mundane, readily achievable things as making motors, power plants, buildings, and appliances more energy efficient. Robert White predicted that “a global market for environmental technologies will develop. Japan, sensing the opportunity, has already begun massive investment in such technologies.” Observed Speth, “most important, perhaps, is producing and marketing the green automobile. There’s probably no other product that causes so much environmental damage. The day is fast approaching when we’ll have to move beyond vehicles that operate on fossil fuels. Hydrogen- and electric-powered vehicles are possible, and hydrogen and electricity can be made from renewable sources of energy such as photovoltaic cells [that convert sunlight into electricity] and wind power.”

Robert Williams looked at the energy future. He acknowledged that we may have to reduce greenhouse-gas emissions by 60 to 80 percent over the next several decades, but said this may not be as painful as it sounds. “Energy demand

The smoke cloud issuing from this steel plant might not be so black if tropical nations had ready access to the newest technologies for producing basic materials.



“By the middle of the next century, I think utilities will be primarily marketing energy services. They’re going to go back to Thomas Edison’s original concept of a utility as a purveyor of lighting, instead of a purveyor of electrons.”

in the industrialized countries could actually decline for decades to come. The U.S. and other industrialized countries appear to be approaching saturation in the demand for the energy-intensive basic materials like steel, cement, glass, and fertilizers, whose production has dominated much of our energy use.” And energy consumption in developing countries, where demand for these materials is far from saturated, might not grow as rapidly as ours did. As these countries build, “they’re not going to retrace our paths of development, but rather they’re going to take advantage of modern materials and methods. We should think about technological leap-frogging, introducing new technologies for producing steel, cement, fertilizer, and the like in developing countries first.” Furthermore, as energy efficiency in *all* economic sectors increases—just doing things we already know how to do would have a dramatic effect—energy demand declines. And again, developing countries can install energy-efficient systems to begin with. White agreed that the developing countries need to be in the forefront of technological development. It’s therefore critical, he said, to build an indigenous scientific and technological base in developing countries.

But even with declining energy demand, said Williams, we won’t be able to meet greenhouse-gas reduction targets unless electricity and hydrogen become our energy currency by the late 2000s. “Hydrogen could emerge much more quickly than most people think, due to the confluence of concerns about global warming, air pollution, and oil imports. Southern California’s

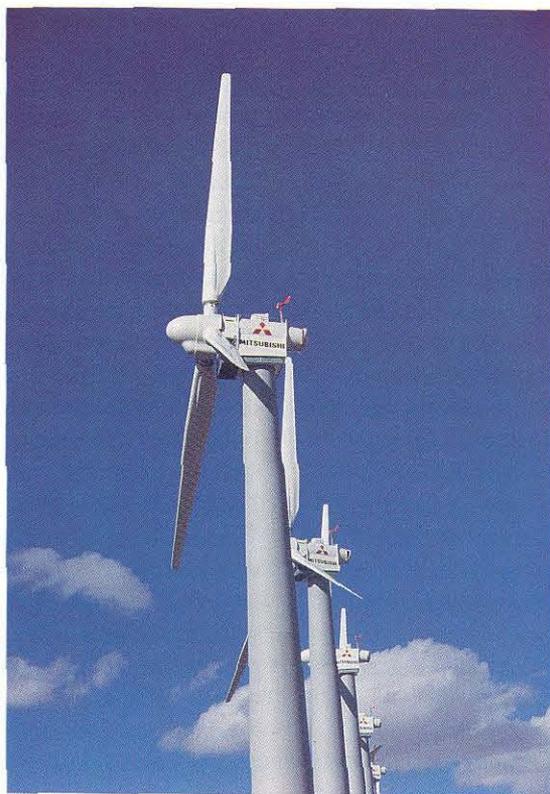
mandate to have some 10 percent of the motor vehicles in the year 2003 be zero-emission vehicles provides a fine incentive. The hydrogen-fuel-cell car is going to be even more interesting than the electric car. Hydrogen can be derived from many sources, and hydrogen-fuel-cell technologies that convert chemical fuel directly into electricity are improving rapidly.” The fuel-cell car will offer zero emissions without the prolonged recharging time and limited cruising range of the electric car. Several demonstration automobiles are being planned for the 1990s, and Williams speculated that fuel-cell cars could be competitive with gasoline-powered cars by 2010.

Williams recommended developing the embryonic industries that market, not energy, but the services that energy provides—space conditioning, lighting, motive power, and whatnot—a field with enormous growth potential. “By the middle of the next century, I think utilities will be primarily marketing energy services. They’re going to go back to Thomas Edison’s original concept of a utility as a purveyor of lighting, instead of a purveyor of electrons. Electricity generating will cease being a monopoly activity, because of the growing number of options for generating electricity competitively at a modest scale.” Williams predicted that today’s large, centralized 500–1000 megawatt power plants will be rare, replaced by 50–200 megawatt plants. There’ll also be a welter of local generating systems, ranging from 5–200 megawatts—typical of today’s industrial cogeneration systems, which derive heat and electricity from one fuel source—down to photovoltaic systems that

“Doing the right thing environmentally should be the cheap thing, not the expensive thing as it almost always is today.”

Right: Doing the right thing environmentally. Each one of these windmills—part of a farm of 300 in California’s Tehachapi Mountains—can meet the energy needs of 62 average households.

Below: Doing the cheap thing. Drums of toxic waste mingle with household trash in this third-world dump.



generate just a few kilowatts, in rooftops and south-facing windows. Buildings of all sorts will have cogenerating fuel cells powered by hydrogen, natural gas, methanol, or biomass. The ubiquitous steam turbine will be displaced by cleaner, less costly, more efficient gas turbines, powered by the same sources. And windmill farms and other intermittent renewable energy sources will be more prominent.

In the transition to a hydrogen economy, Williams expects the first hydrogen suppliers to be small: off-peak hydroelectric power, or the reforming of natural gas. Then, on a larger scale, the cheapest sources of hydrogen are likely to come from the thermochemical gasification of biomass and coal. Coal gasification could include a step to separate out and store carbon dioxide—perhaps in depleted natural-gas reservoirs—which could reduce CO₂ emissions from coal use by up to 90 percent. “Greenhouse-friendly coal is not necessarily an oxymoron.” Eventually, once the electrical market is saturated, wind farms and solar farms could produce hydrogen electrolytically—for export, as it were—in regions such as the windy Great Plains and the sunny Southwest.

“In order to bring about these new technologies,” Williams remarked, “we must find out what it takes to launch new industries. In particular, we have to find ways to promote the demonstration of a wide range of technologies. What are the best ways of sharing the risks, without depending on the federal government? We’re already seeing considerable activity in these areas in Japan and Germany. We need to catalyze creativity in the U.S. as well. Innovation in the energy sector could be much greater than it is. I’m not talking about innovations like cold fusion or even hot fusion, but rather about many technologies that have reached an advanced state of development but haven’t yet attracted the backing to make it into the marketplace.”

Speth spoke for most panelists when he said, “If we’re going to achieve this technological transition, we’ll need an economic transition in which prices really reflect long-term environmental costs. Doing the right thing environmentally should be the cheap thing, not the expensive thing as it almost always is today. It’s been said that the planned economies failed, in part, because their prices didn’t reflect economic realities. The market economies—our economies—will one day fail unless our prices reflect ecological realities.” Gillespie suggested issuing a “sustainability card” that would accrue value as people turn off lights, use less water, and so on, saying, “we have to give value to sustainability as we give value to currency when we shop, and

“Pricing reform can go hand-in-hand with tax reform, shifting at least some of the burden from things we want to encourage, like labor and savings, to things we want to discourage, like pollution and waste.”

value to sustainability’s symbols as we give value to military insignia.” Several panelists called for pollution taxes (or “environmental user fees”) in various guises—on carbon dioxide or fluorocarbon emissions, or on the cost of replacing nonrenewable energy or revegetating land. Speth hoped such measures could finance the revolution. “Pricing reform can go hand-in-hand with tax reform, shifting at least some of the burden from things we want to encourage, like labor and savings, to things we want to discourage, like pollution and waste.”

Lance Davis was less sanguine. “Technical progress may well be a necessary condition for economic growth, but it’s not a sufficient one. An invention like Ford’s assembly line may hold the promise of a revolution in production technology, but it can’t have any effect unless it’s been embodied in physical or human capital.” New capital—resources provided but not consumed—is in very short supply. Davis noted that the personal savings rate—the amount of money the average American puts in the bank, which the bank can then loan to industry—has declined from about 14 percent in the late 1950s to about 3 to 4 percent today. This decline, coupled with massive government deficits, which he called “dis-savings,” have led to high interest rates that discourage investment in general and steer what investments *are* made into ones with rapid payoffs and away from long-term ones such as new manufacturing plants and machines that embody the new technologies. Things won’t get better soon: demographer Richard Easterlin has found that, in contrast to the youth of the 1950s,

almost all of today’s teenagers work part time. However, they save no money and “probably have the highest level of discretionary income that they’re ever going to achieve in their whole lives. They don’t pay for housing; they don’t pay for food; they don’t pay for health care. What’s going to happen to the savings rate 10 years from now, when these people try to support a spouse and children while maintaining that pattern of discretionary spending?”

Michael Davis agreed that “our ability to make decisions to allocate our limited capital is, at best, poor. Our oil industry can’t possibly produce its market, so what do we do? We subsidize it. Our agricultural industry can *overproduce* its market in a New York second. What do we do? We subsidize it.” He bemoaned the time wasted in irrelevant debates, such as about CAFE (the Corporate Average Fuel Economy act), whose stated objectives are to produce cleaner air and more efficient vehicles, but which doesn’t address oil dependence because it never mentions alternative technologies such as biofuels. “CAFE is an unfortunate discussion, but what doesn’t get discussed is even more unfortunate.”

He was optimistic that the rural economy can be rebuilt around biofuels, without subsidies, pollution taxes, or increased personal savings. “Almost everybody looks to the peace dividend. I don’t. We have better examples closer to home. We’re willing to spend 120 to 150 billion dollars under a highway bill in debate right now. We’ll have the best roads and bridges in the world on which to drive imported vehicles running on imported fuels. What would happen if we spent a couple of billions of those dollars actually working on those fuels and vehicles instead of simply creating a stationary platform that doesn’t do anything for our future?”

White pointed out that some economic incentives already exist. For example, electric utilities have found that promoting conservation is more cost-effective than building new power plants. But “incentives generally imply taxation or systems of trading pollution rights, and taxation is divisive because of the potential effects on national economies, and agreeing on incentives will be difficult because each nation will weigh economic costs and environmental benefits differently.”

All agreed that summoning the political will to make the changes happen was going to be the hardest part. Gillespie observed, “It’s going to be very difficult to bribe people to want less.” Speth commented, “I’m a technological optimist. Not optimistic that it *will* happen, but optimistic that it *can* happen.” □

The Economic Transition: Recognizing Total Costs

The session, moderated by Daniel Kevles, the Koepfli Professor of the Humanities at Caltech, included John Ledyard, Caltech professor of economics and social sciences; Paul Portney, vice president and senior fellow, Resources for the Future; Roger Noll, the Doyle Professor of Public Policy, Stanford University; and Alvaro Umaña.

Daniel Kevles, during his opening remarks for the session, talked about the problem in economics of recognizing *total cost*. "If someone is concerned with developing something economically and uses a natural resource, for example a tree, there are direct costs involved in cutting down the tree, but there are also indirect costs. To cut down a tree you not only destroy the tree, you also destroy the ecosystem that the tree gives life to. You reduce the ability of the forest to absorb carbon dioxide, and you may foster soil erosion as well. These are what economists call *externalities*. It's difficult to measure these costs. You can attach a market value to them in some cases, but in many cases you cannot."

Paul Portney discussed the problem of making the transition to sustainability, suggesting that the first step must be to clearly define that state. He raised three questions.

"First, can we exploit fossil fuels, nonfuel minerals, and other nonrenewable resources in getting to this sustainable world?" He felt that it would be impossible to avoid doing so. "Second, could we use up some renewable resources—for example, a particular fishery—so long as we use the wealth generated thereby to make it possible for future generations to live better? Third, could a sustainable future be one with even greater income inequality than we suffer from today, so long as those at the bottom finally have what most of us would consider a decent life?"

Then Portney raised a fourth question: "How will we get people in the industrial democracies to care more about the less-fortunate on this planet, if in all these countries over the past 10

years, the electorate has evidenced a marked disinclination to care even about the less fortunate in the societies in which they live, where they step over the homeless on a day-to-day basis?" This last question—of how to get people to care about what they need to care about—was perhaps the most difficult of all to answer; it received considerable attention in several other sessions.

Portney went on to make a case that for some time now a number of very good economists have worried about the problem of the limits imposed on economic growth by environmental degradation and the exploitation of natural resources. "I think today we recognize the practical importance of this research more than we ever have before. In addition, lending practices of the international lending agencies now reflect this recognition."

He felt, moreover, that there is "an influence that runs in the opposite direction. That is, economic growth has a dramatic effect on individuals' demands for environmental quality. If we lay too many restrictions on developing countries, or if we don't assist them in putting in place wise environmental policies, they will have no interest whatsoever in clean air or water or the more careful management of soils, because they will be busy trying to meet more basic needs." He suggested that it was no accident that "Visions of a Sustainable World" was being held "in one of the wealthiest communities in the richest country in the world." He went on to say that perhaps "the single most important challenge facing humankind today is that of assisting the developing countries in raising their standard of

It's difficult to measure these costs. You can attach a market value to them in some cases, but in many cases you cannot.



Left: Factories along the Ohio River pollute water and air. Right: Another tree falls in Borneo.

living, while at the same time not exacerbating the environmental problems that the already developed countries created and are struggling with.”

Portney insisted that many economists are dealing with the external costs mentioned by Kevles. “A number of my colleagues are now working with the Department of Energy and a number of foreign countries on an ambitious project to account for the full social costs associated with all elements of the various fuel cycles—not a theoretical project, an actual empirical project—in which we’re trying to measure these adverse environmental effects and put them into the prices associated with products, so that when we make choices between various energy sources, we’re doing so on a full social-cost basis.” Similar work is being done with New York and other states on *environmental costing*—determining environmental and other social costs associated with new supplies of electricity.

