The Social Impact of Advanced Technology

DISCOVERIES International Symposium

OSU 1982

SYMPOSIUM PROCEEDINGS

THE SOCIAL IMPACT OF ADVANCED TECHNOLOGY

DISCOVERIES INTERNATIONAL SYMPOSIUM

THE OHIO STATE UNIVERSITY

MAY 10-13, 1982

To the memory

of

Ithiel de Sola Pool

Participant in four DISCOVERIES Symposia

and

Pioneer in the study of man and society

PREFACE

The Fifth DISCOVERIES International Symposium was held at The Ohio State University on May 10-13, 1982. Sponsored by the Honda Foundation of Japan, the Symposium dealt with issues relating to the theme of "The Social Impact of High Technology." Earlier DISCOVERIES Symposia had dealt with similar themes of the interaction between technology and man.

The Fifth DISCOVERIES Symposium brought a varied and stimulating group of participants to The Ohio State University's conference rooms. Eleven participants came from Japan, while seven persons representing six different countries attended the Symposium from Europe. The remaining one hundred twenty-five participants were from the United States. University scholars made up the largest group of participants: many of the eighty-five scholars were from The Ohio State University, but the University of Tokyo and Massachusetts Institute of Technology also each had several representatives. Among scholars thirty-one disciplines were represented as the Symposium brought together persons from a wide variety of engineering and scientific backgrounds with representatives of the social sciences, law and education. The fifty-nine participants from corporations and the professions included persons representing high technology companies like Bell Telephone, General Telephone and Cincinnati Milacron, high technology research centers such as Battelle Memorial Institute or other institutions where new technologies were in use or under study. In addition to the one hundred thirty-four participants, twenty-five special observers from the Honda Motor Company and Honda Foundation, led by Soichiro Honda, joined the Symposium.

The Fifth DISCOVERIES Symposium focused on what is called the "high technology age," the "information society" or the "second industrial revolution." Some participants addressed the issue of the current state of the art of the development and application of new technologies in communications and manufacturing; other speakers were concerned with evaluation of the current level of technology itself, such as the participants who discussed new medical technologies. Finally, both the needs of an advanced technology society and the implications of such a society for institutions like educational systems and labor markets, and more general social relationships such as the nature of authority in the workplace, were considered and discussed. As participants from near and far left Columbus at the end of the Symposium sessions, the general feeling was that many new perspectives had been developed which would help understanding of the nature of ongoing technological change and its social implications.

Many persons contributed directly or indirectly to the planning of the Symposium, to its execution and to the preparation of this book of proceedings. We are indebted to the Organizing Committee for their decisions on program development and to President Edward Jennings for his support throughout the planning and holding of the Symposium. Messrs. Taizo Ueda, Yasuro Nakano and Kohachiro Suzuki of the Honda Foundation were supportive at all times in planning the Symposium events. At Ohio State, Heather Arscott was a tireless organizer while Sandy Rich and Christine Hashimoto worked for several long months on proceedings drafts. Finally, we at Ohio State are indebted to the Honda Foundation for the funding which made the Symposium possible.

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GREETINGS FROM PRESIDENT RONALD REAGAN

I wish to welcome the participants of the DISCOVERIES International Symposium who have traveled to The Ohio State University from around the country and the world.

The impact of technology on modern society is one of today's vital issues. May we all soon realize the benefits of your discussions at the DISCOVERIES Symposium.

I would also like to express my appreciation to the Honda Foundation for the role it has played in making these deliberations possible. Best wishes for a successful week.

Read by Governor James A. Rhodes

GREETING FROM PRIME MINISTER ZENKO SUZUKI

I wish to congratulate you from my heart on this day of the opening of the 1982 DISCOVERIES International Symposium.

This symposium, which was held previously in Tokyo, Rome, Paris and Stockholm, will examine thoughtfully, and from a global perspective, the philosophical underpinnings of technological society. I firmly believe that the results stemming from these discussions will help pave the way for a society based on respect for mankind in the coming century.

It is very significant that this meeting, wherein leaders from different fields are gathered together to discuss the theme of the social effects of advanced technology in a frank and open way, is held in the United States of America which has led the world in advanced technology.

I strongly pray for the success of the 1982 DISCOVERIES International Symposium and for the development of the DISCOVERIES activities in general.

Read by Ambassador Yoshio Okawara

Humanity and the Bonds of Science

S. L. Fawcett

Human history reveals an interesting relationship between how people live their knowledge of science and their ability to use that science in their lives. The bonds between humanity and science are, indeed, strong, and scientific knowledge has had much to do with how people live - not only the creature comforts people enjoy but their ideals and social behavior.

As each new bit of scientific knowledge has been added to man's storehouse, he has used it to feed his dreams - to let his mind soar to new heights. In so doing, man has invented new devices to make his work easier; new materials to improve his habitat, clothes, and surroundings; new drugs to improve his health; and new toys and other devices to amuse him.

Thus, man's progress has had a number of bonds with science in the past, and his present and future are bonded to his knowledge of science and his ability to use it. Most of these bonds are beneficial in that they have made his life better, safer, longer, healthier, and happier. Some have been destructive. All, however, have been man's choice to use, and in that sense they must be considered positive bonds.

Other bonds I consider negative in that they were unused by man to change his life. Even though certain knowledge was available at a given point in history, man was unable or unwilling to put this knowledge to work.

Let us examine these bonds - both positive and negative - to see how they have advanced or failed to further the progress of humanity in the past. Let us then look at the present and at the negative bonds that result in a lack of human progress in certain areas, to our great peril.

When we look back in time at how science has influenced human life, we can imagine that in primitive times what I refer to broadly as "science" was actually nothing more than man's astute observation of natural phenomena. These observations suggested ways in which he could improve his life.

Very likely it was a tangled collection of branches and brush floating on a stream that suggested the possibility of a boat, and a natural waterfall that suggested the usefulness of dams and the use of water power to do work. Thus, from very simple observations, man began to build a storehouse of knowledge concerning flotation and hydrodynamics.

By the same token, man's knowledge of mechanics probably began with such simple observations as a rolling stone or a tree branch bending in the wind. These, in turn, led to wheels and to bows and arrows, and ultimately - over thousands of years - to carts, bicycles, and automobiles.

Similar suppositions can be made that a leaf drifting to earth was the first harbinger of aerodynamics and modern aircraft, and that observations of water boiling may have been the beginning of a body of knowledge we now know as thermodynamics - knowledge that has led to the steam engine, the internal combustion engine, the jet engine, and heat pumps.

As we approach modern history, it is interesting to note that it is combinations of ideas drawn from different bodies of knowledge that lead to increasingly more sophisticated devices. Early on, perhaps these combinations were happy accidents, but as we get to the nineteenth century, we see a great upsurge of conscious inventiveness. The steamship, railroads, automobiles, farm machinery and airplanes are just a few examples.

The development of man's world - as opposed to the natural world - began to accelerate more rapidly when he used his knowledge of materials and devices to build still other devices to study nature. With his ability to build devices for X-ray diffraction and electron microscopy, he was able to develop new insights that led to an understanding of the atomic and organizational structure of metals, chemicals, and biochemical materials.

Thus, in the 20th century, we have come to the formalized and well financed search for new scientific knowledge and the means to apply it. "Research and develoment" became part of the lexicon of business and industry.

This, of course, is a very much oversimplified and telescoped account of how man has generated scientific knowledge and used it. However, I hope it is sufficient to make the point that man, over centuries, has arduously gained the power to change and rearrange the physical world. What is every bit as important is that the changes he has wrought through the use of science have also brought dramatic changes in human society. In effect, man has changed man. So it is important that we look at the social effects of the bonds of science.

Consider, for example, how labor-saving devices have changed our way of life. The cotton gin is a classic American example, and, indeed, we can see that it not only changed our way of life but the course of history. Many of you, I am sure, are familiar with the story of Eli Whitney - how, as an unemployed boarder with a Georgia family, he evolved his epoch-making invention. In retrospect, we can say it was an absurdly simple contrivance that might have occurred to anyone who might have been living in the American South at the time. Nonetheless, it changed the economic, political, and industrial face of the country. Without that invention, historians have concluded, it is highly conceivable that the Civil War would never have occurred, that Abraham Lincoln would have remained a small-town lawyer, and that the deep South would have labored under the smoke clouds of factories.

A similar case can be made for the reaper and other farm machinery that boosted farm productivity to almost unbelievable levels. The result was the mass exodus of people from farms to the cities to work in the factories - also the result of man's innovation. And what of the cities? Elevators, escalators, mass transit systems, and plumbing and sewage disposal systems - all part of man's technology - helped to make the cities livable. At times, some of us may question whether today's cities are very livable, but from the descriptions of the medieval cities of Europe, there has certainly been notable progress.

And what of the modern home? In my lifetime, and that of many of you, improvements in houses and apartments, themselves, and in furnishings and appliances have changed our life style markedly. Automatic washers and dryers, frozen food storage, and microwave cooking have probably done more to "liberate" women than all of the rhetoric on the subject. Women, as homemakers in the 1920s, literally had a 24-hour job. Whereas, many women today are able to maintain a home and pursue a career with relative ease. Of course, I should add that a change in attitudes about the division of work in the household between husband and wife has also contributed to a change in life style.

Perhaps the examples I have cited so far with respect to the social effects of science are particularly American. But there are others that are almost universal. Think of what radio has done to the world - and to a lesser, but important extent, what television has done and is doing. Even in the most remote parts of the world, the inexpensive battery-powered radio has made it possible for people from all walks of life to know what is happening in their own immediate surroundings and throughout the world. Political leaders certainly are aware of the implications of this development. Television, too, is having a similar effect - at least in the developed world.

And now we are coming to the combination of television, telecommunications, and computers that may drastic alter work, travel, and recreation patterns. In time, the home may once again become the primary work place for many of us, many of the errands and chores now done on foot and with a car may be handled at a keyboard, and we may be able to stay home and confer eye-to-eye with people in many parts of the nation or the world.

I have only touched the surface.

So much for what has happened. Now, what are the bonds of science that are presently pulling man further toward his destiny? With today's modern methods of communication, it is easy to identify some of them.

First, one can't ignore the fantastic impact of communication/information/computation science. This combination of technologies is so pervasive in today's life and consciousness.

The second set of current scientific bonds is similarly impressed on the public consciousness. This is the area now properly called biotechnology: use of our knowledge of biological processes to improve our health and to provide useful chemicals, foodstuffs, and other products. In some cases, there is more speculation and anticipation concerning the value of this scientific area than there is actual progress. However, all of us, including me, see a great new frontier of useful science immediately ahead of us. Certainly, these are strong bonds.

Other not quite so well recognized, but nevertheless strong bonds with science are being applied at the present time. These lie in the area of composite plastics and directly formed metals. Right in Columbus' own "front yard," the Owens Corning Fiberglas Technology Center in Granville is bringing forth a whole new era in the use of reinforcing plastic technology. Already, we have seen Fiberglas-reinforced boats, swimming pools, and bathtubs become commercial realities. In the next several decades, we will undoubtedly see entire automobiles, trucks, and household appliances with integral hydraulic and electronic systems evolved from only a few pieces.

Another area of quite spectacular progress is being spearheaded at Battelle Memorial Institute in directly formed metals. These metal bodies featuring unusual electrical conductivity, magnetic permeability, and ease of fabrication are just coming on the world stage of utilization for human benefit.

The list goes on. I will not attempt to complete it here today. Needless to say, all of these scientific areas have their role to play in making man's world a better one for his habitation and quality of life.

It is always tempting for scientists and engineers to tell the good news. They are not alone! Everyone from the butcher and the baker to the candlestick maker likes to tell the world how important and irreplaceable his or her particular field or endeavor is. No one likes to point to his failures. Nevertheless, throughout history man has had knowledge available to him that he didn't use, and, because he didn't use it, the course of history was different than it might have been. The result, at times, has been untold disease, suffering, hunger, pain, and loss of life.

Some of man's failure to use knowledge was the result of his inability to invent and to innovate beneficial applications of existing knowledge. Some of it was because of his taboos - man's belief that doing something constructive at a particular time was wrong, or a mass superstition that some kinds of knowledge should not be applied.

For example, man had all the materials and the energy forms necessary to hang glide thousands of years ago. But only in the past decade has he done so. Why not much earlier? Was there some new technology added recently? Probably not. Was it a superstition that only birds, but not people, were meant to fly? Certainly it was not fear. Was it because he didn't want to or didn't need to? This does not appear to be the case.

Historians can speculate on how the course of history might have been changed if our ancient (or not so ancient) ancestors had used hang-gliding paratroopers as a part of their military components along with cavalry and catapults. How many sieges would have been lifted by such a weapon system? Would the castles on the Rhine have been obsolete from the start? Would the Great Wall of China ever have been constructed? I am sure a little thought would yield myriad examples where man had knowledge and simply didn't use it.

It is tempting to look back from our lofty perch on the pinnacle of present scientific knowledge with a certain smugness. It is easy to apply hindsight in viewing man's past efforts to improve himself by applying knowledge, and to wonder at what he had that he didn't use. But what about the present? What scientific knowledge are we overlooking or simply not using to our great suffering and peril right now? What are our negative bonds?

When one views the present state of scientific knowledge and its application, one is struck more by the significant areas we are neglecting -those where we are simply not applying our present state of knowledge - than those areas where we are. And this neglect may well result in needless pain and suffering for untold multitudes of people of present and future generations. Surely God must weep at man's inability to use what has so generously been given to him!

What are man's present negative bonds with science? Let me cite just a few. The whole world has built its civilization on the use of liquid hydrocarbon energy sources. Those who happen to live above its sources are reaping great wealth. Those who aren't so lucky are paying an incredible ransom to those who do. Wars and other power struggles are being fought over who owns the source of this energy.

Despite this situation, relatively little is being done to apply our existing knowledge to use energy more efficiently. Heat engines should be at least twice as efficient as they are now. Thermally powered heat pumps could heat and cool our homes and offices with one-half to one-third the present energy. An automobile could be developed with present technology that would get 100 miles to the gallon of diesel fuel under normal driving conditions. Even these several improvements, if applied extensively within present technical knowledge, could reduce the world energy crisis to a non-problem, force down prices of many consumer items, lessen the threat of war over energy, and save billions of dollars in military spending.

Why isn't something being done? Apparently the world business and government leadership mentality cannot conceive of significant departures and risk taking beyond some steady state norm. In the area of a fuel-efficient automobile, Congressman Robert Shamansky of Columbus, Ohio and Senator Ted Stevens of Alaska have introduced bills to provide an incentive for some organization to develop and market a highly fuel-efficient automobile. It remains to be seen whether the concept is taken seriously.

Perhaps the greatest human folly of all time is in the buildup of opposition to the peaceful use of nuclear energy. From every logical viewpoint, nuclear energy is the greatest boon to man since he learned to use fire. Just as with fire, it must be applied under safe conditions. Just as with fire, we know how to use it safely and efficiently. Nevertheless, a large and vocal segment of the population has developed an unreasonable fear of the use of nuclear energy. Consequently, man is facing the pollution of his atmosphere, energy wars, possibly the melting of the polar ice caps, and general economic malaise because his nuclear "taboo" will not permit him to move ahead with the application of nuclear energy. Future generations will probably look back on us the same way we look in wonderment at the violent opposition to Robert Fulton's first steamboat.

Another negative bond we can identify easily is the high cost of rust and corrosion from the exposure of metal devices and structures to the hostile environments of normal commercial application, and the cost of wear and fatigue of materials in normal use. These areas are receiving attention locally both at Ohio State University and at Battelle, but until we have applied all we know about these physical phenomena, they will be negative bonds.

One could certainly go on and examine other scientific areas. Certainly consideration of food and the use of biomass would yield some significant negative bonds. The important point, however, is for scientists and technologists and all of us to realize that these negative bonds exist, and, because they exist, the human race, and the world in general, is not so well off as it might be.

Although it is tempting, time is limited and I am not clairvoyant enough to set forth in any credible way the future bonds that man may develop with science to pull him forward, nor to speculate on how to avoid future negative bonds.

However, I think there is some value in commenting on how these future bonds might be developed - that is, how new scientific knowledge may be more directly found that will be more easily applied to man's benefit.

In the past much of our scientific knowledge was gained by undirected research conducted by individuals. Work between individual scientists was either the result of a student-teacher relationship or discussions between peers. While team effort on the development of new technology has been present for some time, team effort on pure research has been evolving only over the past several decades.

One wonders if the future will see more team effort on pure research programs as a means of facilitating progress in gaining new knowledge. It may be that the increasing complexity of fundamental research and the equipment it requires will force more and more team effort in fundamental research as it has in applied research and development.

The cost in manpower and equipment may make the choice of research areas to be pursued an even more urgent topic than it is today. Scientific research of the future may become more structured and directed than it has been in the past. This will not be all bad. Time and brain power are too valuable to waste; human needs demand answers that can lead to practical end results. Perhaps we should and will spend more time and effort at modeling world progress and attempting to define the important problems to be solved. Hopefully, by so doing, every new bond with science will turn out to be a very useful one.

There is much discussion these days about maintaining academic freedom in fundamental research. In principle, freedom of thought is inherent in almost any human endeavor where progress is made. However, the essence of leadership in scientific research is the ability to channel free thought and effort by others toward areas where knowledge is needed and advances can be made. Our scientific leaders should be continually seeking to stimulate the thinking of the whole scientific community, as well as students, toward areas that will provide new knowledge for eventual useful application.

Another area for improvement in the future is our creativity: our ability to invent useful applications for the new knowledge we gain, and our ability to reduce these inventions to practice.

Right now we actually know very little about the mental process of creativity. We don't know how to maximize it for a specific individual, nor how to determine selectively before the fact who is creative and who is not. It is incredible than so little is known about the processes of invention and innovation when the progress of the world depends so heavily upon those very processes. Without the invention of useful things, and the innovation of new and better processes, all bonds between science and humanity are negative.

A final area that can only be mentioned here, but a crucial one in terms of moving inventions and innovations into commercialization is the process of "entrepreneuring." Whether it be by an individual launching a new enterprise, a large industrial organization initiating a new product line, or a government setting forth an innovative agency, this step is vital in actually completing the positive bond.

We still have much to learn about this process - who makes the decisions, who takes the risks, and how the process is financed.

The conclusion one draws in viewing the processes of bonding scientific knowledge to humanity in a positive way is that they are complex and not well understood, but vital to ensure human progress.

Central to this theme is the unique characteristic of man, his ability to dream of ways to continually improve the quality of life. Dreams become hopes; hopes become desires; desires become needs; and needs become inventions and developments that translate into products and benefits. It has always been so. But now some of this creative process can and should be systematized and channeled to obtain beneficial results.

And while this is desirable, some part of the process - a very precious part - should always be free and unstructured. For only here do we make the quantum jumps that we can now hardly imagine.

New Concept - Biomation - Its Revolutionary Impact on Industry and Society

Kazuhiko Atsumi

Introduction

Japan, a chain of small islands situated in the Orient, is a beautiful country of scenic mountains and rivers, and is subject to four distinct seasonal changes. But unfortunately, my country has no natural resources, no energy and produces only a small portion of its domestic food requirements.

Japan has, however, a large population of more than 100 million, a mainly homogenous race of highly educated people sharing one common language. If we Japanese want to survive the future crisis threatening mankind, there is no alternative but to develop the potential for greater application of science and technology in modern industry.

Japanese culture is originally agriculturally based, and from this comes the so-called herbivorous thinking of the Japanese. By this, I mean our Japanese appreciation of a spirit of harmony and concord with others through an intimate, almost telepathic communication born of our homogenous nature. This is revealed in the specific relationship between capital and labor in our country, which consists of a strong awareness of being part of a community bound together by a common purpose and fate. The Japanese worker is diligent, functioning as a member of a group through which he receives a sense of purpose and identity in society and which also determines the basis of his relations with others. His strong loyalty to the company can be seen as a product of a vertically structured system that still exists not only in governmental organizations, business and school but in Japanese society as a whole (see Figure 1).

The Japanese language is also unique in that it consists of many vowels. From this, we can infer that the style of Japanese thinking belongs to the left-hemisphere-superior type of the brain. It means that Japanese thinking tends to be more intuitive than logical and more analogue in nature than digital.

It is very interesting to compare the characteristics between Western and Japanese science and technology:

- English research and development on science and technology belongs to the Apollo type while those of the Japanese belong to Dionysos type.
- The basic character of England aims toward advanced technology; however, that of Japan seeks mass-production technology.
- Their research methods are different. England is a breakthrough type while Japan is a system type.
- The research field of England is basic science and that of Japan is applied development.
- The research leadership of England is government and that of Japan is enterprise.
- The research result of England is discovery and invention of principle while that of Japan is improvement and application of principle (see Table 1).

Not only are the Japanese a highly-educated nation, with almost 40 percent of our young people college or university graduates, but traditionally we tend to possess also a certain degree of manual dexterity. These two factors combined with a high degree of mutual cooperation in enterprise and other institutions, give our society and economy a solid basis and a high potential for prosperity and development. Furthermore, our government has been promoting the research and development of science and technology, which it sees as of the utmost importance. The type of research and development on science and technology that has blossomed in Japan as a result of government support is, in my opinion, unique. The hard work of the Japanese, coupled with a favorable economic climate and the extensive post-World War II support of the West in financial, cultural and technological fields, has enabled our country to become one of the most advanced in modern science and technology. And now a Japanese contribution to the international community is required.

Present Status of Science and Technology R & D in Japan

The Japanese Science & Technology Council, the supreme semi-government body on science and technology-related policy formation in Japan, issued a report in May 1977, proposing to (1) resolve the problem of limited resources, (2) preserve the environment, (3) maintain and promote the health and well-being of the Japanese people, (4) compete but also cooperate with other advanced countries in the application of science and technology, (5) promote advanced science and technology, and (6) develop the basic sciences.

In the past, Japanese science and technology have been rather focused on improvement of principle and application. However, they are now required to have grown to the breakthrough and creative stage. In order to promote creative science and technology, the country must prepare the appropriate background base. Political and economical development promotes social and cultural activation that cultivates the basic background for science and technology, such as: increase of interest in science, fruitful intellectual life, free social circumstances, bettering of culture media and quality improvement of education, et cetera. The surroundings stimulate motivation to science which, combined with creative researchers, can only produce creative science and technology. The Japanese Science and Technology Agency in May 1981 introduced a new research and development program for creative science and technology. Among the various projects, R & D on the following four are already underway: (1) ultra-micro particle, (2) special-structured substance, (3) fine polymer, and (4) complete crystal element. These four together accounted for a 3.3 billion yen outlay in the 1981 fiscal year (see Table 2).

In April 1982, the Japan Economic Security Committee issued a report relating to the "Establishment of Economic Security." Its purpose is, through mainly economic means, to resolve various problems arising from international economic upheaval that affect the Japanese economy. The three major items are as follows:

(1) To contribute to the development of the world economic system by promoting open-market policies and international economic cooperation.

(2) To secure supply of important materials such as minerals, foodstuffs, etc.

(3) To conduct research in the unexplored fields of science and technology and contribute those findings.

In this report, Japan's international contribution as an established science and technology-based nation is strongly stressed. The Committee, recognizing science and technology as the common property of mankind, proposed three subsequent steps. These are: (1) to challenge the unexplored fields, (2) to cooperate with the technologically advanced countries, and (3) to transfer this technology for use in the developing countries. The committee pointed out the challenge of the unexplored fields classifying it into three categories: (1) human survival, (2) new frontier, and (3) new-generation technology.

The Japan Society of "Science of Technology and Economy" reviewed the question of new industries in February 1980. In this report, the new industries are classified into two categories: (1) new industry triggered by new technology, and (2) new industry triggered by social need. In the former group, the eight potential new industries are: (1) electronic element industry, (2) new information industry, (3) mechatronics industry, (4) aerospace industry, (5) engineering industry, (6) bio-industry, (7) nuclear industry, and (8) new energy industry. In the latter group - namely new industry triggered by social need - the six new industries are comprised of: (1) ocean development industry, (2) medical industry, (3) 1.5-generation industry, (4) integrated distribution industry, (5) disaster prevention industry, and (6) recycle industry.

I would like now to discuss the problems of the past, present, and future trends and effects of various technologies. Advanced technology is divided into two groups, the breakthrough-type technology and the improvement or combined-type technology. The progress of these is described as two wave motions moving symetrically so that a peak in the one corresponds to a bottoming out of the other as shown in Table 3.

Table 3 shows the development of the four major technological fields, electronics, power, material, and chemistry, from 1925 to 2000 A.D. At present, as shown here, the breakthrough-type of technology is undergoing a surge of increased development, for example, the Josephson element, light communication, ion engine, nuclear fusion, super-conductive material, anti-cancer drug, interferon, etc. In my opinion, the five revolutionary technologies are those of: (1) information, (2)mechatronics, (3) materials, (4) light, and (5) bio-technology. In particular, biotechnology as a newly emerging field has become the object of general public interest in Japan.

The Ministry of International Trade and Industry is also planning a nationally sponsored R & D program on technology for new generation industries. This includes R & D on: (1) new materials, (2) biotechnology, and (3) new functional elements, involving a total investment of 10-billion to 12-billion yen over a 10-year period. Table 4 shows the MITI 10 years' project fo R &D on biotechnology that commenced in October 1980, comprising four major areas: (1) bio-reactor, (2) mass-cell culture, (3) gene rearrangement, and (4) cell fusion.

The future potential of genetic engineering is considered so wide that it will be able to be applied to a wide range of industrial fields, such as medicine, agricultural chemicals, fiber, fertilizer, food, fermentation, stock breeding, fisheries, mining, agriculture, forestry, disposal, etc. It will also have biomedical applications, for example, gene structure analysis, gene function analysis and analysis of character manifest regulation.

Up until now, I have restricted my subject to a general rundown of the present status of science and technology in Japan and its background. Here, I would like to take up what my colleagues and I call "Biomation." Biomation is a new term that comes from a combination - or if you like a hybrid - of the words bio-organism and automation. It indicates the concept of hybridizing man-made technology with biological life.

Through the development of Biomation and its application, I see mankind as passing from the present period that I term "mechanical civilization" and entering a new era of "Humanistic Civilization." Automation has brought about a system of efficient industrial mass production that has made our dream of a fully developed cybernetic and information society a reality. Our mechanical society in its present form has reached the vertex of its potential. To develop a truly new and brighter era for human society, it needs a reshaping of approach, a metamorphosis of technological enquiry (see Figure 2).

What do we mean by this concept of biomatic hybridity? For this answer, the structure and functions of a bio-organism should first be examined and clarified. Figure 3 shows the scheme of structure and functions of a bio-organism. The future pattern of development of a cell is programmed by the gene of heredity. The cell divides and multiplies. And, then, the newly formed cells combine to become tissue that in turn repeats this process developing into an organ. Finally, an organism consisting of many organs is formed that maintains its survival through sophisticated interaction with the external environment.

In order to maintain homeostasis in its internal environment, an organism requires various highly efficient functions such as metabolism, feedback regulation and adaption. The chemical reactions carried out in the process of metabolism in an organism are extremely efficient and are considered to be of a different type from that of the usual chemical reactions. They are non-linear and non-thermodynamic. Feedback regulation is performed by use of a multichannel network that keeps the function of the organism reliable and stable. Adaptation is an essential function in the survival of an organism. When an organism is confronted with a sudden change of environment, it has many ways of dealing with the situation, for example, by employing its in-built potential for absorbing change or by a highly-developed capacity for self-transformation and functional alternation that even extends to an ability to adjust itself to anticipated environmental change.

An organism consists of a collection of organs. Under normal conditions, each of these organs performs its designated functions independently, but if any one organ malfunctions, the other organs will immediately come to its aid, compensating for this functional breakdown. In emergency situations that threaten the very survival of an organism, a system of hierarchic regulation is carried out whereby the functioning of the brain and heart is maintained at the expense of less important organs. Coexistence of organs under normal conditions and hierarchic regulation in life-threatening situations are considered to be the specific characteristics of a biosystem.

While each individual organism will eventually reach the end of its lifespan, the continuity of the species will still be ensured through the system of reproduction.

Science can learn a lot from the array of intricate functions in living organism - programmed heredity, metabolism, feedback regulation, adaptation, coexistence of organs, reproduction - all incorporated into the tiny, compact dimensions of the biosystem. We can overcome the present deadlock of mechanical society by fully realizing the potential of these remarkable characteristics of the biosystem and working to develop a biotechnology. This will lead us to the realization of our aim of "Biomation" technology.

Next, I would like to suggest some examples of possible future application of "Biomation." Figure 4 shows a history of the mechanization of various human activities. First, the steam engine was produced for substitution of heavy manual labor. The locomotive and car were produced to aid transport; the telegraph and telephone to aid communication, and the conveyor to aid in light manual work. Broadcasting, the radio; duplication, the xerograph and tape recorder; calculation, the computer, and for precision work, the NC machine and robots were constructed. For amusement, the TV game; for manipulation, the automatic trolley, and for learning, the intelligent learning computer were constructed.

These aids and substitutions are expected to become more complete and more efficient with the utilization of biomation technology in the future. However, even if it were to become technologically possible - which is unlikely - to produce a replacement for the essentially human function of creative thinking, I believe it would prove catastrophic for mankind. The reason is quite plain. If this did happen, man would lose the very purpose and dignity of his being, and this, in turn, would have dire, almost unimaginable consequences, threatening the very fabric of humanity.

Figure 5 shows the shift of main employment areas with technological advance. In 1860, almost all workers were employed in the primary industry area. In 1920, the percentage of workers employed in primary industry dropped to 50 percent while the percentage of workers in the secondary and tertiary industries increased. In 1980, following the oil shock, 55 percent of workers were shown to be employed in tertiary industry and this percentage is expected to increase to around 68 percent by 1990. By 2000 A.D., with the advent of the biomation society, the percentage of workers involved in tertiary industry is anticipated to increase to 85 percent.

In recent years, technological innovation such as computers, high polymers, lasers, space and ocean development could produce economic growth, new environment and realize information society. These surroundings change human values. The changing of human values revolutionized social and intellectual structures and functions gradually and steadily. And now, new civilization, new philosophy and even new religion are going to be created as shown in Figure 6.

Figure 7 shows the historical transition of human society. Some 100,000 years ago, humans started with primitive society and built up collective society, agricultural society, handiwork society. In 1766, the primary Industrial

Revolution occurred and industrial society was built up. The secondary Industrial Revolution created mechanization society. The Automation Revolution made automation society. Cybernation Revolution could create our information society. According to Mr. K. Tateishi's opinion, biomation revolution will create optimization society and psychomatic revolution will stimulate autonomous society and finally revolution of meta-psychomation will create natural society which is thought to be an ideal society for humans.

In 1972, Mr. Tateishi reported the SINIC theory (Seed Innovation to Need-Impetus Cyclic Evolution). Figure 8 shows the SINIC diagram. The seed of science produces new technology and by the application of the technology innovation occurs in the society. On the other hand, social need requires production of new technology that stimulates the promotion of basic science.

Figure 9 shows the relationship of society, technology and science. The need of primitive society produced primitive technology that innovation stimulated to create collective society. On the other hand, primitive religion stimulated primitive technology that gave impact to ancient science. In a more recent state, electrical control technology innovated information society. The need of information society stimulated biocontrol technology. On the other side, electrical control technology stimulated bionetics. The seed of bionetics contributed to produce biocontrol technology. This diagram indicates that our mechanization society will transfer to the mental or psychology oriented society in the future.

