The Era of Evolutionary Governance

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The theme of evolutionary governance is arising often in the public discourse now- usually either in regard to some aspect of biotechnology, or in connection with our modifications of ecosystems through climate change and other interventions. It is a favorite subject of science fiction writers who weave marvelous tales about future worlds and beings shaped by human artifice, and it frames the controversy between those who welcome such power as somehow a part of human destiny and those who see it as unnatural, dangerous and even sacrilegious.

In this paper I intend to explore some aspects of evolutionary governance present and future. But first I need to point out that evolutionary governance has not only a present and a future, but a past- and a long one. Human beings have manipulated the breeding of other species and modified ecosystems for many thousands of years- and what we are experiencing now is a disturbing new encounter with an old dimension of the human experience, one that people in the past either overlooked or regarded as simply a matter of improving on nature. This is shaped by a convergence of two developments: (1) a rapid increase in human *ability* to manipulate the genetic evolution of species and to modify ecosystems, and (2) an increasing body of *information* about the impacts of human action, especially in regard to large-scale (including global-scale) ecological changes. These force us to recognize the reality of evolutionary governance for the first time in human history- a recognition that transforms our understanding of humanity's relationship to the Earth. It is an end of innocence.

As a preliminary definition of evolutionary governance, I will identify it as any activity- deliberate or inadvertent- by which human individuals or organizations intervene in the survival or reproductive selection of life forms, either directly by activities such as selective breeding or indirectly by modifying ecosystems. This may (or may not) involve formal institutions of government. The word "govern", from the Greek root *kubernetes*, refers to steering or guidance, and not exclusively to public policy; the actions of a farmer plowing a field or a couple planning a family may have evolutionary impacts. But now more and more of the activities with evolutionary impacts are entering the public arena, becoming matters of political concern and controversy leading to legislation, court decisions or global treaties.[1]

The concept of evolutionary governance sprang at me full-blown out of the pages of a 1968 issue of the *Journal of Humanistic Psychology*, in which I read a passage from a book (1957) by Julian Huxley. Sir Julian- first director-general of UNESCO, grandson of Charles Darwin's colleague T. H. Huxley- declared in no uncertain terms:

It is as if man had been suddenly appointed managing director of the biggest business of all, the business of evolution- appointed without being asked if he wanted it, and without proper warning and preparation. What is more, he can't refuse the job. Whether he wants it or not, whether he is conscious of what he is doing or not, he is in point of fact determining the future direction of evolution on this earth. That is his inescapable destiny and the sooner he realizes it and starts believing in it, the better for all concerned.[2]

I cannot recall precisely what was my reaction to this statement. I had never heard such an assertion before, and I was not altogether sure what it meant. I was probably put off by its hearty masculine-by-preference language (this was about the time when we were

becoming careful about that) and, since I was deeply involved in the environmental movement, offended by its assumption that it was all-right for people to meddle with nature. But there was something about its sense of conviction and urgency that stayed with me.

Some years later, in the mid-1970s, I began to understand at least a part of what Huxley had been getting at -- and also to understand something about the history of my own country that had been omitted from my education.

The American Episode in Evolution

I was, at that time, writing an introductory text book on American government, to be organized in three parts: history; government and politics; and public policy.

My research for the first part included works of "natural history" as well as the history of people and institutions, and it was there- in books about the American experience with plants and animals and soil and water systems- that I began to form a new understanding of my country's origin. I had known that the early Americans came from Europe and created new institutions and, eventually, a new nation. But I had not known that they also created new ecosystem- indeed, rebuilt the land and transformed its flora and fauna- and altered the territory.

They didn't know they were governing evolution, of course. The remodeling project was well underway before Darwin was born. But in another sense they did know what they were doing. They were transplanting European civilization to the New World, and to do that they had to transplant the various life forms necessary to European-style agriculture, and to shape the land and water systems to make them more hospitable to farms, cities, and commerce. They were carrying out a large-scale project of directed evolution - not following any single master plan, yet with a clear social consensus on what needed to be done.

That project began soon after the discovery of America. On his second voyage Christopher Columbus carried seeds, clippings, and fruit stones to supply familiar food for the Spanish settlers. One of those plants, sugar cane (which had first been introduced to Europe by returning Crusaders) eventually became a major commercial crop in the West Indies. Meanwhile, the Spanish contribution to the evolutionary project was carried westward by missionaries to Mexico and California who established crops of citrus fruits, figs, dates, grapes, olives and alfalfa - all newcomers to the Western Hemisphere.