He added that gross national product, the traditional measure of a nation’s wealth, is not an unambiguous measure of social well-being because it doesn’t take into account such costs.

John Ledyard continued the theme. Many of the problems being discussed, he said, involve what economists refer to as *public goods*, a term that refers to “commodities” such as air, water, or rain forests, where actions taken can affect large numbers of people because the effects of those actions are hard to avoid. Examples of such actions include pollution, overcrowding, disarmament, and behavior affecting biodiversity. “Suppose we could actually know and measure

such effects on public goods,” he asked. “What could we do?”

The first point he made is that “reliance on altruism is not enough.” We cannot rely on individual decision makers—whether corporations, families, or nations—to make their contribution to preserving the supply of public goods. “People will not forego driving alone, they will not stop using products that cause ozone depletion—there’s a lot of data, both historical and experimental, to suggest that telling them they’re doing something wrong is not in itself enough to get them to stop doing it.”

He summarized the research. “If everybody’s interests are identical, if the group involved is small, and if people can communicate repeatedly face to face, then you can generally achieve 75 to 85 percent of what is optimal. But if there are asymmetric interests—for instance, if there are rich and poor—and if there are very large numbers—the world has large numbers—and if face-to-face communication is difficult, then all the evidence suggests that you may get a small rate of contribution, 10 to 15 percent of what’s desirable.” If grass-roots volunteerism is not the answer, though, what can be done?

“The standard knee-jerk economist’s reaction is that free markets will solve the problem,” Ledyard said, arguing that they wouldn’t work either. “For example,” he said, “suppose we want to stop harvesting the rain forest. Suppose everyone in this room is willing to pay for it—in fact, suppose a lot of people are willing to pay for it. Suppose we can identify who to pay—that is, suppose property rights are well defined and we

There’s a fundamental problem in coordinating payments and making sure everyone contributes the appropriate amount, and that’s a problem that markets alone will not solve.

can identify the owners. Finally, suppose we can monitor whether or not cutting stops, so that we can make our payments contingent on this.”

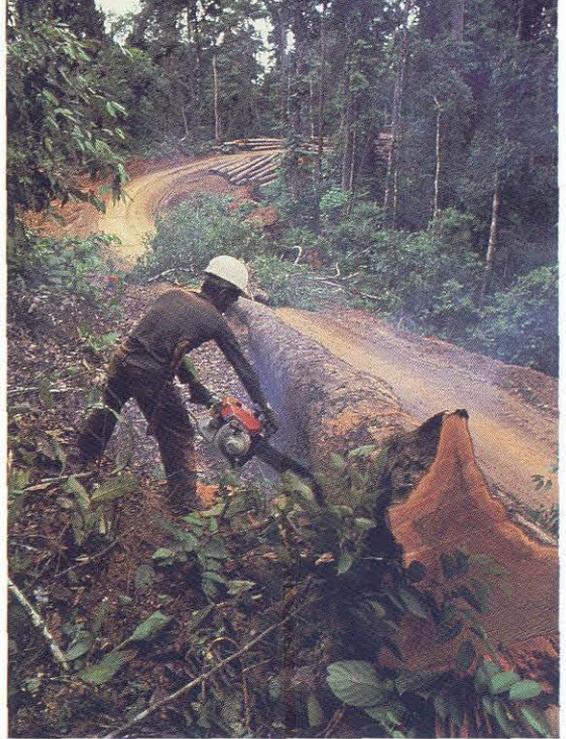
Even that would not be enough, he maintained. There would still be a fundamental problem, which he called “the free-rider problem.” If everyone pays, the payment of any particular individual becomes correspondingly less important. Chances are individuals will try to cut their payments a bit. “If we all do this, we end up back in a situation where too little is paid and too much is cut.” There’s a fundamental problem in coordinating payments and making sure everyone contributes the appropriate amount, and “that’s a problem that markets alone will not solve.”

“What about political solutions?” he asked. Unfortunately, at the international level there is no single authority like the state of New York, or the United States, that can enforce compliance. Also, there are asymmetric effects: groups hurt by any imposed solution will resist it. In the end, solutions—whether political or economic—must be sustainable and must be voluntary. Individuals must agree to carry them out.

To Ledyard, the “nonoptimality” of currently predicted outcomes implies that “there’s a possible reallocation of worldwide resources that would make everybody better off.” In principle, for instance, a reduction in pollution can be achieved in such a way that “winners compensate losers, and everybody is a winner.” The problem is communication. The market already tells tree cutters how much they’ll get for cutting down a tree. “The part that’s not being communicated is how much we are willing to pay to prevent that from happening.”

If compensation is going to be contingent upon action, he added, technology will play a central role. The actions “of individuals who create these kinds of public externalities” will have to be measured and monitored—Earth-orbiting satellites represent a step in that direction. In addition, if compensation is to be provided in response to action, some kind of worldwide financial arrangement—most likely electronic—will be necessary.

“Finally, each of us must . . . be kept from trying to obtain a free ride.” According to Ledyard, this will require new methods for calculating shared costs, “based on how much we said we would be willing to pay.” In theory procedures already exist for doing this, but they are extremely complex. The important point is that any transition to a sustainable world must be based on the willing participation of all. “If we do the early part right, the last part should follow.”



Roger Noll expressed a certain faith in self-interest—that people would recognize the problem of the global commons when they saw their own welfare at stake. But self-interest can also have deleterious effects on policy making. He pointed in particular to the tendency for environmental policies to be used for “allocating goodies” to the friends of those in office rather than for the purpose of carrying out the policies themselves. “We still have power plants burning hydrocarbon fuels in the most polluted basin in the world, when they ought not to be here anymore, and we are still using environmental policy as a mechanism for protecting investments in dirty technologies as opposed to creating mechanisms where people have a positive incentive to undertake investments in cleaner technologies.”

The bright side of self-interest is that people might possibly recognize the opportunity for mutual gain. An example of such insight is the agreement between the United States and Canada to control acid rain. The agreement utilizes economic incentives combined with the coercive power of two nations, which highlights the fact that a certain loss of sovereignty by both the United States and Canada was required in order to solve a mutual problem. Unfortunately, said Noll, the world trend today does not favor increasing aggregations of nation-states. Nation-states are disintegrating in eastern Europe and in parts of the developing world, and in the United States itself the tendency is toward fragmentation, and deregulation at the federal level. There is a conflict of values. “How do we overcome this

tendency toward decentralization in order to solve these kinds of problems?"

An equal problem is that of impatience, of "ever-foreshortening time horizons," which Noll to a certain extent credited to a kind of Malthusian doom-and-gloom outlook. If that outlook is true, he said, "then in fact saving is not rational because the instruments of saving themselves become consumed and valueless. You can't rely upon your stocks and bonds or even your capital investments to provide you with anything in the future, because the consequence of the Malthusian state is that you will ultimately be in a permanent state of abject poverty no matter what." He felt that our tendency to institutional-ly and economically obstruct benign technologies, and encourage dirty technologies, was making "the Malthusian doom-and-gloom version of the resource-management problem . . . more likely to be true."

Alvaro Umaña was, in his own words, "a little harsher than the previous speakers" regarding the role of economists in dealing with the problem of the global commons. "Although economists individually have recognized problems," he said, "collectively economic science has not really dealt with this in a serious way." More damaging, he added, was the fact that concern with "externalities" has not made its way into the realm of economic policy. "In most of the tropical world, a tree is not a capital good like a tractor or a cow. You can't go to the bank and say, I have this forest and would like to manage it sustainably, and I would like to use the forest as collateral for a loan to do this. You can do that with tractors or cows, but not with trees." He went on to talk about his tenure as a government minister in Costa Rica. "Many people came to me and said, 'You are stopping me from cutting my trees.' I said, 'Did you plant those trees?' Not once did they say yes." For those who might wonder whether it's really necessary to pay such people not to cut, Umaña pointed out that under present concepts of property rights, in Costa Rica and elsewhere, we must. Otherwise the "owners" of the trees have nothing better to do than simply cashing in what amounts to natural capital. "It's much cheaper in the short run just to cut the trees and invest in something else. That's why we are losing the forests . . . all forests."

Umaña went on to say that one of the most important global environmental services provided by trees is that of carbon storage. Europe and Japan have both decided that carbon dioxide emissions must be stabilized, but the United States doesn't want to go along: the United States, said Umaña, is the biggest free-rider in

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the world today with respect to the atmosphere, emitting five tons of carbon dioxide per person per year, which can be compared to the 0.2 to 0.5 tons per person per year emitted by the developing world. What's needed, he declared, is a treaty to link fossil-fuel usage with solutions to reduce carbon dioxide emissions. He proposed that a carbon tax of a dollar per barrel—that works out to about a nickel per gallon of gasoline—could generate 60 billion dollars a year to finance energy-efficiency and biomass-buildup programs. "In Costa Rica, for example, we have calculated that we can remove a ton of carbon from the atmosphere by planting trees and forests, for \$10 to \$12 per ton." With the nickel tax "we could remove two to three tons of carbon for each ton of fossil fuels burned. . . . The developing countries could get a tremendous amount of positive benefit from removing this carbon by planting forests—in the North, this could be sold as action against global warming, and in the South, this could be sold as rural development." Similar arrangements that paid developing countries for the sustainable use of their resources would also go a long way to protect biodiversity, he maintained.

He stressed that economics must be reformed. "Less than 10 years ago, the economic textbooks dealt with air and water as free goods. You still can find textbooks that talk about free goods." According to traditional theory, "value arises out of individual consumers choosing among baskets of goods. But these baskets do not include environmental resources and services.

"We have to change that." □

Transnationalism and the Politics and Governance of a Sustainable Society

by John Steinbruner

There's a breakdown of the old order going on spontaneously, and it's plausible to believe that a new one is forming, even if it's hard to see.

"All of history and most of human nature are against you; what have you got going for you?"

A U.S. senator said that to me recently, after I had tried to explain to him that the problems we face—population growth, the probability of a serious energy shock, the short-sightedness of current decision making, among many others—demand more effective international coordination and a new pattern of international politics.

Obviously the senator didn't buy it.

There's a temptation to say that problems of such magnitude require a radical answer, that we must design new politicians, and new electorates to vote for them. But admitting that's unlikely in the short run, let me explore some answers that might connect with the senator's perspective—a perspective that basically says, "Why should I pay attention? Why should I disturb myself about this? What's going to force me to do so?"

One answer is fairly obvious—it's going on all around us—and that is spontaneous change. Even the most hard-bitten politicians have recognized that since 1989 there's something different about the world. There's a breakdown of the old order going on spontaneously, and it's plausible to believe that a new one is forming, even if it's hard to see. We are unequivocally seeing a breakdown of the confrontation of alliances that has traditionally constituted organized international security. We are unequivocally seeing a breakdown of the economic barriers that once separated the centrally planned economies and the market economies and that thereby structured a lot of world politics. Finally, we are seeing the standard conceptions of

sovereignty being qualified extensively, as an agenda of human rights and of international concerns extends itself into what was considered to be, with a few exceptions, protected sovereign territory.

Even the politicians most dedicated to preserving tradition and most skeptical of change, recognize that they are in the presence of extremely powerful events based upon widely diverse political attitudes, that they were being driven by forces they don't fully comprehend. All of them have that instinct, and I think it's correct. So that's part of the answer: like it or not, it's happening.

Part of the answer as well is that there is more design implied in what is happening than we have yet fully fathomed or recognized. The political changes, the revolutions in Eastern Europe and the Soviet Union that were so striking from 1989 onward, were not entirely spontaneous. They were in part triggered by changes in policy, particularly in the Soviet Union, that enabled them to happen—that unlocked them, if you will. For quite some time, Soviet decision makers had been struggling to escape the burdens of a confrontation they couldn't sustain, and to overcome their own self-imposed economic isolation. They had been designing the content of their policy as best they could—always imperfectly—to adapt and reinforce what they saw as the more constructive elements in Western policy. We see in retrospect, going well back into the 1970s, substantial arms-control initiatives, changes in their military doctrine, and remarkable changes in their



economic policy. All of these changes were in some sense deliberately initiated, even if the Soviets didn't foresee how rapid the consequences would be for life as they knew it. They were picking up themes in Western policy they thought they could live with and build upon. Let me try to pull out from those themes what I think the implicit design of the new order is, a design that will provide a different basis for international order.

One theme is represented by the principle of cooperation we used in dealing with the Germans and Japanese after World War II, when we had the authority of an occupying power. That principle offers a different way for military establishments to deal with one another—the opportunity for a complete shift in the principles of security that have structured international politics for decades now. Today we are not only seeing the dissolution of confrontation, we are also seeing the initial stages of its replacement by this very different principle. I've been calling it cooperative security, or you could call it cooperative engagement.

We need to develop that principle, in dealing with our erstwhile enemy and with other military establishments that we haven't as yet had a whole lot to do with. The idea is not to confront them with counterpoised military power, but to engage in mutual regulation for mutual benefit. There are several features to this. One is to be much more preventive in dealing with security issues than we have been in the past. The traditional idea of collective security—which grows out of a confrontation of alliances—is that you wait for some international crime to happen, an aggression, and then you gang up on the aggressor. That's what we did in the recent Persian Gulf affair. We did not disturb ourselves much until Iraq attacked Kuwait, and then we organized a coalition to beat them.

Cooperative security, on the other hand, imagines that military power would be generally regulated—comprehensively regulated—by agreement in advance, such that it would be extremely difficult to get an offensive force into position to successfully invade another country. An arrangement of this sort would, by mutual consent, set rules for the allowed size of force deployments, their geographic location, their operational practices, their investment practices and modernization rates—by mutual agreement. It would enforce these understandings by rules of transparency, which would make everyone keep everyone else informed. It would include all elements of military power and all major countries, and would thereby build a comprehensive

arrangement designed to regulate military power. That is the implicit idea, imperfectly formed, but you can see in it the emerging elements of a new, very different order.

A second idea is that of economic integration. This idea has also been propelled by changes in Soviet policy. The Soviet Union recognized some time ago that it was in serious trouble, trying to conduct a completely separate economic system isolated from the main industrial economies, and that it had to connect in some way with the outside world. I doubt if the Soviet leaders fully realized the implications of that, but they certainly understood that much. I think that imperative goes for everyone else, as well.

