Science, Technology, and The Prospects for Utopia

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LAST SPRING, when it was announced that I would give the Faculty Lecture this year, December seemed as far away as the stars. But all too soon-in the words of the September Song, "The days dwindled down to a precious few." September came and went, and I still hadn't chosen a topic. Confronted by a crisis, I followed the tradition of generations of O'Connors-I panicked. Crises aren't new to me, and I have my own way of handling them . . . I throw things out. Sort of a symbolic clearing the decks for action, I suppose. Under the stimulus of panic, I have discarded clothing, jettisoned old letters and photographs, even sorted through trays of nuts, bolts and washers-weeding out rusted or defective ones.

This time I attacked my filing cabinets, which turned out to be the largest repository of academic junk west of the Alleghanies. I culled and sorted ruthlessly. Waste baskets overflowed with the detritus of almost 20 years. Finally, as the rising tide of paper lapped at my ankles, the fever fled, and I found that I was holding in my hand a kind of academic joke that some unremembered colleague had given me in the early days of Xerox. It was a list of some of the most preposterously absurd projects and questions anyone ever imagined. Some examples:

From a laboratory final in electrical engineering. Design and construct an atom-smasher using only parts commonly carried in a woman's purse. And here's one from a mathematics final. Make a list of all the prime numbers that contain the numeral three.

Now, as I read these words, a wild idea began to form in my mind. "Why not?" I asked myself. "Why not pick something like these ridiculous examples? How about exploring the possibility of a world in which no one dies for lack of food; a world in which most of the ravages of disease can either be prevented or cured; a world in which renewable, low-cost, non-polluting forms of energy make it possible for all the earth's citizens to enjoy the bounties of the planet . . . and to do so secure in the knowledge that this legacy will pass to future generations? In short, how about the prospects for a Utopian society? Not the mythical country invented by Sir Thomas More, but the ideal world for which the word Utopia has become a synonym.

"No! No!" I told myself. Even considering such a project was audacious. Only an idiot would stray from the limited area of his expertise-and risk humiliation before his peers and fellow citizens. Surely, only a fool would tackle something as broad and complex as this... AND try to do it in under 60 minutes! And so, dear friends, I have chosen as my topic, "Science, Technology, and the Prospects for Utopia."

Let me say at the outset that I shall probably raise more questions than I answer. That's part of my strategy, because, if you're busy pondering the questions, you may not be so critical of my answers! I'm going to examine each of the three areas that could contribute to Utopia in this way: first, I'll briefly describe the obstacles that stand in the way; second, I'll describe the areas of research and development that seem to offer the greatest promise of removing these obstacles; and, finally, I'd like to speculate on the likelihood that our goals will be reached, and on some of the possible consequences if they are.

Before I start, I think it would be helpful to present a different view of the role of science and technology that has many supporters, some in high places. This viewpoint is defended by Robert Heilbroner in his book, Inquiry Into the Human Prospect. His opinion is that the world is in a mess, and science and technology are largely to blame.

The gist of his argument is this: new technology is responsible for industrial growth; but such industrial growth by some nations can only take place at great cost to others, since the non-industrial nations must spend an ever-increasing share of their resources to obtain needed goods and services. Population increases in these industrially static societies create unemployable surpluses of manpower that stream into cities in search of work. Overcrowding leads to social disorders and imperils the environment. The threat of war increases when leaders of underdeveloped nations try to enforce a redistribution of the goods.

As you can see, he is not alone in his perception of some of the problems. But, while I may agree with his selection of the problems, I strongly disagree with his premise as to their cause-and most emphatically disagree with his pessimistic predictions regarding their cure.

According to Heilbroner, continued industrial growth has other consequences. At the present rate, energy consumption will double every 18 years, quickly exhausting the known reserves of coal, oil and gas, and placing an intolerable burden of heat and pollution on the environment that will trigger weather changes and crop failures, and send the oceans surging through the streets of every coastal city on the globe.

The solution to these problems envisioned by Heilbroner requires a fundamental change in the nature of industrialized societies from product oriented to service oriented. He calls this "industrial deceleration" and argues that it will save both our dwindling resources and our fragile environment. But the economic and political realities are these: a government that asks its citizens to give up what they have, or to scale down their aspirations, is not going to win any popularity contests; therefore, the kind of government most capable of enforcing such a change is powerful, well-organized-probably a dictatorship. Heilbroner's solution, then, is no solution at all. He merely substitutes the bleak prospect of an Orwellian society as an alternative to the slow decline of a civilization strangled by pollution and starved for resources. I don't think it's an exaggeration to call this prospect more than a tad depressing.