The English colonists who settled along the Atlantic seaboard also brought plants with them, and by the early 17th century the gardens of Massachusetts were growing cabbage, turnips, spinach, peas and beans descended from seeds brought from England. In the following century, Benjamin Franklin found many useful vegetables and grains during his travels in Europe, and Thomas Jefferson, experimenting with plants at his home in Monticello, imported not only food crops but also Lombardy poplars and silk trees. Animals as well as plants figured prominently in the project. Among the passengers on the famous voyage of the Mayflower were pigs and sheep and cattle, as well as moths stowed away in woolen clothes.

At the same time that new plants and animals were being imported and bred, native species- particularly those considered hazardous to people, crops or domestic animals- were being battled (sometimes to extinction) by settlers. The young federal government also undertook extensive programs of cutting interstate canals, dredging coastal harbors and laying out roads through the fields and forests. All of this added up to a massive and irreversible transformation of the Eastern seaboard.

And, as settlement spread westward, so did what some have called the "biological colonization" of the American continent. Forests were cleared and fruit trees planted, fields plowed for farms, weeds and predators controlled, domestic animals bred. In California, the most rapid changes of all took place following the 1849 gold rush, as settlers by the thousands reproduced the familiar pattern of introducing domestic species and exterminating native ones, and also permanently altered the terrain

of the gold country by methods such as hydraulic mining which washed away entire hillsides.

All this, I learned later, was not a deviation from the earlier course of human events. The American transformation only took place more quickly and happened at a relatively recent stage of history- and is therefore better-documented than the transformations of other continents by other peoples, centuries earlier.

I learned also that North and South America had been extensively remodeled by native populations long *before* the era of colonization began. American Indians had burned forests to increase habitat for deer and other favored game populations, built dams, cultivated plants and- in California - even "farmed" the native oak.

Modifying ecosystems is what people do; it is only recently that we have begun to learn the extent of it.

Human Evolution and Ecological Change

Even prehistoric human beings, as they began to develop language, tools, and new social organizations, found ways to alter the terrains they inhabited. They also moved by imperceptible stages into animal breeding and plant agriculture: hunting became husbandry, while gathering became farming. And husbandry and farming are, no matter how primitive, forms of evolutionary governance; they involve modifications of ecosystems, and manipulation of the breeding of plants and animals.

This happened, for example, when early hunters of ancestors of modern sheep began to live by following the herds rather than by randomly pursuing individual animals - and then began to guide them into areas where they might graze under supervision and be protected from predators. The wild animals evolved into domestic ones, the hunters into shepherds. And countless impacts on the evolutionary careers of other life forms result from the changes that take place whenever an ecosystem is invaded by herds of grazing animals.

One well-documented transition from food-gathering to plant agriculture took place about 10,000 years ago at the north end of the Dead Sea. The people who inhabited that region were an advanced civilization who already had well-built houses and a sophisticated social structure, and tools such as flint sickles and stone mortars and pestles that they used to harvest and process grains. Then, as the climate in the region became hotter, they made the transition to planting grain and cultivating it. The warmer climate favored the annual species of wild grains and legumes over the perennials. The annuals had large seeds, protected inside husks, that were able to survive the powerful summer droughts and then germinate in the cool and rainy winters. Some food-gatherers observed this process and began to help it along each year by saving seeds when they harvested grains and then planting them in the next wet season. The shift from hunter-gatherer life to agriculture set in motion an ongoing series of further changes. Food supplies grew, and populations increased. Changes in the genetic evolution of plants also resulted. Without any concept of breeding at first, the primitive farmers tended to gather mutant varieties that were easier to harvest and save. The archaeological evidence indicates that, within a short period of time, the cultivated fields in the Jordanian region were taken over completely by the seed-retaining, fat-grained mutants. As agriculture developed there it spread northward and soon wheat, barley, peas and beans were being grown in Turkey and Mesopotamia, with corresponding impacts on ecosystems and on the evolution of local plants and animals.

The Beginning of the End of Innocence

Such early modifications of species and ecosystems took place with little understanding of how extensively they impacted the world, but in the latter half of the nineteenth century a series of events led to a growing understanding of how biological change takes place - and how human actions contribute to it.

