TECHNOLOGY AND SOCIAL JUSTICE

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Technology and Social Justice

It is easy to find historical examples illustrating the thesis that technology may have something to contribute to social justice. In the fourteenth century the new technology of printing changed the face of Europe, bringing books and education out of the monasteries and spreading them far and wide among the people. Printing gave power to the Bible and led directly to the Protestant Reformation in Northern Europe. One may question whether Luther's Germany and Shakespeare's England enjoyed social justice, but they were certainly closer to it than the medieval Germany and England out of which they grew. Luther and Shakespeare brought at least the idea of justice—if not the reality—to ordinary citizens outside the nobility and the priesthood. The Protestant ethic, which took root in Germany, England, Holland, and Scandinavia with the help of printed books, carried with it a perpetual striving for social justice, even if the Utopian visions were seldom achieved.

More recent technologies that contributed in a practical way to social justice were those of public health—clean water supplies, sewage treatment, vaccination, antibiotics. These technologies could only be effective in protecting the rich from contagion and sickness if they were also available to the poor. Even if the rich and powerful receive preferential treatment, as they usually do, the benefits of public health technology are felt to some extent by everybody. In countries where public health technologies are enforced by law, there is no large gap in life expectancy between rich and poor.

The technology of synthetic materials has also helped to erase differences between rich and poor. Throughout history, until the nineteenth century, only the rich could afford to dress in brilliant colors, furs, and silk. Fine clothes were a badge of privilege and wealth. In the nineteenth century the chemical industry produced artificial dyestuffs. The twentieth century added artificial fur and silk and many other synthetic fabrics

cheap enough for working-class women to afford. No longer can one tell a woman's social class by her clothes. It is a measure of social justice in modern societies that the children of the rich now dress down, imitating the style of the majority both in clothes and in behavior.

Household appliances are another technology with a tendency towards social justice. When I was a child in England in the 1920s, my mother employed four full-time servants: a cook, a housemaid, a nursemaid, and a gardener. We didn't consider ourselves rich. My father was a schoolteacher. We were an average middle-class family. In those days an average middle-class family needed four servants to do the hard manual work of cooking, cleaning, child care, and gardening. To do all this work a whole class of people existed who spent their lives as domestic servants. The professional and intellectual classes to which we belonged were riding on the backs of the servant class. Because of the servants, my mother had leisure to organize socially useful projects, such as a club for teenage girls and a birth control clinic. The birth control clinic was undoubtedly a godsend to the women who came to it for instruction in the art of not having unwanted babies. But it did not in any way narrow the gulf between her and them. She always spoke of her birth control clientele like a mistress speaking of servants.

My mother was a kind mistress and treated the servants well, according to the standards of the time, but the servants knew their place. They knew that if they disobeyed orders or answered back, they would be out on the street. Now, like the antebellum South, the servant class in England is gone with the wind, and the wind that blew it away was not the ravaging invasion of Sherman's army, but the peaceful invasion of an army of electric stoves, gas heaters, vacuum cleaners, refrigerators, washing machines, drying machines, garbage disposals, freezers, microwave ovens, juicers, choppers, and disposable diapers. The technology of household appliances made servants unnecessary, and, at the same time, the children of the servant class began to go to college and make the transition to the middle class. The transition was not painless,

but it was less painful than a civil war. It was a big step on the road to social justice.

I remember with great fondness the nursemaid, Ethel, who cared for me as a young child. She had left school, as girls of the servant class did in those days, at the age of fourteen. When my sister and I were safely in bed in the night nursery, we sometimes heard the "putt, putt, putt" of a motorbike approaching the house, stopping, and then driving away into the night. That was Ethel's young man taking her out for the evening. The motorbike was the first harbinger of the approaching social revolution. The motorbike was the technology of upward mobility. After Ethel left us and married the young man, she had three daughters of her own, and all of them went to college. One of her grandsons is now a university professor.