We are in the midst of a tremendous revolution in information technology, which is likely to have profound implications in the way economic activities are conducted. National barriers are being irretrievably broken down. National governments talk about national competitiveness, and in pursuit of advantage they attempt to set up special trade zones. I think the underlying reality is that they've lost control of this process in national terms. We are seeing the creation of a truly international economy that will have its own new set of rules whether we like it or not.

In order to cope, we will have to organize market access on equitable terms, because it will be essentially impossible to deny anyone. Much more than we currently do, we will have to organize the extension of capital investment to areas where economic depression is simply intolerable. At the moment, we have an extremely serious situation in the center of Europe, where we have two very different standards of living between which all the barriers to movement and access have been broken down. It is hard to see how we are going to deal with that situation without creating political pressures for migration, which will be extremely difficult to manage.

The only answer is that there will have to be some leveling of living standards and, for that to occur, there's going to have to be a much more robust organization of capital investment to absorb risk and provide physical connections. Markets will not do this by themselves. It is a major demand on international policy, and it will transform the way we do economic policy.

And finally, as these issues drive us more deeply into the question of how entire societies are conducted, there will inevitably be a difficult sorting out of the legitimate claims of sovereignty and the legitimate standards of international human rights—questions to which we as yet have no answers. Clearly, there must be given some scope for diversity—for different cultures to

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The last of the Soviet Union's SS-23 shorter-range nuclear missiles await destruction at a Kazakhstan base in October 1989. While these were scrapped in accordance with the treaty banning medium-range missiles, others that remain since the disintegration of the Soviet Union present a new security problem.

organize their political processes as they wish them to be. At the same time, there are very serious constraints on what we can tolerate by way of their treatment of people, particularly their own citizens who don't necessarily meet local standards of ethnicity.

We cannot avoid these issues of forming cooperative security arrangements, of revising economic policy to accommodate an increasingly internationalized economy, of dealing with the limits of sovereignty. Whether we like it or not, we are being propelled into a different concept of international organization. That's part of my answer to the senator: look around you—there's an implicit design for a new order, much further along than you recognize.

But the answers most likely to be heard in Washington have to do with the motives for accepting these new imperatives, and even for designing them, so I will quickly run through some of the short- and medium-term pressures that I think are significant enough to force the United States to change its mind about transnational governance and the desirability and necessity of it—pressures that will drive even the most hard-headed politicians into a much more coherent form of international organization than we have had in the last 40 years.

The first of these is simply a transformation of the standard security threat. We have been concerned for forty years about the possibility of Soviet aggression on the ground or with long-range nuclear weapons, and we've been prepared to deter and contain such threats. It's not only that those problems have receded in significance.

It's that they've been entirely replaced by a very different kind of problem. The problem now is the threatened disintegration of a Soviet military establishment still possessing large numbers of very destructive weapons. We cannot handle that with confrontation, even mild forms of it. Deterrence and containment are essentially irrelevant—indeed, largely counterproductive. We must worry about the Soviet military establishment maintaining enough integrity to handle nuclear-weapons deployments responsibly. We must involve ourselves directly, and we're only just beginning to realize that fact. That's an entirely new security problem just beginning to capture attention in Washington.

A derivative of that problem is the broader fact that as long as nuclear weapons are maintained—and it will be very difficult to get rid of them in short order—they have to be operated safely. At the moment the underlying volatility of the interaction between the U.S. and Soviet military establishments is a problem that must be dealt with. Both establishments are designed to react so rapidly to a perceived threat, and the warning systems that mediate this reaction are so fragile, that when the world comes to understand this situation it will demand a much higher standard of safety. That is what it gradually did with regard to nuclear reactors, whose meltdown would be a disaster of much less consequence than an accidental nuclear exchange. This safety issue is likely to affect politicians in the course of this decade and to force very different conceptions of international organization.

Similarly, the technical diffusion endemic to an international economy means that we have a problem of weapons proliferation much greater and more sophisticated than what we've been used to seeing. We will have to come up with a much more organized and integrated response, or we will be in serious trouble. At the moment, the United States has the only power-projection machine capable of global operations. We don't have any competitor in that regard. This is a problem for most of the rest of the world. We think it's a great idea, but not everyone else is so clear about that. There are technologies available that would not so much match the U.S. capability—a massive investment would be required for that—as negate and counteract it with technologies that are widely available. And if we drive competitive development the way we usually do, we're going to be in trouble 10 or 15 years from now. So we have tremendous incentive to protect ourselves from the inevitable reaction of worried competitors, and to form a larger, more cooperative security arrangement. Again, Washington is

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in the process of discovering this particular imperative. We've got to integrate the various mechanisms for controlling weapons proliferation, and we've got to have everyone on board. Otherwise, we ourselves are going to be in trouble.

I want to underscore the implications of the information revolution. The transmission and processing of information have gone through the most radical transformation of any commodity in economic history by a large factor. We don't, I think, yet know what the full implications will be, but it's very clear that they will be substantial. The revolution will restructure a lot of microeconomic activity and will change the character of macroeconomic management. A lot of good things can come out of this, but tremendous dislocation is possible, and to politicians that means trouble. Therefore, we're facing a tremendous agenda of coping with this technical transformation of information technology, and its economic consequences.

It's clear that major improvements in international management can be derived from this technology, in particular in the management of security arrangements. Cooperative security, systematically implemented, would enable us to save on the order of \$500 billion in a \$2.6 trillion defense bill in the course of a decade and on the order of \$100 billion a year thereafter. Those are significant sums. That possibility will capture attention as people begin to look at the increasing fiscal pressures in the United States.

Finally, the threat of spontaneous civil vio-

lence that we see emerging in Yugoslavia, and that potentially could occur throughout Eastern Europe and the Soviet Union, is something that cannot be dealt with in terms of our traditional mechanisms of collective security. If we are going to do anything about it at all, we'll need much more robust forms of cooperation than we have now. The threat is serious enough to cause practical politicians to change their attitudes about international governance.

Let me summarize by saying that the imperative of events is, I believe, powerful enough to change even the reluctant minds of U.S. senators and the people who elect them. In the course of a decade, we are likely to see immense changes along these lines, and if you project beyond a decade, I think we are headed, for reasons we can't avoid, toward a security order that is all-inclusive—a single global alliance, if you will, to which everyone is required to belong by incentives they cannot ignore. We will live, furthermore, in a single integrated economy that we'll have to learn how to operate, with rules of equity yet to be defined. Moreover, in the context of a single security order and an integrated international economy, there is likely to be a radical decentralization of political power, brought about because it is becoming possible to do many more functions at more local levels, with much more interaction between localities. This will be a very different pattern, and we are already substantially into it. I believe that on the whole it's a much better pattern; it is certainly feasible. We should attempt to shape it, to bring it about more rapidly than it might otherwise occur.

The alternatives are not very good. □

John Steinbruner has been director of foreign policy studies at the Brookings Institution since 1978. His areas of expertise include East-West relations, national security policy, and the strategic balance.

Transition to Effective Global Governance

Session chair and panel moderator was Jessica Mathews, vice president of the World Resources Institute; participants included William Drayton, chair and president, The Ashoka Fellowships; Bruce Murray, professor of planetary science, Caltech; Peter Ordeshook, professor of political science, Caltech; and John Steinbruner.

If John Steinbruner's concept of cooperative security or engagement offers the possibility of a new pattern of international politics, the question remains as to what specific form that pattern might take.

As the moderator of this session, Jessica Mathews described her panel's agenda as one of looking at currently unfolding political and economic trends and at conceivable results, with the hope that such a discussion would illuminate which paths we might want to follow and what key decisions might determine the paths we take. The term *governance* as used by the panel, she indicated, would cover not only the work of governments as the key actors that they have been in the past—particularly in relations between nations—but also the actions and influences of nongovernmental actors, including individuals as well as businesses and other multinational institutions. Transnational relations from the grassroots level all the way up to the highest level of agreements between states would be looked at, she said. In a similar vein, she had remarked in the session on ideology and culture that “one of the most profound trends we see around the world” is the delegation of “power and authority from nation-states, both voluntarily and involuntarily, to other actors—international business, and, in particular, individuals, both acting alone and in self-organized groups. . . . Groups of individuals, whether they are scientists, businessmen, laborers, or citizen activists, tend to offset the centrifugal forces that govern relations between states.”

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Harlan Cleveland made a similar point during his talk in the opening session. “It is of course increasingly true that world government consists mostly of what nongovernments do; that more of the initiative, more of the thinking, more of the control over real resources, more of the transnational behavior represent the actions of people who are not working in governments.” Even some governmental systems are working internationally. “We found a huge laundry list of things that are working that you never hear about because they *are* working, starting with the world weather watch and the civil aviation and international telecommunications arrangements and so forth. . . . I was particularly struck, not with the more obvious point that these arrangements reflect win-win situations, but with the more subtle point that in all of these international institutional arrangements that are working more or less the way they're supposed to work, people forget to talk about sovereignty. Now this is not what the world federalists and others used to recommend—that we should abolish sovereignty. Not at all. It is that there has been a trend toward *pooling* sovereignty.” Increasingly, he said, people are realizing that sovereignty can be used “in league with other people's sovereignty in order to do something that neither of you can do alone.”

Bruce Murray made a comment that threw a somewhat different light on international arrangements that work. In terms of the earlier economic discussions, he said, “we realize that in order to get the price right, we really have to

If we look at those federations that have formed since the Swiss Federation in 1291, the objective in every case has been to counter an external economic or military threat.

have governmental arrangements with coercive capabilities in order to make something like the Montreal protocol—which phases out chlorofluorocarbons—work.”

Peter Ordeshook, in his talk, addressed just this issue. He began by discussing the Persian Gulf War. Whereas John Steinbruner had emphasized the traditional confrontation-of-alliances aspect of the United Nations coalition, Ordeshook took from it the oft-reiterated lesson that, in the face of a threat, nations are able to put aside their differences and engage in collective action. “Suppose we tentatively agree to the existence of a new type of threat—an ecological one. Will this universal threat lead to a fundamental change in the way nations or people go about their business?”

Speculating, Ordeshook looked at the types of governments based on federalist principles, “because they illustrate the circumstances in which states voluntarily abrogate a degree of sovereignty.” This focus raised two questions: what are the preconditions for the formation of federal states, and what are the conditions for their successful operation? “If we look at those federations that have formed since the Swiss Federation in 1291,” he said, “the objective in every case has been to counter an external economic or military threat—in general, a military threat. For the purposes of argument I think we can accept the hypothesis that ecological dangers pose a threat that might transcend other interests and fundamentally alter incentives for international cooperation. However, history and a good bit of theory tell us that such threats

merely provide the necessary conditions for collective action. They do not provide *sufficient* conditions because political institutions often fail to adequately accommodate two facts.

“First, social policy in general and environmental policy in particular entail the redistribution of wealth. That debate rarely has an outcome that, once agreed to, terminates disagreement. Second, cooperation emerges only if there is a reasonable expectation of enforcement, and is sustained only if that expectation is realized. Because ecological issues concern matters in which people fail to take full responsibility for their actions and prefer to free-ride on the actions of others, contracts must be written to preclude free-riding—and contracts require enforcement.”

One class of federal agreement involves loose confederations or alliances that “may or may not allow for sanctions against those who defect.” This, Ordeshook guessed, might typify the “new world order” implied by the Persian Gulf coalition. The more typical fate of such loose alliances, however, is illustrated by the events leading up to the drafting of the U.S. Constitution. When jurisdictional, territorial, and tax disputes arose among the original states after the revolutionary war, the Articles of Confederation proved inadequate even in the face of a continuing military threat. Of course, he added, the formation of the Western Alliance or the development of today’s global economy might seem to be counterexamples to the idea that confederations are inherently unsuccessful, but they actually illustrate another fact: in response to free-rider problems, decentralized cooperation generally requires a central authority, “in whose interest it is to bear most of the organizational and enforcement costs. Indeed, this is the traditional source of enforcement. In assessing the feasibility of decentralized confederations today, I think we should ask: ‘Is anyone capable of playing this role in the foreseeable future?’ To be honest, I doubt that it can be Japan. Few see Japan as a leader of anything except the pursuit of market share. I doubt it can be the United States, which is incapable of balancing a budget, or Western Europe, which is led by a burgeoning bureaucracy and encompasses states that still dream of lost empire.” Nor could he include the remnants of the former Soviet Union, even if they don’t “first veer toward totalitarianism.” This was not to say, he made clear, that voluntary confederations are necessarily ineffective, but only that their “effectiveness declines precipitously as redistributive matters gain importance, and as the full cooperation of all decision makers becomes essential.”

The alternative to a voluntary confederation is the kind of agreement “that resembles a centralized federal state in which countries much more explicitly abrogate part of their sovereignty. Returning to my earlier question about the components of successful federal forms, both experience and theory point to two necessary features. First, in a successful federal arrangement, no party can greatly outweigh any other because such disparities again exacerbate redistributive issues. This is the problem the European Community is likely to confront in the future, and it is a problem that precludes any reformation of the Soviet Union on democratic principles. Second, there must exist political organizations that transcend the kind of internal divisions that foster redistributive politics. Consequently, centralized federations based on proportional representation that must contend with geographically based ethnic, religious, or racial cleavages are the most difficult to maintain. The particular problem here is that of imagining an international political entity to which nations abrogate sovereignty without first obtaining guarantees of representation based on size, wealth, or population. Indeed, I have difficulty imagining agreement even on the nature of representation.”

Ordeshook went on to emphasize that his arguments should not be interpreted to mean that collective political solutions to international ecological problems aren't feasible. “Redistributive issues need not be inherently zero sum, and they need not be the policy instruments of governments only. Schemes to compensate people for the short-term economic losses that accompany the pursuit of long-term economic or ecological gains can originate out of individual self-interest such as the desire to develop markets and secure investment opportunities. Also, we shouldn't discount the possibility of inventions in governance and in the structure of markets themselves. After all, the United States is such an invention.”

In summary, Ordeshook said that “although the common threats we face are self-evident, those threats alone will not dictate events. Distributive consequences cannot be ignored, and we should be prepared for strong undercurrents of economic competition continuing to dominate international affairs. Indeed, if we can predict anything, it is that these undercurrents will in all likelihood play a primary role in both correcting our political errors and obstructing our political inventions.”