The most historically significant of these events was the publication, in London in the year 1859, of Charles Darwin's *Origin of Species*. Although mainly about evolution through natural selection, it was also about one kind of evolutionary governance -- the deliberate acts by which people modified domestic plants and animals, creating new varieties that would never have emerged by pure natural selection or (to use the term Darwin borrowed from Herbert Spencer) the "survival of the fittest". Many of these domesticated varieties were not at all fit to survive in their natural habitats, but served admirably (with human protection) as crop plants, ornamentals, milk cows or racehorses. Darwin also noted one kind of "unconscious selection", in which people often modified a breed without any particular intent to do so; an owner of hunting dogs, for example, might merely choose to breed what he considered his best animals, and would find out over time that his dogs were noticeably different from those of other owners.

Darwin did not, however, grasp another kind of "unconscious selection" that takes place when people modify ecosystems - by harvesting forests, for example - in ways that alter the survival prospects and the evolutionary directions of species that inhabit it. There is a passage in the *Origin* in which he compared the sparse vegetation of a heath in Staffordshire to another area not far away that had been enclosed and planted with Scotch fir trees. He referred to the heath as having "never been touched by the hand of man" although it had been touched rather heavily, several times over, by succeeding waves of woodcutters.[3] Much of England was so thoroughly logged over by the thirteenth century that landowners imported trees from the Baltic area, forerunners to the reforestation from Scotland whose results Darwin observed.[4]

Such ecological changes were documented in another book - not nearly as well-remembered but in its own way equally disturbing to prevailing assumptions - that was published five years later. Titled *Man and Nature, or, Physical Geography as Modified by Human Action*, it was written by the American scholar George Perkins Marsh. Marsh, an independent scholar, drew on research by specialists in various fields such as hydrology and botany and wrote the first general study of the extent of such modifications. In its time, Marsh's work had a powerful impact in Europe and the United States, and is regarded as the inspiration for the early "conservationist" movement that emerged in the US, a forerunner of contemporary environmentalism.

Meanwhile, Charles Darwin's cousin Francis Galton was gaining converts to his idea that human beings ought to take evolution into their own hands, to (as he put it) "further the ends of evolution more rapidly and with less distress than if events were left to their own course". He proposed a deliberate program to improve the quality of the human species by scientifically-directed breeding which would, he believed, result in a population of intelligent and gifted people. At first Galton thought the agenda of what he came to call eugenics could be carried out by a noncoercive system of voluntary breeding, but soon he decided that it would be better for the state to regulate reproduction- rank people by ability, permit the most gifted people to have the most children and prohibit the least gifted from having any children at all.[5] This idea- state-directed evolution- is what people generally mean when they use the term "eugenics".

The eugenics movement became immensely influential in the United States, then filling up with new immigrants from Eastern Europe and Mediterranean regions. Its political agenda was not so much to improve the national gene pool as to prevent what Anglo-Saxon Americans feared to be the imminent deterioration of it. It lead to sterilization of mental patients, laws restricting marriage between persons classed as "eugenically unfit", and restrictive immigration policies. Eventually both the science and the politics of eugenics were discredited in the US, but by that time Adolf Hitler was establishing at eugenic a police state in Germany, intended to bring forth a master race - and leading eventually to the mass execution of Jews, Gypsies, homosexuals and others regarded as genetically inferior.

The reaction against such excesses has

now reached the point that all kinds of developments and policies having to do with human reproductivity are likely to be denounced, with the strong implication that anything describable by the word "eugenic" is morally intolerable. These statements are quite understandable, but they are also misleading. They give the impression that eugenics ever went away -- which it didn't- or that it can be excluded from the future- which it can't. Eugenics is part of life in our time, and the challenge is to understand that and manage it wisely. Eugenic issues will be constantly emerging in the bio-information era. As a leading geneticist, Steve Jones of University College, London, puts it: "No serious scientist now has the slightest interest in producing a genetically planned society. But the explosion in genetics means that we are soon - like it or not - bound to be faced with moral problems about whether we should make conscious decisions about human evolution".[6]

So although we may not have the genetically planned society - eugenics *de jure* - more and more people are making decisions that are *de facto* eugenics. Whenever a couple chooses to abort a defective fetus and try again, whenever a prospective parent makes a reproductive decision on the basis of knowledge that he or she carries genes for an inheritable disease, whenever a sperm bank screens prospective donors to find what traits they carry, they are making decisions about human evolution. If eugenics is about people-breeding, about attempting to improve the genetic heritage of those yet unborn, all these meet the definition.