Figure 10 shows the past, present and future of office automation. Traditional business management was first established in Japan in the 1950s, with the development of Katakana typewriter. In the sixties, computers and business information systems came into use in the office after the centralized data processing systems were introduced. The 1980s are seeing the gradual replacement of the older system with the introduction of the office automation system. The 1990s will see this system perfected, but after the year 2000 A.D., it will give way to the decentralized office.

Figure 11 gives us a look at the possible layout of the future home automation system. Home computers will be able to be employed in such areas as home security, energy saving, coordination of house work, home management, learning, leisure and even business in the home. In this home automation system, biomation technology will have great potential for application. The delicate and time-consuming work in the home will now be carried out by new type computers, sensors and energy incorporation biomation technology.

The aim in the development of artificial organs is to reproduce exactly the functions of biological organs using synthetic materials. This can be seen as a truly representative application of biomation technology. First of all, to develop an artificial organ, for instance, an artificial heart, it is indispensably necessary to understand the biological organ's functions. Next, in order to make a functional artificial model, a great deal of R & D is necessary in the areas of appropriate biomaterial, efficient biomechanics, flexible biofeedback, compact and powerful bioenergy. Namely, this process of R & D on artificial organs is in fact biomation.

Table 5 shows the 1980s-1990s forecast of the world-wide annual demand and cost of artifical organs. The total cost of artificial organs listed in the table is estimated at 1,500 billion yen, which puts the potential scale of this industry on a par with the present car industry.

As you know, the next "International EXPO" will be held in Tsukuba in Japan in 1985. The main theme is "Dwellings and Surroundings," science and technology for man at home. In planning for this event, the members of the organization committee have, following much debate, selected from items to give their ideas on this theme concrete expression and focus: (1) re-evaluation of Oriental science and philosophy; (2) Harmonization between science and technology and art; (3) Exploration on "What is Human?", and (4) The challenge of unexplored regions. Examining these, we can believe that the organizing committee's philosophy is very similar to and much concerned with that of Biomation.

Before closing my presentation, I would like to introduce a movie about a new factory, "OMURON TAIYO" by Tateishi Electric Company, that is aiming to realize "Biomation." This is a special welfare industrial factory where handicapped workers confined to wheel chairs are able to take part in production. Honda and Sony have also been jointly involved with this project, and large investments have been offered to make a special kind of automation system for disabled workers. With the warm cooperation of many people, and the new automation technology, this factory has succeeded in giving the disabled not charity but rather a chance to work. The thinking behind this project is similar to the philosophy of "Biomation." This is to create a new technology for mankind contributing not only to greater efficiency in the work place but also to the general quality of life and above all, to a new harmony between man, environment and technology.

At last, I would like to introduce the social impact of "Biomation." Biomation technology will bring revolutional innovation in our human society. Consumer need, production systems, industrial style, labor, and economical, social and political structures will be changed. Consumer need will be changed from an abundance of material goods to an emphasis on the quality of life and from uniform standardization to multiple individualization.

Productive systems will be changed from mass quantity of a few kinds of production to small quantities of multiple kinds of production. Industrial style will be changed from giant and centralized systems to compact and decentralized sytems. In the past, labor power came from the countryside to large cities; that will be changed from city to countryside. Market structure will be changed from giant and massive to specified and subdivided. Social structure will be changed from overcrowding and frustrated residents to the appropriate size of community. By biomation technology, resource shortages will be moderated, labor hours will be shortened, leisure and freedom will be enlarged, and a society of abundance and humanistic civilization will be developed.

However, on the other side, social control and alienation may be strengthened and intensified. The gap between rich groups and poor groups and between the developed and the developing countries may be expanded. Uniform standardization of culture and civilization may also appear. Genetic engineering may invade human dignity. It is our responsibility to assess and to provide the appropriate measures of the side effects of "Biomation" technology.

Figure(1) Japanese Consciousness between Capital and Labor (Socio-Economic Society)

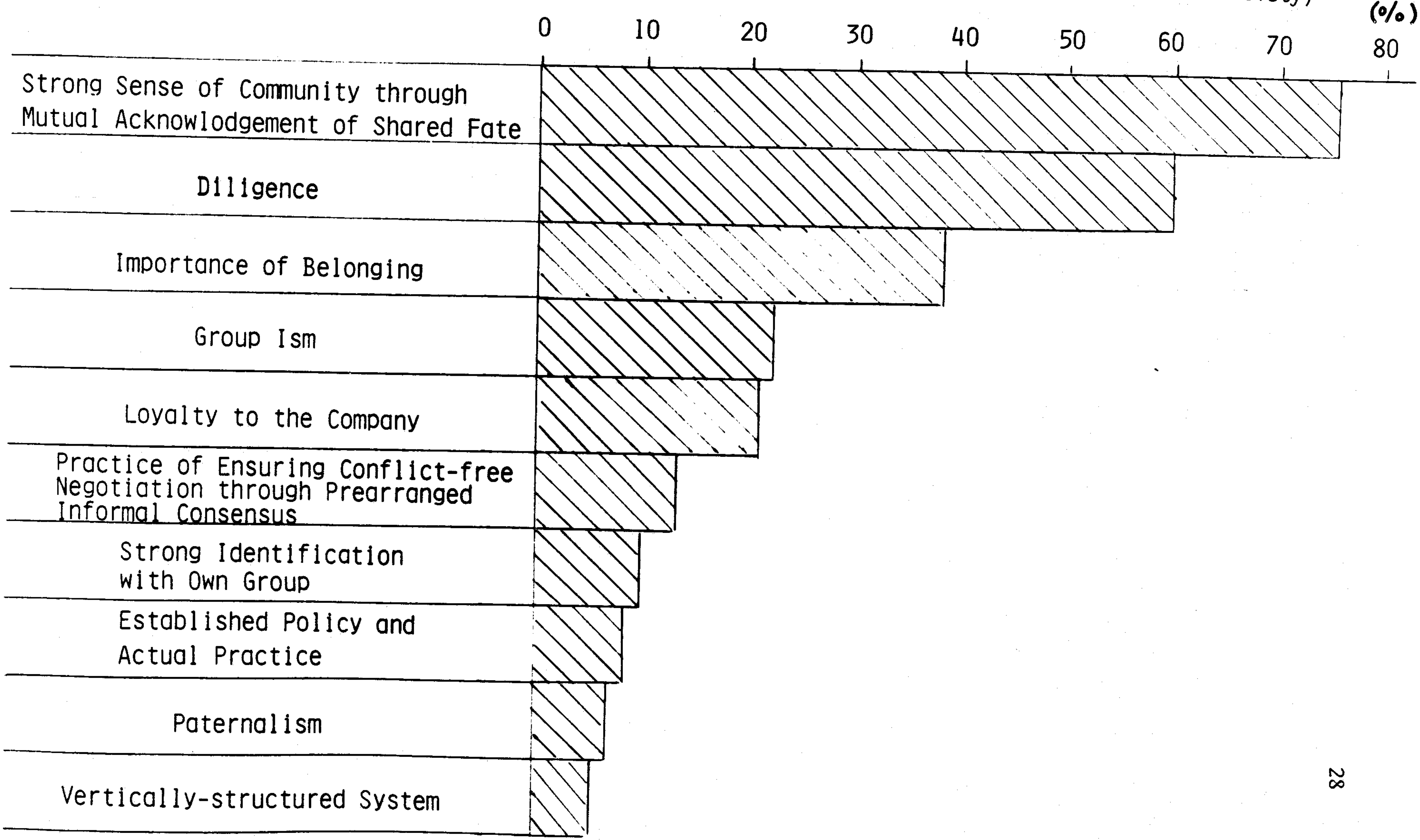


Table (1) COMPARISON BETWEEN ENGLISH AND JAPANESE SCIENCE AND TECHNOLOGY RESEARCH (S. Inui)

	England (Apollo Type)	Japan (Dionysos Type)
Basic Character	Advanced Technology Oriented	Mass Production Technology Oriented
Research Method	Breakthrough Type	System Type
Research Fields	Basic Science	Applied Development
Research Attitude	Cultured	Practical
Research Organization	Individual	Organized
Research Leadership	Government	Enterprise
Industrialization	Weak Binding (Self-completion Oriented)	Strong Binding (Market Oriented)
Research Result	Discovery and Invention of Principle	Improvement and Application of Principle
Contribution of Research Result	World-wide Development of Science & Technology	National Development of Economy

Table(2) <u>Research & Development on Creative Science and Technology</u>

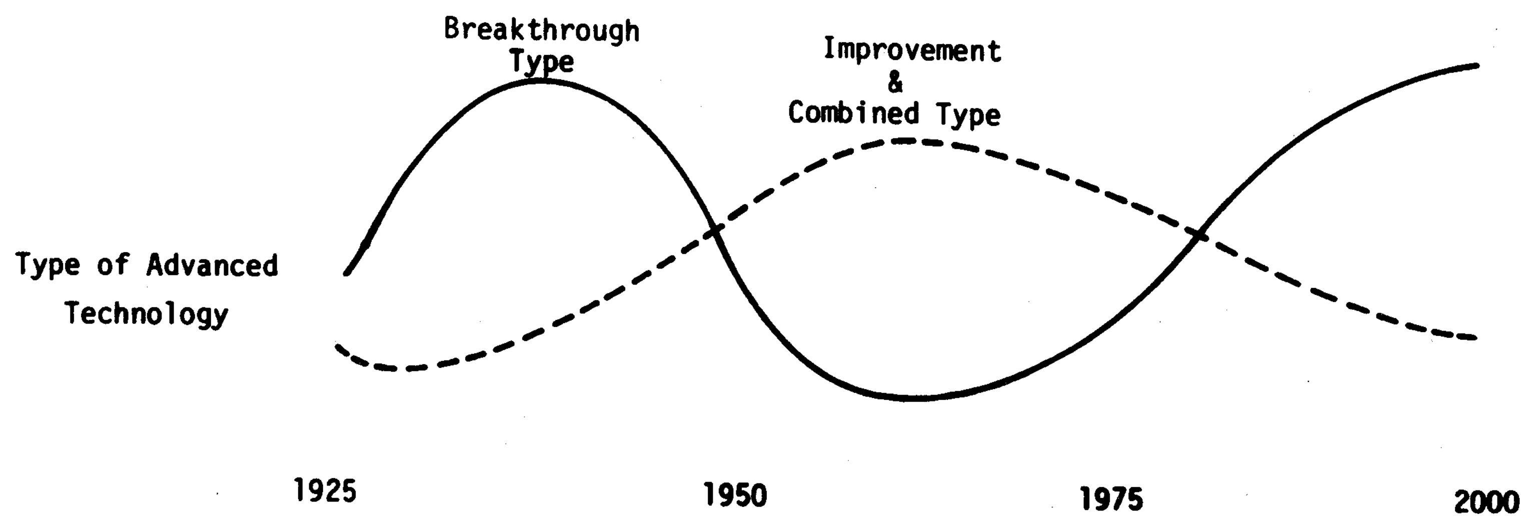
(Japan Science & Technology Agency)

1) Ultra-micro Particle	:	10 - 100 Atoms' Size (Catalyzer, Filter, Magnetic Substance, etc.)
2) Special-Structure Substance	:	Amorphous Material, Laminar Chemical Compound, Non-Balanced Compound (New Material)
3) Fine Polymer	:	Functional High-Polymer (Medical Use, Catalyzer, Enzyme, Ion-Conduction, Photodynamic Characteristics)
4) Complete Crystal Element	:	Complete Crystal (New Electro-induction Element, etc.)

<u>3.3 Billion Yen / 1981</u>

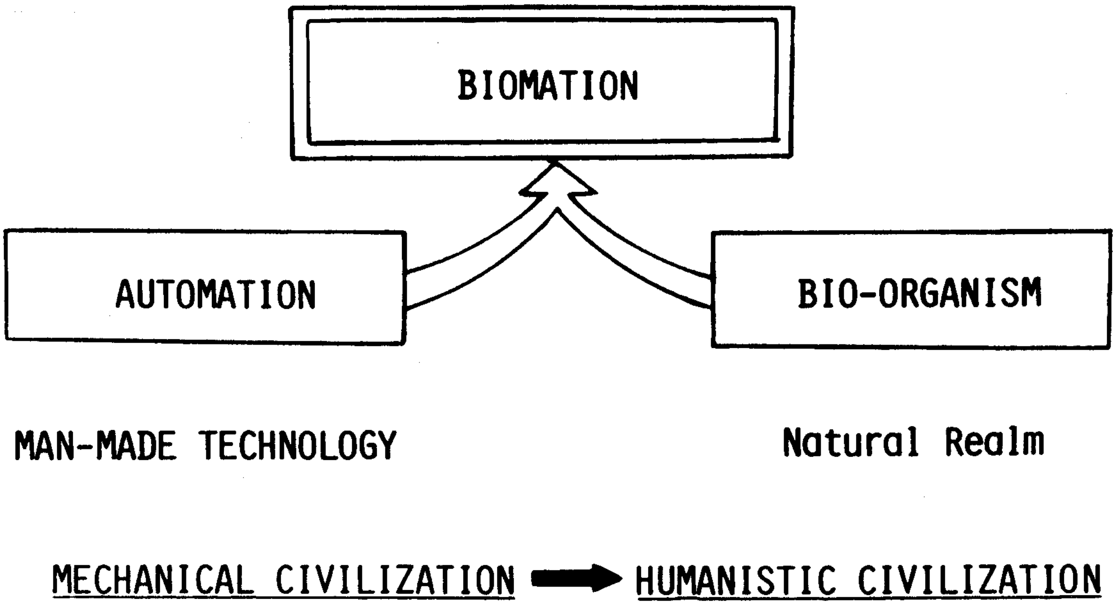
Table(3) <u>Wave Motion of Technology Progress</u> (N. Makino)

Electronics	Television Transistor Computer	I C, LSI Electric Calculator Microprocessor	Josephson Element Light Communication (Laser)
Power	Rocket Jet Engine Nuclear Power	Diesel Engine CVCC Rotary Engine	Ion Engine Nuclear Fusion
Material	Ferrite Duralumin	Composite Material Amorphous Metal	Super-conductive Material Ceramic Engine
Chemistry	Nylon Polyester Penicillin	Silicone Antibiotics Agricultural Chemicals	Anti-cancer Drug Interferon Electro-conductive Polymer

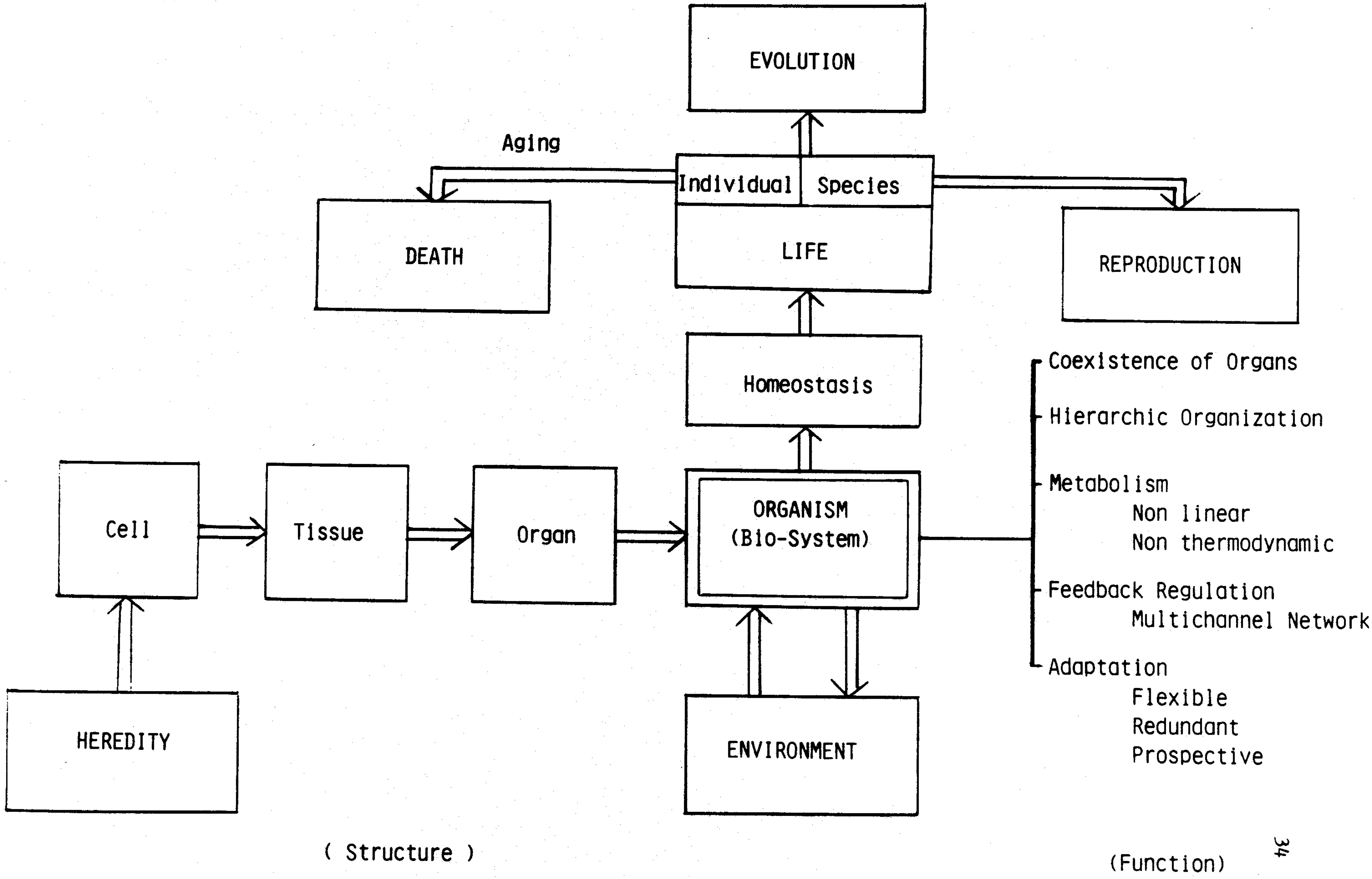


Table(4) The MITI Project on R & D of Biotechnology (MITI, 1980 October)

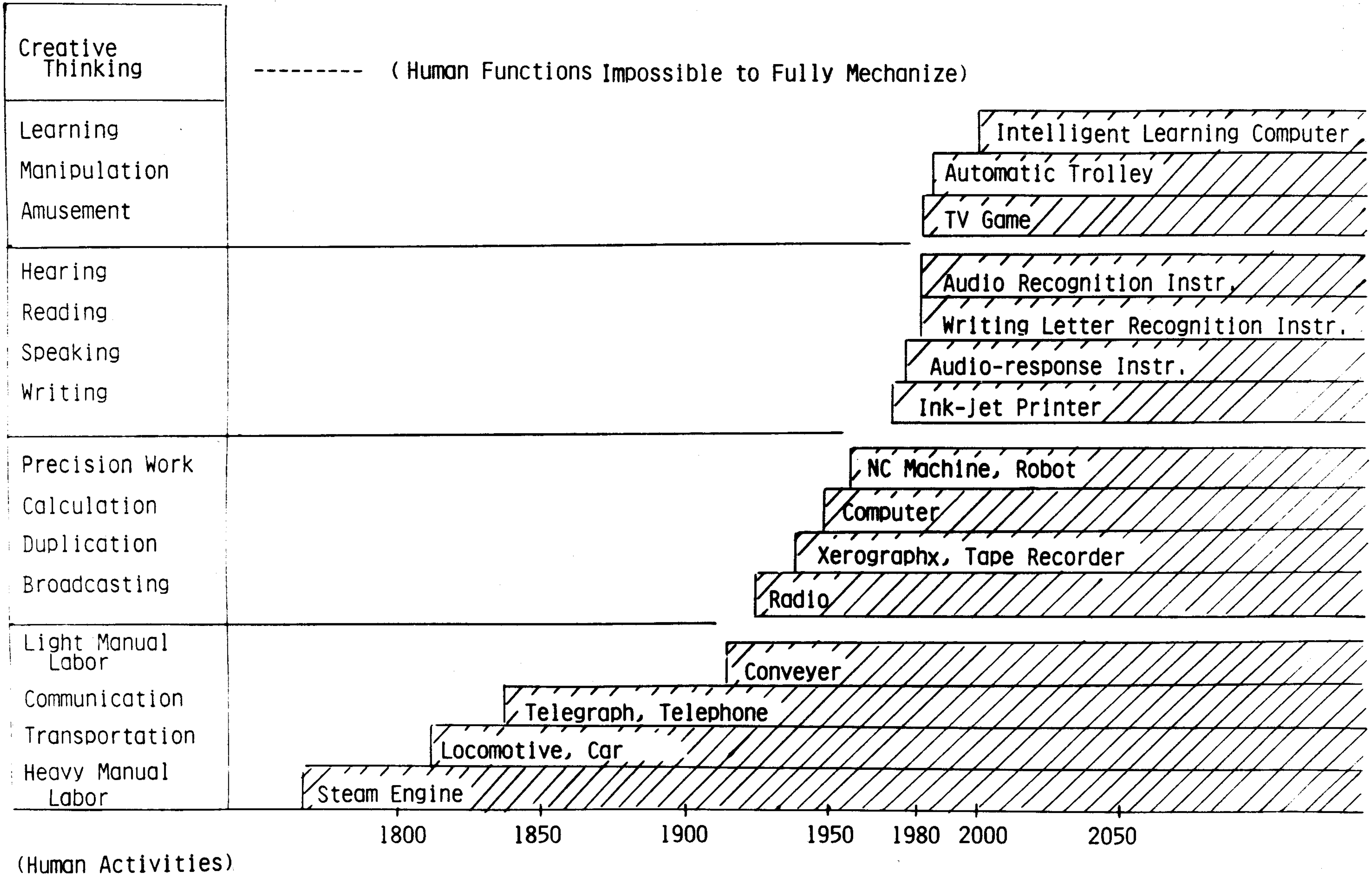
	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Bioreactor	Microbe Exploration			Reaction Methodology		Trial and Evaluation				
Mass Cell-Culture Technology	Analysis of Cell Growth Factors		Development of Optimum Nutrition Culture Ground			Establishment of Mass Culture				
Gene Rearrangement Technology	Gene Separation			Gene Rearrangement			Establishment of Separation and Purification of Products			
Cell Fusion Technology	Analysis of Basic Requirement of cell Fusion			Studies on Optimum Fusion Cell			Establishment of Separation and Purification of Products			



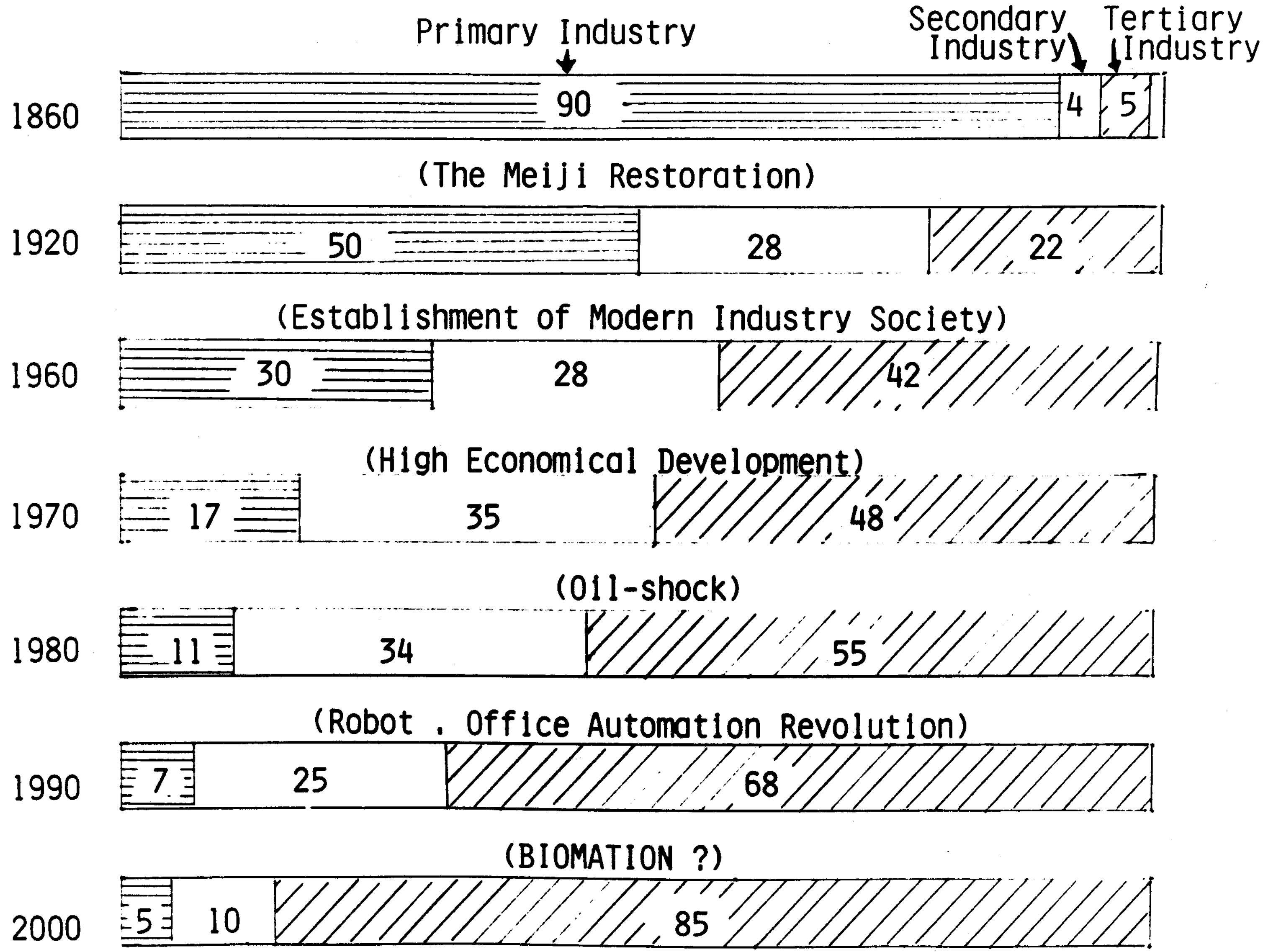
Figure(2) Biomation



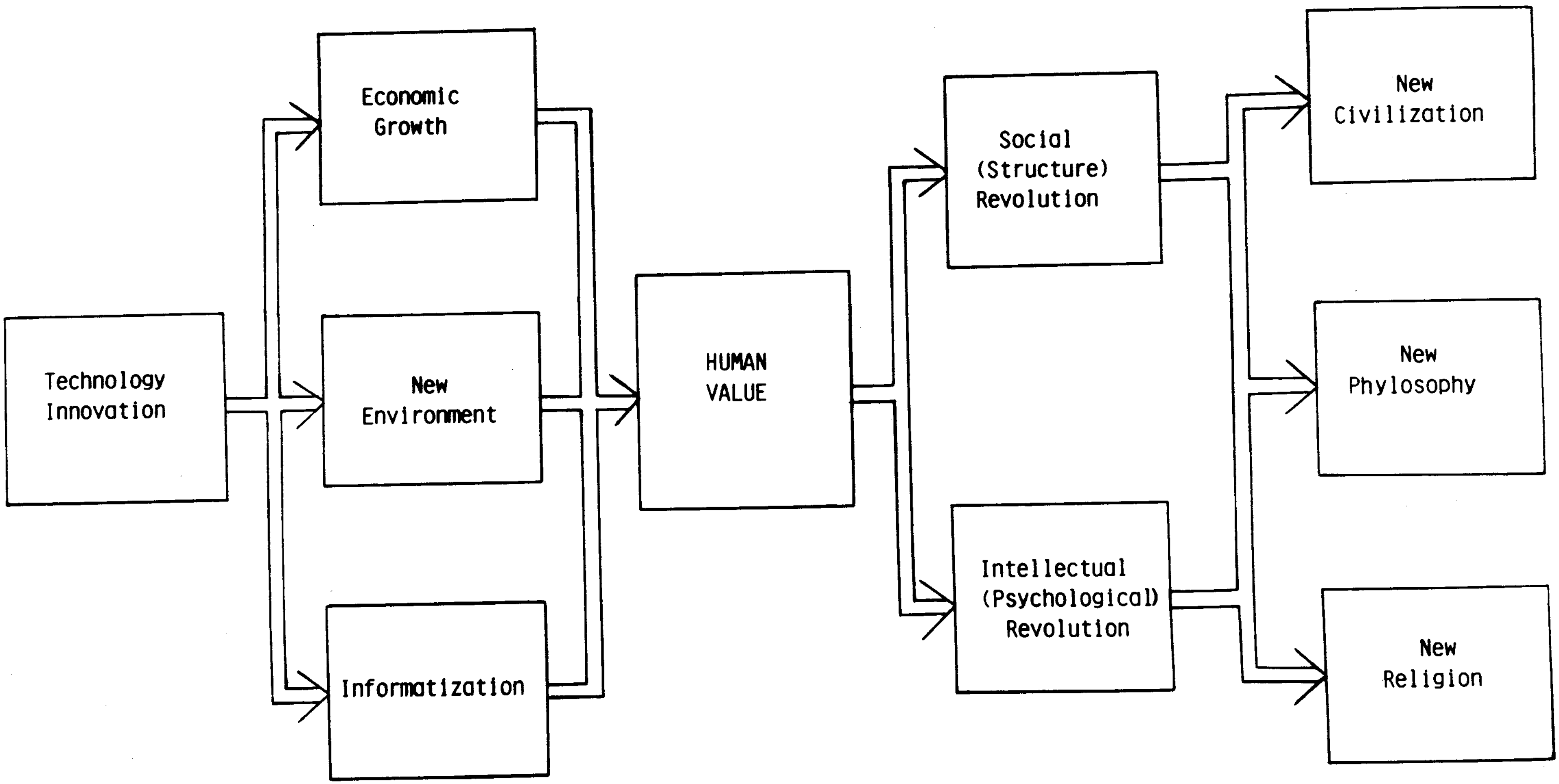
Figure(3) Structure & Function of Bio-System



Figure(4) MECHANICAL REPLACEMENT AND AIDING OF HUMAN ACTIVITIES (Nikkei Business News)



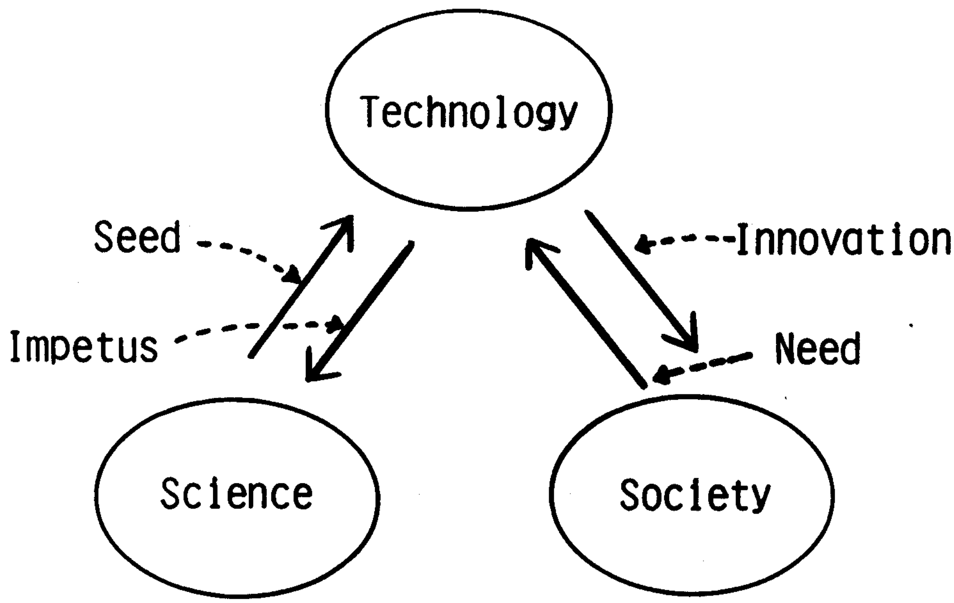
Figure(5) SHIFT OF MAIN EMPLOYMENT AREAS WITH TECHNOLOGICAL ADVANCE (Nikkei Business News)