Those are enough examples to show that technology can be helpful in the struggle for social justice. But in each case, as Edward Tenner tells us in his book *Why Things Bite Back*, a step forward in technology tends to bring with it an unexpected step backward. A step forward for some people frequently brings with it a step backward for others. And it often happens that when an old privileged class of people is dispossessed and the blessings of wealth and power are spread more equally, the burdens of equalization fall disproportionately upon women. When the revolutions accompanying the technology of printing destroyed the wealth and power of the monasteries over much of Europe, both male and female orders were dispossessed, but the nuns lost more than the monks. Nuns in the old convents were in many ways more free than wives in the new Protestant communities. The old monastic society provided a refuge where women of outstanding ability—for example, Hildegard of Bingen—had access to higher education. Sheltered and supported by the monastic orders, women could follow their vocations as scholars and artists. When the monasteries were dissolved, nuns had to find shelter in other people's homes, either as wives or as servants. The new secular society replaced the monasteries with colleges and universities. In the universities

men scholars could find shelter and security, but there was no place for women.

The technology of household appliances, likewise, brought a step backward to the stratum of society to which my mother belonged, the women of the middle class. My mother would be considered by the standards of today a thoroughly liberated woman. Trained as a lawyer, she helped to write the Act of Parliament that opened the professions in England to women. With the help of her servants, she could take care of her husband and children without being confined to the home. She was free to pursue her interests outside the home—her girls' club and birth control clinic. But she was by no means the most liberated of the women in our family. I had a collection of aunts who were in various ways more liberated than my mother. All of them had husbands and most of them had children, but this did not stop them from being liberated. All of them were more adventurous than their husbands. My Aunt Margaret was trained as a nurse and rose to become a matron, which meant that she was the managing administrator of a large hospital. My Aunt Ruth was a figure skater of international repute who kept an Olympic silver medal among her trophies. My Aunt Dulcibella was the first woman in England to receive an airplane pilot's license. She and her husband had an airplane which they used for traveling around in Africa. They loved Africa, and their lifestyle would have fit in very well with the group of adventurers that Michael Ondaatje describes in his novel *The English Patient*. My Aunt Dulcibella was also a professional actress, and if she had only been eighty years younger, she might have had a starring role in *The English Patient* movie. We did not consider these aunts of ours to be unusual. It was normal at that time for middle-class women to do something spectacular. My mother, with her birth control clinic, was the quiet one, the least daring of the four.

Now, consider what happened to the next generation of middle-class women in England and the United States. Thirty years later, in the 1950s, the servants were gone and the electrical appliances were taking their place. For wives and

mothers of the middle class, this was a big step backward. Appliances do not cook the dinner, clean the house, do the shopping, and mind the baby. The middle-class women of the 1950s were far less liberated than their mothers. The liberation that my mother's generation achieved had to be fought for all over again. Even now, in the 1990s, women are only partially liberated. To achieve partial liberation, they have replaced the old domestic servants with day care centers, cleaning ladies, and *au pair* girls imported from overseas. Electrical appliances help, but they only do a small part of the job.

The Institute for Advanced Study, where I have spent my working life, is a peculiar institution with a small permanent faculty. The faculty is supposed to be representative of the most distinguished men and women in academic life. Unfortunately, we have always found it difficult to appoint women to the faculty. The original faculty, appointed in the 1930s, contained one woman, the archaeologist Hetty Goldman. I remember her vividly. She was a formidable lady, small in stature and large in spirit, who led excavations of ancient sites in Turkey, ruling over small armies of Turkish laborers with an iron hand. Her colleagues used to say she was the equal of any two male archaeologists. There was never the slightest doubt that she had the "right stuff" to be an Institute professor. She was a natural leader in her own eyes and in ours. She belonged to my mother's generation of liberated women. She grew up, like my mother, in a society of women with servants. When she retired in 1947, she was not replaced. For almost forty years the Institute faculty was entirely male. In 1985, the sociologist Joan Scott became the second woman to join the faculty. And in 1997 the historian Patricia Crone became the third.

The history of our faculty encapsulates in a nutshell the history of women's liberation: a glorious beginning in the 1920s; a great backsliding in the 1950s; a gradual recovery in the 1980s. It is not altogether fanciful to blame the technology of household appliances for the backsliding. The advent of electrical appliances liberated the servants and shackled their mistresses.