One good argument for thinking open-mindedly about eugenics is the constant reality of dysgenics – deteriorations of the human gene pool as a result of various social and medical interventions. Anything that medical science does to prolong the life into reproductive years of a person who is born with a genetic illness results in offspring who carry the genes for that illness. As treatments for people with cystic fibrosis improve, and as genetic therapy saves children with severe combined immunity disorder, more of those people will be able to marry and lead normal reproductive lives, and more children will be born with those genes. Some bioethicists fear that we may be creating a population increasingly dependent on medical care.

Such issues - about eugenics and dysgenics, *de facto* and *de jure* - will become increasingly familiar. The entire eugenics furor of the twentieth century was the consequence of people grappling with new information about the mechanics of genetic inheritance. And more information is on the way.

Redesigning Humans – and Everything Else

Gregory Stock, a noted futurist and director of the Program on Medicine, Technology, and Society at the University of California at Los Angeles, recently wrote a book titled *Redesigning Humans: Our Inevitable Genetic Future*, and its basic argument is that germline modification of human beings - particularly the deliberate selection of characteristics of unborn children - will bring a new stage of human evolution: "The arrival of safe, reliable germline technology will signal the beginning of human self-design. We do not know where this development will ultimately take us, but it will transform the evolutionary process by drawing reproduction into a highly selective social process that is far more rapid and effective at spreading successful genes than traditional sexual competition and mate selection".[7]

Stock expects that the emphasis at first is likely to be on modifications to prevent diseases, improve general health, and improve longevity - but might also lead to various enhancements of physical or mental performance, and even to choice of eye or hair color. Lee Silver, a Princeton microbiologist, speculates more adventurously that future generations might choose enhancements based on genes borrowed from other species: ultraviolet or infrared vision, the ability to generate electricity, magnetic detection capabilities, a sense of smell comparable to that of dogs or other mammals.[8]

Although any such genetic modifications are still far in the future and certain to encounter opposition wherever they appear,

modifications of other species are proceeding much more rapidly: millions of acres are now growing genetically-engineered food crops, while the newspapers regularly bring reports of cloned and modified domestic animals. Many of these modifications are designed not only for enhancing food production, but also for medical uses: animals producing medicines in their milk, plants (even tobacco) modified to grow medicines, and a new approach to immunization in the form of so-called "edible vaccines" such as bananas designed to confer resistance to various diarrhetic diseases common to children in tropical countries. Yet another rationale for genetic modification is the potential of new industrial materials: A company in Canada plans to produce a material called "biosteel". based on transferring the gene for spider silk into milk animals. The 21st century is likely to see genetic modifications in many kinds of plants, animals, and microorganisms, for many different purposes. Genomes are being mapped and sequenced, and this explosion of genetic information may have consequences of kinds that have yet to emerge in public discourse. For example, the recently-completed decoding of the genomes of the main malaria parasite and the mosquito that carries it may lead, finally, to a victory over one of the world's most troublesome diseases by a number of possible methods: new drugs, a vaccine, perhaps genetically-engineered strains of mosquito that would not only resist the parasite but be capable of displacing their parasite-carrying relatives[9].

Meanwhile, we hear of yet another sort of evolutionary innovation - interactions between human beings and machines. Ray Kurzweil, in *The Age of Spiritual Machines*, confidently predicts that it will become possible to "download" the contents of a human brain into another medium, thus extending the life of an individual's consciousness beyond the life of the biological body.[10] Kurzweil and some other techno-futurists now believe that computer power will soon equal and then pass human intelligence. This event is now commonly described as the "singularity", a leap into a new and incomprehensible world of change in which all kinds of scientific discoveries and innovations - beyond the capability of the human brain - might result. The computer scientist and science-fiction novelist Vernor Vinge first used that word (in this meaning) in a 1993 paper in which he wrote: "From the human point view this change will be a throwing away of all the previous rules, perhaps in the blink of an eye, an exponential runaway beyond any hope of control. Developments that before were thought might only happen in 'a million years' (if ever) will likely happen in the next century".[11]

In this view the history of the third millennium will be told in terms of a new kind of evolution, inseparably biological and mechanical. By the year 2099, Kurzweil predicts, there will no longer be any clear distinction between humans and computers. Furthermore, most conscious entities will not have a permanent physical presence, but will be able to wander freely through space and cyberspace, mobile as an e-mail message.[12]

A darker scenario on mechanical futures was outlined in Bill Joy's widely-read article "Why the Future Doesn't Need Us", in which he discussed the possibility that a runaway evolution of self-replicating robots might take place with disastrous consequences - even threatening the future of the entire human species.[13] This concern lead Joy to propose yet another form of evolutionary governance: slowing down the pace of machine innovation to prevent such an event from taking place. That such an idea could be presented by a reputable scientist, and taken seriously by many people, is an indication of how quickly the new era is approaching.