Figure(6) <u>TECHNOLOGY INNOVATION, CHANGING HUMAN VALUES AND NEW CIVILIZATION</u>

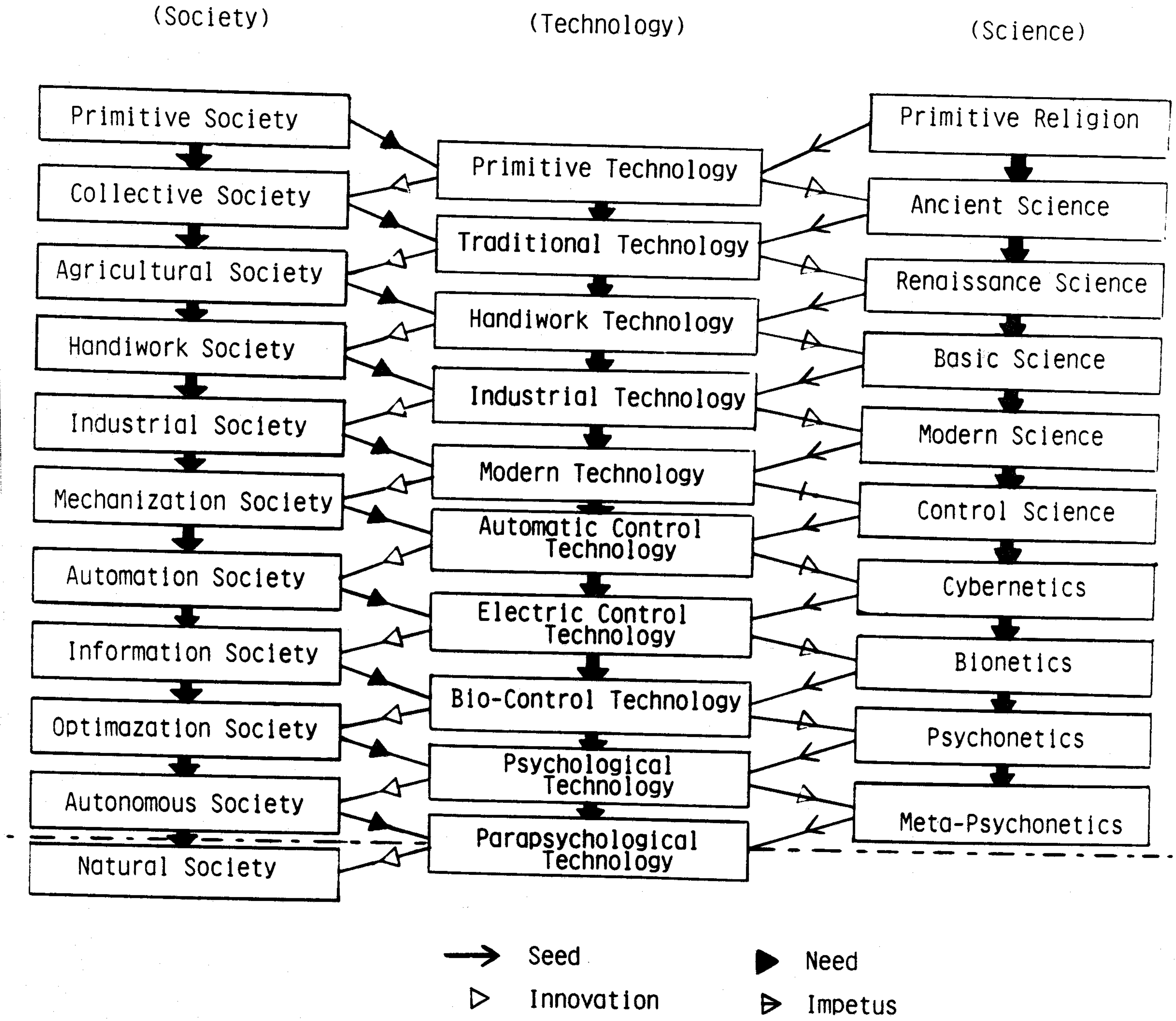
(Revolution)	(Period)	(Society)
	100,000 B.C.	Primitive Society
	12,000 B.C.	Collective Society
	700 B.C.	Agricultural Society
	A.D. 1302	Handiwork Society
Primary Industrial R.	(1760-1830) 1766	Industrial Society
Secondary Industrial R.	(1870-1920) 1876	Mechanization Society
Automation R.	(1940-1960) 1945	Automation Society
Cybernation R.	(1970-1980) 1974	Information Society
Bionation R.	(2000-2100) 2005	Optimazation Society
Psychonation R.	(2020-2025) 2025	Autonomous Society
Meta Psychonation R.	(2030-2033)	Natural Society

Figure(7) Transition of Human Society (K. Tateishi)



Figure(8) <u>SINIC (Seed-Innovation to Need-Impetus Cyclic Evolution) Diagram</u>

(K. Tateishi)

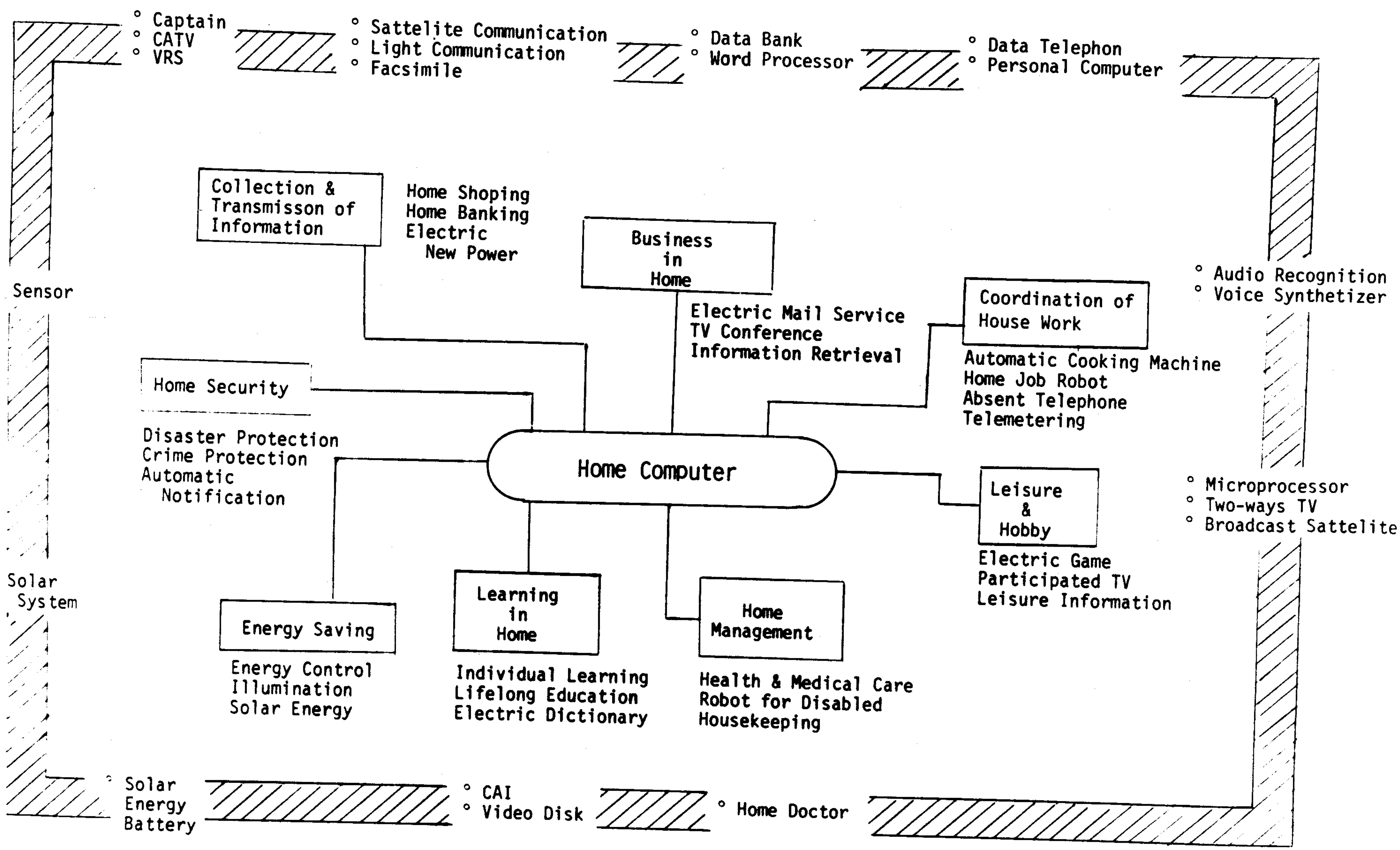


Figure(9) <u>SINIC Diagram of 10 Step Society</u> (K. Tateishi)

1950	Katakana Type Copy Machine Calculator	Traditional Business Management
1960	Computer (General Purpose) Business Information System	Centralized Deta Processing
1970	Electric Calculator Facsimile OCR Office Computer Communication Network	Decentralized Data Processing
1980	High-speed Personal Computer Satellite Communication Word Processor Large Scale Data Base Captain Sustem	Introduction of Office Automation
1990	Audio Input Light Communication System TV Conference Electrical Mail Service Automatic Translation Instrument The Fifth Generation Computer	Office Automation
2000	Office Robot Home Computer Electronics Cottage Business in Home	Decentralized Office

Figure(10) Past, Present and Future of Office Automation

(Nikkei Business News)



Figure(11) FUTURE HOME AUTOMATION SYSTEM (Nikkei Business News)

Table(5) 1980' - 1990' Forecast of World Wide Annual Demand and Cost on Artificial Organs

Demand and Cost / Artificial Organs	1980'				1990'			
	Japan		World		Japan		World	
	No. of Demand	Cost (Billion yen)	No. of Demand	Cost (Billion yen)	No. of Demand	Cost (Billion yen)	No. of Demand	Cost (Billion yen)
Artificial Bone & Joint	1,500	0.5	15,000	5.0	3,000	1.0	40,000	13.0
Artificial Blood Vessel	2,000	0.15	30,000	2.1	5,000	0.35	70,000	4.9
Artificial Heart Valve	1,500	0.9	30,000	18.0	3,000	1.8	100,000	60.0
Pacemaker	7,000	8.4	150,000	180.0	15,000	18.0	400,000	480.0
Artificial Heart Lung Machine	15,000	6.0	300,000	120,0	25,000	10.0	500,000	200.0
Artificial Kidney	8,000	24.0	50,000	150.0	10,000	30.0	120,000	360.0
Artificial Heart {short term {long term	5,000 100	15.0 1.0	50,000 500	150.0 5.0	12,000 500	36.0 5.0	100,000 5,000	300.0 50.0
Artificial Liver	100	0.5	500	2.5	1,000	5.0	5,000	25.0
Artificial Pancreas	100	0.6	300	1.8	500	3.0	5,000	30.0
Total		57.05		634.4		110.15		1,522.9

Information Age Telecommunications Systems and Services

M. Iwama

Communications and computer systems, working as partners, have brought about today's information age. My topic is information age telecommunications systems and services. First I will present an overview of the recent progress in solid state electronics and computer technologies that precipitated the current evolution. Next, I will discuss how these technologies are being utilized in modern telecommunications components or subsystems. Then I will discuss present and future telecommunications capabilities and services.

First, I must point out the limited nature of my report. It is mostly based on what one finds in the Bell System. Being at Bell Labs, I feel more comfortable in resorting to this approach. Also, the report concerns itself with inter-premises rather than intra-premises communications.

Solid-State Electronics - Present Status and Future Trends

It has been said a picture is worth a thousand words. Perhaps one can appreciate the advances in solid-state electronics technology by observing this photograph (Figure 1). It shows a 32-bit microprocessor on a chip that is only only 1.5 cm^2 in area. It contains 100,000 transistors. As a microprocessor, it has a 32-MHz internal clock and a processing power comparable to that of a minicomputer. The technology used is Complementary Metal Oxide Semiconductor (CMOS) with a 3.5-micron feature size (defined simply, feature size is the smallest dimension used in a design), because of the small size, this microprocessor consumes less than a half watt of energy. This 32-bit microprocessor is already a laudable achievement. However, the rapid progress in solid-state electronics is continuing: Since this microprocessor was announced early in 1981, an even more advanced 32-bit microprocessor with 150,000 transistors and a 2.5-micron feature size has been announced.

Figure 2 is a photograph of a four-bit microcomputer - another fruit of solid-state electronics. At the time this microcomputer came into being some three years ago, the scale of integration was not so great as that possible today. Even so this chip, based on the CMOS technology with a 5-micron feature size, contains some 30,000 transistors. Let us now turn to the trend in this technology.

Figure 3 shows the trend in the scale of integration over the past twenty years or so. In this figure, the number of components on a single chip is plotted against year, both for silicon memory and logic. We see that it has progressed by an impressive factor of two every year over the last twenty years.

Several manufacturers have already announced the anticipated production of 256-kbps (kilobits per second) random access memory (RAM) chips late this year, or early next year. Only time will tell for certain, but some technologists believe that it will not be too many years before we see a multimillion-bit memory chip with a feature size of only a fraction of a micron.

Greater integration leads to reduction in weight, volume, and material, improved reliability, faster response time or more processing power, and, perhaps most significantly, reduced cost.

Processing power is one area where rapid growth is occurring. Although MIPS (millions of instructions per second) is but one measure of processing power, it is an indicator useful in illustrating the trend. As demonstrated in Figure 4, the differences among maxicomputers (or mainframe computers), minicomputers, and microcomputers are disappearing. Microcomputers are already offering a processing power approximately three-fourths the power of contemporary minicomputers. Simple extrapolation of the past trend suggests that all three types, except special-purpose "supercomputer," are converging toward 20 MIPS at some time around 1990. Again, only time will tell whether such speculation is sound.

Equally striking is the way the cost of a circuit or gate has come down in a decade or two. This is illustrated in Figure 5. A circuit that cost $1 in 1965 now costs less than one-tenth of a cent. Thus, the cost of "hardware" for memory and logic has been reduced by a factor of 1,000 in about fifteen years - a remarkable technological feat.

These impressive advancements in computer or computing hardware technology should not be allowed to dwarf less glamorous but just as significant progress in computing software. It is a simple fact that computing hardware has no value in itself. Without accompanying software, today's information age would not have arrived. You may find it interesting that the 32-bit processor shown earlier was designed with the aid of computer software containing several hundred thousands lines of source code.

A change in the capability or cost of components by one order of magnitude usually impacts the ways that these components are used. Since recent advances in solid-state electronics have brought about changes far greater than just one order of magnitude, we should expect to find many dramatic evolutions occurring in telecommunications systems. The strong desire to control or reduce the cost and expand the capability of telecommunications systems and services by the suppliers has been the prime factor in the progress in solid-state electronics. Thus, it is not surprising that the telecommunications industry is responsible for many basic inventions in solid-state electronics.

Applications of New Technologies in Telecommunications Systems

I would now like to discuss how telecommunications systems have benefited from solid-state electronics and computers technologies.

The first example is the recently developed echo canceler. All of us, at one time or another, have experienced annoying echo in a long-distance or overseas telephone call. Subjective tests show that the annoyance level increases with the delay associated with the echo. Because voice communication over a satellite link has an inherent one-way delay of about 0.3 seconds, the quality of that communication is significantly lower without an effective and economical means to cancel the echo.

An echo canceler shown in Figure 6, a solution to the echo problem is on a chip no more than 3/4 cm^2 in size. Although this original version uses technology that is already two to three years out of date, it contains 35,000 transistors, provides the equivalent of 3,400 logic gates, and incorporates a 3,000-bit shift register. The echo canceler in this photograph is based on the 5-micron feature size CMOS technology. A more recent vintage contains 50,000 transistors with approximately half the feature size of the original. If discrete components of 20 years ago had been used to construct an equivalent echo canceling device, it would be the size of a kitchen refrigerator.

The small size and the low cost of this device - a child of modern solid-state electronics - has made possible its large-scale deployment in telecommunications systems. As a result, the quality of long distance telephone calls - particularly those via satellite - has improved significantly. The Bell System already has some 60,000 echo cancelers in place. This number includes echo cancelers on approximately 10,000 satellite circuits.

In addition to the echo canceler, solid-state electronics and computer technology have benefited other telecommunications systems. Next example is the striking physical size reduction of memory in a family of electronic switching systems. The first electronic switching system was put to commercial use in 1965. It is called "electronic" because a software program, rather than electromechanical hardware, controls a network of tiny relays to connect and disconnect circuits within the switching machine.

The impact of solid-state electronics on memory size is vividly illustrated in Figure 7. The memory for this family of electronic switching systems, used primarily for switching "local" telephone calls, has experienced a dramatic evolution since its introduction some 16 years age. In this period, the size has been reduced to one two-thousandth of the original, and the power to one seven-hundredth of the original, while increasing the speed ten times. One might entertain the thought to awarding a Nobel Prize in the category of saving energy to solid-state electronics.

In an electronic switching system manufactured more recently, tiny relays that comprise the internal switching network in the earlier vintages have been replaced by gated diode crosspoint integrated circuits that withstand 500 volts, a feature necessary for "local" switching machines.

Before leaving the topic of electronic switches, I should mention that the software used in these switches is not trivial. Approximately one million lines of executable codes are used in one particular local electronic switching system. Close to 1.5 million lines are used in a particular "toll" electronic switching system, one type of system for switching long-distance calls.

Another "technology star" of the information age is optical fiber and its associated optoelectronics. These include solid state lasers, light emitting diodes, and light detectors. Once again, it is solid-state electronics that is making optical communications systems a reality.

Figure 8 is a photograph of a cross section of an optical fiber cable containing 144 hair-thin fibers. The material surrounding the individual fibers provides physical strength and protection. When the cable is used with a gallium aluminum arsenide (GaAlAs) light emitting diode (LED) operating at an 0.8- to 0.9-micron wavelength as the light source, an attenuation (or loss) can be as low as 1.5 dB per kilometer. With this low attenuation, lightwaves carrying information can be transmitted over a distance of about three kilometers without a repeater or regeneration, devices that "boost" the signal and restore the original shape.

One commercial system is designed for a digitial transmission rate of 45 Mbps. This rate translates to 672 voice-grade or 4-Khz circuits on a pair of fibers. This contrast with only 24-voice circuits that are possible today on two pairs of metallic wires in the most prevalent digital carrier system in use in North America. Theoretically, with all 144 fibers in use, roughly 50,000 two-way voice circuits can be provided on just one optical fiber cable.

A system with even better performance in terms of loss (or attenuation) is being field tested. This system uses an indium gallium arsenide phosphide (InGaAsP) LED or laser as the light source. With an LED operating at 1.3 microns as the light source, the attenuation factor as low as 0.5 dB per kilometer has been demonstrated. With single-mode fiber[1] and a laser operating at 1.5 microns as the light source, an attenuation factor of as low as 0.2 dB per kilometer has been achieved in a laboratory. The design objectives for a lightwave system for undersea use have been set for a repeater spacing of

35 kilometers, at a transmission rate of 274 Mbps. This system uses an InGaAsP p-i-n diode as a detector, and is designed for a 24-year life.

Lightwave communication systems are still going through a rapid evolution. Advances in optoelectronics are making possible the multiplexing, bridging, and switching of "light circuits" optically. Today, these functions are performed by converting "light circuit" back to an electric voltage or current.

Lightwave communication systems are on the verge of a substantial growth. For example, the Bell System plans to install 4,000 kilometers of optical fiber cable (or nearly 50,000 kilometers of fiber) by 1985. Optical fiber is likely to find its way into business premises and even into residences before the end of this decade, at least in limited quantity.

Another, but more mature "technology star" is literally an object in the sky, the communication satellite. Figure 9 is a photograph of a communication satellite. Since the 1962 launch of Telstar, the first communication satellite, this technology has progressed and matured both the space segments and ground stations. Modern communication satellites are geosynchronous. Most systems utilize 4 GHz for the downlink and 6GHz for the up-link. Some use the 12 GHz-14 GHz combination. Both frequency division multiplex (FDM) and time division multiplex (TDM) are used. Today's satellite antenna beams are a combination of broad and spot beams.

Figure 10 is a photograph of a telecommunication carrier's ground station for a satellite that operates at bands of 4 GHz and 6 GHz and with a broad beam. In the future, a "scanning spot beam" will be used to increase significantly the received signal strength at ground station. Also, solid-state amplifiers are expected to complement or replace traveling wave tubes that are presently used in the space segment. One such power amplifier design utilizes a gallium arsenide field effect transistor. With a solid-state amplifier, more output power is attainable for a given weight. So, as you can see, communication satellites are also benefiting from the advances in solid-state electronics. With a combination of higher frequency bands (12 GHz and 14 GHz), a scanning spot beam, and a more powerful solid-state amplifier, a single satellite should be able to support about 10,000 64-kpbs individual circuits. This means up to 10,000 independent users, each with one 64-kbps circuit, can be served by a single satellite.

Satellite communication systems are particularly attractive for serving remote or temporary locations. Today, approximately 22 commercial satellite communication systems in total are serving 144 countries. Future systems will be able to operate with smaller ground station antennas. A three-meter antenna will be able to meet the need of most corporate users.

So far, we have discussed ways in which telecommunications networks elements, such as transmission systems, terminals, and switching systems have benefited from solid-state electronics and computer technology in lowering or controlling the cost as well as in increasing the capabilities of the systems.

Another type of evolution, less glamorous and less known, is taking place in telecommunications systems. It is the large scale introduction of computer-based systems in all phases of operation. They include customer service order processing, customer record keeping, equipment and circuit inventory, circuit design, circuit maintenance, network performance measurement and tracking, and billing. As a result, work centers in telephone companies, which in the past relied almost entirely on paper records and manual procedures, are now mechanized. Record retrieval and update are done through keyboard terminals placed in work centers. Over 200 different operations support systems are in use in the Bell System. For example, one computer-based billing system is in use in the automatic collection of billing data for measured services that include toll and credit card calls. About 100 billion measured service calls in total are processed each year by this system in the Bell System.

Another operation system found in the Bell System gives a feel for the magnitude of operations that computer-based systems support. This system supports order tracking and circuit provisioning[2] operations. In a typical telephone company, approximately 500 new service orders are generated per working day, involving about 1,500 circuits and 7,500 electronic components (such as amplifiers) that must be specified and tracked. The cumulative result of this volume of orders is that on any given day, a telephone company may have some 30,000 circuit orders pending. This same company would have half a million circuit records involving over three million components.

When used in a typical Bell System telephone company, this mechanized system contains 25 billion bits of data on more than 100 on-line data bases. Up to 200 cathode ray tube (CRT) terminals (TV-screen terminals) and a similar number of remote printers and teletypewriter terminals are associated with this computer-based system. This system uses a mainframe computer, one of many in use in the Bell System. Incidentally, the Bell System is probably the biggest user of computers in the United States (after the federal government). It has some 300 mainframe computers, 500 minicomputers, and 100,000 terminals in use.

Information Age Services and Telecommunications Capabilities

Advances in technology have no practical significance unless they benefit society. Indeed, society reaps many benefits from these advances that resulted in more efficient, economical, and convenient ways of storing, processing, and transporting information.

Videotex is an emerging information age service. In North America, its first commercial application is the Dow Jones News Retrieval service that began in 1977. Close to 40,000 users now subscribe to that service.

There are many variations of videotex service, but in essence, they all enable a subscriber to call up on demand one of large numbers of frames containing current data or information on a television screen. This information includes a broad range of subjects such as personal want ads, airline schedules, local events, weather information, and self-teaching texts. One system for this service that is in the trial stage would offer the subscribers 76,000 frames or screens that are kept current and that can be accessed on demand via the ordinary telephone lines at a transmission rate of 1.2 kbps. Figure 11 is a typical screen. This screen can be "painted" in just a couple of seconds. In total 12 videotex systems are in operation and 14 systems are in test or trial in the world, including ones in the United States, Canada, Britain, and France. Today's solid-state technology enabled this service to be offered in an affordable price range.

A video conferencing service is another child of the information age. This service enables conferees, who are geographically separated, to hold a "face-to-face," conference using video screens. Facilities that remotely display slides and other forms of still pictures and transmit facsimiles of hard copies also accompany this service.

The bandwidth of the standard television channel in North America is 3.575 MHz. This bandwidth is equivalent to a digital transmission rate of at least 90 Mbps. Fortunately, advances in solid-state electronics have made practical the implementation of a sophisticated algorithm called "conditional replenishment." With this technique, the original bandwidth is compressed 30-fold to 3 Mbps, although the picture suffers temporary distortion whenever the subject moves suddenly. The transmission rate of 3 Mbps is significant. The most prevalent exchange area digital transmission system in North America operates at 1.544 Mbps. Two such systems, using 4 pairs of wires, can provide a video conferencing service at this 3-Mbps rate, making video conferencing practical and readily available. Satellite-provided wideband circuits are another alternative, and in the future, optical fibers are expected to further reduce the cost of transmission for this service.

Videotex and video conferencing services are but just two of many information age services. Many other information age services are already in existence or are in various stages of development. Figure 12 lists some of these in generic category. Note that single category covers many services known by different names. For example, the inquiry/response category includes reservations, banking at home, home office, and remote computer terminal services. Telecommunications carriers can support all of these listed services today, although the capabilities needed by some services are either costly or limited in availability.

From the viewpoint of a telecommunications carrier, it is informative to map each of these services in dimensions more directly related to data transport capabilities. There are many parameters that must be considered in such mapping. However, we will use <u>bits per message</u> and <u>bits per second</u> along with density[3]. The figure in Figure 13 is such a plot. Incidentally, reliability and transmission error rate are other important parameters in characterizing needed telecommunications capabilities. As demonstrated in this figure, wide ranges of transmission rates, information volumes (i.e., bits per message), and densities are associated with these new and traditional services.

The density of information transfer is an important consideration in the choice of the type of transport network: circuit switched or packet switched. Packet-switched transport networks tend to be the economic choice of the two for services in the alarm, telemetry, and inquiry/response categories. They all require low density, or "bursty" transmission. Packet-switched transport is also favored when long-haul or long-distance, bursty transmission in involved.

Telecommunications carriers meet the demands of traditional and emerging information age services with a variety of switching and transmission systems as listed in Figure 14. Switching is provided in both analog and digital forms, and in circuit and packet types. The transmission media include wires, coaxial cables, microwave radio, lightwave cables, and satellite links. For a particular application, the needed capabilities and economics dictate the choice. For example, the economic choice for long-haul transmission is still radio for most applications today. Lightwave systems, however, are expected to compete increasingly with radio systems.

In the area of switching, the demand for services is met in the Bell System today by over 2,000 software programmed electronic switches. These switches are the backbone of a flexible telecommunications network. The number of digital switches is increasing because solid-state electronics is making these switches economical. The first digital switch was put to commercial use in 1976. Ten different types of digital time-division switches are now in use in North America. These switches are manufactured by an equal number of suppliers, including one in Japan. In total, approximately 800 time-division switches are in service in North America.

Using these switches and transmission media, communications carriers offer a wide range of voice and data transport services. Next, let me discuss data transport capabilities that support information age services.

Summarized in Figure 15 are the data transport capabilities offered today. Reflecting the viewpoint of telecommunications carriers, it shows only those systems that are generally available; isolated or special situations are excluded. The information in the chart is also based on end-to-end (or user-terminal to user-terminal) transport capabilities. The word "dedicated" in Figure 15 means "not switched." Dedicated circuits are for exclusive and permanent use by one pair of terminals, or by a community of terminals bridged together. A private network may or may not be switched, but in either case, it is used exclusively by a limited or specified group of people belonging to a corporation or institution.

In addition to "data-on-voice" type of transport services that are abundant today, dedicated digital data transport services are also growing. Use of the latter, however, is limited, for all practical purposes, to corporations or private groups. Data-on-voice is a means of transporting a data or digital signal over voice-grade circuits by transforming it into an analog (voice-like) waveform. The conversion back to the digital form takes place at the receiving end. Today's data transport is accomplished primarily on analog transmission facilities using this technique. The available transmission rates are generally low, except for dedicated 50 kbps on analog circuits, and 56 kbps and 1,544 Mbps on circuits derived from a digital carrier system.

Data transport capabilities have been around for some time, but it was in the mid-1960s when data transmission at higher transmission rates on voice circuits began to emerge as more sophisticated and capable data sets became available. Today, a transmission rate of 9.6 kbps is achievable on dedicated, conditioned voice circuits, and on some private voice networks as well.

Some telecommunications carriers provide a low-speed packet-switched data transport service, but this service too relies on the data-on-voice transmission mode. You may find it interesting to learn that a packet-switched network is used in controlling and managing telephone traffic over the Bell System's toll (or long distance) network. About 200 toll switches are interconnected over one million toll trunks (or circuits) to carry long-distance voice or "data" calls. And to make an efficient use of this network, a form of skinny packet-switched network is used within the "call-carrying network" to exchange signaling (or supervision and address[4]) information among the toll switches. Skinny as it is, this packet-switched network consists of 30 packet switches and 2,700 interconnecting links. Today, it transports 60 million signaling messages during one peak traffic hour. Each message consists of up to nine, 28-bit packets. Another packet-switched network, which serves the United States government, has been in operation since the early 1970s. Thus, the packet-switched network is here already, although it is not presently offered by the major telecommunications carriers for general use in the United States.

Within the next few years, data transport capabilities are expected to evolve significantly as shown in Figure 16. By the mid-1980s, digital transport services at higher transmission rates will become more generally available. Public switched digital network services at 56 kbps or 64 kbps are likely to become operational in the United States and in a few other countries. Packet-switched network services too will become widely available at first at transmission rates of less than 8 kbps, and then at 8 kbps, 56 kbps, or 64 kbps by the end of the 1980s. Non-switched digital data transport services at 1.544 Mbps, and twice that rate, for bulk data transmission and video conferencing, will probably also be introduced in the United States within a few years. With the development of these new capabilities, telecommunications carriers are poised to meet the needs of the information age now as well as in the future. Digital transport services should become less expensive for users. The increased demand enables telecommunications carriers to take advantage of "the scale of economy" in providing the transport capabilities that are needed.

Summary

Let me close by recapitulating the messages I wanted to give. Computers and communications systems, working as partners, have brought about today's information age. It was the rapid and impressive progress in solid-state electronics that accelerated the broad-based technology evolution. Modern solid-state electronics and computer technologies are abundantly found in telecommunications systems. It is the introduction of these technologies that enabled telecommunications systems and services suppliers to control the cost and expand communications capabilities. Advancement in computers also generated new demands for telecommunications capabilities and services. Equipped with the solid-state electronics based modern technology, telecommunications systems are poised to meet this challenge.