High-Tech Medicine and Computers

I have discussed four technologies that led to large expansions of social justice. Although each of them had compensating negative effects, especially on women, the overall effects of all of them were predominantly positive. It will be just as easy to find examples of technologies that had predominantly negative effects. One could mention the technologies of gas chambers and nuclear weapons, useful for the convenient extermination of people to whom we do not wish to extend the benefits of social justice. But the more troubling examples are two of the technologies that are making the most rapid progress today: high-tech medicine and high-tech communication.

All of us who live in the United States are familiar with the ugly face that high-tech medicine presents to the patient: the initial telephone call answered by a machine rather than a human voice; the filling out of forms in the office; the repetitive answering of questions; the battery of routine chemical and physical tests carried out by technicians wearing rubber gloves; and finally, the abbreviated contact with the physician. It is all very different from the old-fashioned practice of medicine, when doctors were personal friends and advisers to patients and sometimes even made house calls. The face of high-tech medicine is ugly even when the patient is rich, and uglier still when the patient is poor. The ugliness results from many factors working together. First, the prevalence of malpractice litigation, which destroys trust, compelling doctors to conform to rigid rules and surrounding them with layers of bureaucratic documentation. Second, the high cost of the equipment that high-tech medicine demands, forcing medical centers to adopt elaborate cost-accounting systems. Third, the size of the staff needed to operate a high-tech center, with many doctors qualified in narrow specialties so that the patient rarely gets to see the same doctor twice. Fourth, the overwhelming cost of hospitalization, allowing patients a bare minimum of days for rest and recuperation after major illness or surgery. These factors, together, led to the situation

that confronts the patient today. What the patient needs most, but finds least, is personal attention.

Since personal attention has become the scarcest resource in high-tech medicine, it is inevitable that it should be distributed unequally. The majority of advanced countries have national health services that attempt, with varying degrees of success, to distribute medical attention fairly. In countries with national health services, medical attention is theoretically available to everybody. This is what the ethic of social justice demands. But the escalating cost of medical attention makes social justice more and more difficult to achieve. One way or another, as personal attention becomes scarcer, people of status tend to receive more of it and people without status to receive less. The national health services in countries where they exist make valiant efforts to preserve the ideal of social justice, but the march of medical technology and the concomitant increase of costs constantly erode the ideal. In the United States, which never had a national health service and does not pretend to distribute medical resources equally, the prospects for social justice are far worse. In the United States a medical system based on the ethic of the free market inevitably favors the rich over the poor, and the inequalities grow sharper as the costs increase.

I have seen in my own family a small example of the dilemma that the growth of high-tech medicine presents to physicians. One of my daughters is a cardiologist. For many years she worked in state-supported hospitals taking care of patients as they flowed through the system, working brutally long hours and still having little time for personal contact with her patients. Her patients in the public hospitals were predominantly poor and uninsured. Many of them had AIDS or gunshot wounds in addition to cardiac problems. The public health system, such as it was, was designed to get these patients out of the hospital and back on the streets as fast as possible. Last year my daughter was offered a job in a private cardiology practice with far shorter hours, better pay and working conditions, and an expectation of long, continued care of her patients. She accepted the offer without much

hesitation. She is much happier in her new job. Now, for the first time, she knows her patients as individuals and can tailor their treatments to their individual histories and personalities. She feels that she is a better doctor, and her new job gave her the flexibility to take time off to have her first baby last July. From almost every point of view, her jump into private practice was a wise move. Her only problem was a small twinge of conscience for having abandoned the poor to take care of the rich. In the private practice her patients are not all rich, but they are all paying for the personal attention that she is now able to give them. She was forced to make a choice between social justice and professional satisfaction, and social justice lost. I don't blame her. But in a socially just society, physicians would not be forced to make such choices.

Similar dilemmas, not so stark as the dilemmas of medical practice but equally important, exist in the world of high-tech computing and communications. Here, too, there is a clash between the economic forces driving the technology and the needs of poor people. Access to personal computers and the Internet is like medical insurance: almost everybody needs it, but most poor people don't have it. The people who are wired, the people who browse the World Wide Web and conduct their daily lives and businesses on the Net, have tremendous economic and social advantages. Increasingly, jobs and business opportunities are offered through the Internet. Access to the Internet means access to well-paying jobs. People who are not wired in are in danger of becoming the new servant class. The gulf between the wired and the unwired is wide, and growing wider.