And, at the same time that we begin to grapple with new issues about the evolution of species, we confront an ever-growing body of information about human impacts on ecosystems - impacts which add up to another kind of directed evolution, global in scale.

The Art and Science of Planet Management

Readers of science fiction are familiar with the word "terraforming", which refers to the transformation of other planets to make them

fit for human habitation - and more like Earth. Kim Stanley Robinson's trilogy about the colonization of Mars - *Red Mars, Green Mars* and *Blue Mars* - is a monumental epic of how such a transformation might take place in the not-too-distant future.[14] An even more grandiose enterprise is described in the *Hyperion* novels of Dan Simmons, in which planets throughout the galaxy are analyzed for their potential as human habitat and - with varying degrees of success - terraformed.[15]

The idea of terraforming other planets is not so fanciful as to prevent people from engaging in heated debates about whether it should be permitted to happen in the future. One thing that makes it possible to take such debates seriously is the dawning awareness that we have already "terraformed" Earth: that human activities have transformed ecosystems everywhere and - through climate change - are having an impact on the biosphere itself.

And people have transformed the Earth in another way: wired it with a huge network of information feedback systems. This dimension of global change is often overlooked; we still have not grasped the significance of the global system of environmental information-gathering that has been put into play over the past few decades. Most people don't have much of an idea of how gigantic that system has become or how central a part it now plays in the life of the planet.

We know now that we live in an information society; we have not figured out that we live on an information planet. Today the Earth system sciences are served by a global network of satellites, observation stations, probes into the planet's crust and the ocean depths, radio transmitters on migrating birds and mammals, computer data banks and modeling software.

Satellites monitor the condition of soils and crops, the growth and shrinkage of forests and deserts, the migrations of birds and animals, the flows of glaciers, the effects of spreading urbanization. Since 1958, the thickness of the Arctic ice cap has been measured by upward-looking sonar aboard submarines operating under the ice sheet. More recently, the US Navy has agreed to let scientists use its global network of underwater microphones. Originally built at a cost of several billions of dollars to pinpoint the locations of ships and submarines, this surveillance system can also detect the distant calls of whales, the movements of schools of fish, tremors in the seabeds, and underwater volancos.

Many environmental observations are made by international research projects. A few years ago *Earthwatch* magazine reported on an "international phalanx" of coordinated activities including "an American Total Ozone Mapping Spectrometer aboard a Russian Meteor 3 space craft, a US-French Topex-Poseidon satellite to measure global sea level rise with an accuracy of two centimeters, a German-built Shuttle Pallet Satellite (to measure atmospheric infrared and the critical chemical radical OH), a Japanese-American test of the NASA Scatterometer, and dozens of other esoteric and complex measuring devices involving dozens of countries... "[16]. In 1987, when scientists from several different nations spent several weeks studying stratospheric chemical reactions and minute concentrations of gases over Antarctica, they employed not only satellites but also balloons, a DC-8 flying laboratory, and a converted high-altitude U-2 aircraft.

And, with advances in the science of modeling, vast amounts of data are synthesized in attempts to comprehend the working of the system as a whole and project future developments.

With the development of the Web, ecological information becomes readily available to the general public. For example, the Global Biodiversity Information Facility, recently launched into cyberspace, will eventually have a Web page for each of the world's 1.5 million catalogued species of animals, plants and microorganisms. Also on the Internet is a map of seismic hazard levels for the entire world, giving estimates of future ground shaking, ranging from "very low" through "moderate" to "very high". It was compiled by the Global Seismic Hazard Assessment Program, and among those who use it are multinational corporations, scientists, policy makers, grassroots environmental groups, and indigenous peoples.