FOOTNOTES

1 Single-mode fiber transmits lightwaves at one particular frequency.

2 This process involved planning and implementing circuits in a telephone company.

3 Density is the ratio of time used for transmission to the total time available. For example, an alarm circuit might be in place and able to function all the time (although it may be seldom used). When it does occur, transmission over the circuit lasts a short time - perhaps just seconds.

4 Examples of supervisory information are indications that the line is busy, that the station is off-hook, etc. Address information is related to the destination of a call.

REFERENCES

Many sources, too numerous to mention, were used in the preparation of this paper. These sources include newpaper articles, trade magazines, Bell System periodicals, and periodicals from professional societies. However, the following two journals provided most of the facts used in this paper:

Bell Laboratories Record - Published 11 times per year by Bell Telephone Laboratories, Incorporated, 600 Mountain Ave., Murray Hill, N.J. 07974, U.S.A.

IEEE Spectrum - Published monthly by the Institute of Electrical and Electronics Engineers, Inc., 345 East 47th Street, New York, N.Y. 10017, U.S.A.

LIST OF FIGURES

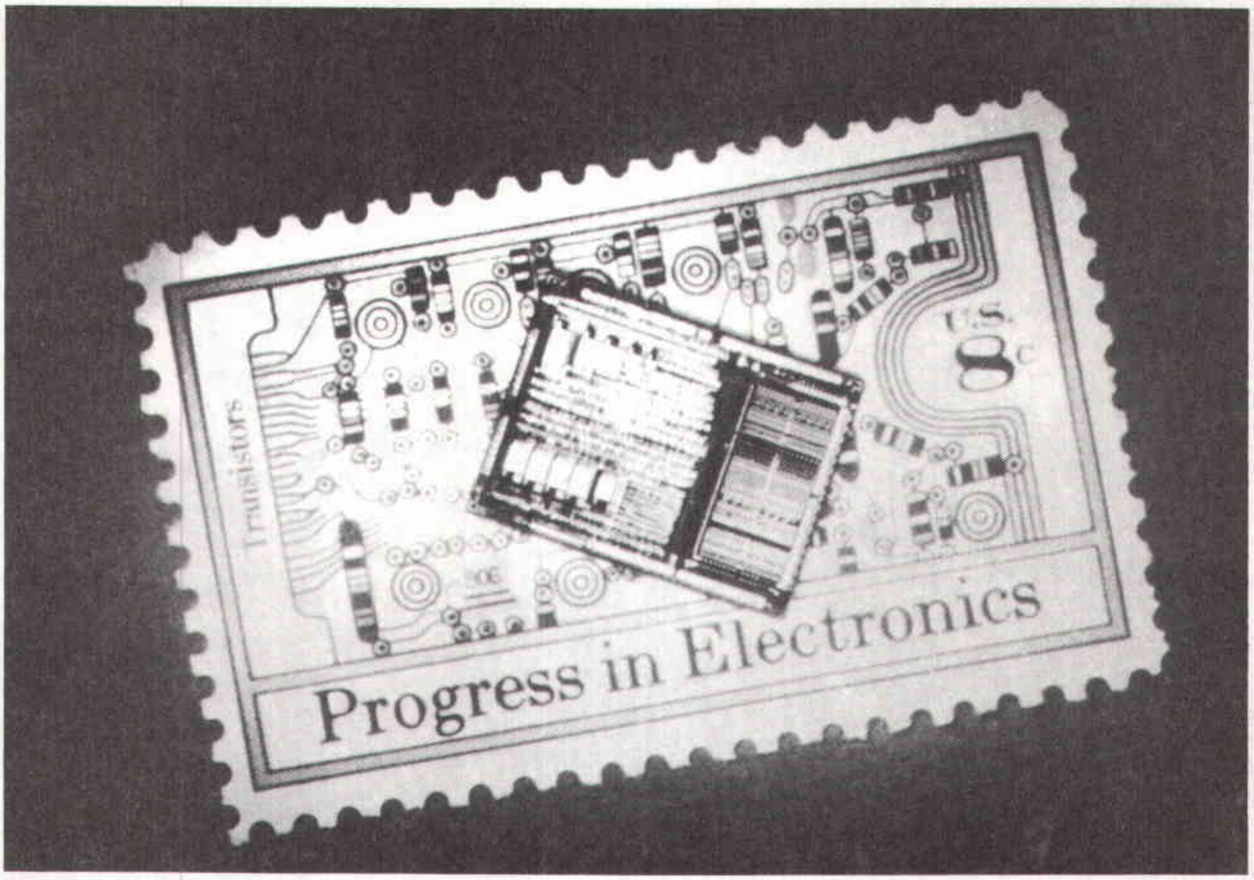


FIGURE 1

Microprocessor

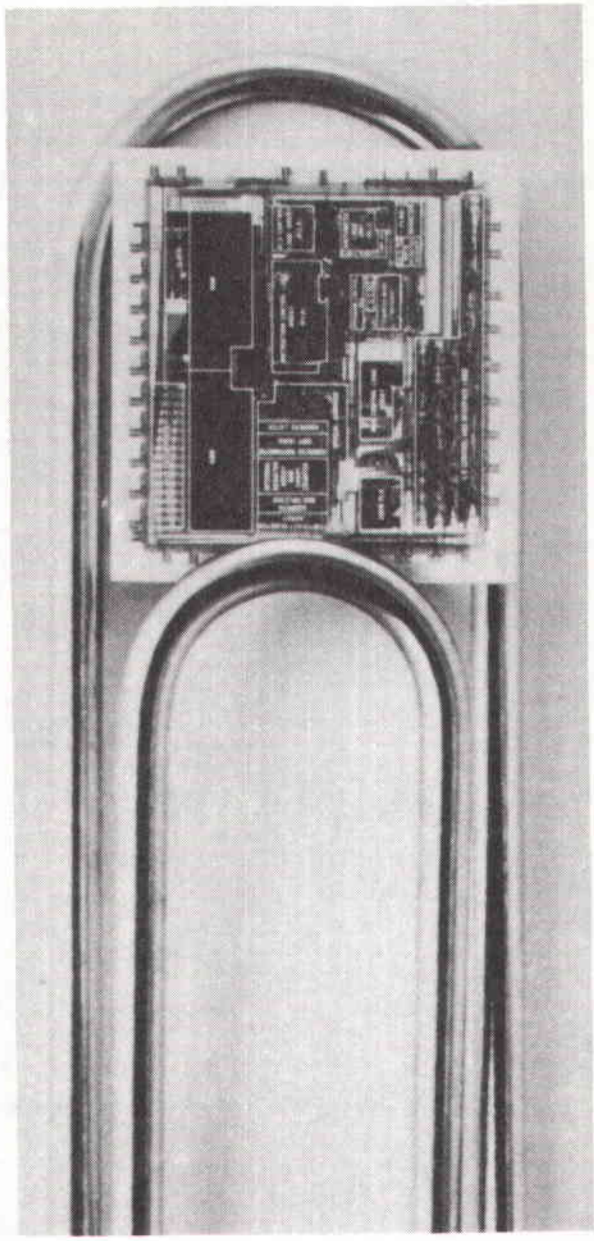


FIGURE 2

Microcomputer

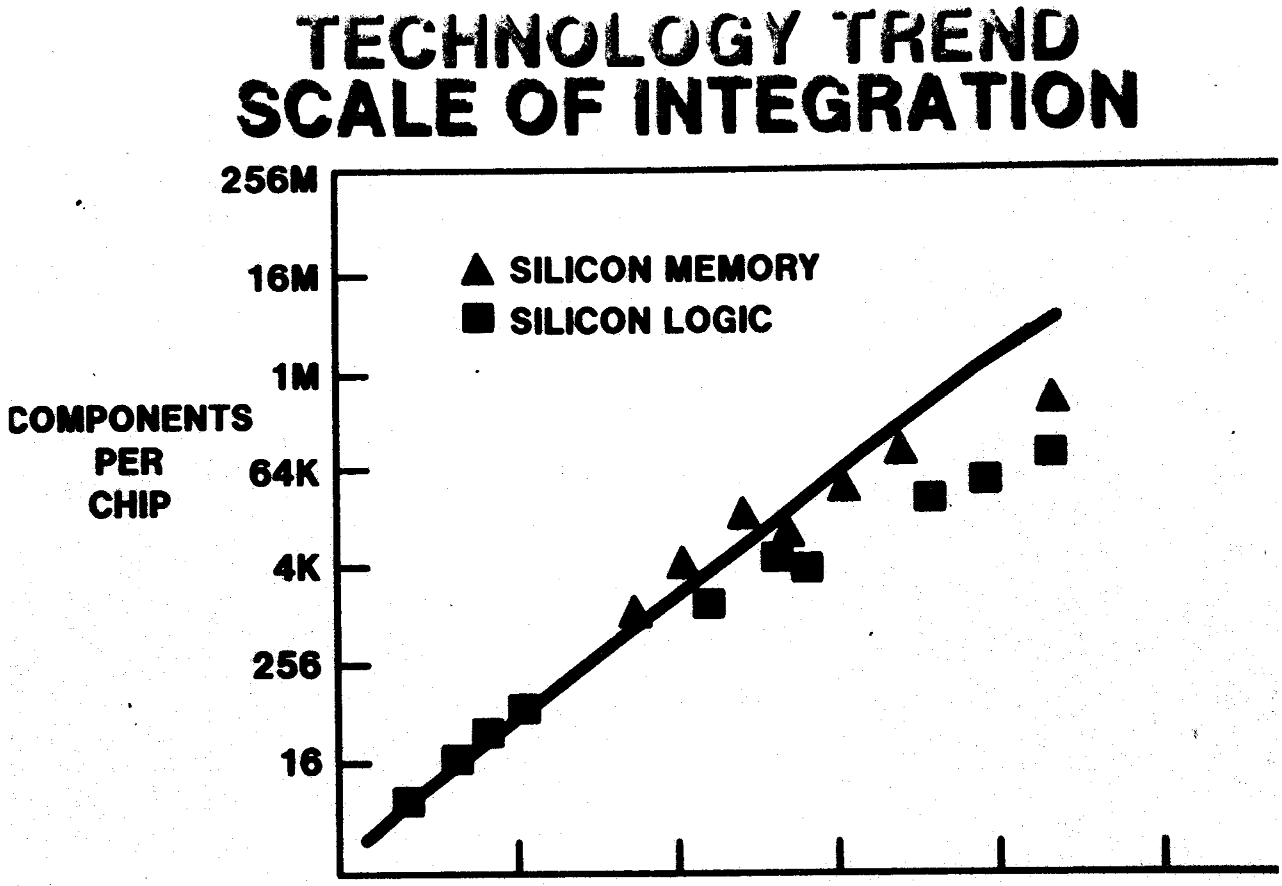


FIGURE 3

Scale of Integration

TRENDS IN PROCESSING POWER

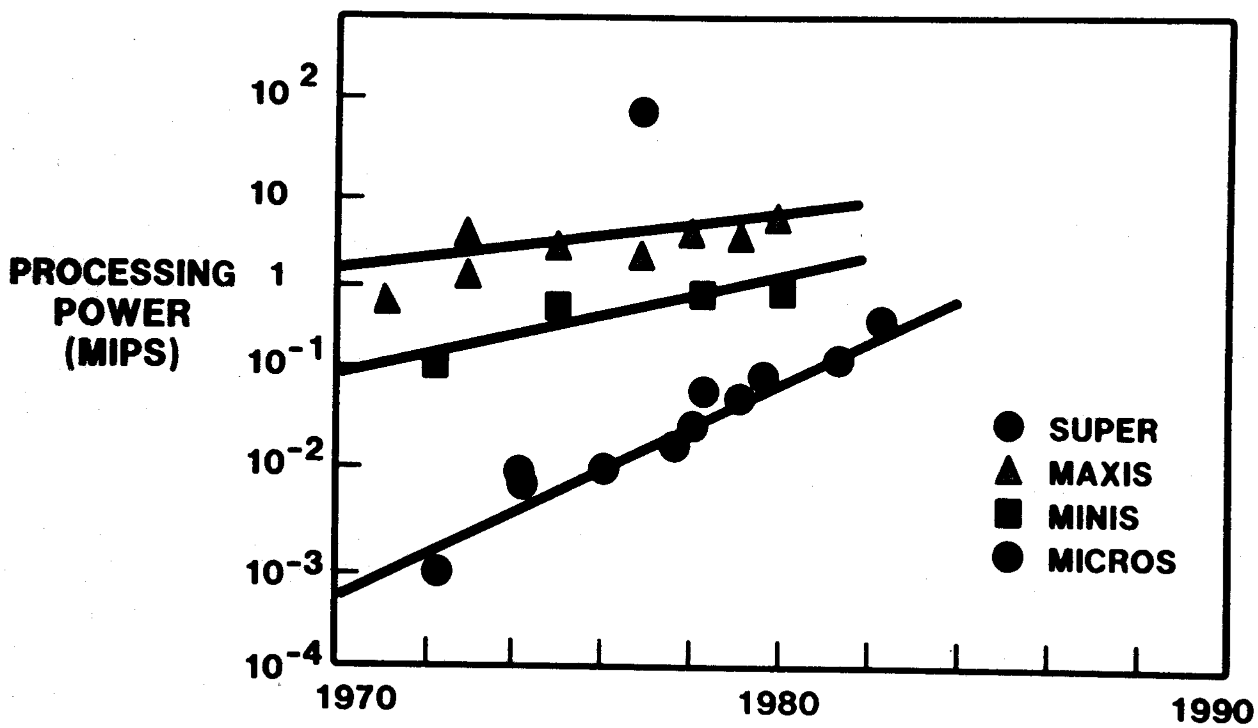


FIGURE 4

Processing Power

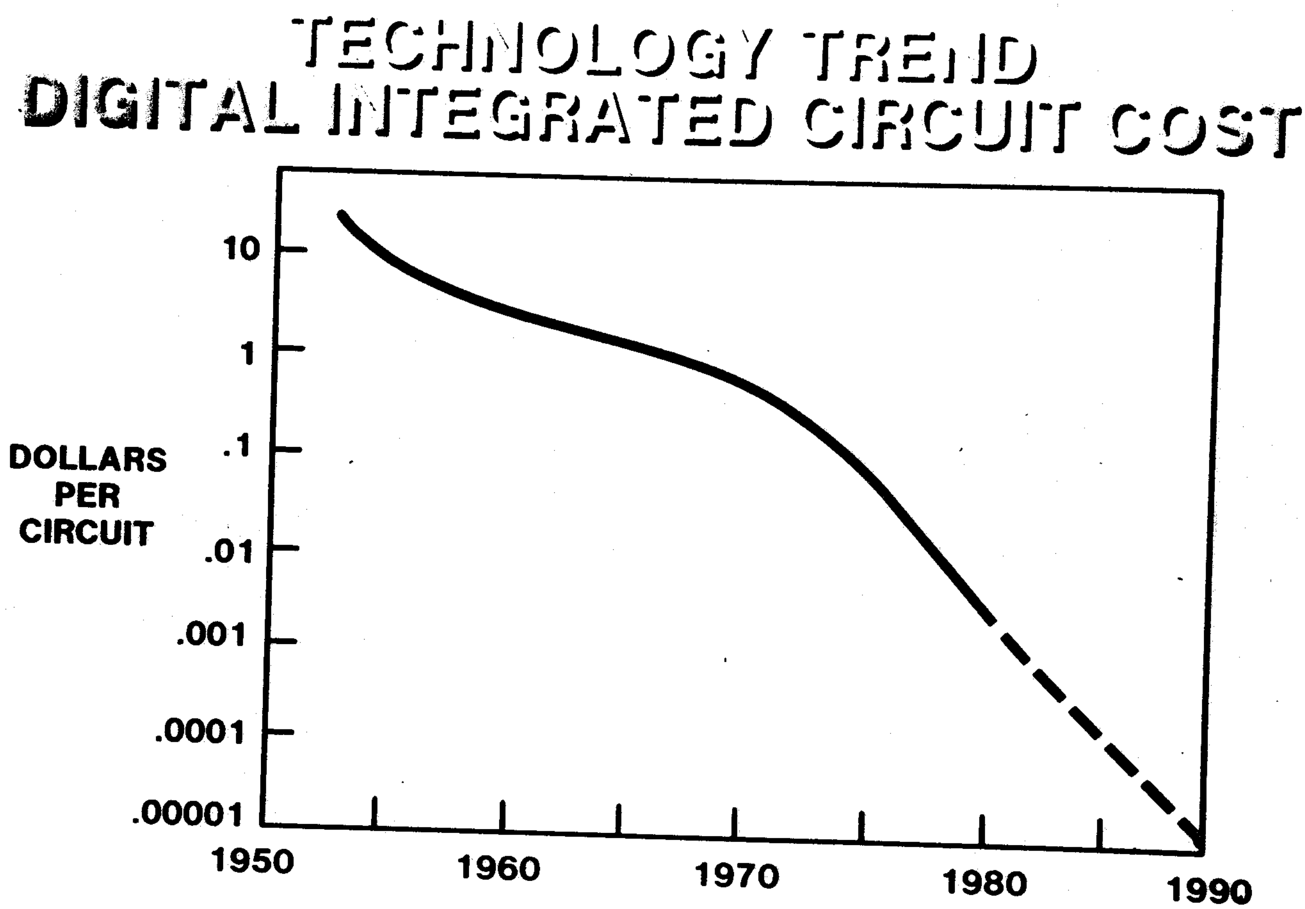


FIGURE 5

Circuit Cost

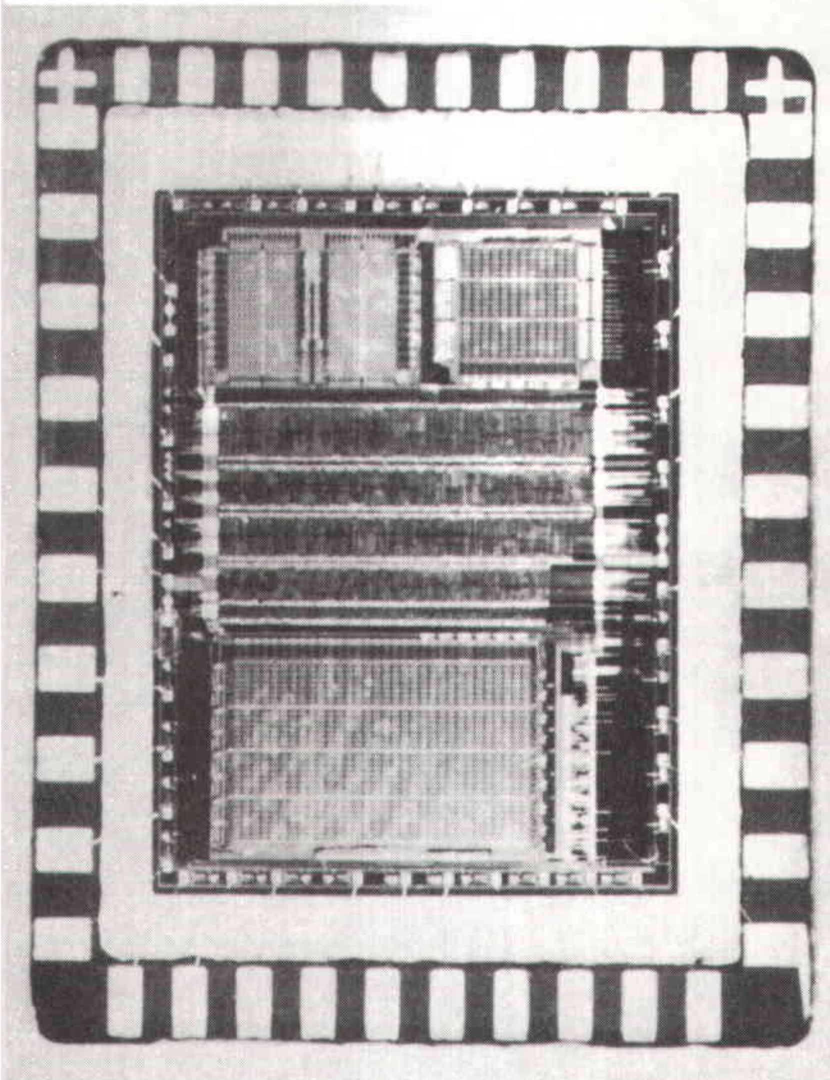
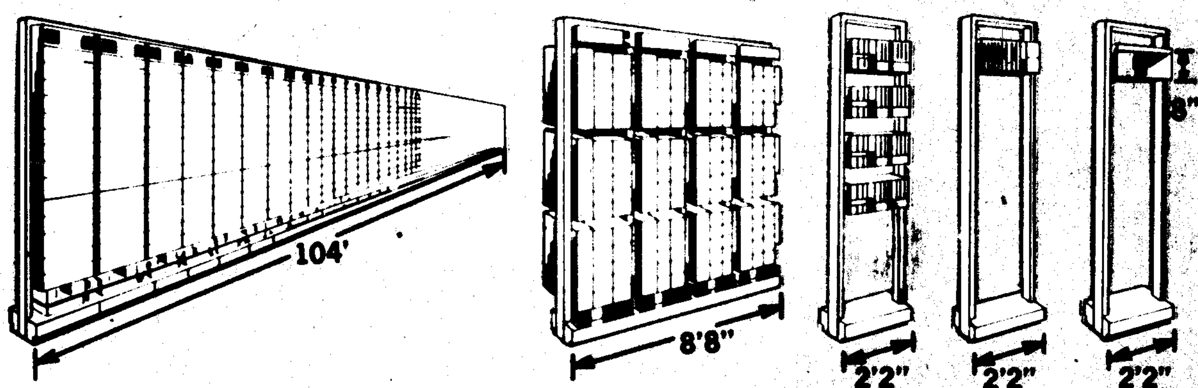


FIGURE 6

Echo Canceler

MEMORY EVOLUTION FOR ELECTRONIC SWITCHES



TECHNOLOGY	FERRITE SHEET	FERRITE CORE	SEMICONDUCTOR 4K RAM	SEMICONDUCTOR 16K RAM	SEMICONDUCTOR 64K RAM
Relative Physical Size	1,920	160	40	10	1
Power(μ W/BIT)	2,800	175	70	20	4
Speed (μ SEC)	5.50	5.5	1.4	.7	.55
Memory Size as shown (M BYTES)	1.18	1.18	1.18	.79	1.05
Year of Introduction	1965	1971	1977	1978	1981

FIGURE 7

Electronic Switch Memory Evolution

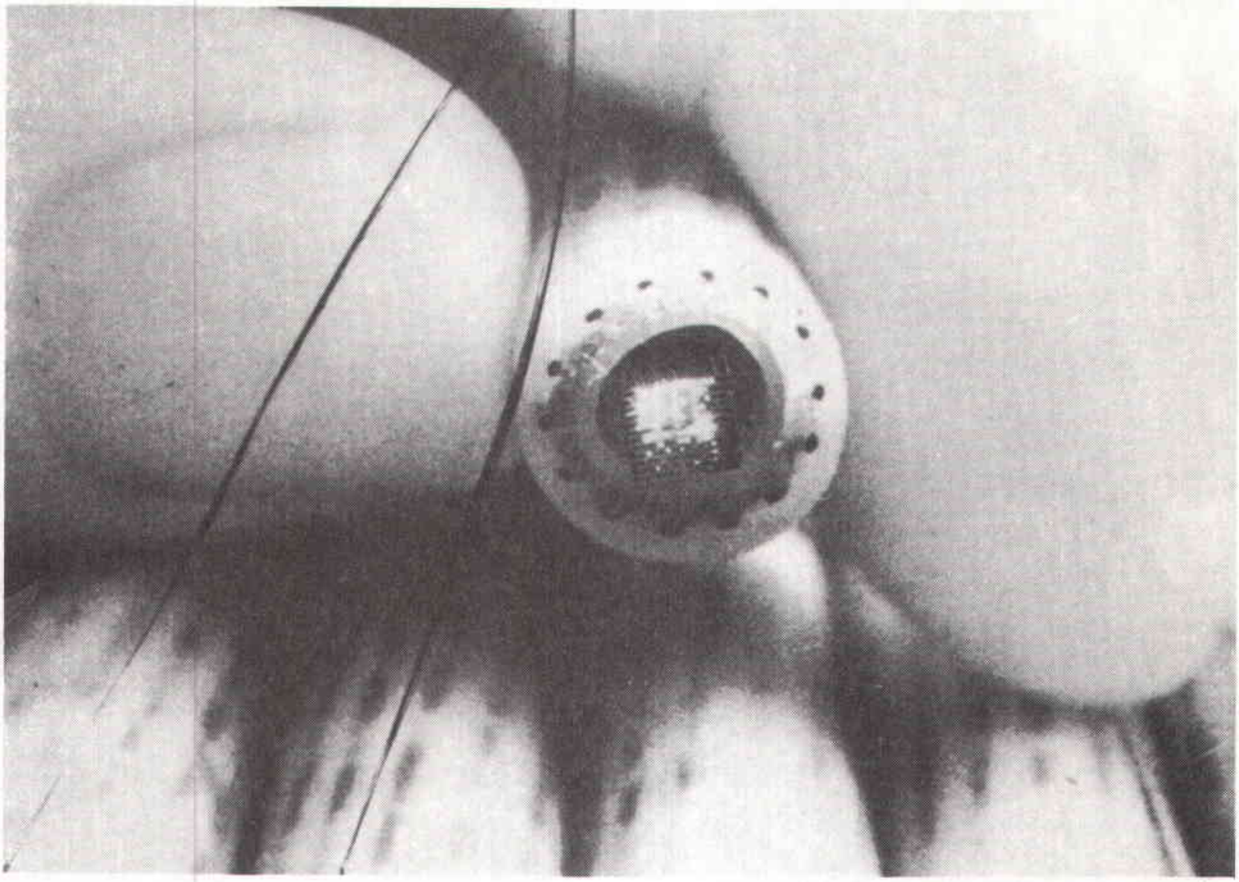


FIGURE 8

Optical Fiber Cable

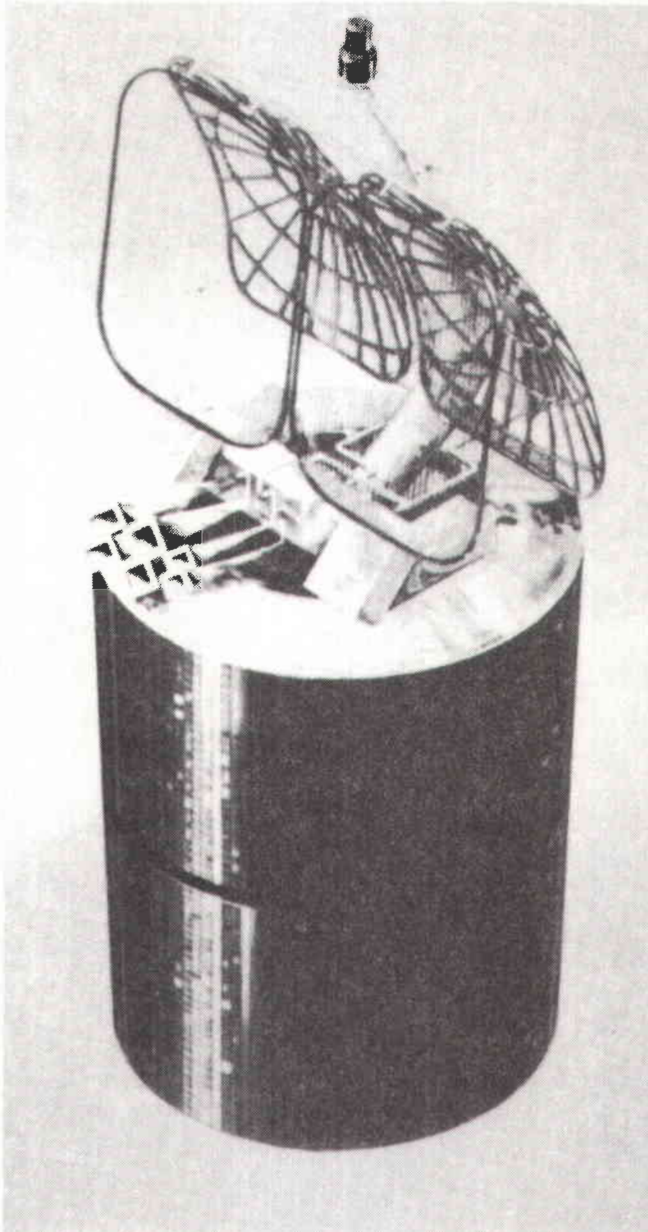


FIGURE 9

Communication Satellite

FIGURE 10

Ground Station

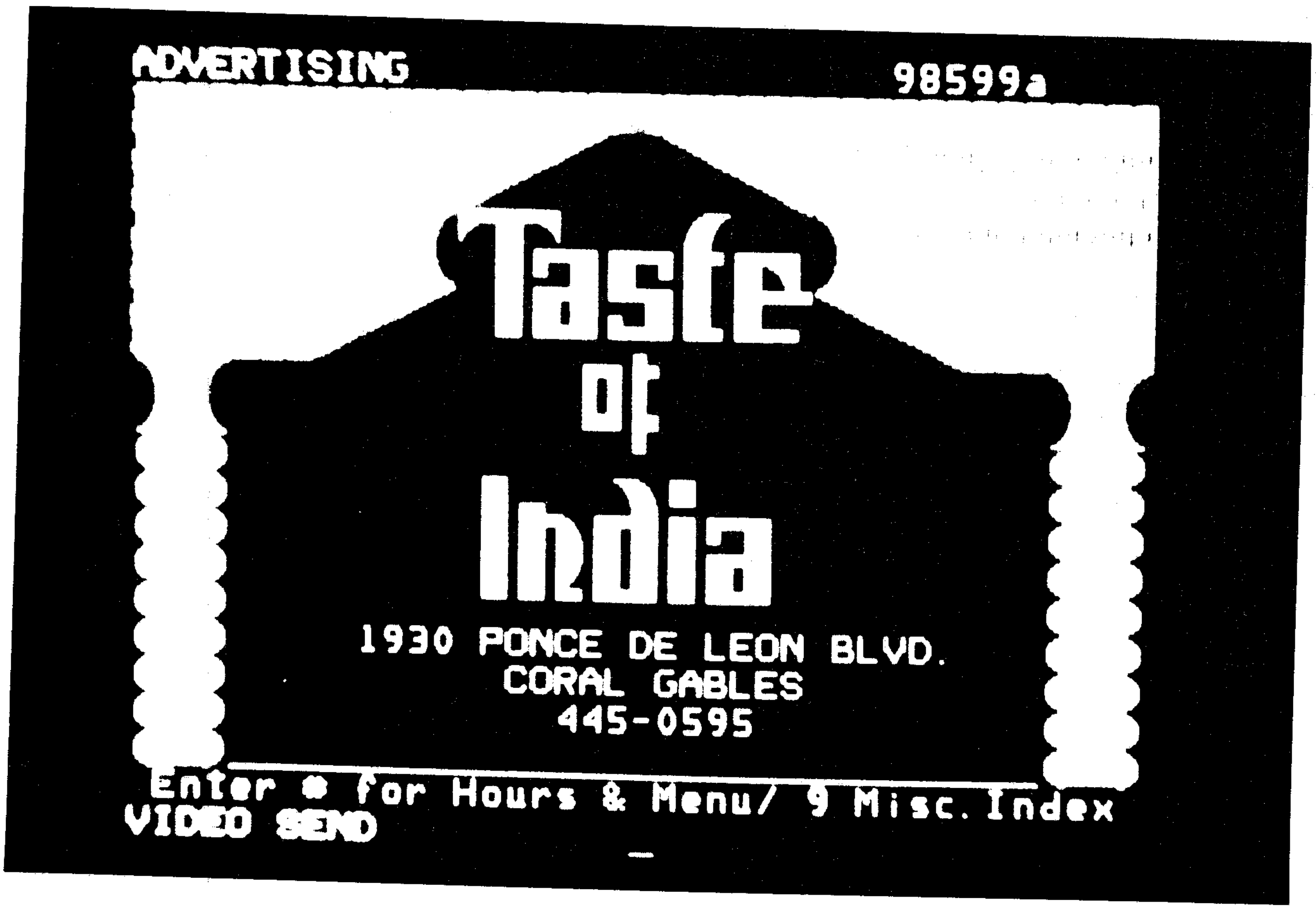


FIGURE 11

Videotex Screen

INFORMATION AGE TELECOMMUNICATIONS SERVICES EXAMPLE

- Alarm
- Telemetry
- Security Monitoring
- Inquiry/Response
- Videotex
- Facsimile
- Bulk Data Transfer
- Video Conferencing