The computer and software industries are driven by two contradictory impulses. On the one hand, they sincerely wish to broaden their market by making computers accessible to everybody. On the other hand, they are forced by competitive pressures to upgrade their products constantly, increasing their power and speed and adding new features and new complications. The top end of the market drives the development of new products, and the new products remain out of the reach of the poor. In the tug of war between broadening the market

and pampering the top-end customer, the top-end customer usually wins.

The problem of unequal access to computers is only a small part of the problem of inequality in our society. Until the society is willing to attack the larger problems of inequality in housing, education, and health care, attempts to provide equal access to computers cannot be totally successful. Nevertheless, in attacking the general problems of inequality, computer access might be a good place to start. One of the virtues of the new technology of the Internet is that it has an inherent tendency to become global. The Internet easily infiltrates through barriers of language, custom, and culture. No technical barrier stops it from becoming universally accessible. To provide equality of access to the Internet is technically easier than providing equality of access to housing and health care. Universal access to the Internet would not solve all our social problems, but it would be a big step in the right direction. The Internet could then become an important tool for alleviating other kinds of inequality.

The Protestant Ethic and the Spirit of Capitalism

Up to now I have been talking as if technology came first and ethics second. I have been describing historical events in which technological changes occurred first and then increases or decreases of social justice occurred as a consequence. I depicted technological change as the cause of ethical improvement or deterioration. This view of history is opposed to the view propounded by Max Weber in his seminal book *The Protestant Ethic and the Spirit of Capitalism*. Weber argued that the Protestant ethic came first and the rise of capitalism and the technologies associated with it came second. Weber's view has become the prevailing view of modern historians. Weber said that ethics drove technology. I say that technology drives ethics.

I am not trying to prove Weber wrong. His historical vision remains profoundly true. It is true that the religious revolutions of the sixteenth century engendered an ethic of

personal responsibility and restless inquiry, an ethic that encouraged the growth of capitalistic enterprise and technological innovation. It was no accident that Isaac Newton, the preeminent architect of modern science, was also a Protestant theologian. He took his theology as seriously as his science. It was no accident that King Henry VIII, the man who brought the Protestant revolution to England, also endowed the college where Newton lived and taught. Henry and Isaac were kindred spirits—both were rebels against authority, enemies of the Pope, tyrants, supreme egoists, suspicious to the point of paranoia, believers in the Protestant ethic, and in love with technology. Henry loved to build ships and Isaac loved to build telescopes. It is true that ethics can drive technology. I am only saying that this is not the whole truth, that technology can also drive ethics, that the chain of causation works in both directions. The technology of printing helped to cause the rise of the Protestant ethic just as much as the Protestant ethic helped to cause the rise of navigation and astronomy.

I am not the first to take issue with Weber on this question. The historian Richard Tawney also studied the interrelationships of religion and capitalism and came to conclusions similar to mine. He held Weber in high esteem and contributed a foreword to the English translation of *The Protestant Ethic and the Spirit of Capitalism.* Here are the concluding sentences of Tawney's foreword: "It is instructive to trace with Weber the influence of religious ideas on economic development. It is not less important to grasp the effect of economic arrangements accepted by an age on the opinion which it holds of the province of religion." Tawney's view is that technology influenced religion as strongly as religion influenced technology. Since my view of history is closer to Tawney's than to Weber's, I now ask the question: How can we push new technologies into directions conducive to social justice? How can we make ethics drive technology in such a way that the evil consequences are minimized and the good maximized? I shall hope to persuade you that the situation we are

in is not hopeless, that new technologies offer us real opportunities for making the world a happier place.

The Sun, the Genome, and the Internet

Finally, I turn to the positive side of my message. Technology guided by ethics has the power to help the billions of poor people all over the earth. My purpose is to help push technology in a new direction, away from toys for the rich and toward necessities for the poor. The time is ripe for this to happen. Three huge revolutionary forces are being harnessed just in time for the new century: the sun, the genome, and the Internet. These three forces are strong enough to reverse some of the worst evils of our time. The evils I am hoping to reverse are well known to you all. All over the earth, and especially in the poor countries to the south of us, millions of desperate people leave their villages and pour into overcrowded cities. There are now ten megacities in the world with populations twice as large as New York City. Soon there will be more. We all know that the increase of human population is one of the causes of the migration to cities. The other cause is the poverty and lack of jobs in villages. Both the population explosion and the poverty must be reversed if we are to have a decent future. Many experts on population say that if we can mitigate the poverty, the population will stabilize itself, as it has done in Europe and Japan. I am not an expert on population, so I won't say any more about that. I am saying that poverty can be reduced by a combination of solar energy, genetic engineering, and the Internet. Our task in the next century is to put the new technologies to work in the cause of social justice. Social justice means making the new technologies accessible to everyone, to bring wealth to poor countries and hope to poor people.