Such information often serves as direct feedback to activities on Earth. Marine biologists in Massachusetts rely on satellites to alert them to sudden warm-weather blooms of algae and plankton off the Atlantic coast. If they find the plankton heavily infested with poisonous cyanobacteria, they alert public health officials who order a closing of the local shellfish beds. Similarly, scientists in India use remote-sensing technology to detect sudden increases in offshore plankton which carry the microbe that causes cholera; the microbe, they have learned, is taken up by fish, carried by fish to humans, and then moves into the drinking water with human wastes.

The various parts of this system are increasingly linking around the world, much as the neural connections grow in the brain of a developing child, and in the process creating a new entity, of a kind we have not yet previously imagined and still do not fully understand even though human consciousness is the creator and custodian of the change.[17]

Governing in a Bio-Information Society

The twin information revolutions, genetic and ecological, are two aspects of the transition into a new social context which is also a new stage of the planet's evolution.

One common reaction to a change of such magnitude is to try to stop it, or at least to slow it down. This is particularly evident in regard to biotechnology, which has been a matter of intense controversy almost from its beginning. Some have proposed that genetic engineering be prohibited entirely, while others have expressed cautious support for its possible benefits but have opposed specific applications such as genetically modified food crops.

Such reactions to new developments are to be expected. In the nineteenth century there was opposition to vaccination from people of several different persuasions - including clergymen who believed it was a violation of God's will to give an animal disease to people, and eugenicists who believed it was enabling the weak to stay alive and reproduce. In the twentieth century artificial insemination was outlawed in many places. Now the innovations are coming at a faster rate and are in many cases more striking: cloned sheep, spider silk genes in milk animals, pigs specially bred to provide replacement organs for human beings, gene therapy and even in vitro manipulation of human embryos. This indicates that the decades and even centuries ahead will be busy not only with new discoveries but also with varying public reactions to them, with intense involvement of governmental, intergovernmental and non-governmental organizations of many kinds - a long era of evolutionary governance.

The overall pattern will most likely be gradual public acceptance of new applications, varying from region to region and influenced by many factors - including, of course, evidence of their successes and failures. But sometimes applications of new technologies run ahead of full public acceptance and even public policy. Government laws, regulations and research policies may influence the development of future technologies but are unlikely to prevent the deployment of any application that some people consider safe and desirable. In regard to germinal choice technology (GMT), Stock predicts:

The legal status of various procedures in various places may hasten or retard their arrival but will have little enduring impact, because ... the genomic and reproductive technologies at the heart of GCT will arise from mainstream biomedical research that will proceed regardless. Bans will determine not whether but where the technologies will be available, who profits from them, who shapes their development, and which parents have early access to them. Laws will decide whether the technologies will be developed in closely scrutinized clinical trials in the United States, in government labs in China, or in clandestine facilities in the Caribbean[18].

Stock's prediction is supported by what is happening now, in an increasingly interconnected world. Abortion may be illegal in one country, but always obtainable somewhere for those with sufficient will and money. A heart transplant may beyond the capability of one coun-

try's medical science, but, again, obtainable elsewhere for some. This relates to what I believe is the most frequently overlooked aspect of the biological revolution: social equity. The question of who has access to what and when is no less urgent than the safety and ethical concerns that tend to dominate public debate about biotechnology and related technologies, but receives far less attention.

Many different initiatives aimed at addressing certain specific equity concerns are underway. Some of these may succeed, but the basic situation - an immense gap between the richest and poorest in terms of ability to receive and use the most advanced medicines, agricultural technologies, information/communications systems and industrial processes - has not changed. In regard to drugs, for example, Africa accounts for 1 percent of world drug sales, while North America, Japan and Western Europe account for 80 percent. The gap is perhaps most evident in relation to life expectancy: In the US and other wealthier countries, average life expectancy is in the high seventies. In several African countries, such as Malawi and Zambia, it is around 37 and projected to go lower with the impact of AIDS. Many medical futurists are now predicting dramatic increases in life expectancy - scenarios in which the "longevity gap" could grow even wider, to the point that the rich and the poor are hardly the same species: the rich living a century or two (in some scenarios, much longer) in full health and productivity, while the poor live miserably and die young.