Now let me give you my analysis of our prospects. Yes, the supplies of coal, oil and gas are limited, and the day may come when the wells run dry and the hoppers are empty. So-called "experts" in government and others in the fuel industry tell us that our fossil fuels will not last another century. They base their forecasts on extrapolations from present trends: that is, they try to predict what's going to happen in, say, 50 years-assuming that things keep on going the way they're going now. Now I feel obliged to point out that extrapolation sometimes leads to false conclusions, as this quotation from Mark Twain's Life on the Mississippi shows so well:

In the space of one hundred and seventy-six years the Lower Mississippi has shortened itself by two hundred and forty-two miles. That is an average of a trifle over one mile and a third per year. Therefore, any calm person, who is not blind or idiotic, can see that one million years ago next November, the Lower Mississippi river was upward of one million three hundred thousand miles long. And by the same token any person can see that seven hundred and forty two years from now, the Lower Mississippi will be only a mile and three quarters long.

I also feel obliged to tell you that virtually all of the forecasts regarding our future energy requirements (including Heilbroner's) are based on the assumption that, when industrial output increases by 1%, energy needs increase by 1%. This is absolutely false. Government figures show that, in the United States during the five-year period from 1973 to 1978, net industrial output INCREASED by 12%, while total energy use DECLINEDby 6%! These figures clearly show that economic growth does NOT require a matching expenditure of energy.

The experts fail to treat energy like other commodities needed for industrial growth-in other words, they try to ignore the law of supply and demand. Government subsidies and pricing policies have helped to make energy cheap and encourage consumption. After all, when energy is cheap, it doesn't cost much to waste it, and it doesn't pay to spend much to save it.

Yet, if we could increase the efficiency of our industrial processes by only 3%, we could save all of the 1.2 million barrels of oil that flow daily through the Alaskan pipeline. I know this sounds incredible, but a 1980 report by the Union of Concerned Scientists estimates that improved efficiency in energy use could cut our energy requirements in half!

Recycling is an energy-saving activity in which everyone can participate, and requires only a small extra effort-but the rewards can be enormous. At the present time, extracting and processing raw materials accounts for about two-thirds of U.S. industrial energy, or about one-fourth of our TOTALenergy consumption. Aluminum can be recycled (including collection, transportation and reprocessing) for about 5% of the energy needed to extract and process it in the first place. Copper can be recycled for about 9% of its initial cost and steel for about 14%. Glass, paper and plastics can all be recycled profitably. This saves energy, lowers its price in the marketplace, ensures its availability to future generations, and reduces the burdens of heat and pollution that the environment must bear.

Sweden, Switzerland and West Germany enjoy a standard of living equal to ours, while their energy consumption per person averages 40% less. Swedish steel-among the best in the world-requires only two thirds as much energy per ton, and some Swedes live in houses so energy-efficient that they are warmed only by heat from the bodies of the occupants and waste heat from appliances. In these countries, a combination of high tariffs on motor fuels and a modern high-speed rail network discourages unnecessary driving, and returns an additional dividend in the form of reduced air pollution.

It seems to me that our government's attitude about energy has a lot in common with that of an aged resident of Arkansas who was approached by a stranger as he sat on his front porch. "Pardon me," the stranger said, "but I can't help noticing that there are big holes in your roof, and I wondered why you haven't mended them."

"Can't work when it's raining," replied the old man.

"Yes, but why don't you fix it when it's not raining?" persisted the stranger.

"Why bless you," came the reply. "When it don't rain, it don't leak!"

We have a lot of holes in our energy policy that the government is slow in repairing. In October 1973, the Arab nations briefly turned off the tap that delivers their oil to the world marketplace. Except for a flurry of saber rattling, the government failed to respond to the possibility of a prolonged embargo until the summer of '79, when Iran's curtailment of oil exports and mismanagement by the U.S. petroleum industry combined to produce a gasoline shortage of crisis proportions. The American public demanded, and the President delivered, an energy policy which was aimed at "producing our way out of the energy crisis." President Carter unveiled a plan that would pump $88 billion into research and development in synthetic fuels, with the goal of meeting 7% of our total energy needs by 1990. Significantly, the same plan allocated only $18.5 billion for upgrading our mass transit system, improving automobile fuel efficiency, and promoting conservation in oil-heated buildings.