The idea that economic competition might deter political inventions as well as errors reemphasized the human and organizational

Also, we shouldn't discount the possibility of inventions in governance and in the structure of markets themselves. After all, the United States is such an invention.

dimension mentioned by Jessica Mathews at the beginning of the session. It is this dimension that William Drayton concentrated on during his talk.

Drayton first of all admitted that he found disturbing the *Brave New World* scenario outlined by Bruce Murray (carried here in the chapter on beliefs and value systems). Drayton expressed the hope that “we are spiritual people and that we will not allow that to happen.” Nevertheless, the past several decades have been discouraging: the disparity in per-capita income, between bottom and top, is more extreme than ever. As our own society has perceived itself becoming poorer, the strong have increasingly taken from the weak. “One could be very pessimistic,” he said. Against that Drayton set what he described as the past 2,000 years of ethical evolution. He expressed admiration for the late Jean Monnet—considered by many to be the father of the European Community—who, said Drayton, concluded that “we just can't continue in this divided condition.”

According to Drayton, there are two basic questions. First, where are we going to find the energy for change—how are we going to find the leadership, the driving force to make all the many changes that must take place? Second, what opportunities will build that kind of momentum? Some elements of the pattern are clear. We know we are going to be dealing with more and more problems—yet, although those problems represent opportunities, many of our existing institutions aren't capable of dealing with them. Such institutions lack sufficient scope, are too rigid, or have the

Spontaneous and widespread political response in November 1989 led to the breach of the Berlin wall and ultimately to German unification.



wrong institutional culture.

Drayton talked about “champions of change.” He hoped that as we learn how to run our large institutions better, and as more and more societies become democratic, that some of those institutions in fact will open up and produce significant change. People are the key. Drayton called for more *public entrepreneurs*—people who will provide the same kind of leadership in the public arena as entrepreneurs do in the private sector, whether in education, human rights, or some other area. There is, he said, a “whole array of areas that don’t fit the commercial reward structure. We need to build the institutions that will support the Florence Nightingales and Gifford Pinchots and the people who founded the antislavery leagues.”

If we are going to have the capacity for that kind of experimentation, investment, and contribution, we must reduce the role of economics, and that probably will require fundamental structural changes. Drayton gave an example, pointing out that millions of adults have no children under 14, have nothing wrong with them physically, and are not involved in any institution—indeed, are not working at all. They represent a vast, unused resource. Drayton wondered whether utilizing that resource might be made more economically feasible if we shifted the price of natural resources and the price of labor in relation to each other. We currently tax employment at roughly 30 percent through social security, unemployment, and other taxes, and he suggested shifting that so that natural resources and labor are taxed on a more equal basis. He felt

that this might produce a more vigorous and environmentally sustainable pace of economic growth, while at the same time decreasing the number of people dependent upon government support.

A secondary but important question is how to help children learn the cultural skills necessary for working with groups of strangers—the kind of skills needed for running a decentralized society. More important yet, how are the children of the poor to be educated as the world becomes ever more information-intensive? As he concluded, Drayton emphasized again that a system must be built to encourage the people with the energy, the strategy, the push, and the entrepreneurship to create a sustainable world.

Perhaps the strongest note of hope was provided by John Steinbruner, during the session’s question-and-answer period. It is true, he said, “that this entire agenda is not going to get very far along until people start thinking about it, discussing it, having opinions about it, and conveying those opinions to one another. Somehow we must lift the horizons of the entire national discussion.” That could already be happening. Sometimes, he said, it is difficult to see the shift from an old order to a new as it is happening. “Witness the process of German unification. As it occurred, no one in power had any idea that it was about to happen, and they were responding to something that was very spontaneous and widely distributed—they were taking instruction, if you will, from widespread political opinion.

“It is a very powerful mechanism.” □

Cultural and Ideological Transitions: Beliefs, Value Systems, and Sustainability

Contributors to this topic included William Drayton; John Gardner, the Miriam and Peter Haas Centennial Professor in Public Service, Stanford University; Hassan Hathout, director of the Outreach Office of the Islamic Center of Southern California; Jessica Mathews; Lloyd Morrisett, president of the John and Mary R. Markle Foundation; Peter Ordeshook; and Alvaro Umaña. Bruce Murray was the panel moderator.

Which cultural and ideological values might be conducive to a sustainable world was a question central to the entire symposium. Stanford University's John Gardner, in his introductory remarks for the opening session, expressed his concern over "the disintegration of communities and the sense of community," as manifested in "family, school, congregation, workplace, neighborhood, because it is communities at that level that are the generators of values and value systems." He wondered what good it would do to "entertain lofty purposes at the highest level of national and international discussion if the foundations are crumbling." He thanked Murray Gell-Mann for touching on the problem of "achieving wholeness incorporating diversity," a problem that Gardner found haunting, and a problem that would crop up repeatedly during the symposium. How, after all, can wholeness incorporate diversity in a world of rising ethnic and religious passions—a subject, according to Gardner, that "our problem solvers vastly underrate"?

As Alvaro Umaña put it, also in the opening session: "The problem with the transitions—demographic, energy, technological, economic—is that they are all interrelated, and that they all have to take place simultaneously." This, he insisted, could only happen through a transition in values.

Bruce Murray made the question of values the centerpiece for the session on cultural and ideological transitions. "As the environmental trauma escalates," he remarked, "the actual outcome depends in large measure on the

behavior of individual people throughout the world. Their behavior will reflect their values," which in turn "are usually influenced in some way by an ideology." Lloyd Morrisett, the first speaker, presented what he felt were the four key ideological concepts underlying industrial behavior in the West.

Morrisett first evoked the period around 1840–1860, a period, he pointed out, within the family memory of many of us alive today. This was the world of our great- and great-great-grandparents. More specifically he evoked the world of the Great Plains, the world re-created by O. E. Rølvaag in *Giants in the Earth*: the broad expanse "stretching away endlessly in every direction . . . almost like the ocean," where enormous herds of bison made possible the culture and economy of the Plains Indians. Between 1862 and 1900, an estimated 50 million bison were slaughtered by encroaching Americans. "The Indians and bison and the sea of grass yielded to the advancement of industrial civilization and the technology of the rifle and the plow," said Morrisett. "As the settlers from Europe and the eastern United States moved west to obliterate a previous world, a world that is hard for us to imagine, they carried with them a set of ideas, an ideology if you will, that gave them strength and justified their actions."

The first component of this ideology, according to Morrisett, is the idea that "nature is opposed to man," that nature is "an object separate from ourselves to be exploited and conquered." The second is social Darwinism, the suggestion that "the wealthiest and most powerful people in

As the environmental trauma escalates, the actual outcome depends in large measure on the behavior of individual people throughout the world. Their behavior will reflect their values.

a society are that way because evolutionary processes have brought them to the top” and that “the wealthiest and most powerful societies are obviously at the peak of the evolutionary pyramid.” The third idea is that of progress, with its connotation of bigger as better, its evocation of accumulated wealth and conspicuous consumption as its measures of success. The fourth is that the modern state justifies itself in readiness for war. All four of these ideas are mutually reinforcing. War, for example, determines who has the right to exploit nature and demonstrates the accomplishments of progress; and victory is construed as evolutionary success. Morrisett presented some scenarios by which these core ideas could be changed—unexpected events, charismatic leadership, a new Darwin—but admitted he was pessimistic that change could come without a period of strong conflict.

The issue of culture and ideology inevitably arose many times during the “Visions” symposium. Bruce Murray’s talk in the session on global governance, in particular, amplified Morrisett’s pessimism regarding the ultimate consequences of industrial ideology.

For his discussion, Murray drew upon Aldous Huxley’s *Brave New World*, which, though written in the thirties, nonetheless deals with many of the same issues facing us today. Drawing an analogy with Huxley’s Alpha Pluses, Murray explored the likelihood that people with assets, technology, and education will have the cohesiveness to create enclaves for themselves and to sustain their lifestyle at the expense of nature and the rest of humanity. He wondered whether the beginnings of such a trend were already apparent in the tendency of some elites to sequester themselves in suburban communities behind locked gates. He speculated that such elites might use biotechnology—genetic engineering and pharmacology—to assure their survival, resulting in a society that would be the ultimate expression of social Darwinism and separation from nature. Murray then reminisced about his 1978 trip to China, a land long overpopulated. There were no songbirds, and he experienced a culture bereft of the idea of conservation, of connection with nature. His ultimate worry is a human civilization stripped of any sense of the importance of nature, a society from which the richness of cultural diversity and perhaps even individuality itself have been expunged.

Such a society, in its oppressiveness, could prove the final justification of the war-preparedness mentioned by Morrisett. The deep-rootedness of the ideology of war was a topic that emerged several times during the discussion on

culture and ideology. William Drayton pointed out that the military technology of Philip of Macedon swept away the city-states of the ancient world, including those with approximations of town-hall democracy, and made possible the great empires on the Roman model. And Hassan Hathout declared that, while a “peace dividend flows naturally downward to the poor and needy at home and abroad, the war dividend flows up against gravity to again feed the need and the greed of the war system whose beneficiaries hold power in most countries.”

Jessica Mathews chose to explore the actual value transitions that might make possible a sustainable world. She identified three, and they contrast sharply with the four concepts—nature as enemy, social Darwinism, progress, and war-preparedness—discussed by Morrisett.

The first transition would require a fundamental change in our relationship to nature. Rather than Morrisett’s “object separate from ourselves to be exploited and conquered” with an emphasis on Darwinian struggle, nature might be seen in the context of James Lovelock’s Gaia hypothesis, which emphasizes ecology and the study of Earth as a living whole. From such a science, Mathews believes, “will come the realization that—despite technology and all its powers, and despite what the major Western religions have taught us, beginning with Genesis—man does not exercise dominion over nature.” Given such a transition, she believes the easiest behavioral change will be in the realm of technology: we need only develop the appropriate rules and institutions. “We will have to change thought and behavior profoundly, but history tells us that that is certainly possible. It wasn’t really very long ago that human slavery seemed essential to economic success, morally acceptable, even rather ordinary. And now it is unthinkable.”

The second transition requires a change in our relationship to the future—“not how we think about it, but whether or not we care about it.” Traditional economics doesn’t deal with the long term; according to Mathews, the attitude of most economists is captured by the John Maynard Keynes axiom that, in the long run, we’ll all be dead. Economists, she said, use discount rates that “effectively make anything that happens even 50 years ahead of no consequence.” Mathews recently participated in a project called “The Earth is Transformed by Mankind,” which examined 19 measures of human-induced change, including population growth, water quality, water quantity, atmospheric conditions, and the use of nonfuel minerals. The study concluded that there has been more change to the planet

We will have to change thought and behavior profoundly, but history tells us that that is certainly possible.

since 1950 than in the previous 10,000 years. "We can no longer discount the future," she said, contradicting the logic of immediate exploitation that is central to the ideology described by Morrisett.

Economics as a value system was mentioned in several other sessions as well, most often in terms of the need for a change. Alvaro Umaña brought up the issue in both the economics session and the opening session. "Economists have taught us that there is no free lunch," he said in his opening talk. "But we still have to get through the message to them that there are also no free resources and that the era of free goods has to end." Hassan Hathout, speaking on the culture and ideology panel, expressed a certain impatience with the values underlying industrial ideology. "If exploitation was the essence of slavery, one wonders whether slavery is gone," he said. "The death of communism is no health certificate for our current capitalism."

As described by Mathews, U.S. industrial economics and the science that has evolved with it seem almost otherworldly. On the one hand there is that short time horizon, where, in our society, any span longer than 10 years "seems almost laughable." The Japanese, she pointed out, have released a 100-year environmental and energy plan. On the other hand, she said, one of the paradoxes of modern science is that we've paid so much attention to the very tiny—subatomic structure, molecular activities in the cell—and so much attention to the very large and the far away—space—while we're paying almost no attention to things on a planetary scale. "We find ourselves with unprecedented power to affect the planet and profound ignorance about the systems on which we depend." Harlan Cleveland alluded to this in the opening session, when he reminisced about wiping out mosquitos on Sardinia "in a demonstration that it could be done worldwide. We then started the malaria-eradication program without having the slightest idea at the time that the mosquitos would develop an immunity to DDT, or that DDT would have all the side effects that it later turned out to have." He saw this as a metaphor for the unforeseeable damage science and technology can wreak. Mathews, in her turn, saw the necessity for a shift in the burden of proof regarding proposed human activities. She saw the United States in particular as moving in the wrong direction when it comes to concern for the future. "I don't think it's a global trend. I think it's peculiar to us."

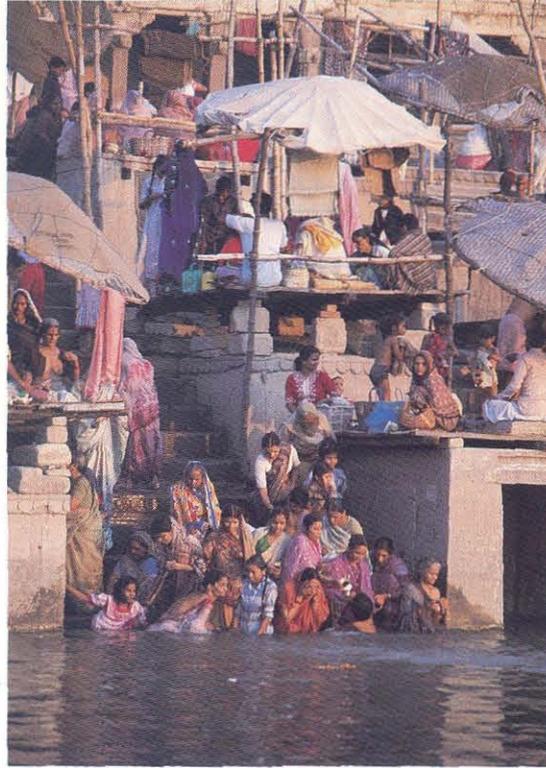
The third transition discussed by Mathews involved the relationship of individuals to nation-

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states. One of the most profound current trends, she maintained, is that of power and authority being delegated from nation-states to other actors—international institutions, individuals, and nongovernmental organizations. Changes of thought, she said, come from people, not institutions. The late Jean Monnet, father of the European Community, knew this precisely. "He said that his intention for European union was not to form coalitions between states, but union among people. And that dream is about to become reality next year."