That is one scenario - unfortunately, a very plausible one - of future human evolution. Let me, summarizing the thinking of various futurists, quickly suggest a few others:

1. Onward and Upward: Worldwide - and equitably distributed - improvements in life expectancy, health, intelligence and physical performance.
2. The new Cambrian Explosion: People choose many different paths of genetic choice, resulting in divergent groups of human beings of vastly different shapes, sizes, abilities and characteristics.
3. Hubris and Disaster: People proceed too quickly into experimenting with genetic choices, resulting in widespread births of horribly defective children, and massive rejection of such technologies.
4. Human-machine Symbiosis: Human beings become cyber-organisms, their minds and bodies dramatically transformed by electronics, robotics, and nanotechnology. (I should point out that, although the more dramatic forms of symbiosis may be doubtful, other forms - pacemakers, for example - are already here.)
5. Left Behind: Machine evolution proceeds into evolutionary leaps far beyond human levels, leaving Homo Sapiens to extinction or irrelevance.

Any of these is thinkable, all are more likely than the prospect that things will remain the same. We face the high probability that Homo Sapiens will become, in the not-too-distant future, a significantly different biological organism from what we are today, and from what human beings have been for tens of thousands of years. This is an evolutionary development that, until recently, was not even contemplated by science fiction writers and moviemakers, most of whose characters ventured out into outer space with conventional twentieth-century bodies and life expectancies. It will be driven by human volition and influenced by public policy, but it is most unlikely to be governed from a single center with a single master plan for human evolution.

With regard to the governance of the biosphere, the issues are much different but no less psychologically disturbing. Perhaps most disturbing of all were the two new concerns that emerged late in the twentieth century: stratospheric ozone depletion and global climate change.[19] With these and other ecological problems in the headlines, people contemplated the reality - not just the possibility - of global-scale problems caused by human action and requiring human response. And we got the news from the global information systems. Nobody simply looked up and saw a hole in the ozone,

or noticed that the weather was warmer than it had been a couple of centuries ago.

The predictable result was a sharp increase in efforts to construct environmental laws and regulations. Richard Benedick, a specialist in international environmental policies, pointed out some time ago that the latter decades of the 20th century witnessed "a virtual explosion of multilateral negotiations aimed at addressing the new global environmental issues". He specified 14 different global environmental agreements concluded in the rather short period of time between 1985 and 1997: among them the Vienna Convention and Montreal Protocol on the ozone layer, the UN Convention on Biological Diversity, the UN Convention to Combat Desertification, and the Kyoto Protocol on Climate Change.[20]

Also there has been a proliferation of *regimes* - such as the Antarctic Treaty System and the European transboundary air pollution regime - which are specialized governing systems, often involving both governmental and nongovernmental organizations. These, too, are information-dependent, but tend to focus on specific concerns: biodiversity, marine pollution, international trade in endangered species, transboundary flows of airborne pollutants or hazardous wastes. Another, more recent, addition to the list of global regimes is the World Commission on Dams, formed following a meeting of diverse groups early in 1997, which conducted a major review of the impacts of some of humanity's most massive ecological interventions and will undoubtedly be a force in future dam-related developments.[21]

Such international developments give us an idea of what the management of a planet looks like, and what it will look like in the future: changing, multicentric, information-based. And, of course, political. If people can have different opinions about how to run a city or a country, it is hardly surprising that they have different opinions about how to manage a biosphere.

For a brief overview of this huge and complex subject, I will describe three scenarios of ecological change, three different models of global governance, and two approaches to biosphere management - all of these vastly oversimplified, but still useful in sketching a picture of where we are and where we may be going. First, the scenarios:

1. Massive Disruption. Severe global warming leading to rising sea levels and coastal flooding, widespread droughts and desertification in other regions, an increase in grass fires and forest fires, frequent and powerful hurricanes. An even more frightening version deals with a sudden reversal into a cooling effect as atmospheric and oceanic disturbances plunge the world into a new ice age. Such a development, wrote William Calvin in an article describing this possibility, "would be a potentially civilization-crashing affair," arising too quickly for any effective governance response.[22]
2. Midrange Climate Change. Various predictions of globally-averaged surface temperature changes in the 21st century range upward from 1.4 degrees Celsius. Within this range, a global climate regime might be able to respond with some degree of effectiveness to such disturbances as moderate rises in the global mean sea level, increases in precipitation and wind intensities, and intensified summer drying in midlatitude continental interiors.
3. All Is Well. This is the future envisioned by dissenters who claim that all predictions of global warming are faulty, based on a combination of poor science, environmentalist hype and bureaucratic empire-building, and that there is no need for any global regime that would lead to further dilutions of national sovereignty. There have even been assertions that global warming will be a boon, bringing increases in agricultural productivity and a reduction of troublesome ice and snow.[23]