I have seen with my own eyes what happens to a village when the economic basis of life collapses, and I have seen how the economic basis of village life can be revived. My wife grew up in Westerhausen, a village in East Germany that was under Communist management. The Communist regime

took care of the village economy, selling the output of the farms to Russia at fixed prices, which gave the farmers economic security. The village remained beautiful and, on the whole, pleasant to live in. Nothing much had changed in the village since 1910. One thing the Communist regime did was organize a zoo, with a collection of animals maintained by a few professionals with a lot of help from the local school children. The village was justly proud of its zoo. The zoo was subsidized by the regime so it did not need to worry about being unprofitable. I visited the village under the old regime in 1975 and found it very friendly. Then came 1990 and the unification of Germany. Overnight, the economy of the village was wrecked. The farmers could no longer farm because nobody would buy their products. Russia could not buy because the price had to be paid in West German marks. German consumers would not buy because the local produce was not as good as that available in the supermarkets. The village farmers could not compete with the goods pouring in from France and Denmark. So the farmers were out of work. Most of the younger generation moved out of the village to compete for jobs in the cities, and most of the older generation remained. Many of them, both old and young, are still unemployed. The zoo, deprived of its subsidy, collapsed.

The sad exodus that I saw in the village of Westerhausen when I visited there in 1991 is the same exodus that is happening in villages all over the world. Everywhere the international market devalues the work of the village. Without work, the younger and the more enterprising people move out.

In the seven years since the unification, Westerhausen has slowly been recovering. Recovery is possible because of the process of gentrification. Wealthy people from the local towns move in and modernize the homes abandoned by the farmers. Cottages are demolished to make room for two-car garages. Ancient and narrow roads are widened. The village will survive as a community of nature lovers and commuters. Lying on the northern edge of the Harz Mountains, it is close to the big cities of northern Germany and

even closer to unspoiled mountain forests. Its permanent asset is natural beauty.

Two months ago my wife and I were back in the village. The change since we had last visited in 1991 was startling. We stayed in the elegant new home of a friend who had been in my wife's class in the village elementary school fifty years earlier. The village now looks well cared for and prosperous. The recovery from the disaster of 1990 has been slow and difficult, but it has been steady. The government did two things to mitigate the harshness of the free market: it allowed every homeowner to borrow money with almost zero interest from the government to modernize houses, and it allowed every farming cooperative to borrow money with almost zero interest to modernize farms. As a result, the houses that were not bought by outsiders are being modernized, and the few farmers who remained as farmers are flourishing. The zoo has been revived. In addition, there are some new enterprises. A Western immigrant has planted a large vineyard on a south-facing hillside and will soon be producing the first Westerhausen wines. My wife's family and many of her friends still live in the village. They gave us a warm and joyful welcome.

The probable future of Westerhausen can be seen in a thousand villages in England. The typical English village today is not primarily engaged in farming. The typical village remains beautiful and prosperous because of gentrification. Wealthy homeowners pay large sums of money for the privilege of living under a thatched roof. The thatching of roofs is one of the few ancient village crafts that still survives. The thatchers are mostly young, highly skilled, and well paid. The farmers who remain are either gentlemen amateurs, who run small farms as a hobby, or well-educated professionals, who run big farms as a business. The old population of peasant farmers, who used to live in the villages in poverty and squalor, disappeared long ago. Discreetly hidden in many of the villages are offices and factories engaged in high-tech industry. One of the head offices of IBM Europe is in the English village of Hursley not far from where I was born. In the

villages of France, at least in the area I know around Paris, the picture is much the same. Wealth came to the villages because they have what wealthy people seek: peace, security, and beauty.