FIGURE 12

Telecommunications Services

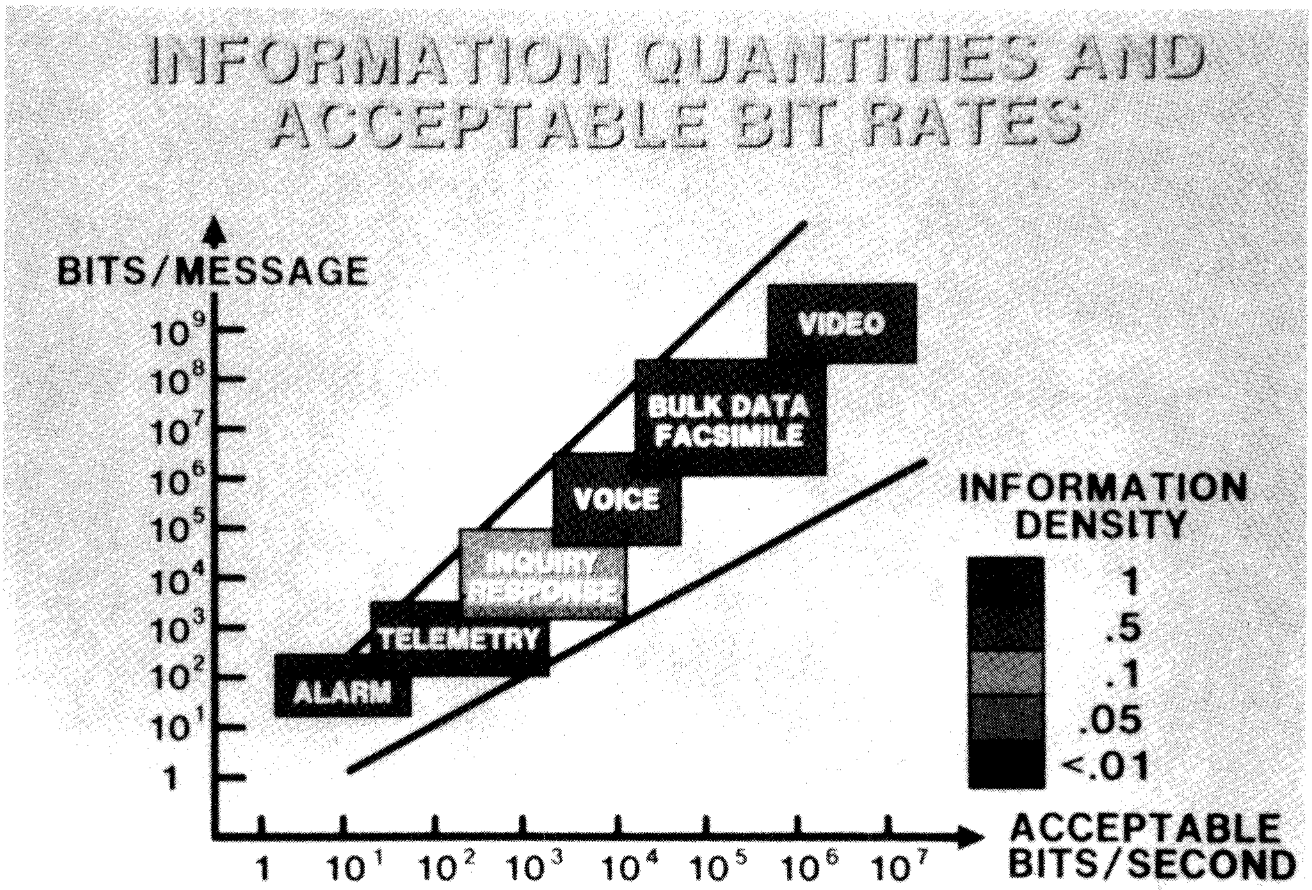


FIGURE 13

Telecommunications Needs

MODERN TELECOMMUNICATIONS SYSTEMS
SWITCHING AND TRANSMISSION

- Switching
  - Electronic Analog and Digital Circuit Switches
  - Time Division Digital Circuit Switch
  - Time Division Digital Packet Switch
- Transmission
  - Digital Carrier on Wire
  - Coaxial Cable
  - Radio
  - Lightwave
  - Satellite

FIGURE 14

Telecommunications Systems

DATA TRANSPORT CAPABILITIES NOW

Analog	
Dedicated	1.2, 2.4, 4.8, 9.6, and 50 kbps
Circuit switched	1.2 kbps 2.4 and 4.8 kbps (Private)
Packet switched	1.2 kbps (Private)
Digital	
Dedicated	1.2, 2.4, 4.8, and 56 kbps 1.544 Mbps

FIGURE 15

Data Transport Capabilities - Now

ADDITIONAL DATA TRANSPORT CAPABILITIES FUTURE

By mid 80's:	
Digital	
Dedicated	**64 kbps, 1.544 Mbps, 2 x 1.544 Mbps**
Circuit switched	**56 and 64 kbps**
Packet switched	**<8 kbps** **56 kbps (Private)**
By late 80's	
Digital	
Packet switched	**8 and 56 or 64 kbps**

FIGURE 16

Data Transport Capabilities - Future

Lawrence Roberts

I'm going to talk primarily on the future trends in communication systems and office automation. The first thing I would like to cover is the overall communications volume in data and voice that one sees when one looks at an office of the future where you might have a large collection of terminals and data devices for each person and his normal voice load.

Looking at those organizations that use electronic mail heavily, one finds that they will send two messages a day and receive about eight. This basically results in an average data rate during peak hours - not a peak data rate - in terms of bytes of useful bytes transmitted, as shown. I am looking at average data rate, very importantly, rather than peak data rate. Peak data rate for all of these services is something in the order of sixty-four kilobytes. That probably could be handled equally well as four and eight-tenths kilobytes in some of the earlier parts of these services. But the average daily rate is far more important, because this is the load that is seen by the network as soon as it is put into packet form; and so this is the load that has to be carried by a cable within your office. This is the load that has to be handled by the switch, and it is the load that has to be handled by the long haul network. And so it is, in fact, the band - let's say of a COAX speaker map - that you would need within your office So that's a fairly heavy electronic mail load.

But on top of that, I am saying this user is also going to sit at his terminal - as will every person in the office - three hours a day doing some interactive tasks, order entry, accounting, drafting, or circuit design programming. Whatever they are doing in their office, whatever their job is, they will be using a terminal fairly heavily three hours a day, and you might envision that going up to a full eight hours in several more years into the future. That puts the load of about forty-four bytes per second on the network, a very small number, but it's what is generated by that user in terms of average traffic that is measured from heavy users on commerical networks today. Word processing and the secretarial people will put an additional load on the network.

The facsimile mail is group four facsimile. Group four facsimile is just starting to be introduced by a number of Japanese firms, far ahead of the United States in terms of facsimile development for obvious reasons. This facsimile will have the quality, speed, and paper-handling capability that will make it turn into your mail handling system. The quality is equal to and greater than today's photo-copying machines, and the paper-handling speeds are between one and four seconds per page. So you can dump all your documents in it and have them sent all over the world to their destination, even within the same office building. And the use of that system for moving your internal mail might go even considerably higher as it becomes more heavily used. Note that for the part that is transmitted, there may still be many copies made of that document when it arrives at my location or my office floor. I might take those seven pages or so per day per person and make many more copies of it.

And the last item is the document processor that can print the electronic mail. I want to print the report that I found with my information retrieval system, and so on. So the same facsimile device, probably, is also an intelligent copier printer and needs to print about seven pages a day, but now in text rather than facsimile form. So there is another additional load for the office.

All of that - none of which has happened in one office today, but all of that added up together - adds up to about ninety-one bytes per second per person, or for a whole office of a thousand people, only ninety-one kilobytes of traffic. Now that seems remarkably small compared to what we are putting in. We are talking about ten megabyte cables running around the office for this kind of thing. The amount is remarkably small, and I expect maybe those figures will double or triple in the next decade, but still it is the most one can see if one doesn't add video conferencing into the list. And video conferencing, I feel, is going to start with freeze-frame technology and progress to full video conferencing on a very wide scale very slowly, if ever, because the relative value it provides that doesn't seem to be substantially greater than a very good graphics movement capability in addition to voice. So that is a picture of the office in the near term, in the next three years.

If you add that to the voice, sixty-four-kilobyte voice using silence detection but no compression, for the average user, winds up to average about six kilobytes of graphic in peak hour. The average user will generate about ninety-eight percent voice in terms of the data traffic today, and a total of about six kilobytes of total traffic or six megabytes for a thousand-person building.

Now I might mention that that is going to change radically. The voice traffic is going to come down. We are introducing voice compression on top of this, which I will be talking about a little later, but that six megabytes will be coming down, not up. The data traffic will be growing slowly, and the voice will be falling very rapidly as compression techniques are used. The figures for data and voice will probably cross, not by virtue of the data growing but of the voice falling to something under a hundred bytes per second average rate per user for the peak hour by the middle of the 1990s. The reason for that is compression. A factor of more than a hundred in voice compression is going to be applied to that kind of number. That leaves us with a data load that is as high as it will ever be and is falling with time because of voice compression. If we are going to introduce these very large systems in the office with a very high band width, we have to find something else to generate information to move.

Now let me look at the network needed to move this. The network has to handle the peak rate of all of this plus the average traffic that is involved, and we have to look at the kinds of facilities and switching techniques, in the office where I have shown both a local area network, a cable system on one side, and a local area network using a PBX on the other side. Both are options for handling the data and voice within the office. Xerox has spent a lot of time advertising the right-hand system, the local area cable. The PBX currently in use for virtually all the voice applications could handle equally well the data applications over the wire pairs in the office, and I will be looking at that tradeoff in a minute.

The second component from the office up is the local access trunk that gets us to some central office of the carrier. In the United States, there will be a large number of competitive carriers, perhaps five, providing the long-haul service and then trying to devise a good local access loop as well. In other countries, a nationalized carrier will probably be providing the upper part of the picture. But, in most countries, at the bottom of the picture will be many competitors for the office equipment.

I might mention here that the majority of the equipment in this whole system, the majority of the investment, will wind up being in the office of the future. The equipment up at the top is data so compressed by the time it reaches the local access trunk, the inter-CO trunk and inter-CO switches that, in fact, the total amount of equipment in those systems will require less investment than there will be in the switch in the office and the equipment on your desk. In fact, the biggest investment of all will be in the desk terminal and telephone. And it goes down from there on through the system. So, the biggest market is, obviously, in the bottom of this picture. That will result from change in technology to the point where all of the data and voice can be compressed together into a single channel and switched as a single group rather than breaking it back down as we do today into individual little channels. The division into channels makes the cost of the system up above very high. Now looking at a piece of that, I find that voice compression technology is the most critical thing that is happening in terms of that long-haul and medium-haul facility. Particularly in the long-haul, voice compression makes a huge difference in terms of the facilities needed.

Silence detection today is done in two different ways. One called digital speech interpralation is used almost exclusively on satellites. Almost every satellite has silence detection and speech. It was originally used, of course, in cables overseas, but that was an analog version that didn't work anywhere near so effectively as the silence detectors do today. You can't detect silence detection as a user. It basically takes out the silence and reduces the total speech by a factor of three. Often times the headers and other information interspersed reduce the effect by about a factor of two, so that the compression ratio, depending on the size of the channel you are moving into, is somewhere between two and three for silence detection.

No matter how you do silence detection, you have essentially produced packet speech. Now, BSI, as it is called, puts a label in and then sends samples for that user every so often. In a pure packet system, you might accumulate a few of those samples with a header at one time, send that, and then send another header and some more data samples later. But, no matter how you do it, you're sending label segments of data through the system and that is basically packetization. Silence detection systems will be used very heavily throughout the entire data voice communication system in the United States and I am sure in other countries as well starting within the next year because that factor of three is not only very critical to reducing cost, but it is also available now virtually at no cost. The technology is to the point where it is of very high quality, and of unnoticeable thing that can be done on any trunk line, on any cable, in the telephone system.

Voice compression, on the other hand, is just starting to make its move in terms of reducing the band width of the peak rate of the voice in the non-silenced period. That is starting with thirty-two kilobytes. Now, SDS, which is the competitive carrier that started out with satellites in the United States, is using both silence detection and voice compression at a thirty-two-kilobyte rate of a factor of two over the current sixty-four-kilobyte rate. The result is that SDS is getting a factor of four in compression, and that is where almost every carrier going into the business today will start out at as a minimum. I do not believe that there is a possibility of a competitive carrier existing in the United States if he doesn't do both of these things to achieve competitiveness with the current Bell system. He needs at least a factor of four because of the Bell system's economy of scale. Competitors are going to be doing that factor of four within a year or two, so that one needs to keep pressing that voice compression scale. And that is happening. Sixteen-kilobyte voice is quite reasonable today and will be introduced commercially within a year or two. It's still rather expensive, but the cost will come down very rapidly in the next two years. And then eight-kilobyte voice, four-kilobyte voice, and two and four-tenths voice are proven very effective but are still rather expensive and need some quality improvement. But, when you get down to two and four-tenths-kilobyte peak rate voice, with silence detection on top of it, you have an eighty to one compression ratio of what is being sent today. I believe by 1992 you will be seeing that in common practice in the system - certainly within the competitive carrier systems if not within the Bell system. So we have that large factor that is going to start being introduced and, based on what I said earlier, that brings the average voice rate per user down from the six kilobytes per second average rate to something like sixty bytes per second. So we have a huge change taking place in that area.

Now on the local access trunks, we have various options available. The most commonly used today, of course, is not only wire pairs but also the local microwave at something in order of T2 speed six and two tenths megabytes, which turns out to be very economical for handling distances of up to about five miles. Microwave uses a single, very small antenna mounted anywhere on the building or a fiber attached to the building that does in fact provide band width way beyond what would be needed, but is about the same cost if right of way is available. Satellite antenna on each roof is less likely for the average building unless you are considering the larger installations where that cost appears to be competitive with the other options. The wire pairs will continue to be used and, of course, the two-on-one wire pair into the building will probably provide much more communication band width than anybody in that building needs for quite a period of time in the future, given that each building has hundreds of pairs coming in. But the competitive carriers really don't have access to that, so you will see a lot of the final three options being installed.

Now looking down at the local net, within the building, I said that I was going to mention the tradeoff between these various techniques that are being introduced. There are two basic techniques used in cable technology: one used by Xerox, called Base Band, and the other by Wang, called Broad Band. Those are probably the primary providers of those two systems. They are almost the same in cost as you can see (Figure 1). Here is the price trend, based on marked-up manufacturers' cost, for 1981 through 1986. The cost trend comes down quickly with LSI and integrated circuits so that you are really looking at the cable installation and the expensive components of the system that can't be changed so easily.

You see three basic sets of curves. The top curve shows the cost of providing ten megabytes of band width to every user. In other words, providing the entire cable interface to each user. And that curve is considerably higher today than providing sixty-four kilobytes - the curve for base band and broad band. Sixty-four kilobytes is done with a controller on each floor providing one wire pair for each user of the local access, so you really go by wire pair for a shorter distance to a controller and then into the cable thereafter. That option is widely used today in cable systems and brings the cost down to a similar number to the PBX that you see at the bottom.

The PBX though, can provide over that single wire pair that is already installed in the building about one hundred kilobytes full deflexive data to the end user with a simple LSI chip at either end of that line. That capability is going to be introduced extremely rapidly by large numbers of organizations to provide not only access in the building but also into the home, that is, using the current wire pair for something in the order of sixty-four to one hundred kilobytes full deflexive data, voice, or whatever it might carry. And so, that wire pair can provide that kind of sixty-four to one hundred kilobytes worth of data to the office desk, each desk in the office, as can the four-port controller on the COAX systems.

It is only the top curve that provides something in addition to that, and that is the ten megabytes worth of band width that we might get out of cable and that is useful for the large computers, the large computer facilities and the source data generation equipment that you might have, but I can find very few uses for it in the normal office; ten megabytes is far more band width than most users will ever generate in terms of either peak rate for their applications or whatever. So, if you need it, it is there and the cost is somewhat higher. It would be quite affordable, but it's not clear at all that you will probably won't wind up using it for the normal office. The PBX has the normal wave for distributing data voice and data to the average user and then the COAX for the very high memory band devices.

Looking at that on a physical basis, those cost curves are the way they are because essentially the same thing is being done in all three cases. In the top case, we get a very long look at a network cable technique or multiaccess technology with a ten-megabyte interface for each terminal - that's expensive. It is still expensive and will stay relatively expensive compared to the lower-speed interfaces. The second case, in the middle, I basically put a little controller there, and have only one interface per user for four users and thereby I have my cost down somewhat. And I run my arrow all the way down to the basement now, however, and put it directly into the backplane of the machine. My local area network is a little box in the backplane of the switch. That box is far easier to handle at a foot distance than it is to handle a local area net at a thousand feet distance. Problems in terms of error detection, collision detection, and everything else are able to be handled without any problem on the backplane, whereas they are very difficult in the office. The interface cost is now one chip rather than the whole collection of hardware. So the cost keeps coming down in each of these as long as the wire pair does not cost so much to drop to the basement. In fact, it adds very little overall to drop it from the first little segment to the basement. These are capital installation costs. Capital equipment costs plus installation - one-time costs - that is the best way to look at this because you are going to buy the system, and the annual cost would be a percentage cost of that for maintenance.

Now, if we drop back to the long-haul for a moment, there are a number of options: the T1 wire, the microwave, more satellite activity, and, of course, the latter will probably be the backbone of the long-haul network in the future. Fiber provides a far lower average costs than any of the other alternatives if you can generate the band width to fill it up. It is very hard to find sufficient band width to put a major fiber route between most cities. They don't generate that much. Also, as voice compression occurs, we are going to have to find something else to fill it up, because we can't even fill up the wire and microwaves we've got installed today.

Now, let's switch back again to the PBX that then winds up in the office or the switch in the central office that provides service to the home. In both cases they are basically the same device. We have a voice data switch that is putting over one, maybe two pairs of wire to the device, to the terminal, either the telephone, a data-access device, a feature phone with a terminal plug on it so that you can plug your terminals into it, or an integrated terminal and telephone workstation that is being introduced. So, you see a single wire pair handling all of the traffic for those devices in the next few years. The attractive part of going to packet switching here rather than circuit switching is so that you can put all of that on one wire into one port in the switch and combine the voice and data together because that cuts the cost of the switch down by a factor of two. There are substantial attractions to start integrating voice and data right out of the device in the office and then on through the switch without paying any attention inside the switch to the difference and without having to worry about the distinction. It can just be switched as several different calls.

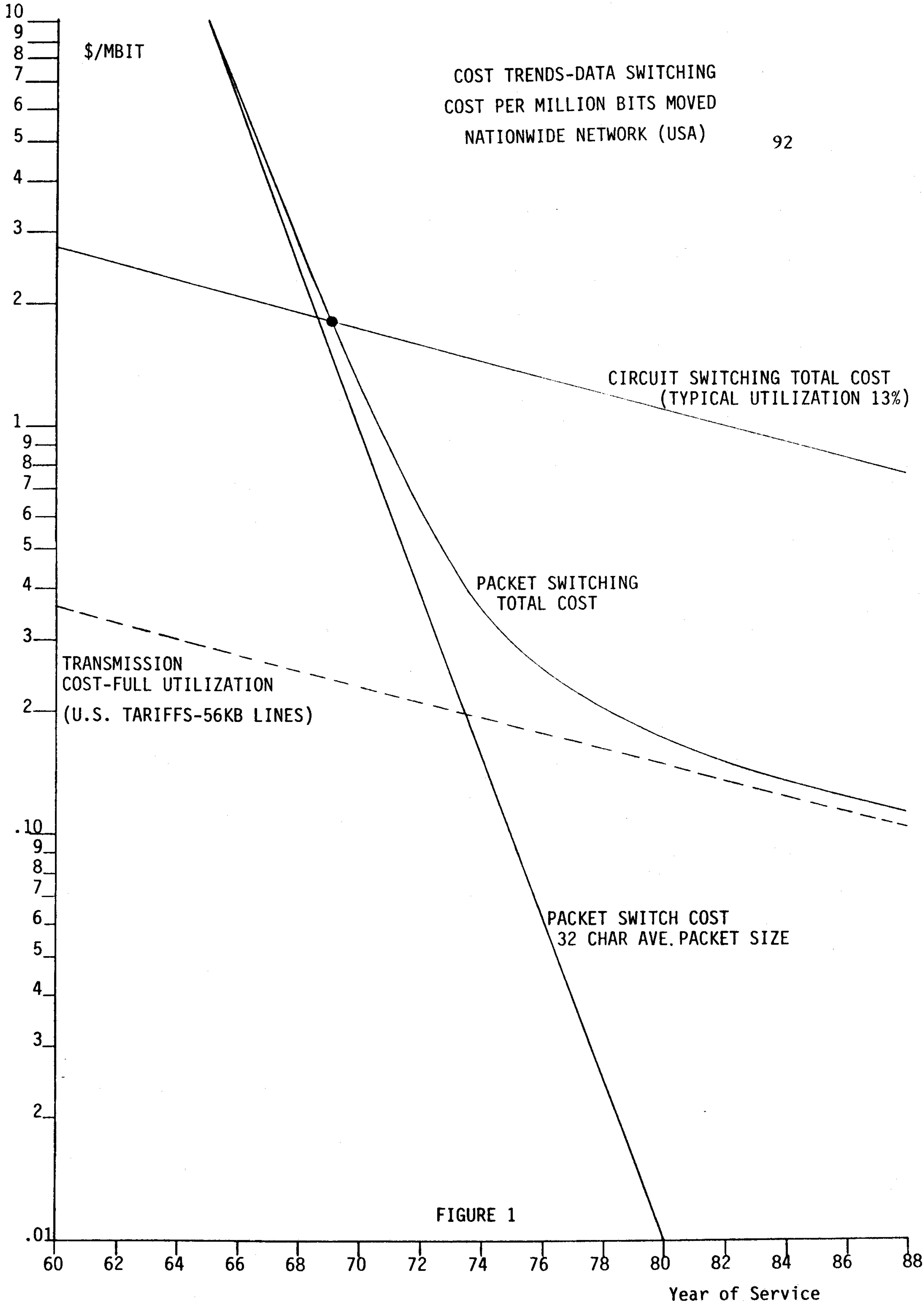
Now looking at data first and then voice, I will look at some of the trend curves that I have developed for the cost of the transmission and the cost of processing in packet switching and in circuit switching to see what drove us to a new switching technology in the data communications world. With all of the semiconductor technology you have just heard about, the cost of processing has been coming down at an extremely rapid rate, a factor of ten every five years in finished products (Figure 2). The cost of communications transmission as purchased from the telephone company, in this case United States Trust, for fifty-six kilobyte service is considerably flatter. It has been dropping maybe five percent a year, vastly less than the overall drop in processing cost. And so the cost of packet switching, which is the sum of the two, to do the extra processing needed to save the band width on that transmission facility, has been falling. Across the circuit switching is a transmission capability that is virtually seven times higher in cost due to the average compression ratio of data, and then the cost of the circuit switch that adds slightly to that curve. The result is that it is basically seven times the current cost of packet switching. Their costs crossed in 1969. After that, the experimental net started and then the carrier facility about six years after that crossover, so we wound up starting to create an industry. It was only a decade later that people really changed world-wide to use the more economical capability to move data. And of course, that is also now being used not only for data but for the control and voice calls as was mentioned earlier in the CCIS system.

Now, when we look at voice, we have a slightly different basis that we should look at it. First of all, we look at a carrier providing this, the owned facilities, and the cost of making the transmission facilities. We are going to look at the smaller thirty-two-byte packets for the long-haul voice. The processing cost includes the determinations for analog voice interfacing, so that has changed the curve slightly from the previous curve. What I have used here for the transmission cost, the circuit-switching transmission costs, is the actual average AT&T investment in the United States over time that keeps coming down. If you built an entirely new network today with fiber nationwide or with satellite nationwide, you would come in at a slightly lower point than that curve, so that you must realize that the curves will switch down if you look at somebody building a totally new network today. But, the result will be the same, no matter how far you move those lines up and down. It is not three times cheaper in the early '80s to do packet-switched voice than it is circuit-switched voice. The quality has now been shown to be perfect also. There is no degradation in this if you used the kind of high-speed switches we are talking about here with delays in the microseconds as you pass through the switch.

The problem gets even more interesting when you look at the bottom of these curves and see that the packet-switching switch cost crossed below circuit-switching switch costs in 1982. Why should the packet switch be cheaper than a circuit switch? The reason is that in the end office, it is not. The interface with your telephone costs the same, but in the central tandem switches, it is vastly cheaper to switch a whole packet one at a time across an interface than it is to break it down into characters and switch each character one at a time. So you have a very substantial cost-saving in the tandem offices in the network. Therefore, as you look at these network curves that are for five offices across the country, you find there is substantial saving already in using packet switching for tandem switching. And this is fully recognized now, I think, in terms of the major long-haul carriers, and will start to be introduced as the mechanism for handling long-haul speech during the late '80s. Still, it takes a decade after that crossover before anybody does much as we saw in data and before it is fully understood.

The switching technology is also changing, and this makes one substantial benefit to the end user. It means that he can mix anything - data, voice, or video - through this system without worrying about what it is and without the carrier having to worry about what it is. It is all homogeneous. It will work up to ten-megabytes or one hundred-megabytes peak rate for the signal. If you want to move ninety-megabyte video and pay for it, then that can be one signal that moves through the long-haul network so long as the long-haul network channels are ninety megabytes wide, which they will be with both fiber and satellites. So the switching system I am talking about here is one that will move any signal from telemetering at one byte per second to video at ninety megabytes per second or video conferencing at mid speeds without any differential issue to the switch in the system. It just moves them all homogeneously through the system, so the user can be flexible in terms of what he chooses.

Now, I have basically completed that picture, but let me add a few comments of impact. One of the things that one sees is that because the system comes out very homogeneously to the end user, the carrier or the provider cannot charge drastically less than video per byte than he did for speech. In fact, the voice handling is going to have to stay at a price that is similar to the competitive prices we have today, or we can't pay for the network that has been installed. As speech becomes compressed, it should get a lot cheaper. As it becomes compressed by a factor of one hundred, it could get a lot cheaper, but the network still costs just as much and investment is there. So the result is, without increased traffic to use up that network, the costs per voice call will have to stay in the same relative ball park, not fall by a factor of one hundred. The result is that in a homogeneous system you cannot charge almost the same amount for a video call as you charge for a voice call, because the user could easily use that same band width any way he chooses. Therefore, there is a real issue about whether video conferencing can be made artificially attractive to the users, which is about the only option to make it attractive at all. If you drop the price artificially for video conferencing, that leaves me at a loss as to how to generate the additional traffic we need to fill all of the competitive networks that are going to spring up and generate two or three times the capacity we have installed today, which will already be fifty times too much by 1995. And the question results, would it become cheaper to move information if we had the information to move?



$/MBIT
COST TRENDS-DATA SWITCHING
COST PER MILLION BITS MOVED
NATIONWIDE NETWORK (USA)
CIRCUIT SWITCHING TOTAL COST
(TYPICAL UTILIZATION 13%)
PACKET SWITCHING
TOTAL COST
TRANSMISSION
COST-FULL UTILIZATION
(U.S. TARIFFS-56KB LINES)
PACKET SWITCH COST
32 CHAR AVE. PACKET SIZE
10
9
8
7
6
5
4
3
2
1
9
8
7
6
5
4
3
2
.10
9
8
7
6
5
4
3
2
.01
60
62
64
66
68
70
72
74
76
78
80
82
84
86
88
Year of Service

FIGURE 1

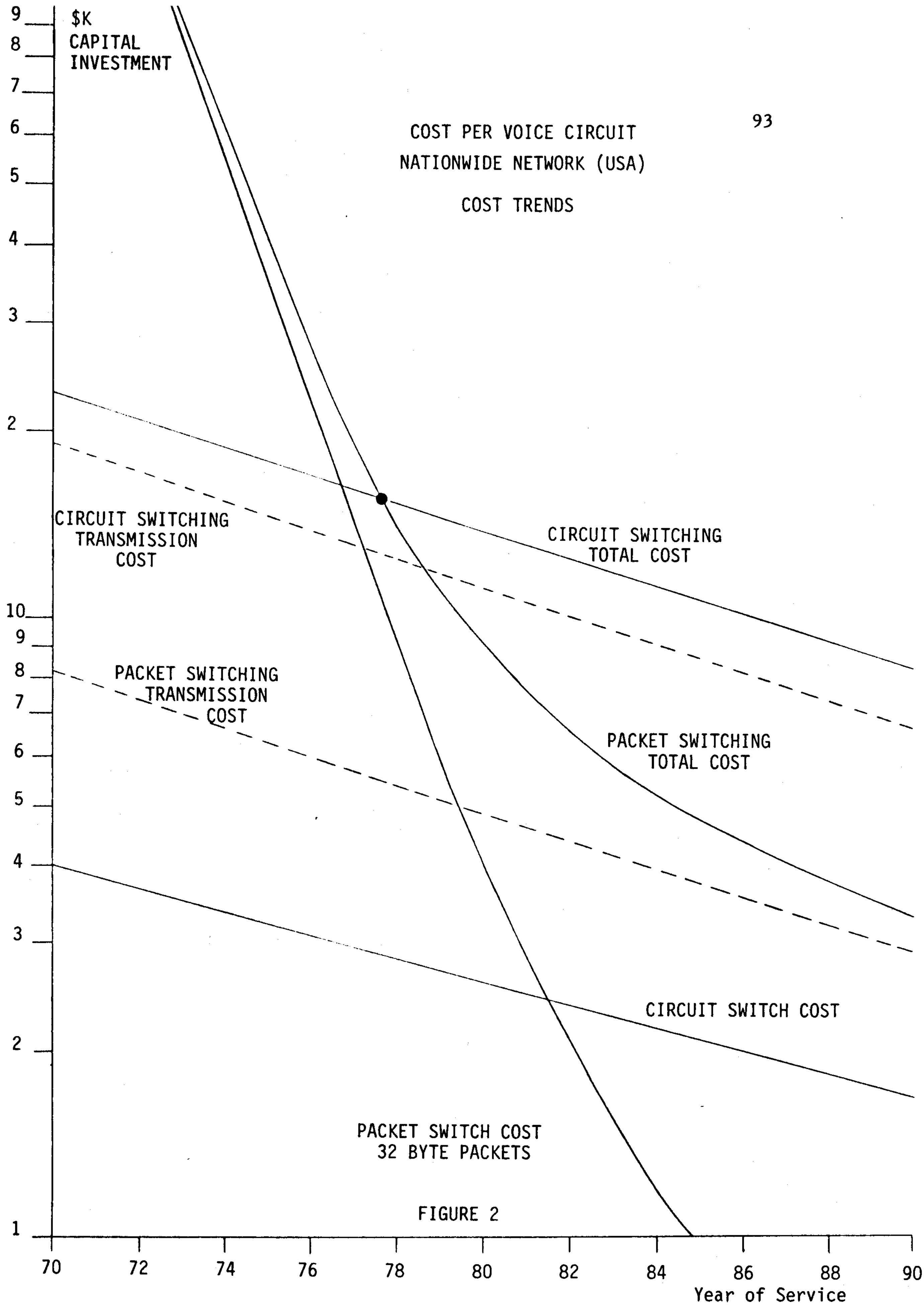

$K
CAPITAL
INVESTMENT
COST PER VOICE CIRCUIT
NATIONWIDE NETWORK (USA)
COST TRENDS
CIRCUIT SWITCHING
TRANSMISSION
COST
CIRCUIT SWITCHING
TOTAL COST
PACKET SWITCHING
TRANSMISSION
COST
PACKET SWITCHING
TOTAL COST
CIRCUIT SWITCH COST
PACKET SWITCH COST
32 BYTE PACKETS
9
8
7
6
5
4
3
2
10
9
8
7
6
5
4
3
2
1
70
72
74
76
78
80
82
84
86
88
90
Year of Service

FIGURE 2

Umberto Pellegrini

The discussion of present transformations that seem to be typical in this society of computer communication technology must not be limited to the technical analysis on how to modify the conventional products and services or even invented new ones, but has to clarify cultural and social impacts as well.