There are also, as we move into an age of decision-marking on a global scale, different ideas about what kind of a system of global governance is most desirable and achievable:

1. Global Government (*world-centered*). This is the ideal of World Federalists and other groups who believe that the needs of a global society in uncertain times can only be met by a global government -- a federal authority with legislative, executive and judicial branches, and with the power to make policies that would be binding on national governments.
2. A World of Sovereign Nations (*state-centered*). "Realists" believe that nation-states are and should continue to be the only legitimate institutions of government, maintaining full sovereignty even when they create intergovernmental organizations for limited purposes.
3. An Ecology of Governance (*multicentric*). This is, for better or for worse, what we have now - a mix of nation-states, international organizations, non-governmental organizations, multinational organizations, regimes (sometimes overlapping) and networks. Some see this as confusing and inefficient; others - of which I am one - believe that a multicentric system is the only kind that is appropriate in a multicentric world. Such a system is, among other things, more flexible in response and more amenable to structural change.

Finally, let us consider two different general orientations to managing a world in which concerns such as global warming are on the public agenda.

1. Shades of Green. Environmentalist orientations to global governance come in many shadings, of which the most radical are staunchly opposed to globalization and in favor of a return to self-sufficient local communities with simpler technologies. Mainstream environmentalists are more pragmatic in this regard, but some positions are held across the spectrum: a preference for renewable energy, sustainable agriculture, conservation of resources, protection of wilderness areas and endangered species; together with a cautious stance toward technologies in general and biotechnologies in particular, and a belief that responses to environmental problems must emphasize changes in behavior (less consumption, particularly of energy) over technological manipulations. Environmentalists tend to regard human interventions as negative and thus to resist ideas of proactive evolutionary governance. However, there has arisen in recent decades a strong interest in one form of active ecological management - the restoration of damaged ecosystems.
2. The Technological Fix. Physicist Gregory Benford, in a study of our possible long-range impacts on the world, makes a case for active "geoengineering," and predicts "the inevitable emergence of a new technovisionary community, devoted to solving global ills with global technologies." This, he notes, "is quite different from simply finding the polluters and telling them to stop."[24] Already, rising environmental concern around the world has led to a vast outpouring of scientific research and technological innovation. Not surprisingly, much of this has to do with alternative energy sources. Some of these - particularly solar and wind power - are compatible with Green agendas; others - such as generating ethanol in "biorefineries" with the use of genetically-engineered enzymes - are regarded with great skepticism. So are proposals for a global-scale assault on CO_2 accumulation by artificially stimulating the growth of carbon-holding plankton in the oceans.

In these two general orientations to technological change and environmental concerns, we can see the emerging outlines of two competing philosophies of global evolutionary governance. Given the enormous number of variables that will determine what happens in the next few decades - all the different possible

developments in science and technology, the good and bad global surprises, the possible psychological reactions and political movements, the changes in governmental structures - it is impossible to say with any degree of certainty what will unfold in the decades just ahead. But this is the framework.

I close this discussion with the statement that one thing is certain: a growing recognition of the reality of evolutionary governance. Perhaps not entirely certain: A rapidly-unfolding civilization-destroying event such as the one William Calvin describes could override any other development we might imagine. But the larger processes that I have described - leading toward greater human involvement in the biological evolution of species (including our own) and the mechanisms of all ecosystems (including the biosphere itself) show no sign of lessening at the present time. In fact, the information explosions of genetic discovery and global feedback may well be at their early stages.

This means, as I have suggested at the beginning, a revision of our understanding of the relationship between our species and the planet, a new evolutionary governance role something along the lines of what Julian Huxley was trying to describe decades ago.

The Green dream of an Earth serenely in balance, regulating its own systems by natural feedback mechanisms while human beings somehow stand apart from this and let it work its magic, is an appealing image. But we never lived in such a world and are not about to begin doing so. Interestingly, James Lovelock, the father of the Gaia hypothesis which is often cited as the model for such an image, doesn't seem to think so either. In the closing pages of his book he described humans as the only creatures with the capacity to gather and store information and use it in complex ways, and thus a part of Gaia, "a Gaian nervous system" with a brain which can consciously anticipate environmental changes. He concluded by exploring "the implication that the evolution of homo sapiens, with his technological inventiveness and his increasingly subtle communications network, has vastly increased Gaia's range of perception. She is now through us awake and aware of herself."[25]

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