This trend toward transnational cooperation and the delegation of sovereignty carries strong implications for the modern state described by Morrisett, which finds its justification in war. John Steinbruner in particular, in his presentation on governance, talked about what he called cooperative security. The idea of military power being regulated by agreement obviously puts a very different valuation on war-making power than that traditionally assigned by industrial ideology.

Concepts such as "cooperative security," "cooperative engagement," "wholeness incorporating diversity," and "integrated decentralization" were discussed several times throughout the symposium. They all to one degree or another represent the same core idea: the importance of empowering individuals and groups of individuals. Even cooperative security, while dealing with traditional nation-states, implies a new form of international governance that dissolves confrontation in favor of "mutual regulation for mutual benefit," a move away from the rigidity of



A 1974 plan to reduce India's growth rate emphasized more opportunities for women, such as these women on the banks of the Ganges in Rajasthan.

The greatest cultural change in our time is the increased potential role for women. What will be the role of women in the future and to what extent will value systems emerge that will bring women more into the mainstream?

collective-security blocs. The central question is whether ideological and cultural roadblocks can be removed, and whether human creative power can be both sustained and released while at the same time human values are being transformed from those of the industrial ideology outlined by Lloyd Morrisett, to the very different values advocated by Jessica Mathews.

Peter Ordeshook, during the session on governance, detailed the possible advantages of federal mechanisms in reforming global governance, and in doing so touched on several issues involving values. He pointed out that achieving a sustainable world would likely involve a certain redistribution of wealth. Any federal arrangement for carrying out a redistributive policy would in turn represent a contract requiring a central authority to enforce it, and Ordeshook expressed a certain pessimism in that he saw no nation capable of playing such a role; he also saw geographically based ethnic, religious, or racial cleavages as being a problem in maintaining a federal system. The only hope he seemed finally to see for removing roadblocks was in an appeal to individual self-interest.

So the question remains. Can a sustainable world be achieved without conducive cultural and ideological transitions? Harlan Cleveland, in the opening session, pointed to a long list of international arrangements that are working, involving areas such as weather forecasting, civil aviation, and international telecommunications, among many others. In all of them, he said, people in one way or another disregard sovereignty. Cleveland earlier in the same talk had said:

"The most important lesson handed down from the history of human cooperation is that people can agree on what to do next together if they carefully avoid agreeing on why they're agreeing. But if you try to agree first on ideology and then on action, you never get to the action."

It would seem, however, that when ideology is involved, appeals to self-interest and action may not be enough. Cleveland went on to talk about the insistence of the United States government that population not be on the agenda for the Earth Summit in Rio. "Most of the other countries of the world know that it's impossible to discuss environment or development . . . without population being somewhere in the middle of the picture." According to Cleveland, the United States government—for ideological reasons having to do with abortion—has created "an intellectual impasse." So ideology is, sometimes at least, a roadblock to problem solving.

The problem of overpopulation serves to introduce a question of cultural values that appeared in several different contexts during the symposium: the status of women. As Bruce Murray said: "The greatest cultural change in our time is the increased potential role for women. What will be the role of women in the future and to what extent will value systems emerge that will bring women more into the mainstream?" During the culture and ideology session, Jessica Mathews discussed the two key steps of "access to reproductive control and to education," and how closely the two are linked because the lowering of fertility rates is so profoundly tied to education: "Even six years of pri-

mary education affects fertility rates profoundly.”

Alvaro Umaña developed the same theme during the opening session. “It is only after people have reached a certain basic standard of living and have had certain basic needs met that population tends to stabilize. We have found in Costa Rica, for example, that equal opportunities for education and work for women have a tremendous impact on reproductive patterns and on population growth. As more options are opened to women all over the world, they tend to marry later and to have fewer children.”

If the difference in status between women and men—and “women’s work” and “men’s work”—is one realm of values that will have a major effect in determining whether or not a sustainable world can be achieved, the difference in the trading status between nations is another. Umaña touched on this as well. The General Agreement on Tariffs and Trade, or GATT, was put into effect in 1947 to regulate international trade, but, he said, “the word *environment* does not appear at all in this treaty. The treaty goes counter to any possibility of incorporating environmental issues, because it does not allow a country to discriminate based on the method of production of a good. If two countries have different environmental standards that make it necessary to have different methods of production, this treaty says that we cannot have any price discrimination or impose tariffs. Unless we start to consider trade and environment jointly, this is going to lead to even wider disparities in environmental enforcement and in environmental standards worldwide.”

Disparities in status, in education, in resources, in wealth and power form one of the chief obstacles to achieving a sustainable world. Moreover, those disparities in turn reinforce ideological and cultural obstacles. Poverty makes access to education more difficult, which reinforces the traditional status of women, which reinforces population growth. If federalism might have a potential role in redistributive policies, such policies themselves would run contrary to the social Darwinism of industrial ideology. The nation-state, another component of that ideology, resists any abrogation of its control over its wealth and resources. Alvaro Umaña, again in the opening session, stressed that while the East–West confrontation has become less acute, the North–South confrontation between rich and poor, between those who degrade the environment through overconsumption and those who degrade it through poverty, has sharpened. The two worlds “are critically opposed to each other,” separated by the very disparities that define their

respective triumphs and miseries.

Ideas such as cooperative engagement, federalism, and carbon taxes may prove important for the functioning of a sustainable world, but in the end no governmental or economic mechanism will work if the people who must live with it reject it. Several participants mentioned religious fundamentalism on the one hand and the upsurge of ethnicity and nationalism on the other as a backlash against what Jessica Mathews called the “movement toward globalization.” Another form of resistance is what Bruce Murray termed protective apathy, and he expressed the hope that new belief systems and value systems would emerge to replace the apathy that seems to especially affect the affluent. “Poverty will produce community,” he said, quoting sociologist Robert Nisbet. “Affluence seems not to.”

So if Morrisett outlined the ideology that is a large part of the problem, and Mathews a potential ideology that might help bring a solution, and if new values and ideas in governance and economics make possible a degree of international cooperation heretofore unknown, what remains if not the human dimension? To a greater degree than others, William Drayton and Hassan Hathout addressed that dimension in regard to culture and ideology.

William Drayton saw the key issue as being “how we manage ourselves, both as societies and as individuals.” He stressed that “the institutions we live in are our most important educational experience.”

He went on to say that we must develop the institutional capacity to meet change with constructive adaptation. If we are going to live together in a world of enormous human diversity, we need ways of organizing ourselves, as individuals and as societies, that encourage us to work together. How we design and develop our institutions, how we run them, how we structure individual–institutional relationships, make up one of the most important dimensions of culture and ideology. Institutions need to be decentralized but integrated: one without the other does not work. What “integrated decentralization” attempts to do, he added, whether in a corporation, a government agency, a foundation, or some other institution, is to “release the energy of individuals and small groups in that institution.”

Individuals are the key. “During the era of the Cold War,” Jessica Mathews remarked, “individuals really were outside the key decisions that were being made. . . . Now individuals by the billions are not only the cause of the problem, but the source of its solution.”

Drayton stressed behavior and how it can be

Now individuals by the billions are not only the cause of the problem, but the source of its solution.

influenced. He bemoaned the fact that many schools are now cutting back on team sports, which he feels balance centralized coherence and discipline with individual energy. In the session on governance he expressed the need for *public entrepreneurs*. Responding to a question during the session on culture and ideology, he pointed out that every time such a person succeeds, he or she becomes a role model for others. "People learn by anecdote more than by theory."

Yet transforming institutions to release the energy of individuals, and changing the values and beliefs of individuals so that people become problem solvers rather than problems, requires leadership. But leaders are subject to the same values and beliefs as anyone else. Lloyd Morrisett expressed disappointment that, in the United States at least, so little leadership is being shown in using television to help generate new ideas; and American television, of course, is widely exported to the rest of the world. It was Hassan Hathout who responded shortly afterward: "It might mean a little loss of dollars for the media if they switch from being the media of pleasure to being the media of ideas and ideals, but if we want a sustainable world in the long term, I think that is what should be done."

What kinds of values and beliefs will determine the purpose of specific technologies, of the media, of governments and economies and the resources on which they depend? What induces leaders to change? What induces anyone to change? "We've become," said Drayton, "selfish people who take from the poor." Both he and Hathout expressed the hope for a spiritual rebirth.

"Legalities are not the answer," commented Hathout, "but attitudes. And that is when white and the colored, man and woman, rich and poor, North and South, developed and underdeveloped, victor and vanquished, feel that the other is an equal and endeared brother or sister." He quoted the Koran: "You people, we have created you from a single pair of a male and a female and have made you into nations and the tribes, that you might get to know and to cherish one another, not to despise one another."

Drayton expressed a similar desire to see a revival of empathy, of the insight to not do to others what we don't like done to us. "Empathy carries with it an unstated first principle of egalitarianism. . . . One can cause major change peaceably by holding up to people the fact that they are not behaving in an egalitarian way. That's what Gandhi and King did."

And yet . . . Alvaro Umaña in the opening session pointed out that it takes only an ignorant

*Legalities are not
the answer, but
attitudes.*

person with a chain saw to destroy a forest, while it takes tremendous knowledge to manage the forest in such a way as to preserve biodiversity and allow communities to develop on a sustainable basis. Will empathy alone open the doors of knowledge, of understanding? To refrain from doing harm requires a certain self-restraint and self-control, and the ideology of social Darwinism, progress, and the exploitation of nature has little to say about such things, let alone their role in understanding a forest.

At the beginning of his presentation on governance, John Steinbruner quoted a U.S. senator's response to the suggestion that transnational solutions will be required to deal with the problems facing us: "All of history and most of human nature are against you. What have you got going for you?"

Hassan Hathout might have had something to say to the senator, when he emphasized self-restraint and self-control as vital values. "The current extolment of individuality," he said, "gives moods, desires, whims, inclinations, attractions, orientations, or whatever, the status of legitimacy. It is a moral obligation to consider harm to self and others while making our choices and to say no to one's self when no is indicated. For this indeed is the other side of the coin of freedom. That is why we Muslims fast one month of every year. Nothing by mouth from dawn to sunset just to train ourselves to say no when no should be said.

"It is," he added, "a matter of conscience, and what would humanity be without the moorings of the human conscience?" □

Contemplating the Unexpected

by Paul MacCready

Extrapolating trends from the recent past allows us to predict with some confidence that the next 50 years will see more new technology developed and used by humans, and more species driven to extinction by humans, than throughout the entire prior course of human history. Simultaneously, the human population will double. If we want to superimpose an even more elaborate forecast onto this "baseline" forecast, we must also take into account the impact of unexpected and unprecedented developments in technology, and in institutional and cultural areas. While it is possible to anticipate some of these developments, it is also obvious that in the year 2041 (when some in this audience will be the age of some of the speakers, and some of the speakers will, through novel medical advances, still be around) the global situation will represent a new ballgame, played according to rules we may not yet have begun to imagine.

In this session, we explore this future with a group of leading scientific innovators and science-fiction writers, whose irrepressible free-thinking will lead us in unconventional directions. Our approach is not to look at many topics—there are simply too many to encompass—but rather to focus on several of especially high priority.

Naturally, it is impossible to foresee everything. An ideal treatment of "the unexpected" would be able to identify the new and future equivalents of the theory of evolution, the fossil-fuel internal-combustion engine, airliners, satellites, nuclear energy, the transistor and computers, and the polio vaccine, to give but a few outstanding examples. But even now, our

somewhat cloudy crystal ball lets us see that we can expect certain emerging technologies to have equally enormous consequences. One of these is genetic engineering, with its potential to treat existing life forms and create new ones. Another is communication and information technology, to connect each of us to one another, to transcend language barriers and let everyone access all information, and, incidentally, to let Big Brother access each of us. We can foresee, and hence predict, some consequences of these advanced capabilities, but certain results are totally beyond our powers to forecast.

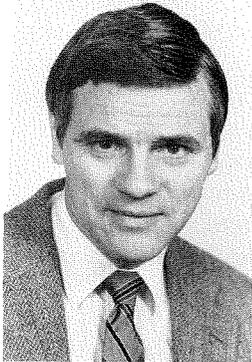
Also beyond our ability to predict, or at least to pinpoint in time, are what we might call events mediated by nature. Some are inevitable, some can be prevented, and some can be predicted, but others are fundamentally unpredictable. Examples are the impact of a giant meteorite such as may have helped end the age of the dinosaurs; success in the search for extraterrestrial intelligence; global warming; agricultural trauma; AIDS-like diseases; a magnitude-8 earthquake rocking southern California.

But leaving aside the undoubted impact of such external events, we can say without question that the most important force on Earth is the human mind. This mind now dominates the course of our planet's future—a responsibility that was once thought to be the prerogative of capricious gods. This human biological device of fantastic complexity is now becoming somewhat understood, but also becoming computer interfaced, expanded, and redefined. In our session we will consider some of the implications of our growing capacity to understand and perhaps ultimately to modify and redefine the nature of both human and artificial intelligence. We will also look at some of the baggage carried by the human mind: at the role of culture, rooted as it often is in ancient institutions, as well as at habits, appetites, prejudices, and our inherent resistance to change. We need technology if we are to achieve a desirable, sustainable world, in some comfortable accommodation with Earth's flora, fauna, and limited resources. But we must beware being lured by technology's benefits into letting technology assume the role of master rather than servant. Serious questions that previously were debated mostly by philosophers now become critical for us all: the meaning of life, the relationship between humans and other species, and the destiny of humans on and off the Earth. □

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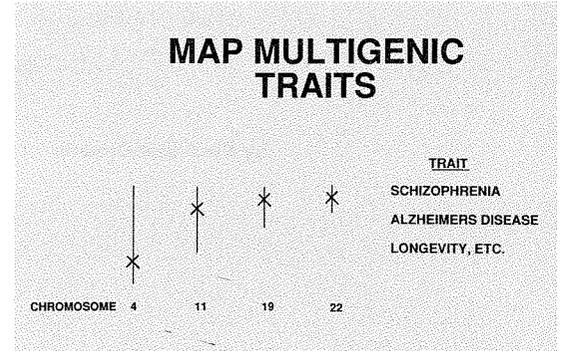
Speculations About Future Humans

by Leroy Hood



There are three forces that may fundamentally change human physiology and/or behavior. One is culture. A second is medicine, which in the future is going to profoundly change how we deal with disease and, possibly, how we view ourselves. The third, and perhaps the most intriguing force, is evolution—either natural or engineered. I will discuss the impact of medicine and evolution on future humans.