The administration that took over in 1980 has put synthetic fuel development on the back burner and virtually turned off the fire under mass transit and other conservation measures. In fiscal year 1982, federally funded R & D on solar energy dropped 56% and conservation dropped45%, while nuclear rose by 44%. The Reagan administration justified the reduction in conservation funds on the basis that the private sector stands ready to take on the activities given up by the government. However, it is difficult to imagine the various sectors of the housing industry (which is probably the most fragmented of all our industries) spending profits on research when current building codes and regulations permit them to sell the same old inefficient products. It is worthwhile to mention at this point that 37% of all energy used in this country is consumed by residential and business users, not including manufacturing. Yet, aside from tax credits for retrofitting certain energy-conserving devices, almost nothing is being done to require conservation in this area.

Now let's talk about energy sources for the future. What are the Reagan administration's nominees? Coal and the atom. What's wrong with them, you ask? What isn't? Burning coal produces the oxides of sulfur and nitrogen that cause acid rain, and invites climatic and environmental disasters by raising the temperature and the carbon dioxide level of the atmosphere. Tunneling for coal is among the most hazardous of occupations, while strip mining reduces land quality. Coal gasification and liquifaction consume and contaminate enormous quantities of water-a resource already in short supply in the western coal mining states. And coal is a non-renewable energy source.

Compared with nuclear energy, coal is almost desirable. Reactors are expensive to build, produce radioactive wastes that we still don't know how to dispose of, and are subject to accidents which are too horrible to contemplate. In addition, developing nations which are given the technology to build their own reactors are indirectly supplied with the means of making their own atomic weapons-as the world learned when India detonated her first atom bomb in 1974. And, like other minerals, the supply of uranium is limited.

Well, how about breeder reactors? In a breeder reactor, the fuel is plutonium 239 and the reactor core is surrounded by a blanket of uranium 238. The plutonium atoms in the fuel rods split, releasing heat and nuclear particles that turn the uranium blanket into more plutonium. Under favorable conditions, the breeder reactor will produce more fuel than it consumes-but not very quickly. Present day designs may take as long as 35-60 years to make as much fuel as they use. Breeder reactors not only share all of the problems of conventional reactors, they have a few nasty quirks of their own. Plutonium is one of the most toxic substances known to man, and only 20 pounds of reactor grade plutonium is enough to make a bomb. Unlike conventional reactors, a runaway breeder reactor CAN explode. Given the potential economic, health and environmental problems of breeder reactors, they should be regarded as one of our last resorts.

Happily, there are a host of other options: among them geothermal, biomass conversion, hydroelectric, ocean waves and currents, solar radiation and controlled nuclear fusion. The only logical way to evaluate these alternatives is to subject them to a systems analysis. This means that it isn't enough just to have the technology to capture the energy: it must be made available in the proper form, at the right time and place, and at a price that people can afford. In addition, the public health, environmental and national security risks associated with its use must be acceptable. Let me use an extreme example to illustrate the point. Developing the technology to generate electricity by burning agricultural wastes (biomass conversion) isn't going to improve the life of a native in rural India who has no power lines, no appliances, and where every scrap of organic waste, including animal dung, is either used as fertilizer or burned to provide heat for cooking.

Some of the potential sources on our list, such as ocean tides and geothermal, are confined to such small areas of the world that their contribution would be almost insignificant. Others, such as ocean current devices, are likely to cause massive ecological disturbances if employed on any large scale, and the energy they capture would, with few exceptions, not be available at the right place. The only sources that survive a systems analysis and are equivalent to fossil fuels in total energy potential are solar radiation and controlled fusion.

To put this discussion in perspective, we need to understand how energy is measured. The unit called the British Thermal Unit (or Btu) is the amount of energy needed to raise the temperature of one pint of water by one degree Fahrenheit. Energy consumption is expressed in quads-one quad is one quadrillion (or one million billion) Btu's. The total use of energy in the U.S. in 1980 was about 80 quads, and, in the entire world, was about 270 quads. By comparison, the amount of solar energy that falls on land in the United States is about 44,000 quads per year!