First of all, I would recall that in our industrial culture the idea we have of a machine is changing: from the concept of machine that transforms energy and materials we go to the concept of machine that also transforms the information. The machine, as we say in technical jargon, becomes "intelligent." A first consequence is that the transformation operated by the information is regulated by the logical processes, that is by the system of ideas that we store into the microelectronic machine through the software. Then its material, as such, remains always subject and constrained in its functioning to physical phenomena, meaning they must satisfy the laws of physics as the mere mechanical machine would do; but the activity performed by the intelligent machine is regulated by programs, and then by the ideas that find a limit in the sole human imagination. The machine becomes also a tool for creating new world friction. In that is to be found the enormous power, and also the danger, that comes from the applications of microelectronics. Then our concept of machine is changing.

The fact that any product can today incorporate microelectronics and become intelligent, that is that anything around us is candidate to an innovation of that kind due to the dimension and cost of the microprocessors, is also gradually changing all our environment: The environment itself becomes "intelligent" and interactive with the man. This change is outlined by Professor

Dertouzos of the Massachusetts Institute of Technology in a U.S. congressional hearing on microelectronics when he is talking about "hidden computers." Not only will the single object be "intelligent," but the environment itself becomes "intelligent" and "interactive" with man. This would change our manner of interacting with things, with nature.

A new form of "literacy" is emerging. No more is it enough to be able to read and write but, if the environment becomes intelligent, it is necessary to communicate, to interact with machines; therefore, man needs to know the machine language and how to program it. When I was a boy, my school teacher in Italy said it was important to learn French because that was the international diplomatic language. After the last war, we found it was necessary to speak English in the present international business environment. Now we realize that in an "intelligent" environment of "intelligent" products, we need to speak and interact also with machines. I will remember always the child, 9 years old, in California, where I was guest of a friend of mine last summer; he forced me to go to his bedroom to see his microcomputer, an Apple II personal computer, and to show how he was able to interact with it. This type of interaction will be always more spread out between young people.

So, "man-machine" interaction becomes a new form of communication that is mandatory to learn for living in our future technological environment. We interact with a computer in a video mode. Some analyses show that our information is derived 70 percent to 80 percent by visual acquisition and only 15 percent to 20 percent by audio-acquisition. In technical language, we say that audio-communication is analytic and narrow bandwidth while video and graphical communication is synthetic and large bandwidth. Even when we develop an easy and simple method of common voice recognition, the visual computer-graphic communication will remain the main form of man-machine interaction. This remark seems to me of basic relevance for future man-machine interactions.

Until the last decade, computer graphics has been considered only a special form of man-machine communication. The rapidly decreasing cost of hardware and increasing features of systems make computer graphics now feasible for the vast majority of computer applications. Present interactive computer graphics allow one to achieve much higher bandwidth in output for man-machine communication. This higher bandwidth improves for orders of greater magnitude I/O data flow and improves the ability to understand computer information; following an ancient proverb, we can say, "A picture is worth a thousand words." However, creating and showing meaningful graphics present problems of new technology and fine arts that must gradually be solved. We need to increase computer graphics "literacy" to increase man-machine communication capabilities.

The introduction and the use of new "videotex" services will vastly increase interactive graphics literacy; therefore, it will be worthwhile to support standards of videotex. Another new technology, the videodisc technology, will improve this communication; it extends the concept of graphics to include not only computer generated-video but also computer-controlled video.

A Concluding Proposal for Honda Foundation

To conclude my remarks, I would like to do a specific proposal for Discoveries Symposia. The proverb, "A picture is worth a thousand words," is Japanese, and we know that the Japanese people have a cultural tradition of symbolical and graphical communication that could be of lasting value in the development of new forms of man-machine computer graphics interaction. Therefore, it should be worthwhile to support Japanese research on computer graphics in man-machine communication.

When a new technology arises, children look to the future for answers, but it could be suggested that adults should look to the past for new answers. We know our environment will be changed by microelectronics technology. The way we interact with this intelligent environment stems from the ideas that we put into the intelligent machines. Therefore, these ideas will be important both to ease man-machine communication and also to face information proliferation. Looking at the information pollution as an "ecotechnology" problem - a typical Honda Foundation problem - I would like to make this concluding proposal to the Honda Foundation: concentrate efforts for the next years on technical and social research of man-machine communication.

Gerald Moody

It has been noted several times that we are entering an era that has been called the information age. In the United States in 1980, for the first time in our history, more that 50 percent of the labor force was employed in the office rather than in the manufacturing plant. Today that number has risen to more 80 percent. The trend is still upward. This is a trend, by the way, that began in the 1920s and is continuing and accelerating with the use of computers. So we are definitely entering into a new kind of era in which manufactured goods are not the key part of our gross national product. Rather, the processing of information is the biggest thing in our gross national product and therefore in our economy. This definitely means that we have to look at our businesses in a different way than we have in the past. And this is a realization that is coming very slowly to this country. I would suspect that other countries are experiencing similar kinds of problems in making this transition.

We have heard speakers talk about rapid and extreme changes in technology over the last fifteen or twenty years. We see computers now that are far smaller than they once were and yet far more powerful, more flexible, easier to use, more fuel efficient or energy efficient. All of these things combined have made the computer an integral part of our society today. Communication is another vital piece of the system with which we must operate. The hardware is only one component; software is another - people are a very big component of the system. Communication is going to allow us to integrate the various technologies that have existed separately before. Just as integrated circuits allowed us to revolutionize the internals of the computer, integrated components or communicating network components are going to allow us to revolutionize the environment around the computer itself: the office, the home, the society. All of these things will change because of the availability of improved, more cost-efficient communications.

There was a question as to whether we will be able to fill all the available communication channels that we are building for ourselves. I wonder if perhaps Parkinson's Law applies here and that we will definitely manufacture enough information to fill all the available channels. One statistic I've seen quoted fairly widely is that better than 75 percent of the information we now use in the business world has originated since 1960. Now if that is a trend and not just a statistic, I think we need not worry about filling the available capabilities.

People are now working from their homes on electronic word processors, computer terminals or personal computers. People are carrying their office computers with them in a briefcase when they travel. People on the road are communicating data back to their central computer for processing or for the preparation of a document, and they don't even have to go back to the office. They don't need to go there. But there are social implications to this. It has been found already in the early stages of such a new environment that people enjoy being in an office environment. They enjoy talking with co-workers. They don't like being at home or on the road all the time. These are factors that were not planned in the technologist's view of the automated office. These are the humanist's views.

More people at more levels are going to become more directly interactive with computers as time passes. Yesterday on the street where I live, a little child who was passing by on a bicycle saw a friend in front of his house and shouted, "Mike, can I come in and play with your computer?" That's a symptom of where we are and where we are going. So if we are into an information age and a new way of looking at things, we definitely are going to have new requirements.

We are going to have some barriers to overcome. Natural resistance to change is one of those barriers. What do we need to overcome the barriers? I feel that we need, first of all, measurements that we do not have now of increased productivity at various levels - productivity of a manager, of a professional worker, of an administrative assistant, a lawyer, an engineer, an architect. It is not so easy as counting the number of blueprints that are produced in a week's time. I think we need education, because more people need to know about the technologies. There has to be a program of education to teach them again. With executives as well as with operators, it's a different kind of training that is needed and a different set of objectives. And finally, I think we need systems that fulfill the true needs of the users, whether those needs be functional, social, psychological, or ergonomic. If we can begin to provide systems that fulfill these needs, we will bridge the gap between where we are and where we wish to be.

James T. Araki

To a humanist such as myself, the world of computers and telecommunications is at once fascinating and forbidding. I have had a few glimpses of the outer surface of this world, and am very pleased to have been invited into it for four days. I trust I shall emerge from it unshaken and with acquired wisdom to communicate to fellow humanists who, typically, are unfamiliar with the terrain of this territory in which physical, natural, medical, and social scientists comingle and disport with apparent ease.

Do rest assured that the simplicity of my remarks will not be reflective of a simple mind (though this statement might later be challenged). What may be construed as simplicity would, more or less, be an indication of the fact that the world of high technology is perceived only dimly by specialists in the humanities. If there is an area in which we humanists at the university may be cited for singular excellence, it is abyssimal ignorance of advanced technology. In this respect we are number one.

However unfamiliar we humanists are with advanced technology, we are quick to recognize its social impact. This recognition is usually retrospective, as we ponder, often deplore, and write about the effects of advanced technology on society. The effects of technological advancements on society are difficult to foresee because often discoveries are made first; then the practical applications are either devised or accidentally engendered. The effects of advanced technology on human beings have ranged from the felicitous to the horrendous, often both simultaneously. Radiology is but one example of a field in which research may harness a potentially destructive force, like that emitted by Cobalt 60, for the purpose of curing human illness.

In medical science and robotics, however, the goals are often discerned and the scientists' research is directed toward attaining them. Robots might someday be useful in aesthetics. Having observed a robot memorize the relatively simple brush strokes of a cartoonist, I am quite certain that the same robot may be refined to the extent where it could be programmed to memorize every movement of a future Rembrandt or Sesshu creating a masterpiece, and promptly begin to reproduce exact copies, to the great unhappiness of professional counterfeiters.

The products of computer and telecommunications research have so pervaded human society that their effects on human behavior are becoming discernible. Whatever is discernible in human behavior eventually seeks expression in primarily aesthetic endeavors, such as literature. This is the point at which technology and the humanities become tangible.

The pervasiveness of computerized telecommunications is a social and cultural phenomenon we must recognize to be a reality. This reality has crept up on most of us outside the sciences much too swiftly. Only the exceptionally few, with the aptitude and interest, have put the silicon chip to wise, practical use. One significant example that comes to mind in my particular area of interest at the university is the use of PLATO (Programmed Logic for Automatic Teaching Operations) in teaching foreign languages, specifically Japanese. Programmed instruction is available to students, who progress in stages from lessons given in romanized Japanese, then in the simple Japanese script (<u>kana</u>) representing some four dozen syllables, then in Chinese characters (<u>kanji</u>), whose great variety and complexity have long proven to be the bane of non-Japanese trying to learn the difficult language. Designing a course in elementary Japanese required far more time than designing an equivalent course in French or German because of the need to compose Japanese and Chinese writings through graphics. Three-dimensional graphics, illustrated this morning by Professor Charles Csuri, may be quite useful. Perhaps as many as 8,000 working hourse at the microprocessor were needed to prepare sufficient material for an eight-credit courseware to be fed into a main frame in Sunnyvale, California.

The development of computerized language instruction will naturally bring about changes in the student-teacher relationship. When it is eventually endowed with synthesized speech, the computer with its infallible memory, pleasant speaking voice, and perfect enunciation might well become the principal instructor. At present the lessons are so structured that when the student presses the HELP button, the response on the display screen reads: "Go see the human instructor."

Television is, of course, the medium with the awesome capability of reshaping society in its many aspects. In the United States, in particular, cable television is quickly overspreading the land. Living in far-off Hawaii, what I read about developments on the U.S. mainland is startling. Depending on the franchise area, viewers have access to dozens of channels offering almost every conceivable form of audio-visual entertainment. The fact that Time cast off Life in exchange for a larger share of Cableland USA is an indication of the coming ubiquity of cable television.

Cable television is now a part of my business. Greater Honolulu, with about 150,000 households, does not yet have access to the Qube System, quite likely the shape of systems to be installed in most major American cities. I have only read about the 60-channel availability and the two-way interactive connection that enables viewers to respond to the television set, and I am almost afraid to be exposed to the Qube System, which incidentally Warner Amex Cable first tested right here in Columbus, Ohio.

From my limited experience in cable television, I have gained some awareness of the influence that men in key positions can exercise over what the audience see and hears constantly. As language-culture consultant to an exclusively Japanese-program cable channel, I may impose my own aesthetic tastes, ethical standards, and perception of Japan on prime-time viewers. The image of Japan held by residents of Honolulu may, in time, be modified to conform with the image of Japan I prefer - a blend of modernity and tradition combined with dignity. Some other consultant, however, might favor the lowest common denominator of viewing tastes if marketing research shows that most viewers would be willing to pay more for it. Whether on television or in the university classroom, an offering must be entertaining to a degree if it is to be effectively educational. Every night in Honolulu, thousands of T.V. viewers enjoy what is best in Japanese culture because the planning and operation is the responsibility of university professors. However, university professors are not good businessmen. If we do not quickly become good businessmen, we shall be replaced by genuine businessmen, who may depict Japan as a land of shameless sex and violence. This would be entertaining.

Narrowing the scope of my concerns further, I may speak about Japanese literature, which is my principal business. Literature in translation is probably the most reliable implement for intercultural information exchange, and so I view the business of translation with seriousness. The computer may be effective in some areas of linguistic transfer, but not so in literary transfer from one language to another. The microprocessor, however, may be a highly effective aid in the task of translation - in composition, editing, revising, and printing. The translator's mind is suddenly freed from blocks that are set up constantly by mechanical annoyances; the process of translation begins to flow, and the result is a better translation, hence better literature.

However numerous and grandiose the benefits eventually to be derived from technological advances in computers and telecommunications, the application might in some instances spell disaster. Sheridan, Vamos, and Aida in their 1981 article ("Adapting Automation to Man, Culture, and Society," Kyoto, 1981) described research toward lengthening the control loop in two-way T.V. communication, whereby a "transparent government administration" becomes feasible. Orwell's fictional vision of 1984 might well become a reality in 1984. Future home automation, described yesterday by Professor Atsumi, would be one of the means toward such an end. Perhaps my being a humanists with little familiarity with advanced computer and telecommunications research causes me to view such advancements with curiosity and fascination, but also with apprehension.

The State of the Art in Robotics

Masahiro Mori

Through the years, Japan has learned a great deal from the United States, and among the many items it has learned are the fundamental concepts of the industrial robot. For this, we Japanese have much to be grateful.

Unfortunately, due to a lack of thorough investigation, my personal knowledge of the current state of robotics in the United States is sorely inadequate, so my discussion here will be limited to the status of robotics in Japan. Furthermore, I would like to preface my remarks by saying that the nature of my discussion relates less to the future outlook of robot technology in Japan than to a consideration of the problems involved in pursuing future progress in robotics.

Twelve Steps

Since late in 1980, an unusual degree of interest has been shown in Japan in the topic of robotics. It has even come to the point where the general public, lacking deeper understanding of the issue, has fallen under the mistaken impression that robots are miraculous machines that can replace human beings in any job imaginable. This notion may perhaps be dismissed as mere naivete on the one hand; and yet, for the reasons I shall outline below, it encompasses certain salient problems which indeed should not be brushed aside so easily.

Consider this analogy. In Japan we have a proverb that runs something like this: (1) One night, I was frightened out of my wits by a snake lurking in the dark. (2) When I calmed down and went to the same spot the next morning, I discovered that what I had thought to be a snake was actually a rope. (3) And a rope, I remembered, is made of hemp. What this analogy illustrated is what scientific research has taught us about the relation between the eye and the mind in animals, or what we have learned from modern robot "eyes" (i.e., pattern recognition): namely, that "seeing" is a conjunctive phenomenon involving both the physical world and the mind, and that in order for one to see "correctly" the mind must be clear. The illusion and resulting misinformation described in statement (1), for example, were fostered by preconceptions of fear and aversion. Similarly, with robots certain preconceptions have been induced by science-fiction movies and television, as well as by exchanges between management and labor, and it is these preconceptions that have given rise to the popular misconceptions of the industrial robot. Of course, we who are engaged in robotics are to blame to some extent for our perhaps unfortunate choice of vocabulary that may propogate these notions.

A realistic, dispassionate evaluation of the present state of robot technology in Japan produces results quite at variance with the prevalent popular conception. Robot technology in fact may be said today to have finally advanced from its childhood into a period of early adolescence. By way of experiment, I would like to articulate this concept into the universal view known as "the twelve-linked chain dependent origination." What this view espouses are a series of twelve fundamental steps outlining how human existence, which bears a heavy burdent of contradiction, can proceed to overcome that contradiction. These steps can be applied both to the process of individual human development from conception to death, and to the evolutionary progress of humanity from a primitive animal to modern man. Furthermore, they can also be related to the changing progress witnessed by "objects" with which man is familiar, such as the development of the horse-drawn carriage, leading to the invention of the automobile, leading to widespread motorization, leading to the oil shocks of the '70s.

The twelve steps are as follows:

1. MUMYO (Ignorance) - the cause of all illusion.

Ignorance refers to the state where the deepest level of the subconscious is not functioning properly. The aforementioned illusion of seeing the rope as a snake needs no further comment; but on deeper consideration, a rope is no more than a long and thin object fashioned of hemp fibers - which are collections of carbon, hydrogen and other molecules - into a shape permitting tying and pulling, in accordance with man's wishes. Furthermore, the carbon and hydrogen molecules themselves consist of electrons and protons and the like (corresponding to point 3 of the analogy). MUMYO (Ignorance), then, is the fundamental action which impedes a clear understanding of phenomena and truth - an understanding based on a thoroughgoing investigation deeper and deeper into origins. When ignorance is allowed free rein, control over existence runs aberrant. Ignorance may also be viewed as the early stage of human social activity, i.e., the confused stage when man is moving toward coherence. It is like the state that precedes the appearance of a new field of research or development, when each individual somehow comes to feel the necessity for a "certain something."

According to this cosmic philosophy, all matters in life, all organizations pertaining to human life, and indeed all objects produced by man to meet his wants and desires may be said to "misbehave" as an outgrowth of ignorance. For this reason, ignorance - the misfunctioning of the deepest level of the subconscious - must be obliterated.

2. GYO (Actions)

Actions are the stage that is engendered by the latent formative powers just described. In man, such action corresponds to conception.

3. SHIKI (Distinction)

Distinction is the stage where differentiations can be made. It is the state where a new field has yet to be named, yet which is recognizable as burgeoning.

4. MYO-SHIKI (Software and Hardware)

In terms of a new scholarly field, this refers to the stage when the internal organization is in the formation process, as exemplified by creation of various meetings. In terms of human development, it is the stage where the fetus has yet to develop its sensory organs.

5. ROKUNYU (Sensory Organs and Mind)

This is the stage when formation of sensory organs and the mind occurs in the fetus. On an organizational level, it is the stage when internal functions are determined, such as investigatory division, sales division, etc.

6. SHOKU (Contact)

Once the sensory organs and the mind have developed, in this stage they begin to activate, seeking to see, to touch, etc. In human beings, it is the period between birth and the age of 2 or 3. In an organization, it is when activity is for the first time directed outwardly.

7. JU (Perception)

Contact gleans numerous types of information, and this process begins to move the mind subtly. It equates with the period in man from approximately age 4 to 15, when he is most receptive. In the organizational framework, it is the period when the results of initial contacts with the outside foster the creation of various strategies of operation.

8. AI (Desire)

This is the stage where affection begins to be felt. In man, it comes after the age 16 to 17.

9. SHU (Attachment)

Once affection is felt, next one begins to long for affection in return. In other words, one begins to yearn for possession. On the other hand, one also comes to seek distance from those things that one finds unpleasant. This phase is thus one where the mind has developed clear powers of discrimination. It is similarly the period in which an organization expands.

10. U (Existence)

Existence is the state where the division between self and others has become definitive. It is the stage where individuals come to make distinctly personal judgments, and where opinions can clash violently. In man, it corresponds to the period following marriage, at which time a definitive distinction is made between one's spouse and other members of the opposite sex. It is the phase generally after the age of 30 when one begins to seek after fame, fortune and power.

11. SHO (Birth)

Marriage leads to childbirth. In organizations, this is the stage where subsidiaries are formed or where the organization splits into two separate new entities. It is exemplified by the period when electronics technology, at the height of the vacuum tube age, gave birth to the transistor; or to the period when horse-drawn carriages evolved into the automobile. From these various new offspring the series of twelve steps starts all over.

12. RO-SHI (Old Age and Death)

Eventually comes old age, followed by death. It is the time when an organization naturally terminates, or dissolves in the process of development. These, in general, are undesirable phenomena.

The state of robotics or industrial robots today may be said to place somewhere near the fourth or fifth of these twelve steps, i.e., the Software-Hardware and Sensory Organs-Mind stages. And without doubt, robotics will continue to proceed through the remainder of the steps as outlined. Our goal, however, is to make the robot serve as useful a role as possible, so that it may become the object of man's affection. At the same time, we must make every effort to use our own minds to the fullest so that man and machine - including robot - may work together in harmony.

The twelve steps just described may also be interpreted to suggest that basic reasons behind unpleasant phenomena in man's life and in affairs relating to mankind, as well as offering a method for eliminating such phenomena. For example, if in reviewing the process by which we gave birth to the robot we discover the escalation of an insatiable desire that is out of our control (step

10), or the presence of a discriminatory mind (step 9), or strong obsession with things (step 8), or excitement of the mind owing to perception (steps 7, 6), or the ignorance of perceiving incorrectly or being unable to understand truth (step 1), then what is necessary is to recommence from that step once more.

How the robot should be designed, how it should be used, how it should be developed, and how it should be integrated into society, are all questions that are man's own responsibility to answer. It is commonly said that merely by looking at a person's tools, you can read into their user's mind. The robot, too, is an accurate reflection of the inner workings of man's mind, and it will continue to be so in the future.

Robot Parts Specialization

Robot technology, as is only too well known, is both comprehensive and systematic nature. In Japan, for example, robot technology avails itself of technologies from such fields as electronics, hydraulics, pneumatics and linkage mechanisms, and control sytems are structured using microcomputers and sensors. This "system" assembly of course is the central notion of robotics, and development technologies based on this notion are vital. Robots, for example, require the characteristic of "good balance"; yet although this balance has been achieved in airplanes and the space shuttle, in the case of robots it remains an unattained objective of sytematic research.

What is more important and urgent even than this sytematic approach, however, is the need to develop parts specially for robots. At present, Japanese robot manufacturers utilize parts adapted from general use and from industrial machinery. This trend is particularly strong in the case of hydraulic and pneumatic valves, cylinders and electric motors. (One exception is the hydraulic servo-valve under development exclusively for robot applications, distinct from its application in aircraft.)

As an example, as you all know print motors are extremely flat electric motors. With robots, on the other hand, what is desired is an extremely long and thin type of motor - a motor capable of high torque at slow speed and, if possible, without reduction in gears. It should also be lightweight. Achieving such lightweight construction in motors and other parts, however, may have inherent limitations; whereupon the desirability of unit construction arises. For example, an improvement in robot performance can hardly be expected simply through such measures as fashioning the robot arm out of metal and attaching an electric motor to it. What is needed, for instance, is a design in which the motor stator serves as one of the structural members of the arm. For this reason, research specifically aimed at developing robot parts is required.

Today's superior automobiles can be produced thanks to the close relationship between the auto industry and the auto parts industry. In the case of Japan, at least, while there is a flourishing robot industry, there is as yet no robot parts industry. Its creation is keenly awaited.

Robotics Learns from Life, Physiology Learns from Robots

Research and development may be said to take two directions. One is goal orientation, as symbolized by the expression "Necessity is the mother of invention." Today's industrial robot industry appears to be taking this route. A research posture such as this is comparable to a short-distance race, and from the point of view of efficiency it certainly has its merits. One the other hand, it is unsuited to achieving long, leaping strides. The second direction is free, non-goal-oriented research - the kind tht might be symbolized by the phrase

"Dreams are the mother of invention." Research of this type yields few practical results in the short run, yet it is capable of leaping beyond the limits of common expectation to produce new and startling achievements or to open up new fields of knowledge. These two directions, which on the surface may appear to be conflicting, are in fact capable of serving mutually supportive roles, and for this reason they should both be pursued simultaneously, in harmony.

Robot research itself began as the latter type of research - free and non-goal-oriented. The robot was born from a simple wish to create a mechanical object that could function like a human being, or to endow a machine with even certain facets of the functionality of the human body. Because such wishes can and at times do come true, I would like to enumerate some of my own "wild dreams" for the future of the robot.

Whiplash is an injury to the bones in the neck that results from a rear-end automobile collision. It is said that the degree of injury is much lighter when advance warning is received of the impending accident and the body has a chance to prepare for the impact. It is also a fact that muscles - the "actuators" in animals possessing skeletal frameworks - are located on both sides of a bone, working against each other. When these two concepts are considered together, a certain hypothesis-like hint can be obtained: namely, that the human arm is stronger due to the functioning of its muscles, compared with its strength derived from its bones alone.[1] A robotic arm could thus likewise be strengthened, and I believe that design technology should advance in this vein. Expressed in another way, the goal would be to create a robot which, when control of its actuator runs amiss, could bend its own bone by the power of its own actuator.[2]

At the Okinawa EXPO of 1975, I exhibited a group of seven robots known as "Triops Congregans MASAHIRO." The group consisted of seven completely identical robots - with no boss created among them. Yet as they proceeded to move about exactly like a group of animals, there was almost always one robot moving at the head of the group and the other robots generally followed behind. I was inspired to create such a group of robots through hints gained by observing cherry petals and starfish - both of which are understood to lack any brain or central system. Observation of such a robot group can, I believe, aid in the understanding of certain social phenomena, such as human behavior in panic situations. Although due to lack of sufficient funding I have been unable to develop research in this area further, I believe that even more interesting results would be achieved by augmenting the number of robots and by incorporating male-female, weak-strong and friend-enemy relationships. Research into robot groups would, I anticipate, reveal various facts that are impossible to learn from computer simulation.

Thanks to the sciences of anatomy and physiology, the physiological and pathological makeup of the human body and other organisms is growing clearer by the day. Still, the contents involved are so detailed, so complex that many components remain in the realm of a black box. And yet, could the day be not far off when the robot will provide the hints necessary to unravel these mysteries? Naturally, for this to happen it will first be necessary for considerable progress to be achieved in robot development itself. However, it is only when one attempts to make a copy of something that one is truly able to understand it. Consider this somewhat extreme example. To shield the robot's eye from overly strong light or dangerous objects, we provide the robot with something of an eyelid. Similarly, to protect the robot from ear-shattering noise such as would damage a microphone, we likewise would want to provide the robot with an "ear-lid." And yet when we reconsider the human body, we realize that while we humans do have lids to protect our eyes, we have no such covering to protect our ears. What might be the reasons for this? An investigation might indeed reveal hitherto unknown information leading to deeper understanding of the human body.

As a part of my research into non-central systems, in 1975 I assigned my students to build a prototype apatetic robot. The robot which they created was flat and rectangular and incapable of movement, but it was capable of reproducing on its back patterns on its abdomen. My original intention was for them to create an apatetic function without resorting to a central system as far as possible; but the end product was made using a central system relying on a computer. The systematic structure of apatetic functionalism remains unclear even in the realm of biology. In cases such as this where the real-life inner workings are unclear, the best approach is, I believe, to build a robot with identical functions and then to seek out the inner workings of real life through study of the robot. In this way, not only can robotics learn from biology, it also has the potential to contribute to biological understanding as well.

I would also like to add a word in connection with robot movement patterns. There is a famous ballet by Coppelia in which mechanical dolls play the leading roles. One of the important points of the ballet is in having the dolls dance intentionally so as to look like mechanical dolls. The industrial robots that exist today are precisely as awkward-looking as these dolls in Coppelia's ballet. With all due respects to Coppelia, I believe that efforts should be made to achieve robot movements that are more human-like. In contrast to human movements, in which acceleration is performed extremely smoothly, mechanical movements are very abrupt. Also, with machines, movement from point A to point B is carried out at a uniform speed, which is disturbing to persons watching them. These facts may be thought to be among the reasons why machines induce in man the general preconception that machines are inhuman. For this reason, I wish most strongly to achieve more beautiful, more graceful "human-like" movements in robots.

Human Phenomena Defying Imitation

It is an extremely vexing fact, but in the process of ongoing robot research we are frequently confronted with the stark realization that we are sorely uninformed of the true workings of our own human bodies. Take two-handed manipulation, for example. It is extremely simple for us humans to use two hands to hold a piece of paper and, moving from left to right, to flatten it smoothly. Trying to program a robot to perform the same action, however, is extremely difficult. If the robot's two hands are not equipped with sensory perception, the paper would probably tear or slacken. This observation was made by American researchers over a decade ago. Of course, if the robot is equipped with sensory perception and is controlled using an algorithm of some sort, then to all appearances the robot can perform just like a human. Nevertheless, in the final analysis it would seem easier for the robot to perform the action with one hand rather than two - despite the fact that using two hands is easier for us humans. I find this whole circumstance thoroughly perplexing. I have tried to use my own body as a reference and to closely observe my own actions, and yet I am completely at a loss to understand the algorithm with which I manipulate my own two hands. It is almost as though it were not my own body. As a result, unfortunately I have as yet been unable to build a model robot that can satisfactorily recreate double hand coordination. If such research has been successfully carried out here in the United States, I ask for your kind instruction in this matter. At the moment, I would have to confess that I feel totally frustrated at my ignorance of the workings of my very own body.

There is another problem which currently defies precise interpretation. Consider, for example, what happens when we prick our finger with a needle. Obviously, the point where the needle has pricked the skin immediately becomes painful. This is perfectly clear. What happens, though, when the same situation is recreated in a robot? First, a sensor located in the robot's finger detects the presence of the needle. A signal is then sent through the circuitry in the robot's arm to the robot's "brain," - the computer. The computer is normally composed of a CPU and RAM which controls the robot's fingers. That which actually experiences pain, then, are all those areas that are excited due to the pricking action of the needle. In other words, the robot's sensor in its finger, the circuitry in its arm, and its computer all experience pain simultaneously. In us humans, however, it is the pricked finger alone that is painful - and neither the nerves that transmit that pain to the brain nor the brain itself feel any pain. The pain-sensing process in the human body must, I would imagine, involve far more complicated systemization than I have just described, and I cannot help but feel that this realization can provide an important clue leading to the development of a higher-grade robot. Indeed, our bodies incorporate numerous phenomena that at present defy imitation.