What would it take to reverse the flow of jobs and people from villages to megacities all over the world? I believe the flow can be reversed by the same process of gentrification that is happening in Westerhausen. To make gentrification possible, the villages themselves must become sources of wealth. How can a godforsaken Mexican village become a source of wealth? Three facts can make it possible. First, solar energy is distributed equitably over the earth. Second, genetic engineering can make solar energy usable everywhere for the local creation of wealth. Third, the Internet can provide people in every village with the information and skills they need to develop their talents. The sun, the genome, and the Internet can work together to bring wealth to the villages of Mexico, just as the older technologies—electricity and automobiles—brought wealth to the villages of England. Let me talk briefly about each of the three new technologies, in turn.

Solar energy is most available where it is most needed—in the countryside rather than in cities, and in tropical countries, where most of the world's population lives, rather than in temperate latitudes. The quantity of solar energy is enormous compared with all other energy resources. Each square mile in the tropics receives about 1,000 megawatts averaged over day and night. This quantity of energy would be ample to support a dense population with all modern conveniences. Solar energy has not yet been used on a large scale for one simple reason: it is too expensive. It cannot compete in a free market with imported coal, oil, and natural gas. The country that has used solar energy on the largest scale is Brazil, where sugar was grown as an energy crop to make alcohol as a substitute for gasoline in cars and trucks. Brazil protected and subsidized the local alcohol industry. The experiment was technically successful, but the cost was high. Brazil has now reverted to free-market policies, and the

experiment is at an end. What the world needs is not high-cost subsidized solar energy, but solar energy cheap enough to compete with oil.

Solar energy is expensive today because it has to be collected from large areas and there is not yet a technology that covers large areas cheaply. One of the virtues of solar energy is the fact that it can be collected in many ways. It is adaptable to local conditions. The two main tools for collecting it are photoelectric panels, which convert sunlight directly into electricity, and energy crops, like the Brazilian sugar plantations, which convert sunlight into fuel. Roughly speaking, photoelectric collection is the method of choice for deserts, and energy crops are the method of choice for farmland and forests. Each method has its advantages and disadvantages. Photoelectric systems have high efficiency, typically between 10 percent and 15 percent, but are expensive to deploy and maintain. Energy crops have low efficiency, typically around 1 percent, and are expensive and messy to harvest. The electricity produced by photoelectric systems is intermittent and cannot be cheaply converted into storable forms of energy. Fuels produced from energy crops are storable and, therefore, more convenient.

To make solar energy cheap, we need a technology that combines the advantages of photovoltaic and biological systems. Two technical advances would make this possible. First, crop plants could be developed that convert sunlight into fuel with efficiency comparable to photovoltaic collectors, in the range of 10 percent rather than 1 percent. This would reduce the costs of land and harvesting by a large factor. Second, crop plants could be developed that do not need to be harvested at all. An energy crop could be a permanent forest with trees that convert sunlight to liquid fuel and deliver the fuel directly through their roots to a network of underground pipelines. If those two advantages could be combined, we would have a supply of solar energy that was cheap, abundant, ubiquitous, and environmentally benign.

The energy supply system of the future might be a large area of forest with species of trees varying from place to

place to suit the local climate and topography. We may hope that substantial parts of the forest would be nature reserves closed to human settlement and populated with wildlife so as to preserve the diversity of the natural ecologies. But the greater part could be open to human settlement, with teeming towns and villages under the trees. Landowners outside the nature reserves would be encouraged, but not compelled, to grow trees for energy. If the trees converted sunlight into fuel with 10 percent efficiency, landowners could sell the fuel for $10,000 per acre per year and easily undercut the present price of gasoline. Owners of farmland and city lots alike would have a strong economic incentive to grow trees. The future energy plantation need not be a monotonous expanse of identical trees in regular rows. It could be as varied and as spontaneous as a natural woodland, interspersed with open spaces and houses, villages, towns, factories, and lakes.

To make this dream of a future landscape come true, the essential tool is genetic engineering. At present, large sums of money are being spent on sequencing the human genome. The Human Genome Project is motivated primarily by its medical applications. It will contribute enormously to the understanding and treatment of human diseases. It does not contribute directly to the engineering of trees. But alongside the human genome many other genomes are being sequenced—bacteria, yeast, worms, and fruit flies. For advancing the art of genetic engineering the genomes of simpler organisms are more useful than the human genome. Before long, we shall also have sequenced the genomes of the major crop plants—wheat, maize, and rice—and after that will come trees. Within a few decades, we shall have achieved a deep understanding of the genome, an understanding that will allow us to breed trees that will turn sunlight into fuel and still preserve the diversity that makes natural forests beautiful.