As we move into the 21st century, the Human Genome Program will profoundly alter how medicine is practiced. This program plans to decipher the units of human heredity—the 23 pairs of chromosomes present in each and every human cell. Chromosomes are made up of DNA, linear strings with four different letters in an alphabet. Thus the language of DNA uses its four letters to generate the information necessary for making humans. These chromosomes, collectively known as the human genome, direct the complex process of human development, in which we all start as a single cell, the fertilized egg, and go through a successive series of cell divisions and development to generate the 10^{14} highly specialized cells of an adult human. Our genome contains approximately 100,000 units of information, or genes, which are differentially expressed to make each type of cell distinct—for example, a hair cell different from a brain cell. Each gene specifies a protein molecule, a linear string composed of 20 different types of subunits. The order of these subunits dictates how each protein folds to become a three-dimensional molecular machine. (Proteins give our body shape and form, and catalyze the chemistry of life.)



Hence, the Human Genome Program will provide valuable information for understanding how humans function in health and disease.

For each human chromosome, we are defining a genetic map that will permit us to identify the genes that determine certain human traits such as blue eyes or brown hair. We are also creating a second type of map—the so-called sequence map—that will enable us to specify the order of every gene's subunits, so that we can identify and decipher each of the 100,000 or so genes that exist in the human organism. We are hoping these maps will allow us to identify the genes responsible for such simple traits as skin color or blood types, as well as those responsible for diseases such as Alzheimer's or cancer. The important point is that once we have detailed genetic and sequence maps, it will be very easy to find the unknown genes that control additional important human traits, such as schizophrenia, longevity, and heart disease. Every one of these genes has the potential to serve as a diagnostic or therapeutic agent in medicine of the future.

We will certainly be able to use this genetic mapping approach to understand and eventually treat disorders caused by defects in a single gene—diseases such as sickle-cell disease, cystic fibrosis, and Huntington's disease. Even more important, we will be able to look at traits and diseases that are caused by a multiplicity of genes and to develop both diagnostic and therapeutic approaches to dealing with them. Here, we will have thousands of new opportunities to use genes as therapeutic agents for a variety of different diseases.

Detailed genetic and sequence maps such as the example at left will allow identification of numerous human diseases and traits.

It is clear that in the future we will be able to engineer three-dimensional biological shapes such as proteins, and that this will give us the capacity to custom-design biomedically useful molecules. For example, we might be able to design a cancer-specific protein that is able to recognize a particular type of tumor cell and to which we can attach functions that can specifically destroy those cells. We'll be able to carry out genetic-engineering therapy in which we will substitute "good" genes for "bad" genes. Currently, there are significant technical problems in genetic therapy, but in 25 years, we will be able to manipulate genes with complete facility, put them specifically into particular types of tissues, and have them function in a fully normal way.

The techniques of genetic and cellular engineering will offer new and powerful insights that will profoundly change our approach to many of the diseases we worry about today. I fully expect that the 21st century will be the century of preventive medicine. We will take DNA from each child as he or she is born and examine the perhaps 100 genes that predispose humans to common diseases, such as cancer, heart disease, and autoimmune disorders. We will then know which diseases each person will be susceptible to. We will be able to circumvent the limitations of any bad genes a person might have, either through chemical therapeutics or through appropriate genetic engineering.

Let me talk about one category of especially perplexing diseases—mental disorders. The brain is a marvelous instrument with 10^{11} different cells (neurons) that communicate with one another via chemicals transmitted over the sites, or junctions, at which they touch one another. We now know that there are perhaps 80 of these little chemical messengers, or neurotransmitters, and that they almost certainly play a critical role in how we think, behave, and feel. As we come to learn more about these messengers, we will be able to deal with many types of mental diseases. For example, *L-dopamine* has played an incredible role in alleviating, even reversing, Parkinson's disease for some patients. In the future, we will understand the types of neurotransmitters that are necessary to bring about permanent kinds of changes in a wide variety of brain-related disorders, such as schizophrenia and manic-depressive disorders.

As we come to understand the brain, it seems to me that two questions will be of remarkable interest. The first is, how much unexploited potential is present in the brain, and can we learn to exploit that potential? We all know that children are extraordinarily adept at learning

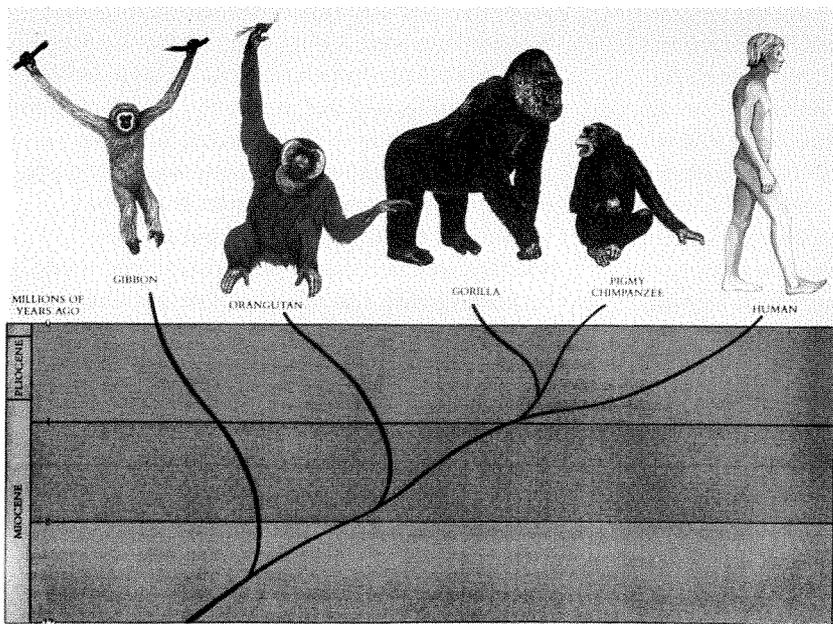
languages, not only their own native language, but any language. What other kinds of permanent knowledge-imprinting can be done early in life, at midlife, or later in life, and how can these imprinting processes be effective? I believe we will have powerful opportunities for enormously enhancing the capacities that we have. The second and equally intriguing question is whether we can enhance our existing potential by playing with the balances of neurotransmitters that exist in the brain or by making other kinds of modifications in these molecules. I think there will be real opportunities to develop the essential properties of the mind in the future.

The aging process is another area in which I think we can expect to make great advances. Here again, there are two central questions—will it be possible for us to live longer, and, even more important, can we extend the duration of a high-quality life? In the future, will we have 80-year-olds with the vitality of 20-year-olds? My own belief is that genetic mapping will make it possible to identify genes that play a key role in longevity; and that we will ultimately come to understand a great deal about the physiology of aging. Perhaps we will live longer; even more important is my conviction that the quality of life will be significantly extended for most of us.

But here I need to make a critical distinction. The kinds of changes I have been discussing up to this point have had to do with genetic engineering of somatic, or body, cells as opposed to sex cells. In other words, these are changes that do not alter the genetic instructions that are passed on to the next generation. The changes are specific to the individual, and they die with the individual. In contrast, modification of the germ line, which alters the genetic material in the sex cells—the sperm and egg—*adds these changes to the gene pool*. Once this is achieved, it becomes possible for humans to pass these changes on to their children and thus change the course of their own evolution.

I noted earlier that of the three forces—cultural, medical, and evolutionary—that have the potential to fundamentally alter human behavior and/or physiology, evolution was the most intriguing in that it is potentially the most far-reaching. Up to now, evolutionary change has proceeded with agonizing slowness. Earth was created 4.5 billion years ago. The first cell that had a nucleus arose about 1.4 billion years ago, and the creation of multicelled organisms occurred just 600 or 700 million years ago. Humans are, of course, a much more recent evolutionary invention. Our hominid ancestors branched off from the chimp and gorilla evolu-

The aging process is another area in which I think we can expect to make great advances.



tionary line about 4 or 5 million years ago, and *Homo sapiens*, our own particular species, emerged perhaps half a million years ago. One of the incredibly interesting questions is, are we the final product of primate evolution, or will there be another branch that will perhaps end up viewing contemporary humans as we now view the chimpanzee? That is a deep question, with some extremely interesting implications. If further human evolution is to proceed, then it must operate by virtue of the two major mechanisms of evolutionary change, namely, mutation and natural selection. Mutations are occurring all the time in human populations, so that is no problem. However, natural selection does not operate effectively in human populations, in part because of modern medicine. Hence, it appears that humans cannot evolve further without directed efforts. Humanity today comprises one large, interbreeding gene pool. It offers very few opportunities for the isolation of small communities that appears to be a necessary precondition for the emergence of new species, unless we were to undertake a deliberate program of germ-line genetic alteration.

There are two logical possibilities. One is selective breeding, which has been carried out successfully with dogs for centuries. You only need to look at a Chihuahua and an Irish wolfhound side by side to realize what an incredible divergence in phenotype has been generated by selectively breeding dogs over the last 5,000 years. There are also dramatic differences in humans. These include not only considerable differences in physical traits, but in mental

abilities as well. By selective breeding, we could effect significant physical and/or mental changes in humans. But while humans *could* do this, I think it is unlikely. Not only would it take a directed and committed effort over many generations to bring about these changes, but one would also have to keep these selectively breeding individuals isolated from the larger human gene pool. Even slight interbreeding would dilute and cancel the desired genetic changes you would need to create the kind of evolutionarily superior "post-human" species I alluded to earlier. Indeed, enormous ethical concerns would arise from any such attempts, and certainly it would be difficult if not impossible to reach agreement on the so-called "desired" traits. So it appears unlikely that humankind will change through selective breeding.

There is a second option, germ-line engineering. It is certainly going to be possible to discover anti-aging and anti-cancer genes, and perhaps to permanently enhance qualities such as intelligence and memory. We will have the capacity to choose whether or not to genetically engineer beneficial changes in humans that would then be passed on to their descendants. Would germ-line engineering benefit humans? Should it be seriously considered? Obviously this possibility, distant though it is, raises a host of serious social, ethical, and legal issues. I would argue that scientists have an important obligation to raise these questions for debate in society, outlining the opportunities and the dilemmas they raise. We must communicate to the public the benefits and challenges raised by future genetic-engineering possibilities. We also have to make a serious commitment to improve education, particularly from kindergarten through grade 12, so that we have a public capable of understanding the alternative choices that are before us. In the future, scientists will have to become more involved in the process by which society makes decisions, for some, perhaps directly, as politicians, rather than indirectly as advisors. In the not-too-distant future the genetic engineers will be able to engineer themselves. The fascinating question is, to what extent will they engineer themselves and for what purpose? □

Leroy Hood, BS '60, PhD '68, the Ethel Wilson Bowles and Robert Bowles Professor of Biology and director of the NSF Science and Technology Center for Molecular Biotechnology, has been a pioneer in developing the instrumentation for sequencing and synthesizing proteins and DNA.

In the not-too-distant future the genetic engineers will be able to engineer themselves.

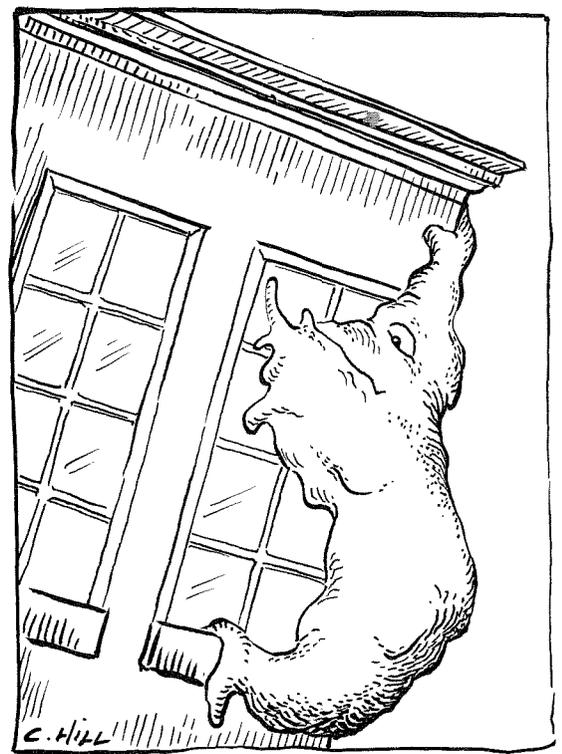
A Biological Century?

by Gregory Benford

Keeping in mind the theme of this session, I'm going to try to be fairly crazy. Perhaps unfairly crazy. The best way to contemplate the future, it seems to me, is not to think in categories of the present, but rather to learn from history, to the extent that it's possible, and extrapolate from that. It's tough to do. The hardest thing to realize about the future is that it can be qualitatively different from the present, just as our time is qualitatively different from the era of westward expansion through the Great Plains a century and a half ago.

I tend to believe that the 19th century was dominated mostly by the metaphors and technology of chemistry and mechanics. The 20th century has been dominated by electronics, and, of course, by physics, culminating in the incredible marriage of the atom and the rocket. Many of these developments can be traced back to the middle of the 19th century, when James Clerk Maxwell formulated electrodynamics, which ultimately gave us electronics. In the middle of this century, Watson and Crick discovered the structure of DNA, setting the stage for a 21st century that will be dominated by biology. And it will contain as many surprises, if not more, than we have seen in this century.