"Ah, ha!" you say. "What about the systems approach requirement that the energy be available in the right time and place? I'll bet there isn't enough solar energy on a winter's day in Portland, Maine to cook a three-minute egg!" Not so: Portland receives, on the average, nearly 70% as much solar energy per year as Tucson, Arizona. In fact, even the most unfavorable sites in the United States seldom receive less than half the annual energy of the most favorable place.

Let's get down to specifics. Solar radiation isn't just the light that makes driving to Goleta in the late afternoon such a pain in the eyes. Living plants convert one kind of solar radiation into chemical energy, which ultimately sustains all living things. A different kind is responsible for uneven heating of the earth's surface which induces and sustains the wind. Solar-driven evaporation of water is part of a cycle which includes rain, snow and the mighty force of rushing rivers.

Solar energy is renewable, non-polluting, and the technology for using it already exists and is extremely versatile. No nation can deny it to another, and its price should not respond to every flutter of the economy. Assuming that processes for trapping and utilizing solar radiation operate at an average efficiency of 20%, the entire current energy requirements of the United States could be collected on 36,000 square miles-an area roughly the size of Maine.

Solar energy can be collected as heat, or converted directly to electricity by photovoltaic cells, or indirectly by wind-driven generators. Photovoltaic cells have many inherent advantages: they are modular, which means that systems can be designed on any scale just by adding more units; they are silent, have no moving parts, are reliable, and have a long life. They can be installed at, or close to, the point of use so that transmission lines are virtually eliminated. The current obstacle to their use is price: but this has fallen from $11 per peak watt in 1978 to $7 a year later, and is currently in the neighborhood of $1. When the price falls below 75 cents, photovoltaic cells become competitive with electricity generated by fossil fuels. And the price will be lowered because increased demand has spurred competition to design more efficient cells and make it profitable to switch to mass production methods.

Wind-generated electricity is already competitive in certain parts of California, Wyoming and the New England states. Wind machines require relatively small land area, minimal maintenance, and deliver efficiencies close to 40%. Estimates of the energy potential of wind are uncertain. A 1977 General Electric study concluded that as much as 20 quads per year could be obtained from high-wind areas in the United States on land that is not presently used or contemplated for use.

Finally, let's consider controlled fusion, which is essentially a simple process. All you have to do is take a pinch of lithium, add a little hydrogen, and stir them together at a temperature roughly five times that of the sun's surface! At this temperature (about 100 million degrees), a pinpoint would boil water 10,000 miles away!

The difficulty is that no substance can be heated to more than a few thousand degrees without vaporizing, and, at about 100,000 degrees, it becomes a witch's brew of electrons and atomic nuclei called plasma, which will vaporize any container it touches. The most promising technique so far employs a magnetic field to squeeze the plasma as it is heated by laser bursts. Scientists at Princeton University hope to reach breakeven by 1986: that is, to get as much energy out of the fusion process as they put into it. Even if they achieve their goal, the experts predict that the process will not be commercially feasible before the second quarter of the next century-if at all.

The sands in the hourglass tell me that I don't have time to discuss the various modes of storing and transmitting energy, so I'll summarize my main points thus far.

Conservation, recycling and greater efficiency in the ways we use energy can reduce the demands of industrial nations for fossil fuels, making them available to developing nations at lower cost. This would stretch our reserves, and also give us time to develop technology for suitable substitutes. The beneficial effects on our environment would be significant.

Solar radiation, in its various forms, has the potential for providing most of the world's energy needs. The technology is within reach, and the price will soon be competitive with fossil fuels. Solar technology would have the least effect on the environment of all the options being considered.

Now let's speculate on some of the consequences of a solar-powered world. How would the widespread use of solar energy affect the OPEC nations? Faced with the loss of their main source of income, and the continuing need to import food and manufactured materials, isn't it likely that they will attempt to take what they cannot afford to buy? I suggest that there is a greater risk of war as long as petroleum is such a precious commodity. Memoranda originating within our own State Department call for the application of political and military counterpressures in the event that our suppliers reduce their shipments to us by 6 million barrels per day.

However, I don't think that the market for petroleum will dry up just because alternate energy sources become available. Plastics, fertilizers and lubricants are all derived from petroleum, and the manufacture of these products from other raw materials may prove too difficult and expensive.