As soon as we can genetically engineer trees to use sunlight efficiently to make fuel, we shall also learn to breed trees that convert sunlight into useful chemicals of other kinds,

including silicon chips for computers and gasoline for cars. Economic forces will then move industries from cities to the country. Mining and manufacturing could be economically based on locally available solar energy, with genetically engineered creatures consuming and recycling the waste products. It might even become possible to build roads and buildings biologically, breeding little polyps to lay down durable structures on land in the same way as their cousins build coral reefs in the ocean.

But the third, and most important, of the triad of new technologies is the Internet. The Internet is essential to enable businesses and farms in remote places to function as part of the modern global economy. The Internet will allow people in remote places to make business deals, buy and sell, keep in touch with their friends, continue their education, and follow their hobbies and avocations, with full knowledge of what is going on in the rest of the world.

This will not be the Internet of today, accessible only to computer-literate people in rich countries and to the wealthy elite in poor countries. It will be a truly global Internet, using a network of satellites in space for communication with places that fiber optics cannot reach and connected to local networks in every village. The new Internet will end the cultural isolation of poor countries and poor people.

Two technical problems have to be solved to make the Internet accessible to almost everybody on a global scale: large-scale architecture and the problem of the "last mile." Large-scale architecture means choosing the most efficient combination of landlines and satellite links to cover every corner of the globe. The Teledesic system of satellite communication now under development is intended to be a partial answer to this problem. The Teledesic system has 280 satellites in a dense network of low orbits, allowing any two points on the globe to be connected with minimum delay. If the Teledesic system fails, some other system will be designed to do the job. The problem of the "last mile" is more difficult. This is the problem of connecting individual homes and families, wherever they happen to be, with the nearest Internet termi-

nal. The problem of the last mile has to be solved piecemeal, with methods depending on the local geography and the local culture. An ingenious method of solving the last-mile problem in urban American neighborhoods has been introduced recently by Paul Baran, the original inventor of the Internet. Baran's system is called Ricochet and consists of a multitude of small, wireless transmitters and receivers. Each user has a modem that communicates by radio with a local network. The feature that makes the system practical is that the transmitters constantly switch their frequencies so as not to interfere with one another. The system is flexible and cheap, avoiding the large expense of laying cable from the Internet terminal to every apartment and every house. It works well in the environment of urban America. It remains to be seen whether it is flexible and cheap enough to work well in the environment of a Mexican village or a Peruvian barrio.

Suppose, then, we can solve the technical problems of cheap solar energy, genetic engineering of industrial crop plants, and universal access to the Internet. What will follow? My thesis is that the solution of those three problems will bring about a worldwide social revolution, similar to the revolution we have seen in the villages of England and Germany. Cheap solar energy and genetic engineering will provide the basis for primary industries in the countryside. After that, the vast variety of secondary and tertiary economic activities that use the Internet for their coordination—food processing, publishing, education, entertainment, and health care—will follow the primary industries as they move from overgrown cities to country towns and villages. And as soon as the villages become rich, they will attract people and wealth back from the cities.

I am not suggesting that in the brave new world of the future everyone will be compelled to live in villages. Many of us will always prefer to live in large cities or in towns of moderate size. I am suggesting only that people should be free to choose. When wealth has moved back to the villages, people who live there will no longer be forced by economic necessity to move out, and people who live in megacities will no longer

be compelled by economic necessity to stay there. Many of us who have the freedom to choose, like the successful stockbrokers and business executives in England and Germany, will choose to live in villages.

So this is my dream: Solar energy, genetic engineering, and the Internet will work together to create a socially just world in which every Mexican village is as wealthy as Princeton. Of course, that is only a dream. Inequalities will persist. Poverty will not disappear. But I see a hope that the world will move far and fast in the directions I have been describing. Ethics must guide technology toward social justice. Let us all help to push the world in that direction as hard as we can. It does no harm to hope.