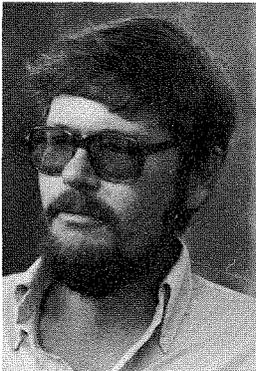
What would a biological century look like? If the 19th century was characterized by hardware and this century by information, that is, software, we might believe that the next century will be informed by liveware. Living technology. I think the first evidence we'll see of this phenomenon will be consumer products. Microbes residing in your teeth that fight plaque. A

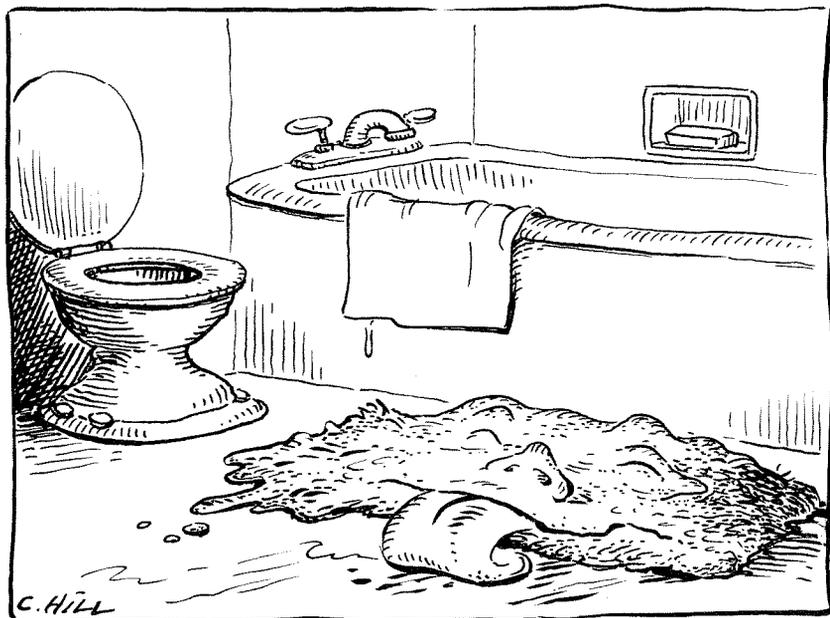


kitchen or bathroom mat that is alive and cleans the room because it lives off what it eats. Or a service that does windows because it's in fact a green fungus that crawls around the outside of a large building and lives there permanently, again living off what it eats. Another possibility is a grow-your-own-home. Why grow trees, chop them into pieces, and then reassemble them? In the long run, it might be much smarter to simply engineer the genes of the trees and grow your own house. We can imagine lots of these kinds of things that will change the landscape of personal life.

Now, what about the larger picture? As we heard from Professor Hood, the human genome project proves again something we learned in grade school: Learn to read a book and there arises in some of us, regrettably perhaps, a temptation to write a book. I believe we will one day do that. But that will come further downstream.

A biological century also raises the possibility of brave new approaches to preserving threatened tropical ecosystems. Suppose you're in the library in Alexandria after it's caught fire, and you can only save as many books as you can carry in one basket. Do you rummage through the shelves saying, "This is by Aristotle, but this is just Alexander the Great's laundry list, so I'll take the Aristotle?" Not if you're trying to work fast. You would probably just grab everything you could carry. Perhaps one of the things we ought to discuss right now is a crash program to preserve everything we can salvage out of the tropical biospheres. Flora and fauna, sampled widely and





This biological-century business also has a dark side that we must think about very seriously.

stored long term, perhaps in liquid nitrogen, with the expectation of restoring them to nature at a later date. We can't effectively use that information now, but that's the point about the future—it will be different. A biological century may well be able to recover information from anything that we save, analyze genomes, do exotic restorations, perhaps revive whole systems—and the more we save, the better. Contemplate how much effort we're currently spending to recover everything we possibly can from a fellow frozen near a Swiss glacier 5,000 years ago.

Such capabilities will bring into focus a choice we may eventually have to make. Remember that awful sentence from the Vietnam War: To save the village we had to destroy it. Perhaps to save the biosphere, we will have, not to destroy it, but to substantially modify it. That may mean, for example, changing the nature of many major species, so that they are more amenable to living with us. I know some people may feel that this is immoral and maybe it is, but we've been doing it for millennia in agriculture and animal husbandry. Consider the acacia tree, which has an ant that lives in a symbiotic relationship with it. The ant polices the weeds around the tree and drives off other insects that like its bark. In return, the ant gets to eat some of tree's blossoms. Imagine adapting that mechanism to trees that bear fruit for us, like orange trees. You set up a new symbiotic relationship, tuning the insect's response and tuning the plant. I don't think that's crazy on a scale of a century.

This biological-century business also has a

dark side that we must think about very seriously. One of the great concerns we're going to have will be a huge wedge of population in the tropical regions. This demographic explosion could produce billions more people than Earth can support, given our current habits. (Our current habits, I often think, are expressed aptly by simply noting that the average person thinks he isn't.) I believe there's a fair chance that someone will notice that on the one hand we have enormous biological technology, and on the other we have an enormous excess of humans. Some maniac may attempt to kill billions of people in one shot with a plague, maybe a super-influenza conveyed from mouth to mouth. The last time a lunatic did something so vast, he wasn't a research biologist. He was an Austrian and, incidentally, a vegetarian. You can't predict where your enemies will come from. There will be a dark side, and we must remember this.

The most extraordinary challenge ahead of us, however, will come from a brand-new field, which I will call humanistics. It will involve specialists in artificial intelligence, evolution, and computer languages, as well as brain scientists, biotechnicians—yes, even humanists—in the combined study of what it is to be human. We're going to have to hack out a definition of what human actually is, because the ability to produce things that look the same and walk the same—although maybe they won't talk the same as we—may occur within a century. That will be the greatest challenge to our species, and I hope we don't have to face it before we can save the biosphere. Knowing, however, that God has not only a sense of humor, but also, obviously, a sense of irony, I expect we'll have to deal with both issues simultaneously. □

Award-winning science-fiction writer Gregory Benford is professor of physics at UC Irvine and has served as an adviser to the Department of Energy, NASA, and the White House Council on Space Policy.

Computers and Society: Evolution and Revolution

by John Hopfield

Humans are at the top of the heap now, but there's no question that in about 20 years, that role will be filled by computers.



I will limit my contemplation of the unexpected to the information and computer revolutions, which I have no doubt will have a profound impact, not only on the future, but quite possibly on the vision that future generations will have of a sustainable world. In 1981, I bought my first desktop computer. Today, 10 years later, I have a different one that costs about the same amount of money, but has approximately 100 times as many transistors, five times the speed, four times the CPU (Central Processing Unit) capacity, and perhaps 2,000 times the effectiveness of my original model. This rate of change isn't going to stop, and it isn't restricted to desktop computers. Megacomputers have grown equally and perhaps even more rapidly, thanks to the advent of parallel-processing techniques. Many of the costly and complicated calculations we perform in engineering, science, and economics are now carried out on these large machines. Megacomputers are also going to play a part in making predictions about such things as ecological systems, a role that's in a sense both more important and more ominous than their current function in science or economics. It's ominous because, unlike biological systems, computers and their programs tend to be relatively brittle. They're engineered to do what they do fairly well, but they aren't designed for a large number of possible eventualities. Remove a few parts from a biological system, and it still tends to function. Do the same with a computer, and suddenly there's no phone service in New York City. The real hazard of this change is that mankind is going to invest responsibility in computers that

computers haven't had before. There is a real potential for danger there.

In another sense, however, this whole scenario is just a replay of a universal evolutionary trend. The evolution of animals has really been the story of the evolution of information-processing systems. The animals that function best are those that can most effectively use information about the present to predict what might happen in the future. Humans are at the top of the heap now, but there's no question that in about 20 years, that role will be filled by computers. And in this arena, I think the great challenge to humans will come, not from the megacomputers, but from smaller systems somewhat like today's desktop model. The human brain has approximately 100 million more computing elements in it than a typical desktop computer. But the computer has hardware that works about 100 million times faster. If we project the current pace of advances in computer technology into the not-too-distant future, it's quite clear that 25 years from now, we're going to have in our homes and our workplaces something of greater-than-present human intelligence. Computers are going to completely take over many mundane tasks that people now do and take great pride in. They will be the best medical diagnosticians. They'll be the lawyers who can present the most convoluted arguments. They'll be the safest and most alert cross-country truck drivers. They'll take over the jobs now held by secretaries and postal clerks. In the 19th century the Industrial Revolution displaced large numbers of people who had made their living by skills of the hand, and the result



Thirty or fifty years from now, silicon-based machines are going to be the most intelligent systems on the planet.

was massive unrest and social turmoil. In the 21st century, the computer is going to have exactly the same effect on an immense number of jobs now held by the middle class. Thus, my first real suggestion for the unexpected is a strong anticomputer movement in the workplace, spearheaded by those seeking to preserve traditional human jobs. At the same time, there are going to be only a relatively few people who have a detailed understanding of how all this computer technology works. And that means that there's going to be an enormous amount of power concentrated in those few hands.

My second candidate for the unexpected comes from quite another direction. We all know the extent to which television, movies, and interactive games have the ability to captivate people for long periods. Our current megacomputers can generate extremely complex and realistic artificial worlds of moving 3-D images and sounds that respond to a participant's motions and actions. The most sophisticated of these interactive systems go by the name of "virtual reality." Twenty-five years from now, these "hypertelevisions" are probably going to be in millions of homes. What use is going to be made of them? Taking the optimistic view, they could be a powerful force in education—perhaps the only means we have left of bringing our educational system up to the standards that will be needed in the 21st century. But it is just as easy to envision virtual reality being used as an opiate of the masses, to pacify or manipulate a large underclass of undereducated citizens. I can see it also as a fatal intruder into our political process, complet-

ing the job that television has already begun so well of replacing substance by form.

I don't mean to be a complete pessimist. I'm enormously enthusiastic about this computer revolution as a way of eliminating simple drudgework. But we must remember that, historically, technologies are never purely benign. The same technology that makes it possible to navigate airplanes safely in foul weather has also produced the television that allows children to sit for hours in a mind-numbing trance and is undermining our educational system. What is going to be the dominant use of this hypertelevision medium—education or anti-education?

The final question I wish to raise brings me back to our conference theme of a sustainable world. Perhaps we ought to start thinking about what that concept might mean to a computer. I mentioned earlier that the history of evolution has been characterized by the emergence of increasingly intelligent systems. Thirty or fifty years from now, silicon-based machines are going to be the most intelligent systems on the planet. Are they going to make decisions that emphasize preserving diversity in the biological world, or are they going to be looking out for themselves? Stay tuned to see whether life on Earth, 100 years from now, is based on carbon or on silicon. □

John Hopfield, the Roscoe G. Dickinson Professor of Chemistry and Biology at Caltech, was previously a physicist at UC Berkeley and Princeton. He currently works on biological neural networks and heads the PhD program in Computation and Neural Systems.

Unexpected Challenges to a Sustainable World

Participants in this session, moderated by Paul MacCready, included Gregory Benford, Leroy Hood, John Hopfield, and science-fiction writer Gentry Lee, currently on leave from his position as chief engineer for the Galileo project at the Jet Propulsion Laboratory.

The central question to emerge from the panel's impressive demonstration of the rapidly dissolving boundary between science fact and science fiction in the late 20th century was this: Do humans have the will and the vision to constructively shape a future that, constructively or not, is bound to reshape them? Not without a fundamental commitment to addressing some extremely sensitive and divisive issues, said Gentry Lee. Asking, "How can we bring the things we've talked about at this panel into the vision of a sustainable world and actually implement them?" Lee went on to say, "I expected some of the earlier panels to cover the need for changed attitudes toward the following subjects: money, knowledge, and even the preferred or desired models of life embodied in such diverse minicultures as religion and entertainment. For the most part, they didn't. Somewhere along the way, we've got to confront the real issue, which is that human values are based upon attitudes toward those subjects. You can't just change these attitudes by changing institutions. You have to come to grips with a reorientation of what's important."

Lee's comments were seconded by panel chairman Paul MacCready, who noted that "social, governmental, political, and religious institutions that were honed by the pressures of the past are often completely inappropriate for the rapid changes that are going on now and which we have every reason to expect will continue into the future."

With regard to sustainability and securing Earth's future, said Lee, a key stumbling block is

the enormous discrepancy between the urgency of the issues that need attention and the number of people actually concerned about addressing them. He called on scientists to make some attempt to bridge the gap. "The problem is that the group at this conference represents the high end of awareness and concern about what happens in the future, and that the great majority of people have such low awareness and interest by comparison. If there is one task that is necessary to overcome the challenges that have been discussed here, it's that all of us who are scientists and technologists must in one way or another become preachers. I mean that literally and figuratively. There are two problems that beset scientists and technologists in the United States today. The first is that most scientists have no idea whatsoever how to communicate, and the second is that most reporters know nothing at all about science. So you put scientists who don't understand how to communicate together with reporters who know nothing about science, and the public returns to *Roseanne* night after night after night. You want to do something about the future, to handle the unexpected, to have a sustainable world? You structure society in such a way that its focus is on education—a lifetime of education. Every human being must know upon his or her first moment of sentience that his or her life is to be dedicated to constantly learning things. We must recognize that the single greatest gift that we can give to those who come after us is not the individual discovery or invention, but rather the understanding of how to spread that discovery or invention through society, so that those of us who are concerned about a sustainable world are joined by a scientifically, technologically literate population who also understand. In the absence of that global education we are kidding ourselves."

Both Gregory Benford and MacCready commented that the talks by Lee Hood and John Hopfield threw into sharp focus the question of how a world already ill-prepared to deal with pressing issues of planetary sustainability and survival would be able to cope with a future marked by the power to redraw the human genetic blueprint on the one hand, and the emergence of a powerful and conceivably competitive artificial intelligence on the other. Said MacCready, "I think it's obvious that the tremendous potential powers in genetics and computers will be controlled, or maybe not controlled, by regular humans with all our frailties. It is frightening to consider this and to try to figure out what can realistically be done to make the transition a positive experience. The only possi-

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bility I can come up with is trying to get genuinely open-minded thinking skills spread around the school system so that literally hundreds of millions of kids are there with all their vitality and inquisitiveness asking penetrating questions, and not being afraid to do so.”

What role besides that of intellectual torch-bearer might scientists be able to play in this process? Instruction by example, said Lee, adding, “I have often been asked, ‘What can nontechnical people, including artists and politicians, learn best from technologists?’ The answer is simple: the value of test. Think how many new, patently absurd systems have been put in place by politicians when any test would have shown that they wouldn’t work.”

In fact, said Benford, the federalist system in the United States offers potentially valuable and largely unexplored opportunities for testing the soundness of various social and political arrangements that might be more conducive to global sustainability. For instance, he suggested, some subset of the 50 states could serve as laboratories for reforming an American educational system “[we all find] deplorable. Why don’t we take three states, one rural, one urban, one intermediate, and try doing something different, such as a voucher system, for five years and see how it works. Why are we so afraid of doing an experiment? Not everything has to be run from the top down. In fact, few things are run well that way. The fact that we’ve got 50 states in this country is supposed to be an asset. It’s turning out to be a liability.”