One benefit that would be shared by all petroleum importing countries is a more favorable balance of payments. A large portion of the debt of the Third World countries can be traced directly to their imports of oil and oil-based products. Should these nations default on their loans, the industrialized societies will be shaken to their economic foundations.

All in all, it seems to me that a reduced dependence on fossil fuels can have only beneficial effects.

In recent weeks, newspapers and television have given us shocking accounts of mass starvation in Africa. Many of us are moved to ask ourselves, "How did this happen? Is the world's population approaching its limit? Are there more people than we can feed?" Happily, the answer to the last two questions is a resounding NO! The answer to "How did this happen?" is more complex. Some of the more obvious causes are economic, some are political, and some are cultural. Mother Nature, and, to some extent developing technology, are also involved.

Let me give you an over-simplified analysis. During the quarter-century prior to 1972, famine had virtually vanished from Africa and the Indian subcontinent. Grain surpluses, produced mostly by U.S. and Canadian farmers, kept food prices low and stable. U.S. farmers produced such large surpluses that, after monsoons in 1965 and '66 failed to deliver the needed rainfall in India, the United States was able to ship one-fifth of its wheat crop to that country. However, in 1972, after several crop failures, the Soviet government decided to import grain rather than ask Russian citizens to tighten their belts. Within months, the world price of wheat had doubled.

At about the same time, the OPEC nations raised the price of oil, resulting in even greater drains on the resources of Third World countries and aggravating the situation still further. They couldn't afford to import grain, and they had to divert money away from projects that would have increased their own production and distribution capabilities. As is apparent from the news reports, many low-income countries still lack the roads and equipment needed to move grain to their people-even when it is given to them.

The roots of the present misery lie not in our inability to produce enough food, but in waste, in government strategies that regard food as a political and economic weapon, in a failure to devote enough of our resources to research and development aimed at increasing yields, and in a poverty cycle that enmeshes hundreds of millions of people.

How much food is wasted? Well, waste occurs at many points in the food chain-so let's just pick one example. Gray rats. By World Health Organization estimates, there are presently more gray rats on this planet than people. One rat eats up to 30 kg (about 65 pounds) and spoils another 150 kg of foodstuffs per year. If we just consider what they eat, rats consume about 480 billion pounds of food-the equivalent of 100 extra pounds per year for every man, woman and child. Large scale attempts at trapping rats have been remarkably unsuccessful. However, current research in pheromones (the chemicals involved in animal communication) could lead to the use of lures to trap not only rats, but also many kinds of insects that chew, siphon, shred and contaminate everything from asparagus to zucchini.

But let's approach this in a more orderly fashion. Here are the problems as I see them-and not necessarily in the order of importance:

A large percentage of the cultivated land is of marginal quality. The reasons are varied: not enough nitrogen, not enough minerals (especially potassium and phosphates), poor drainage, accumulated minerals from repeated irrigation, and on and on.

Plant and animal diseases take an enormous toll, weakening or killing entire crops, flocks and herds.

In addition to food eaten or spoiled by rodents and insects, there is the food that rots from overly long or improper storage.

Weather conditions may freeze, parch, or drown both plants and animals.

Large-scale agriculture is an energy-intensive activity. Huge amounts of energy go into tilling the soil, planting, weeding, spraying, fertilizing, harvesting and transporting. The manufacture of fertilizer, alone, consumes half as much energy as all the other activities combined.

The policies of some governments artificially support food prices, keeping them so high that poorer nations can't afford what they need.

Food is beginning to be treated as a political and economic weapon-something to be given to friends and withheld from adversaries. And, since we're on a roll, let's throw in a few more problems like transporting the food from where it's produced to where it's needed, and the potential for severe ecological damage from over-fertilization and the use of pesticides.

What are the solutions? The political considerations will vanish when the collective will of the people mandates a change. Science and technology can handle most of the rest-AND PROBABLY DO IT BY THE END OF THIS CENTURY! Ah! I can see you rolling your eyes and nudging each other. You think the fumes in the lab have pickled my brain. Well, at the risk of reinforcing your belief, I'll give you the answer in just two words-Designer Genes. No, I haven't misspelled the second word. I'm talking about tailor-made pieces of genetic material, called genes, that can be inserted into a plant or animal cell, enabling the cell to do something it couldn't do before. The technology to accomplish this is called genetic engineering, and the genetic material is recombinant DNA.