Guiding Principles on the Man-Machine Relationship

As anyone who has ever attempted to build a robot knows quite well, such an attempt is fraught with a plethora of technical difficulties - problems relating to pattern recognition, artificial intelligence, the actuator, and the energy source for locomotion, to name just a few. At times these problems are the cause of deep frustration and despair; yet at the same time they frequently serve as an inspiration. There is no "proof," for example, that a super-sophisticated robot fitting the common preconception I mentioned above cannot indeed be built. A quick look at American and European scientific and technical history reveals a never-ending concatenation of accomplishments wherein the "impossible" has been made possible. Robot technology too shall undoubtedly proceed over the technical barriers now standing, sometimes through a direct frontal approach, and sometimes by skirting around through the backdoor. I look forward to such a day, and hope to play even a small role in hastening its arrival.

On the other hand, robot development cannot be pushed forward with total disregard for the "sins" that modern civilization has brought forth - and will no doubt continue to produce. Until now, whenever such criticism of civilization has been raised, it has generally advocated a halt to - or even reversal in - civilization's progress. The discussion that I am about to elaborate upon here, however, is of a different dimension. I am embarrassed to admit to my lack of familiarity with Western philosophy; the views I am about to express are deduced from Oriental philosophy, Zen in particular.

Fundamentally speaking, Nature is filled with the vibrancy of life, and every existence born in Nature was meant to utilize its naturally given functions to 100 percent of capacity, and to harmonize collectively thereby. Under Nature's perfect control, there are none that are given life only to regret their existence. And yet, it is man alone which, though he is a full-fledged member of the universe, is tormented by the contradiction of being unable to fulfill his potential - to know the vibrancy of life - 100 percent. The relationship between mankind and civilization is part of this contradiction. And in particular, the robot - as a man-made man - may be the ultimate factor in such a contradiction. Why is man's life burdened with contradiction? Why is he unable to know the total vibrancy of life?

There is a Buddhist principle that states that "total activity is the root of harmony." In other words, full utilization of each component's inherent functions is the basic condition for overall harmony, and harmony is thus the state where functions are all being performed to perfection. The fact that only man and man-made objects are burdened by contradiction means that man is not performing at total capacity. Why? I believe that the answer relates to the vast number of human brain cells, and the difficulty in attempting to use them all. When the human brain does not perform at total capacity, then man reverts to step 1, Ignorance, wherupon the ability to control oneself runs amiss. At that point, the 12 steps lead in an undesirable direction.

The key point, then, is for each and every person to perform at the maximum of his capacity. When man operates at the peak level of his potential, his control of himself is perfect. When mankind attains this self-control, then man himself, his actions (civilization), robots (the pinnacle of civilization) and human society can all work in harmony, developing with the vibrancy of life, living with the vibrancy of life, and dying with the vibrancy of life.

Accordingly, in order to achieve mutual harmony between robot and mankind, and between nature and the artificial, man must first strive to acquire control over his self. Before asking others to acquire control of themselves, first it must be done of one's own self. For when one strives to achieve one's own self-control, that effort of itself is passed on to others. The following passage is taken from the Shobogenzo by the Zen priest Dogen Zenji:

> "To learn the Buddhist Way is to learn about oneself. To learn about oneself is to forget oneself. To forget oneself is to perceive oneself as all things. To realize this is to cast off the body and mind of self and others."

Information begins from the first one bit. When we strive as just described, we come to understand the source of this one bit: namely, zero bit. This zero bit corresponds in Zen to "Mu." And the one bit which derives from zero bit is like yes and no, plus and minus, man and woman, day and night, tension and relaxation, psychology and physics, individual and group, induction and deduction, technology and ecology, invention and discovery, enemy and ally, life and death. At first glance, all of these pairs seem to be comprised of mutually conflicting entities; but when perceived with a mind functioning at total capacity, it becomes clear that each components is assisting the other...or the brain itself realizes how to perform so that these pairs may aid each other. The following are several examples of how such a brain should work.

The first involves the relationship of invention vs. discovery. Technology to date has been achieved through an inventive stance whereby human wisdom permits man to utilize certain materials to invent certain functions. This stance has reached a limit today. The reason is the lack of its counterpart: discovery. Discovery is a modest stance in which Heaven allows man to discover certain functions in the physical world that have been place there through Heaven's own wisdom for man's discovery and use. This is what Dogen Zenji refers to as "forgetting oneself and perceiving oneself as all things."

A second example is work vs. leisure. Honda Giken sponsors a companywide idea contest that is both fun and difficult. The contest is an exercise not aimed at achieving rationalization on the job, but rather aimed at fostering creativity - regardless of its usefulness. As Honda's Supreme Adviser Soichiro Honda spoke of the contest to his employees: "Our objective in holding this contest is not to devise new products for tomorrow. We simply believe that the contest is interesting for you, and that's why we want to continue it. To do so requires money, however; so let's build good cars to get that money." In other words, the contest is for leisure - and that in turn makes work go smoothly.

Another example is the relationship between the development of "things" and the enlightenment of the mind. The mutual assistance provided by two conflicting components - when carried to the fullest, this means incorporating the two parts into one whole - leads to harmony. For this reason, the current contradictions brought about by modern civilization are the natural result of overly enthusiastic interest in the development of "things" to the neglect of the enlightenment of the mind. It is for this reason that we must learn from ourselves to perform at full capacity; and by performing at full capacity we can then forget ourselves; and by forgetting ourselves we can expand our capacity even further, thereby breaking out of the harness of ignorance.

Conclusion

The relationship between proceeding forward and backward works according to the same principle. Smooth operation of a car, for example, requires the use both of the accelerator and the brake. For this reason, pursuit only of forward progress accompanied by a denial of reversal cannot produce true progress. Only by pausing in our steps and taking a cool-headed evaluation of ourselves can we be guaranteed to move ahead.

In this paper I have presented a general outline of my thoughts about robots and the principles guiding their development. First the contradiction of modern civilization must be accepted as one's own. Then what is necessary is not a denial of the robot, nor the forced acceptance of the robot in disregard of the contradiction, nor the advancement of the robot in obfuscation of the relationship between robot and man. Instead, I believe that man must and will find the wisdom, courage, peace of mind, and pleasure of overcoming the contradiction.

FOOTNOTES

1 I use the phrase "hypothesis-like hint" because I believe that robotics research should not aim to understand organic structure completely and then attempt to create the identical structure in machine. Rather, robotics research should gain hints from such organic structures and then proceed on the basis of, but not restricted to, such hints. I do not believe that the ultimate goal of robotics should be to create artificially a mechanical object exactly like man or animal. Its goal should be to create an object similar to man or animal, based on such hints.

2 A healthy bone breaks due to the application of external pressure; it does not bend of itself. This fact may also serve as an important point of reference.

Robotics in American Industry Today - And Tomorrow

George T. Rehfeldt

Computers, or more broadly electronics, are revolutionizing manufacturing. Common terms in industry today are "computer-aided design", "computer-aided manufacturing" and "flexible manufacturing systems". I submit that one of the most powerful manifestations of electronics in the manufacturing process will be robotics. Robots are the computer tool par excellence. They are a physical extension of the computer. Industrial robots will be one of the most important building blocks for the industrial revolution of the 20th century.

This was not so easily predicted when the original work in American robotics was begun by a man named George Devol in the 1950s. Devol's work was innovative. His concepts of the mechanical structures that were required to make robotics possible are still with us and form the basis for many current designs. However, the coming of age of the computer, and the continuing price decline of computer memory are the driving forces behind robotics.

The full potential of robotics is not readily apparent, even today. In the majority of instances, robots today perform specific and isolated tasks such as welding, simple material handling, drilling and so on (see Figure 1). These jobs treat the robot as a piece of fixed automation, not much different from any other type of computer-controlled machine tool (see Figure 2). That is today's robot market. We are automating the majority of tiresome, difficult, tedious, dangerous, and dirty jobs.

But single task applications don't take advantage of the full power and flexibility of the robot. In the long run, the greatest impact of robotics in manufacturing will be the use of robots as flexible automation to perform a variety of functions in the areas of sophisticated material handling, inspection of component parts, final assembly, and above all, serving as an interface with all the fixed automation around it on the shop floor. By combining these operations, the robot will serve to create a completely automated manufacturing cell (see Figure 3).

Indicative of the long gestation period already experienced by robotics is that Devol's company has only recently begun to make small amounts of money, some 30 years after the original work and 20 years after its formal incorporation. Robotics in America has not been a commercial success to date. The participants in the robot industry have been more involved in a technical crusade than a business.

All of that is changing. What I would like to do is briefly review robotics in the United States, both today and in the future, and to share with you some thoughts on the significance of this electronic tool.

First, there are misconseptions on what a robot is. Let me tell you what is not. A robot is not an R2D2 from "Star Wars" (see Figure 4). It does not have a brain. It does not move about the manufacturing area, and finally, it does not resemble a human in any way. A robot is a reprogrammable, multi-functional manipulator. There are several other definitions, but this is the most straightforward and accepted terminology.

Basically two categories of these manipulators, or robots, exist in American industry today. One is termed "non-servo." Simply stated, a non-servo robotic device cannot follow accurately, or stop, at multiple points along its path of movement. Its motion cannot be constantly monitored. What a non-servo machine does well is to repeat set positions with accuracy. This type of equipment is most commonly used in "pick and place" material handling applications. The "servo-controlled" robot, on the other hand, can stop at multiple points throughout its path of movement. It will repeat those points along the coordinated access route with great accuracy. The various axes of motion are closely coordinated and continual control of their movement is maintained.

The balance of my remarks will be directed toward "servo-controlled" robots and where this type of equipment is used in American industry. So much for technology.

Where are these sophisticated, electronically driven and servo-controlled robots being used today in American industry? More than half are performing the function of spot welding. The original installations were for single robots in automotive plants to perform spot welds on car bodies. The use of robots for this kind of work has evolved into systems where 20 to 30 robots will completely spot weld a car body together on a moving assembly line (see Figure 5). The system is made possible by electronic intelligence. For example, the robot records when it misses a weld for any reason. It sends that information to another machine, or to an interface in the form of a high-speed printer or a CRT so that its human co-workers know where and when to make a correction.

A spot welding robot is a cost-effective device. It is also quality effective. Prior to the use of spot welding robots, a car designer had to specify perhaps 30 percent more spot welds than were actually required to maintain the structural integrity of the automobile. The human welder simply missed a number of welds in the course of any given day. The robot doesn't miss a weld application, and when it does, it makes note of the fact so things can be corrected.

The next major market for robotics in America is arc seam welding. Arc welding is a tough and dirty job. People doing arc seam welding in our country today average 53 years of age. We have had insufficient input of younger people into the trade. In addition to solving the problem of too few human welders, robots are better welders than people in the quality of work performed. Arc seam welding carried to the ultimate will be the first full utilization of the sophisticated robot's capabilities. It will require sensors to control the depth and width of the arc and the ability to follow the irregularities of the workpiece. This technology is becoming available through weld sensing and vision capability. It will be further developed to allow welding systems where complete fabrication of seam welded part assemblies will become possible without human participation.

There are other clear market segments that are emerging. They are spray painting, material handling, drilling and routing, laser waterjet and plasma cutting, machine loading, and finally assembly. Assembly is the ultimate market for robots, but it is full of problems, both technical and social. The application of robots in random part assembly is at least three and perhaps five to ten years away.

But in the last 20 years we have come a long way. Thousands of robotics devices are installed and working in American industry. The productivity improvements so necessary and the product quality levels we must achieve in this decade will largely depend on new manufacturing technologies. How do robotics fit into that picture? Where do we go from here?

First, we must examine the broader context of manufacturing in the United States. Successful manufacturing is critical to the future of our country. Manufacturing must be viewed as a form of creation of wealth. The social needs of America can only be met by creating a growing economy so that the individual citizen can have a growing piece of that future.

Many books are published by erudite economists and academicians that pose solutions to our current malaise. But, let's remember that there are only three ways to add value to a commodity and create wealth. The first is agriculture, creating food from earth, air, water and seed. The second is to practice the extractive industries. Upgrading raw materials derived from mining and petroleum recovery, for example, is the creation of wealth. And finally, manufacturing is an integral part of wealth creation since it adds value in its process. Without its vital manufacturing base, the United States cannot have a continuance of its present form of government and social system.

The manufacturing climate today is one of intensified worldwide competition. This issue transcends all else. Unless American manufacturing can become competitive, we have only the alternative of protectionism. History has shown that this is not an acceptable choice. Manufacturing in the United States is confronted with a rising cost picture. The cost of energy, labor, material and capital are leaving less absolute dollars to be reinvested in wealth creation.

If we examine these segments of cost, we must consider each one against the relative position of our worldwide competitors.

In energy, the United States is better off than Japan or Germany or any of the other industrialized nations. As a point of reference, perhaps the highest cost per kilowatt hour of electricity in the United States is on Manhattan Island in New York. That cost is the average kilowatt hour rate in Japan. The United States has, and will continue to have, an enviable position in its energy costs on a relative basis.

On the labor front, the United States is not out of line with its counterpart industrialized nations. We hear too much of auto workers making $20 an hour. We should remember that the average hourly rates in all U.S. manufacturing in dollar terms are no greater than those of Japan, as an example, and lower than Western Europe in some instances.

The most significant labor issue for the United States over the next 20 years will be a lack of absolute numbers of people available to run our factories. The statistics of our demography are very clear and acknowledged. According to the U.S. Census Bureau, the population of the job-entry level, 18 to 24 years old, is going to drop nearly 15 percent in absolute numbers between 1980 and 1990. The industrial robot becomes important in that context. The shortage of new labor force entrants will boost the installation of robots to do the more tedious and repetitive factory chores. This will be mandatory; we will not have enough human arms and legs to do all that is necessary in the process of creating wealth.

The material used in manufacturing processes in the United States is changing and will continue to change radically. The substitution of metal with plastics is an example (see Figure 6). That is already taking place. One thing that people tend to forget about in this material conversion to plastics is the driving force of capital utilization. Plastics, and plastics products, generally have no work-in-process inventory connection with their production. The United States is in a relatively good position, again compared with its counterpart industrialized nations, in terms of the availability and cost of the feedstocks used for many types of material conversion.

The last key element, and the one where the United States is failing and has much work to do, is in the utilization of its capital base (see Figure 7). Our capital base in manufacturing is grossly underutilized today. In simple terms, the average part produced in the discrete part manufacturing process is being worked on only 5 percent of the time it is in the shop. The balance of 95 percent is consumed in holidays, vacations, underutilized second and third shifts, parts set up times, parts handling, etc. (see Figure 8). The single most fertile area for improving manufacturing efficiency lies in better utilizing our capital investment.

The reindustrialization of America must include new approaches to batch manufacturing. We have been able to automate high volume, repetitive parts manufacturing. Some 70 percent of American manufacturing consists of batch sizes of fewer than 100 parts. Automating low volume manufacturing operations with flexible manufacturing systems and the robot offers the greatest opportunity for productivity improvement.

Let me show you some of the reasoning behind this statement. In the metalworking field, for example, we have clear breakpoints of volume as opposed to the levels of capital investment. If we look at a few in concept today, we must first divide them by economics of scale. Volume dictates the type of system, or whether it should be dedicated system, a flexible system or even stand-alone machines.

The vertical axis of this slide indicates productivity, or the efficiencies possible from economy of scale, from low to high (see Figure 9). The horizontal axis does the same for flexibility, or the ability of the system to handle random parts generated by the batch manufacturing process.

Manufacturers in the United States have concentrated, and exploited, the productivity improvements possible in high volume parts manufacturing through the use of transfer lines and to a lesser degree dedicated systems. We have also done a good job of capital utilization by employing stand-alone numerically-controlled machines in the very low volume segments. We have failed to answer the question of efficient batch manufacturing. Those answers lie in the two blocks entitled "VMM" or variable mission manufacturing and the second entitled "Cell and Robots."

The optimum use of America's manufacturing capital will be achieved in the next few years. The systems we will see will produce a random selection of parts and assemblies on an unmanned, around-the-clock basis with an absolute minimum of in-process inventory.

Now let's look at a few slides to orient you.

This is a transfer line used to handle a large volume of identical parts - in this case machining the hull of the U.S. Army's main battle tank. More than a concept, here it is at work in Lima, Ohio (see Figure 10).

This is a dedicated system used to handle a volume of similar parts. Through a series of work stations we are machining six different frame assemblies for crawler dozers (see Figure 11).

This is a flexible system handling random parts from a parts family having dimensions within a prescribed cube size. There are no people involved in the process. The workpieces are transported from machine to machine aboard wire-guided carts. The system is controlled by a hierarchial computer system that schedules machine time as available, downloads the part cutting instructions, and makes the cart arrive on time. This is what batch manufacturing in the future will look like. It is state of the art technology. It is available and will be improved (see Figure 12).

This is a robotic cell where a robot is loading and controlling two numerically-controlled turning centers while gauging and sorting each part produced. The driving control in this cell is the robot (see Figure 13). Again, few people, if any, one involved in the process. And, finally, this is a stand-alone numerically-controlled machine. This machine is today utilized in very low volume batch manufacturing. It is loaded, unloaded, set up, and operated by a human being (see Figure 14).

Robots will be the keystone in the variable or flexible manufacturing systems of tomorrow. These manufacturing systems are the basic building block for improving our capital utilization. These systems, including robots, will answer our demographic problem: that of too few blue-collar workers available in the next decade to run our plants. The industrial robot is a flexible and general purpose tool. It will perform many tasks. It will simultaneously serve as a worker, a traffic controller, a troubleshooter and most importantly, it will be the intelligent interface with the machine around it. Robots will be the device that raises capital utilization in America to new and higher levels in the next decade.