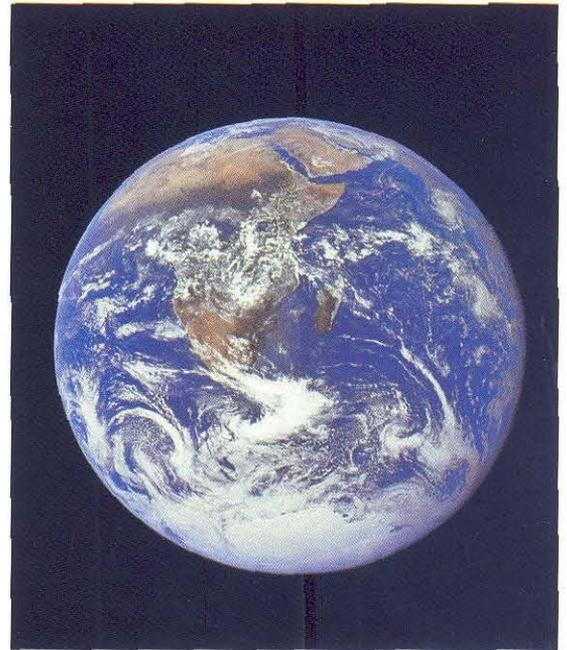
Not surprisingly, the discussion then turned to some of the “brave new world” issues raised by Lee Hood in his talk on genetic engineering and organisms of the future. While Hood limited his immediate observations to tomatoes (he noted that a team of MIT and Cornell scientists had recently identified and isolated the four genes largely responsible for a tomato’s juiciness, and speculated about the commercial potential this might have for Heinz), those panelists involved not only in science but also in science fiction had no hesitation in venturing farther afield. Said Gentry Lee, “We should acknowledge up front that it is a brief step from using genetic engineering to treat disease to using these techniques to enhance what are considered to be desirable characteristics. It should be an immediate connection that people make that there are some physical and mental and developmental characteristics that are positive contributors to a sustainable world and some that are not. Now, just to trot out a controversial issue, in my view a sustainable world is one in which people have

more appetite for education than I currently see. And I’m not alone in this view. If you find the set of genes associated with intelligence, I guarantee you that somebody’s going to figure out how to use that information in a way to produce a more intelligent member of the species. People do not want to deal with this issue because it’s scary. But I say this to them over and over again, *if we don’t deal with it, the politicians will*. And *that* is scary. If Lee Hood were to say to me, ‘Hey, Gentry, I figured out a way to make all these new people come out much more interested in learning,’ I would say, ‘Don’t tell anybody, Leroy, because that would put the politicians out of a job, and what we want to do is make sure we get it done.’

“If I can add one more thing, imagine that it’s 50 or 100 years from now, five days after conception. The expectant mother goes in for her checkup and is run through what we’ll call ‘Hood’s Data Management System.’ And she’s told the sex and the intellectual aptitude of her unborn child, along with its proclivity toward cancer or hardening of the arteries, and what its eventual height will be, assuming a certain kind of nutrition. This is five days after conception! Then the smiling doctor says, ‘Oh, by the way, you can change anything in column A.’ And then we might have the flavor of the month. This week we have tall, blue-eyed blonds. Next week, something else. We’re serious, folks. We’re serious. This is the kind of thing we’re talking about, and we are not prepared for it as a society.”

Confronted with such unfamiliar challenges, added Benford, humanity may have recourse to familiar remedies in strange new forms. “Imagine,” he said, “the hubbub in this society if, for example, we discovered that only one gene determines your ability to play baseball. These possibilities are fraught with so many issues that I suppose there’s a good chance we may even see the birth of a new religion centered around a new messiah. This faith will have highly original elements in it and, in fact, a kind of strange, magnificent eugenics may be in the soup, in which case, we’re going to get some bizarre creatures. It may come fairly quickly. And when it does, it’s going to be unsettling to a lot of people.” □

Afterword



What did the “Visions of a Sustainable World” symposium accomplish? Did it provide any new insights, indicate any new directions, produce any *visions*? What did Caltech and the symposium’s organizers hope would come out of three days of intellectual grappling with the difficult issues that face life on Earth? What was this “very impressive group of people—probably one of the greatest groups of PhDs assembled in one room, benevolent about the destiny of the world and trying to save the world from God knows what” (according to Daniel Schorr of National Public Radio), actually supposed to be doing? “We wanted to bring together people to *think* about the issues,” said Murray Gell-Mann later, “about how they’re related, how to conceptualize them. And these are issues that go beyond just the environmental. They include military and diplomatic problems; issues of cultural diversity and the opposite side of the coin, ethnic strife; questions of political organization, poverty, health, demographics—they’re all closely knit together.”

How did this work? In his wrap-up of the sessions on global perspectives, Schorr noted that the symposium was divided along several axes. “The program tells you this is a conference about *vision*. But in the subheads you read that almost every panel is a panel on *transition*. There seems to be some tension about whether the question is where do we want to go? But even that is two questions. One question is where do we get when and if things go on as they are going on now? The other, perhaps more important, question is where do we end up 10, 20, 60 years

from now, given that something is done about it, given that we do manage to make the word *community* a meaningful word and to find ways to implement a sense of community? That’s vision.”

Later, Paul MacCready remarked on “how hard it is to get anybody to look at a vision of where we want to go, as opposed to how we get there.” Too many of the participants were doing what MacCready calls, “Ready, Fire, Aim.” Murray agreed: “The lesson we learned is that the world is not ready to talk about these problems yet, because too few of the scholars, generalists, and specialists who should be involved have even begun to consider them.”

“Not surprisingly, many people simply cannot face the disturbing projections,” said Murray. “They take refuge instead in a protective apathy, enhancing vivid details of the present in order to blot out a frightening future.” Some of those vivid details of the present, however, are also frightening. MacCready likes to jar people into thinking about the global situation with the statement that 250,000 more people are born on Earth every day. And on that same day humans have caused the extinction of 300 species of flora and fauna.

The symposium reminded Schorr of the early days of the arms-control community. “About 25–30 years ago, a group of people—scientists, people interested in foreign policy—came together to try to control nuclear arms. They weren’t taken seriously at first. They came from different fields and different disciplines, but they worked at it and worked at it, and after a while

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they began to have an effect—but only at a point where they had been together long enough and heard one another’s viewpoints often enough that they began to listen to each other, rather than merely speaking to each other. And then they reached a consensus about what to urge governments to do, and slowly they began to work on that.”

Bruce Murray also picked up the analogy later, comparing the symposium to the “Pugwash [for the Nova Scotia town where the meetings were held] phase” in the arms-control movement. “Then intellectual pioneers responded to the unprecedented danger of nuclear weapons. Now, we must similarly create a dedicated, self-recognizing community of scholars and generalists equally committed to mitigating unprecedented hazards.” Harrison Brown, to whom the “Visions” symposium was dedicated, also played an important role in the early arms-control movement. “He brought people together from different countries, from the various national-security establishments,” said Murray. “He made it respectable to talk about the problem.”

How difficult it is to get people to talk about the problem was one of the main lessons learned from the “Visions” symposium, the organizers agreed. According to Murray, “the primary task for the near term is to organize networks and discussions and to get people to realize what the problem is—not so much the solutions.” Schorr expressed confidence “that this is one conference, one step in what will be a series of many conferences; it can’t be done all at one time.”

Others weren’t so sure that talk among the experts was enough. In an early session Carl Djerassi expressed his “enormous frustration this morning at listening to two panelists who impressed me more than almost any panelist I’ve heard in recent years. These were speakers who spoke movingly and persuasively about important issues, and I look at the auditorium, which is either two-thirds empty or one-third full, where I think most of the people are at middle age or beyond. There are few students.” Djerassi assumed that students made an economic decision, a cost/benefit decision, that it wasn’t worth cutting classes to hear a bunch of speakers. “Now consider that for a moment: If they made the decision that way, how will we persuade anyone in a group that is much less persuaded about the importance of the issues?” He challenged the panelists to imagine the auditorium full, not of experts and academics, but of farmers, automobile workers, loggers, fishermen; what would they say then? MacCready concurred: “It can’t just be a bunch of professors talking to

another bunch of professors. We’ve got to make it accessible and interesting to people.”

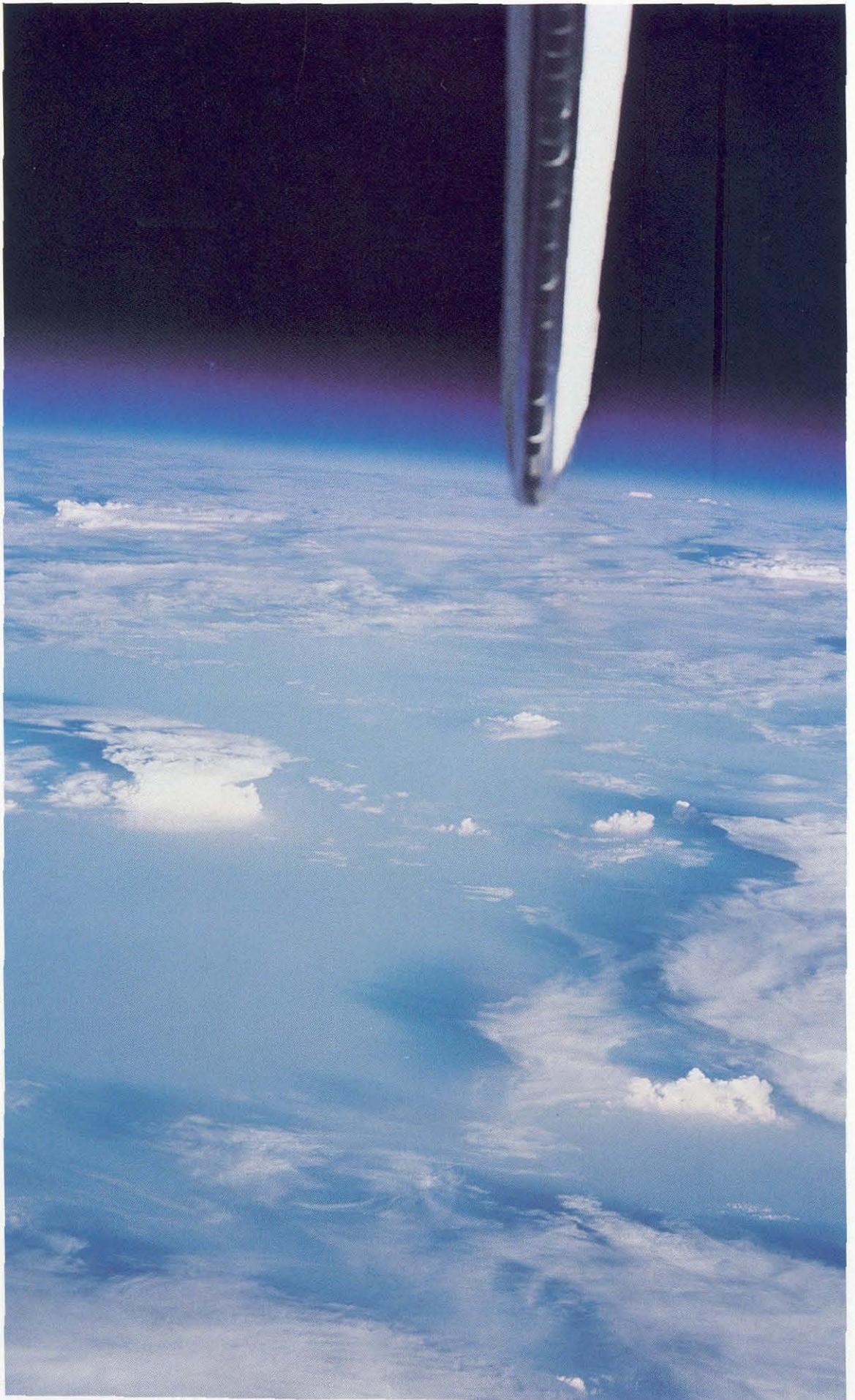
Daniel Schorr posed a final question at the end of his wrap-up session: “Why did the conference organizers decide against accomplishing anything beyond pontificating? Why no dialog to achieve whatever degree of consensus among scholars is possible? Why no conference statement? Why no plans to mobilize and promote consensus expertise for Brazil in 1992?”

That wasn’t the intent, however. Any conference with *vision* in the title isn’t likely to produce a plan of action or even a consensus (there wasn’t even a consensus on what sustainable meant), and the organizers indeed did not have that in mind. On the occasion of Caltech’s 100th year, they wanted participants to envision what they wanted the world to look like after another century or at least by the middle of the next one. They weren’t looking for short-term prescriptions. Therefore the organizers were disappointed and frustrated to some extent by the panelists’ recurring focus on the near term—the next 10 years—and on solving current problems. “They refused to take on the time scale,” said Murray of some of the participants.

“But there were many excellent insights,” according to Gell-Mann. “The issues of sustainability needed to be discussed all together, and that was understood and done well by most of the participants. It’s a revolutionary way of doing things, because most scientists are not used to taking a crude look at the whole. From that point of view the symposium was a success.”

“The speakers and panelists did address the approaches to the transitions, but we hoped they would go beyond that,” said Gell-Mann. “They were unwilling to address the transitions themselves—what the world would be like afterward, what the desirable states of the world would be.” This was indeed difficult to envision. MacCready’s view was that “even 30 years from now, things are going to be so changed that they will be unrecognizable.”

Perhaps Linda Fetter, a Pasadena resident who, with her husband, had supported the “Visions” symposium financially, best summed up the intended scope of the conference and added a touch of nonpontificating optimism: “We have three sons. We’re very, very interested and concerned about the world for them and for their children.” She also said that she had received a gift through this conference, “and that’s a new respect for the challenges that we all face. I feel a pride in us as a civilization, and I feel that we are going to continue to seek and find the answers to the issues raised.” □



All the features in this view of the Amazon River basin in South America are completely obscured by smoke from slash-and-burn agriculture and tropical-forest clearing. This photo was taken from the space shuttle *Discovery*, whose tail can be seen at the top, between September 29 and October 3, 1988. The smoke cloud covers at least one million square miles, an area more than three times the size of Texas.