How does it work and what can we use it for? Before I answer those questions, I would like to give you the world's shortest course in molecular biology.

Every living organism is made of cells-even microscopic ones like bacteria, algae and molds. Cells generally grow until they reach a certain stage, and then split into two identical smaller cells. Within each cell is a set of instructions written in an alphabet that has only four symbols. Each of the symbols is actually a molecule. Let's use the letters A, C, G and T to stand for these four different molecules. The instructions are written in the same way you write words-by stringing the molecules together-except that all the words in this language are three letters long. So the entire language contains only 64 words. The entire message resembles a molecular ticker tape, and is so small that, even when it is magnified to the limits of our ability, we still can't read the message.

Since each organism starts out as a single cell, it must contain all of the instructions that will be needed during the lifetime of that organism. Before a cell divides, it makes a duplicate of everything so each of the new cells will be identical.

The instructions, then, are like the script for a play: each member of the cast receives the entire script, but reads only his or her own parts. So each cell gets all the instructions, but carries out only certain ones.

We are prevented from reading the message by a complementary strand that meshes with the message strand like the other half of a zipper. Under the right conditions, the zipper opens and exposes the message. The next step is not technically correct, but it preserves the essence of the process, which is the translation of the message.

Let's read the message. The first three-letter word, TAC, is a signal to begin. The next two words, CTA and AAG, instruct the cell machinery to join the amino acids, aspartic acid and phenylalanine, in that order. The last word, ATC, is a stop signal. And we have just seen how a cell would carry out instructions to make about 90% of the molecule called aspartame (an artificial sweetener whose trade name is Nutrisweet).

How do we get these instructions into the cell? Bacteria contain a doughnut-shaped strand of genetic material called a plasmid. It is a relatively simple matter to remove the plasmid, snip it open, splice in a new gene, and return the plasmid to the cell-which now begins to carry out its new orders. By using this technique, scientists have created strains of bacteria capable of producing human insulin, interferon, or antibiotics. Scientists at General Electric have produced a bacterium that eats oil. Research projects aimed at introducing new characteristics into plant cells are well under way, and are expected to bear fruit by the end of this century.

Let me tell you a story that may help to convey the power of genetic engineering. Cereals provide 70-80% of the total calories in the diets of persons in underdeveloped countries and more than two-thirds of their protein. Wheat is the largest single crop in the world. The two cereals, rye and wheat, belong to different species. Rye, from the genus Secale, is hardy, resistant to diseases and has a high content of the essential amino acid, lysine. Wheat, from the genus Triticum, is high in protein (but low in lysine), more affected by diseases, poor soil and bad weather-but produces high yields when conditions are favorable. Although highly nutritious, rye flour doesn't make satisfactory bread or pasta unless mixed with wheat.

The hybrid, Triticale, is cheaper and more nutritious as animal feed than soybeans, makes excellent bread, and produces high yields under poor conditions. Creating this hybrid by conventional plant breeding methods took almost 30 years: genetic engineering may be able to accomplish the same thing in about three.

I'll choose just one other problem from the list I gave you. Fertilizers. All plants need nitrogen, phosphorus and potassium to grow. Ultimately, all of the nitrogen used by a plant comes from nitrogen molecules in the air. Unfortunately, plants can't use these molecules directly-it must be in a soluble form like ammonia or nitrates. Bacteria and molds in the soil cause the decay of plant and animal remains, or of animal wastes, and provide some of the nitrogen. If these materials are not available or in short supply, nitrogen fertilizers are used. Some plants (including soybeans, peas and clover) form a partnership with bacteria that live in swellings on their roots, and "fix" the nitrogen from the air into soluble forms. One of the main goals of genetic engineering is to introduce genes into plants which will enable them to fix nitrogen on their own, eliminating most of the need for nitrogen fertilizer.

Other current projects are aimed at increasing the efficiency of photosynthesis and giving plants the ability to tolerate salt buildup in the soil. There is no major barrier to the achievement of these goals-except the scarcity of research and development funds. However, a 1980 Supreme Court decision may make it harder for Third World nations to benefit from this technology. The court ruled that engineered life forms could be patented. This has the effect of increasing the financial support for research, but licensing fees for their use may prevent poorer nations from using them. There is a way out. An individual's property is sometimes appropriated by the Right of Eminent Domain when its use by the public constitutes a higher good. Surely this is a higher good than using someone's land for a parking lot or a freeway.

Finally, we come to the problem of health maintenance. As you might suspect, the technology that can introduce a new gene into a plant cell should allow us to do the same to animals. For what purpose? Current estimates place the number of human diseases caused by missing or malfunctioning genes close to three thousand! Most of these are rare-affecting an extremely small part of the population, but some are known all too well: three hundred varieties of cancer, alone, plus diabetes, hemophilia, sickle cell anemia, Huntington's, thalassemia and pituitary dwarfism. Even heart disease is believed to have a genetic predisposition. As one doctor put it, "About the only medical problem that doesn't have some kind of genetic link is being hit by a truck."

Take sickle cell anemia. This usually fatal disease is the result of abnormal protein molecules in the red blood cells that cause them to lose their usual LifeSaver shape and curl up into crescents or sickles. The disease can be traced back to the insertion of a "T" in a spot where there should be an "A" in the genetic message.

It is theoretically possible to correct the information in a human cell to make it function normally, or to insert the proper gene if it is missing. How close are we to doing this? It has already been done in animals. A gene that directs the production of a growth hormone in rats was implanted into mouse embryos, which grew into mice twice their normal size. Three generations of descendants from Super Mouse were also oversized. However, this kind of transfer-promising though it may be-is not contemplated for humans. Recombinant DNA research is the most closely scrutinized and regulated type of scientific investigation. A lengthy screening and review process must precede any experiments of this type. One UCLA professor was stripped of his job and a half-million dollar grant for altering the design of an experiment involving a terminally ill patient. Perhaps this means that scientists are recognizing their moral responsibilities regarding the effect of their work. At any rate, only experiments involving somatic-or body-cells of humans are being contemplated at this time.

The first approved clinical trial of gene therapy has been scheduled for some time before 1987. The target disease-Lesch-Nyhan Syndrome-is the failure to produce an enzyme needed to prevent buildup of uric acid. The disease affects the nervous system, causing mental retardation and cerebral palsy. I must point out that the only human tissues that can be used for gene transfer at the present time are bone marrow and skin cells. No other cells can be taken out, grown in culture, manipulated, and put back successfully. Considering that most of the technology for genetic engineering has developed in less than 10 years, it would not be surprising to hear of successful gene manipulation within another decade.

One major health problem that isn't likely to benefit from gene therapy is that parts of our bodies wear out. Arteries become clogged or develop leaks, or the liver gets balky, bone surfaces erode, the heart loses its rhythm. Organ transplants have achieved some small success, but the problem of rejection has not been solved. Artificial body parts may be the solution for many problems. The Jarvik heart. Artificial hip joints. Synthetic finger bones. An implanted insulin pump. The variety of synthetic parts seems limited only by the imagination.

Last, but far from least in our litany of ailments, are those which are caused by microbes-measles, malaria, hepatitis, herpes, polio, plague and all their horrible cousins. Many of these are caused by bacteria, and there is almost none beyond the reach of antibiotics. Viral diseases don't respond to antibiotic therapy, but there are strong indications that they can be mastered by interferons-a class of natural compounds that seem to stimulate the immune system and change the cell surfaces to prevent the virus from entering. Clinical trials with interferons are underway, but are hampered by scarcity of material-once valued at $3 billion per pound. The recent success in engineering bacteria to produce interferons should lead to a rapid evaluation of these promising materials. The same genetic manipulations are helping to speed the development of effective vaccines against malaria and AIDS.

So where does this leave us? There seems to be little doubt that people in the next century will live longer and be healthier. But will they be happier? Will the quality of life be greater just because it lasts longer? And who will be able to afford these medical miracles? The recently publicized heart surgery on baby Fae typically costs more than $75,000. Health care costs are rising at a rate three times that of other services, and governments are going broke trying to pay the bills and provide pensions to an ever-increasing percentage of their populations. Will it be worth the cost?

Well, we've reached the end of the line. Maybe the picture I've drawn of what is possible isn't your idea of Utopia, but to me it represents a considerable improvement in the human condition-and I'm willing to settle for that. Who really wants Utopia? After all, the word Utopia was derived from two Greek words meaning "not any place!"

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