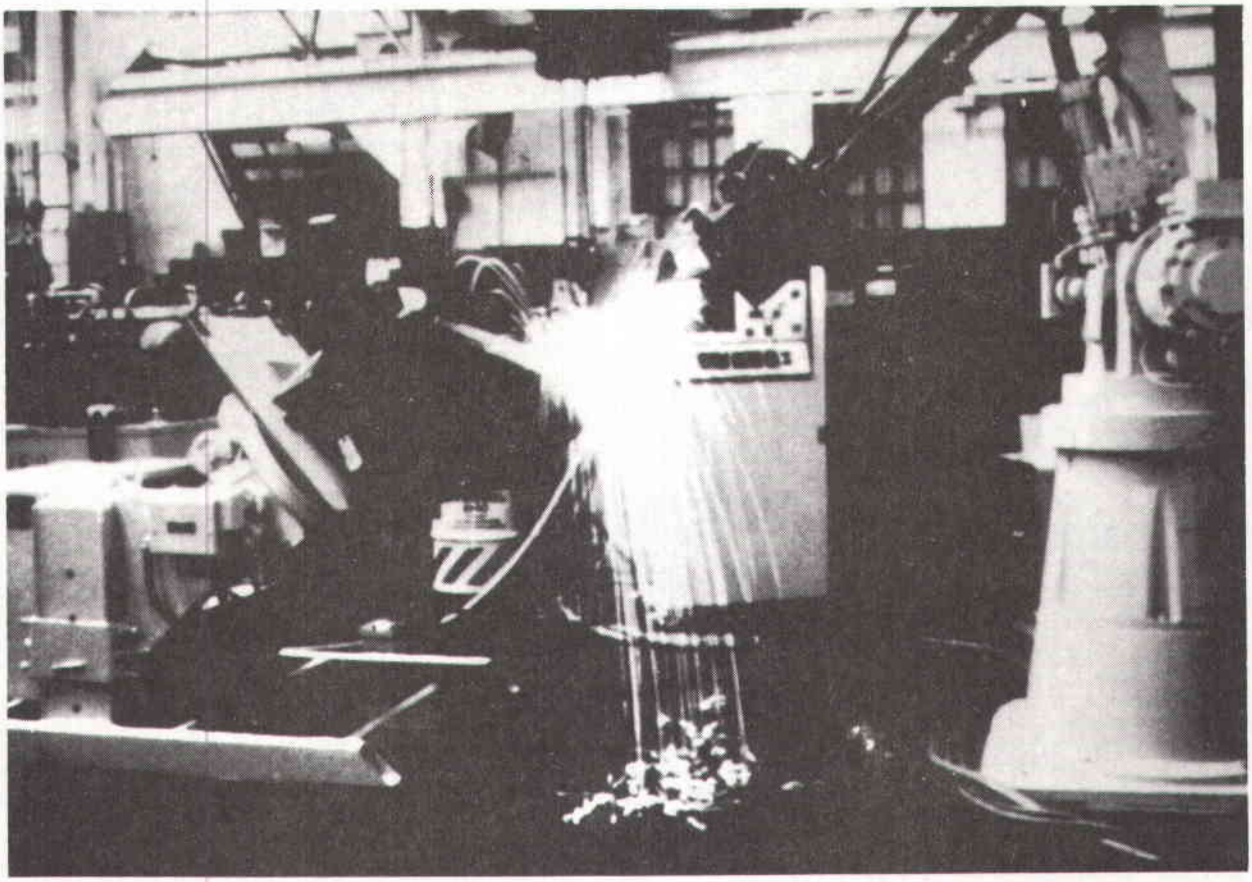


Figure 1

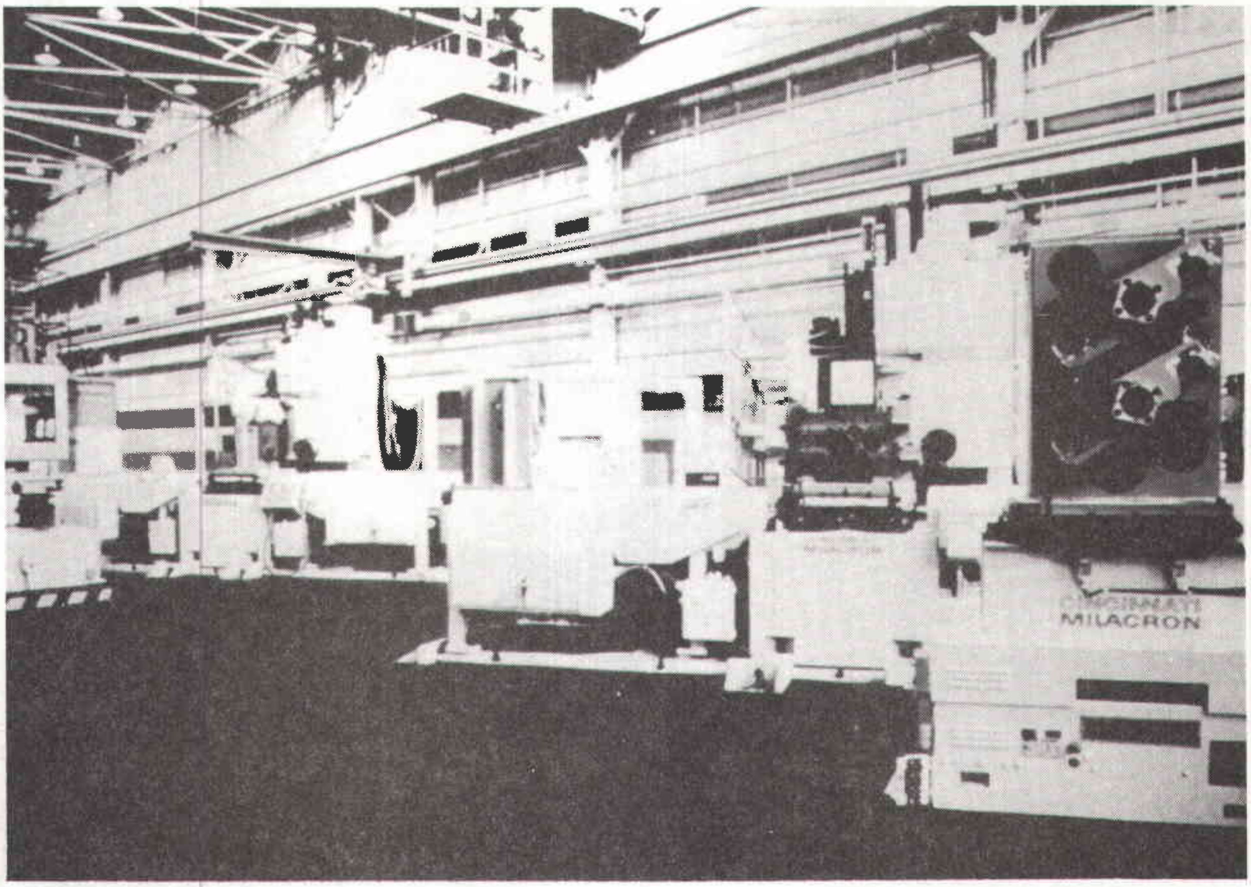


Figure 2

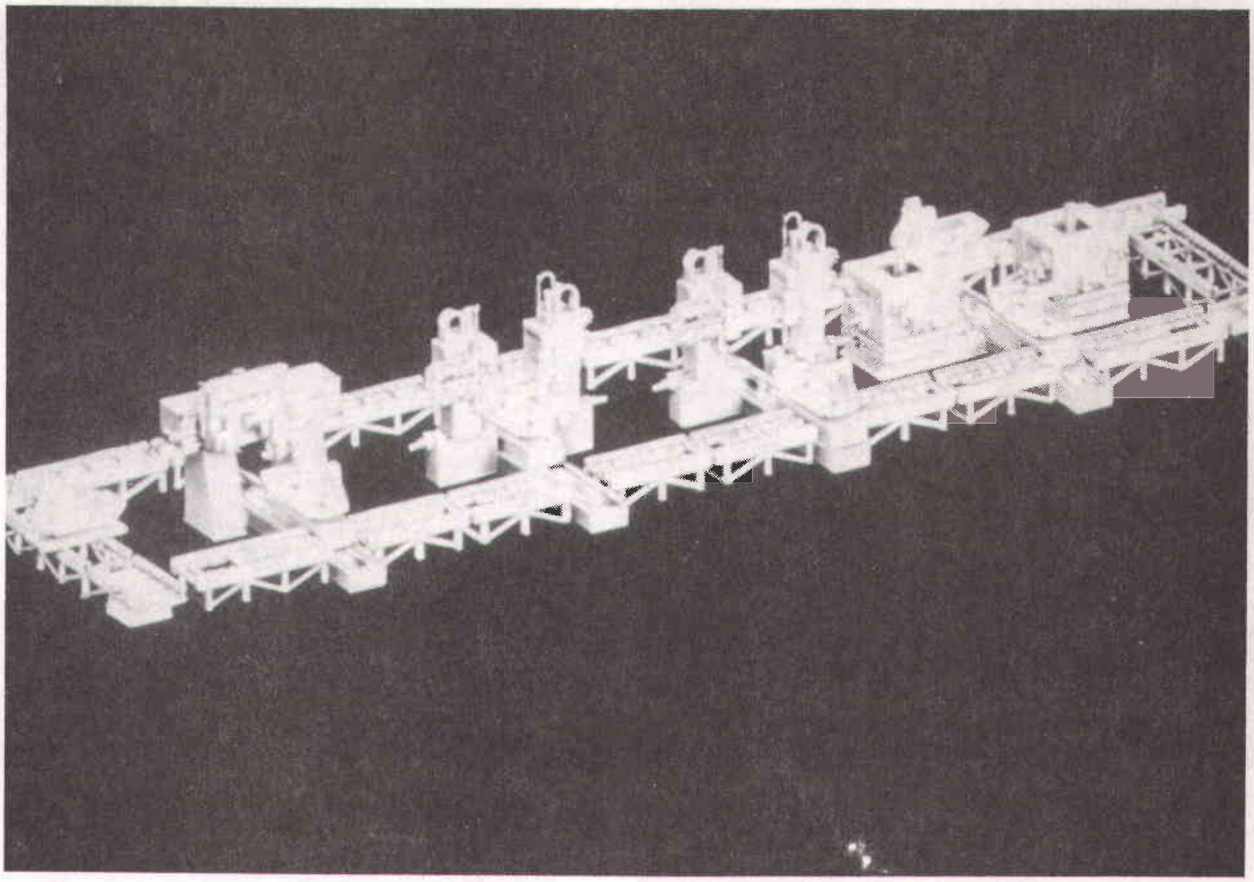


Figure 3

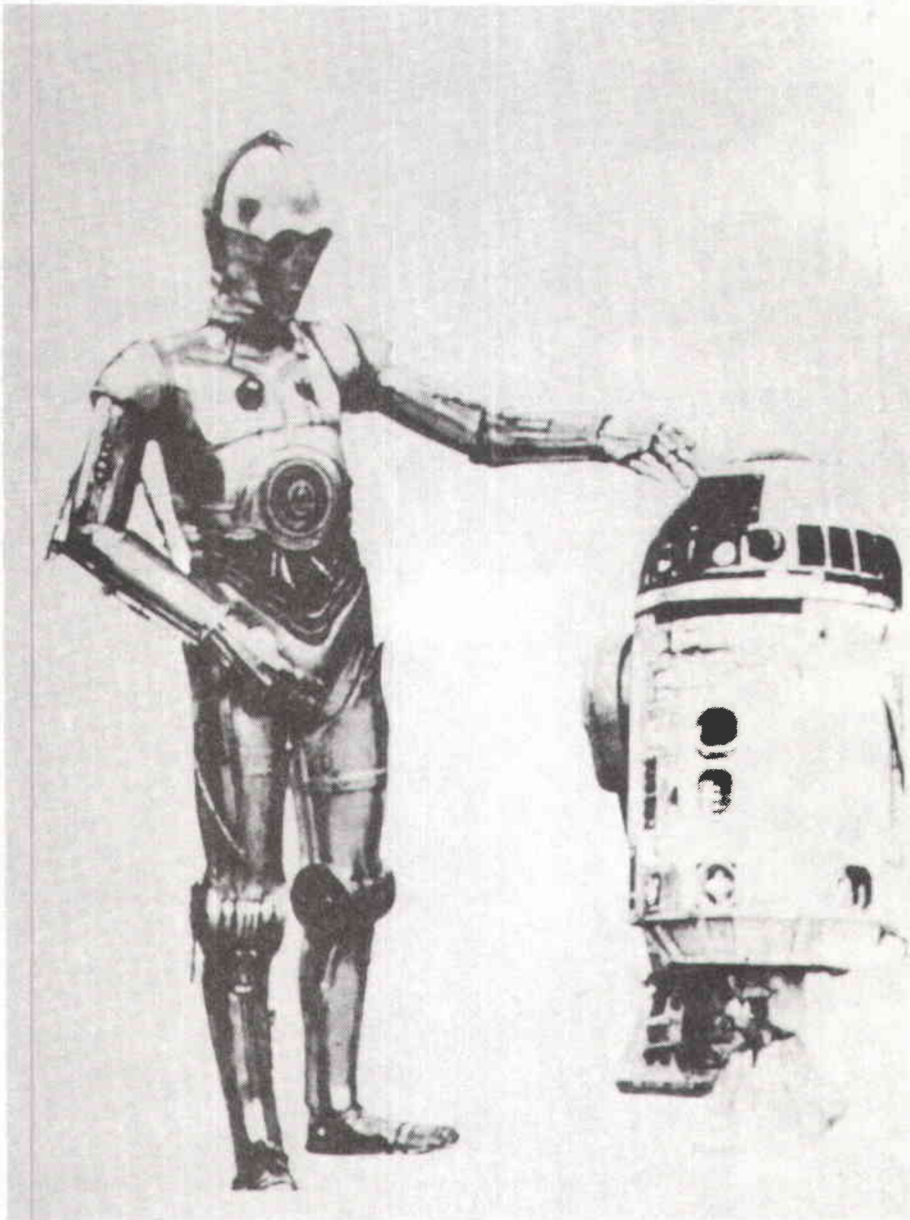


Figure 4

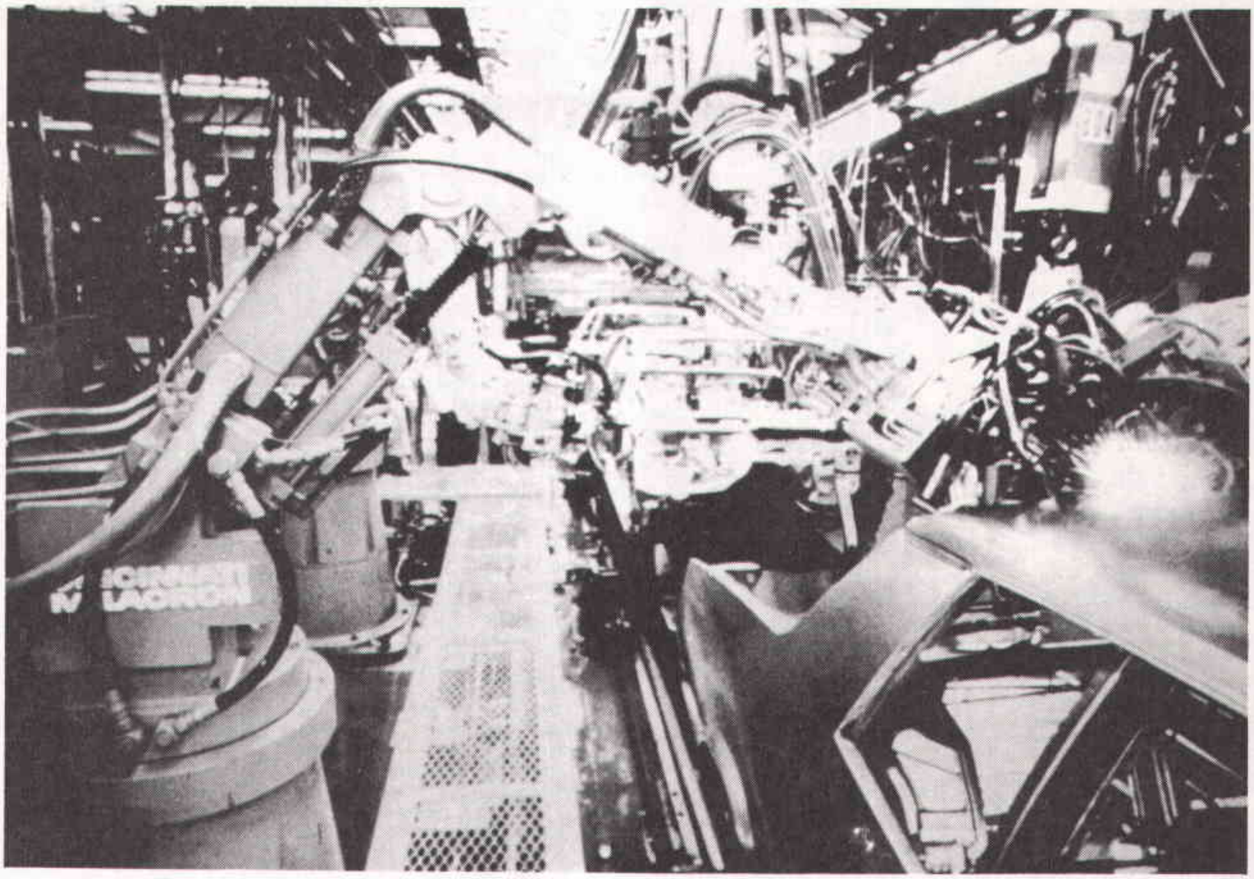
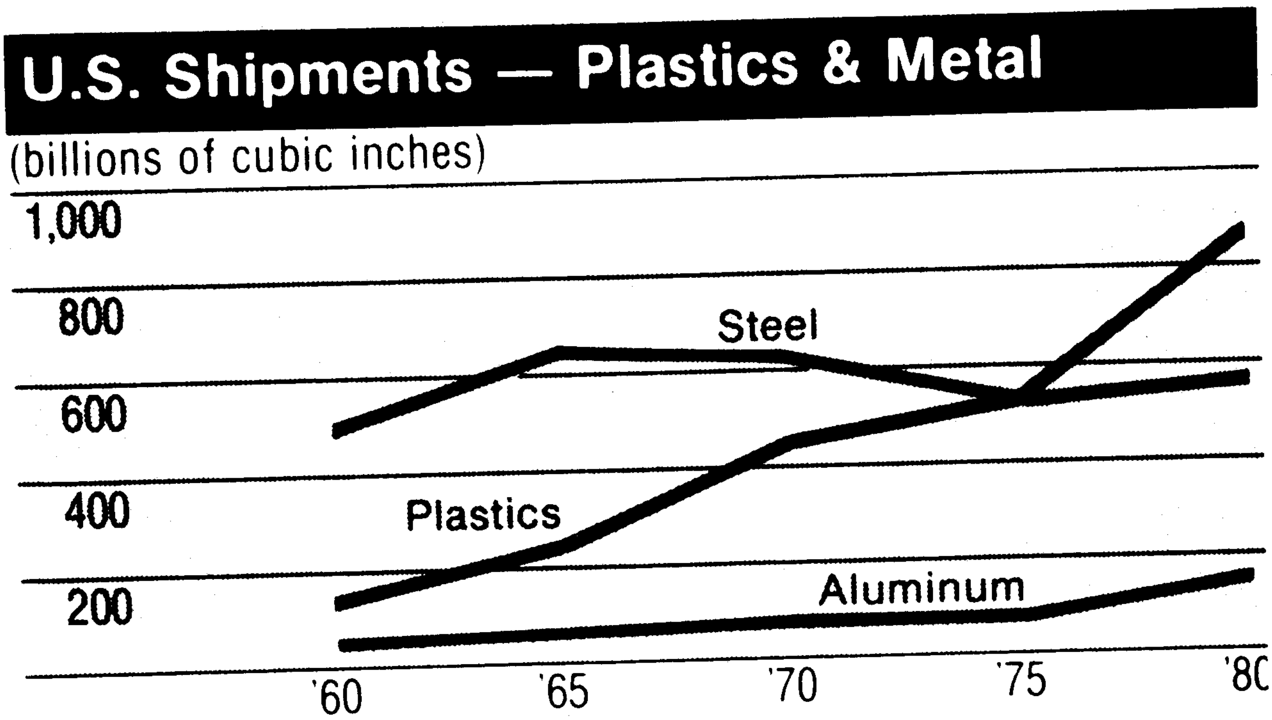


Figure 5



Source: Society of The Plastics Industry, American Iron and Steel Institute, U.S. Bureau of the Census

Figure 6

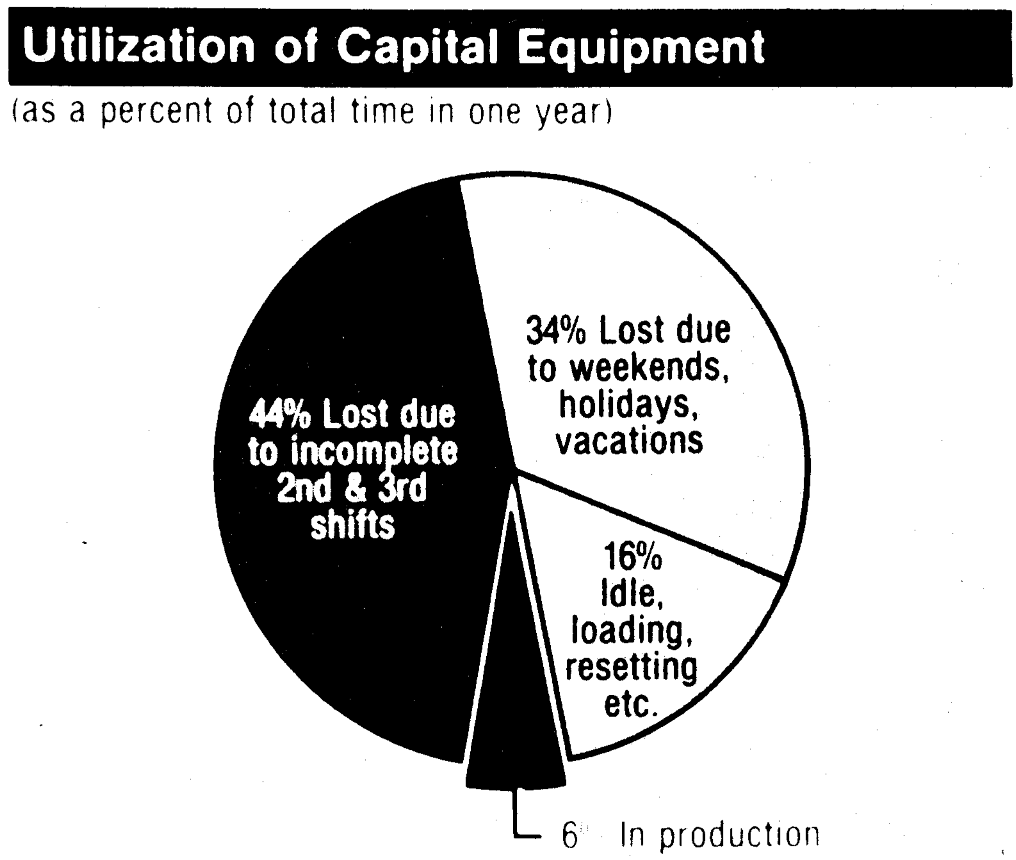

Utilization of Capital Equipment
(as a percent of total time in one year)
44% Lost due to incomplete 2nd & 3rd shifts
34% Lost due to weekends, holidays, vacations
16% Idle, loading, resetting etc.
6 In production

Figure 7

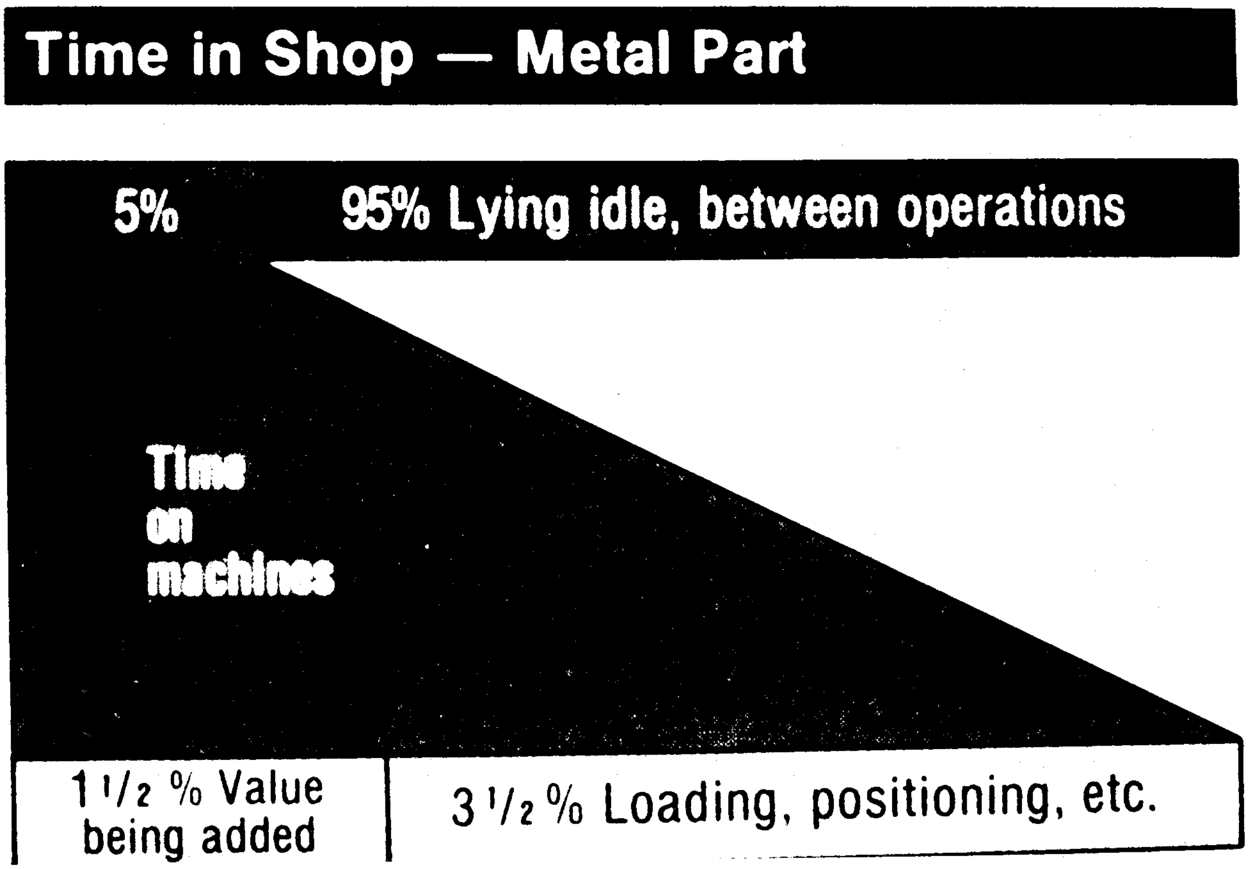

Time in Shop — Metal Part
5%
95% Lying idle, between operations
Time
on
machines
1 1/2 % Value being added
3 1/2 % Loading, positioning, etc.

Figure 8

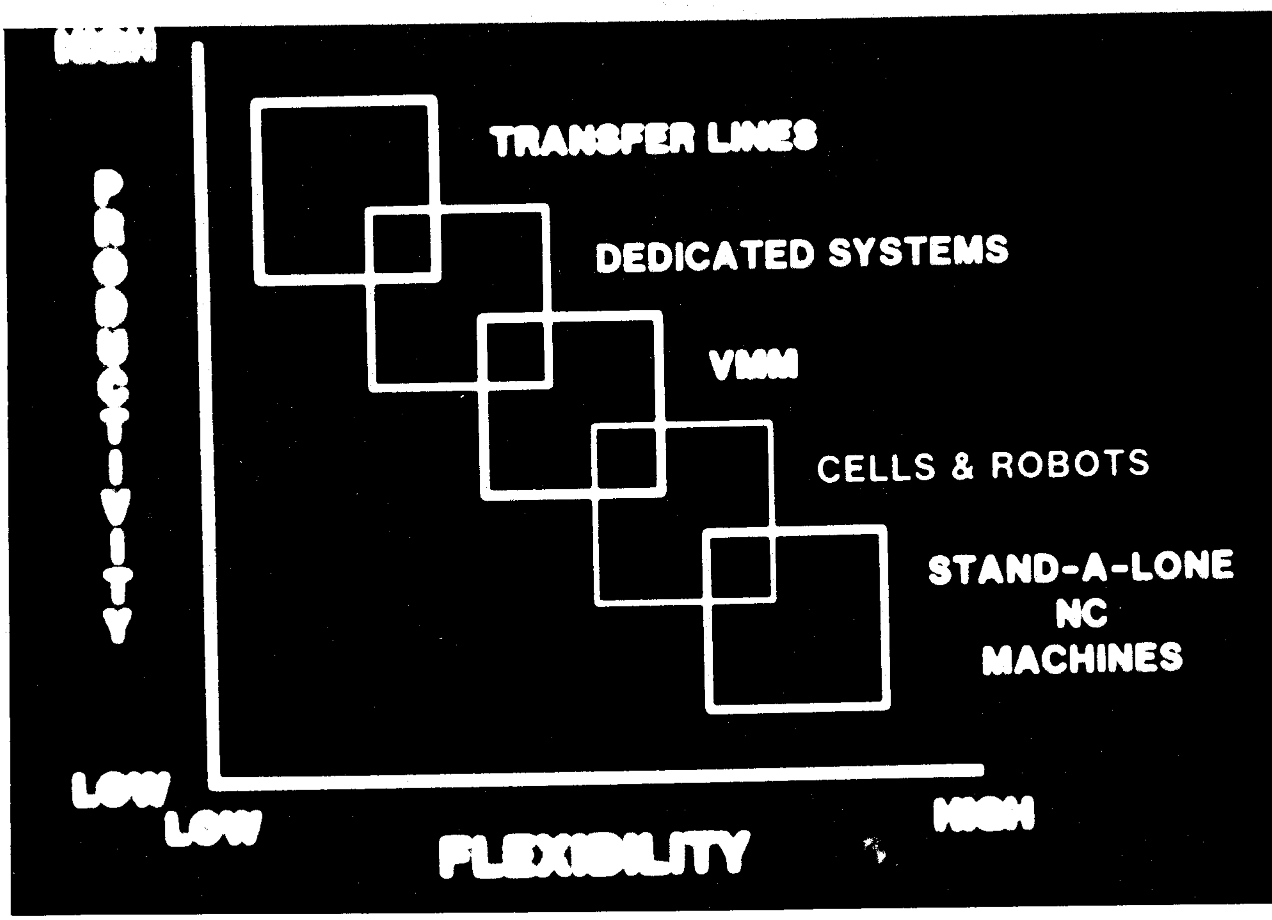

TRANSFER LINES
DEDICATED SYSTEMS
VMM
CELLS & ROBOTS
STAND-A-LONE
NC
MACHINES
PRODUCTIVITY
LOW
LOW
FLEXIBILITY
HIGH

Figure 9

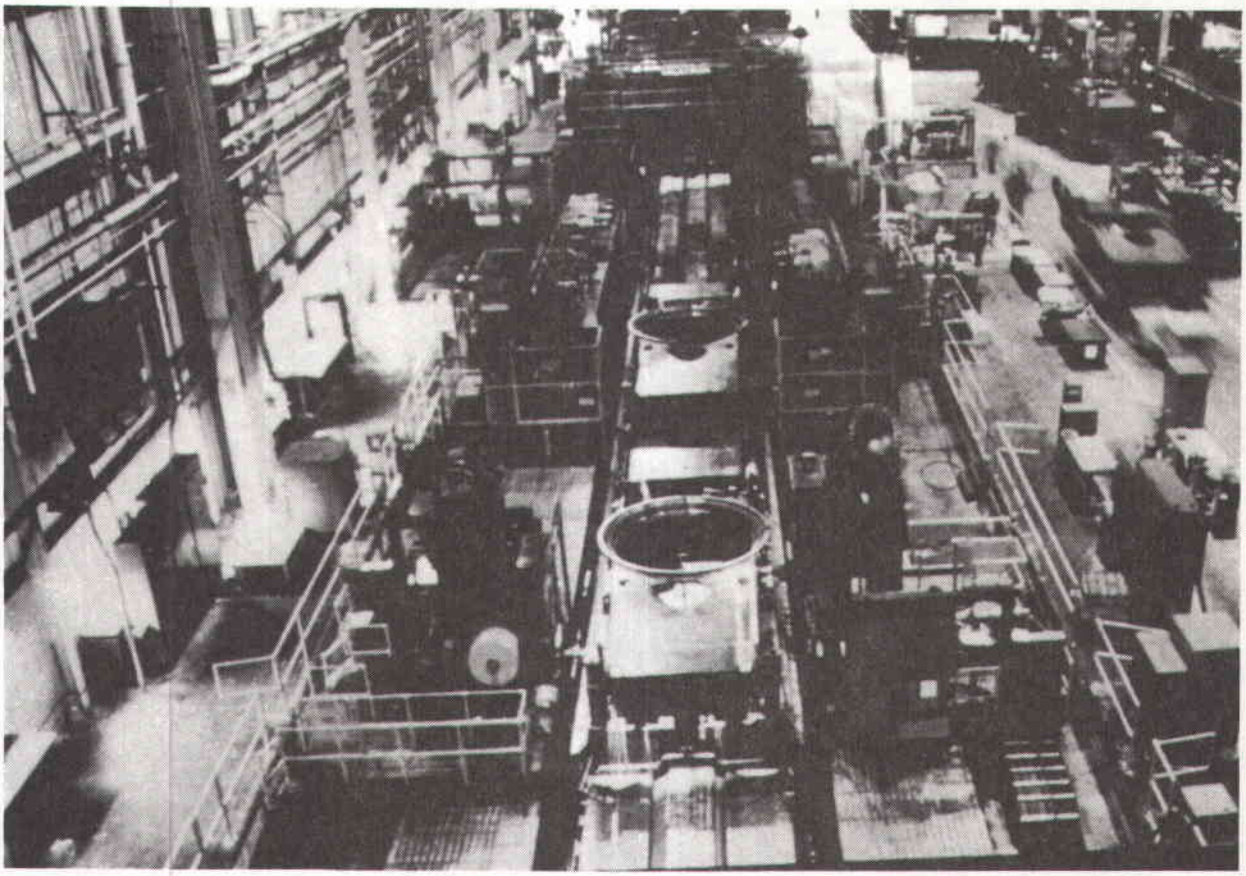


Figure 10

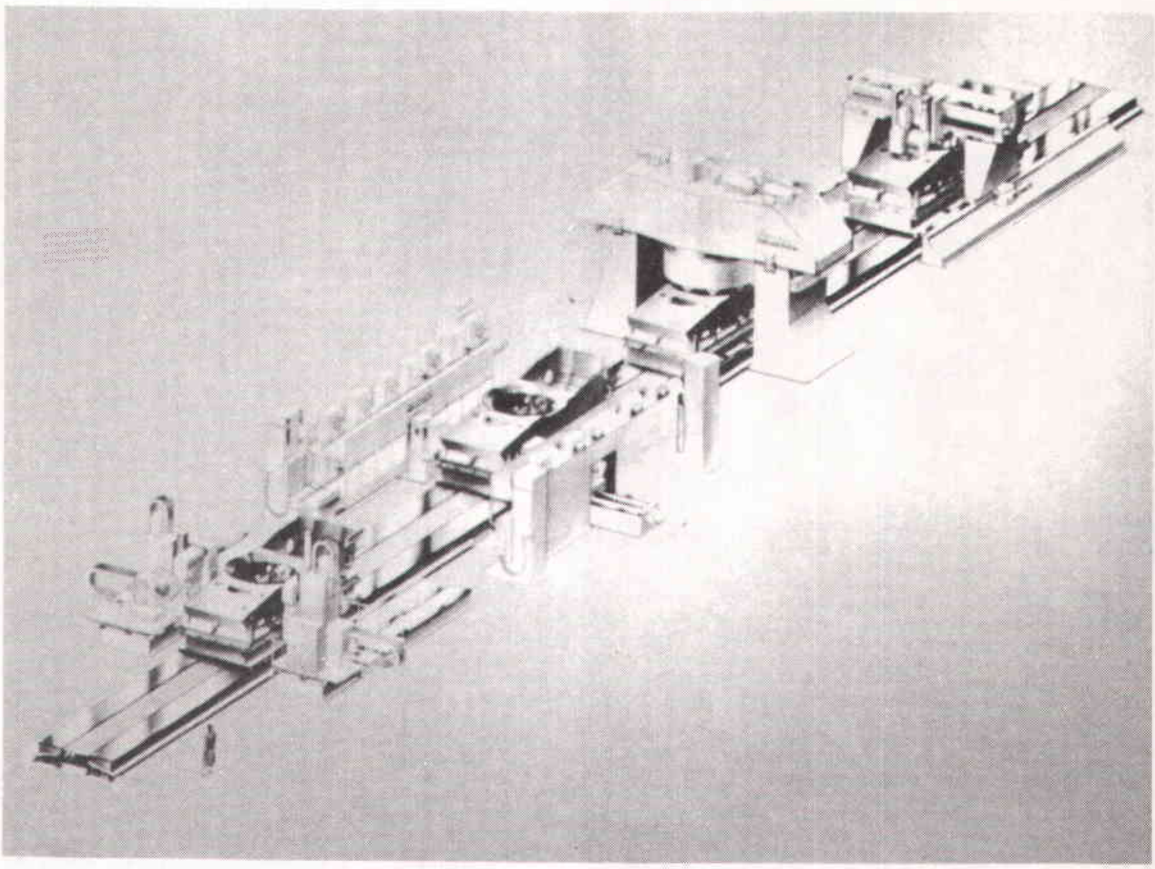


Figure 11

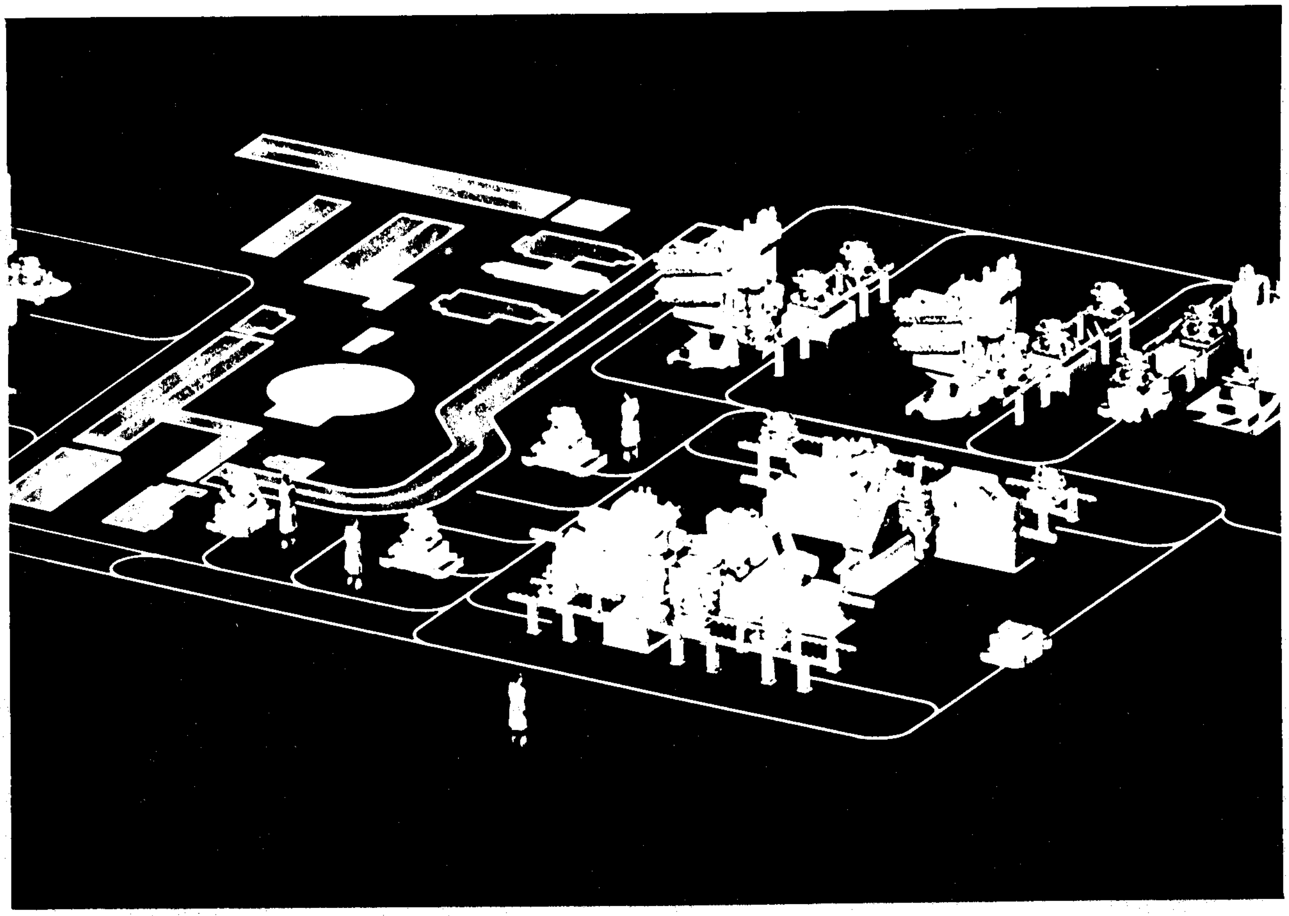


Figure 12

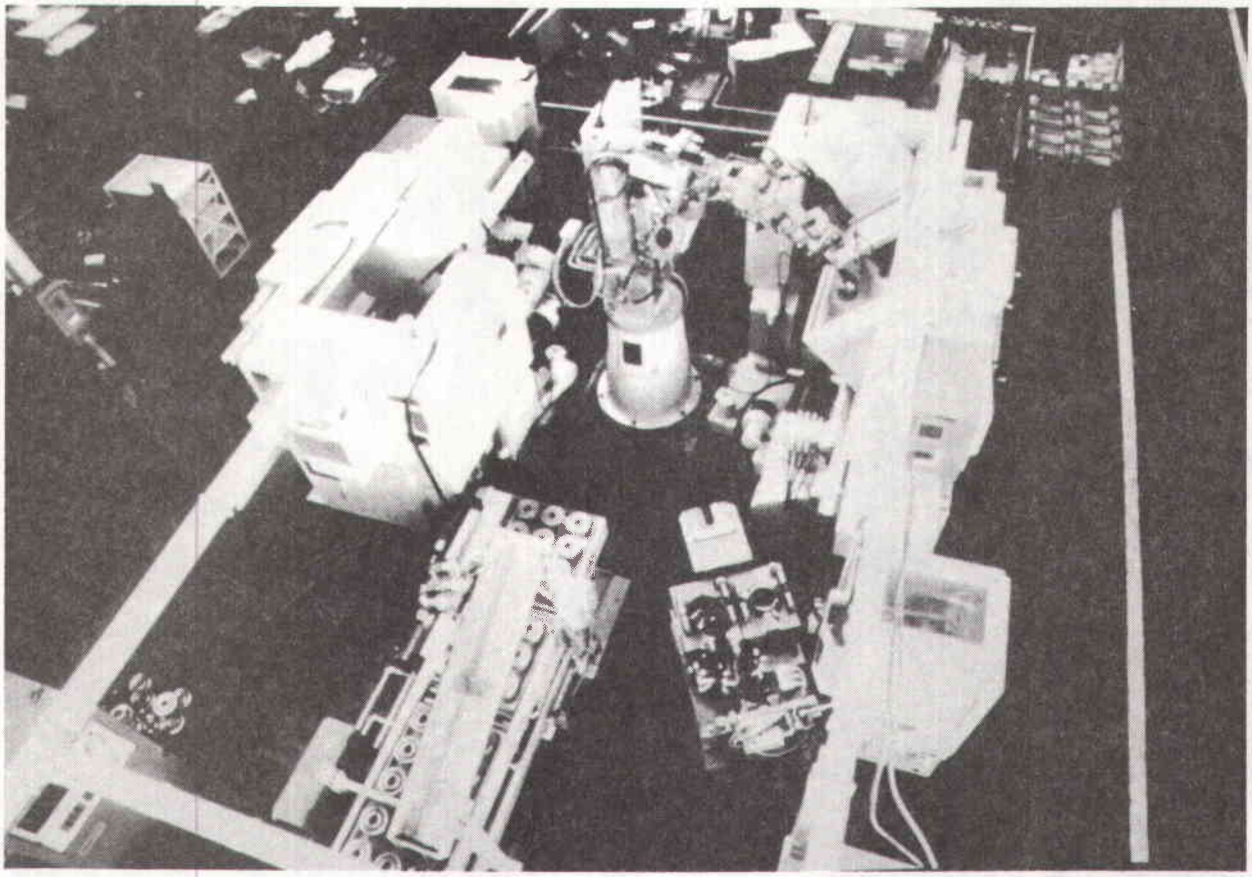


Figure 13

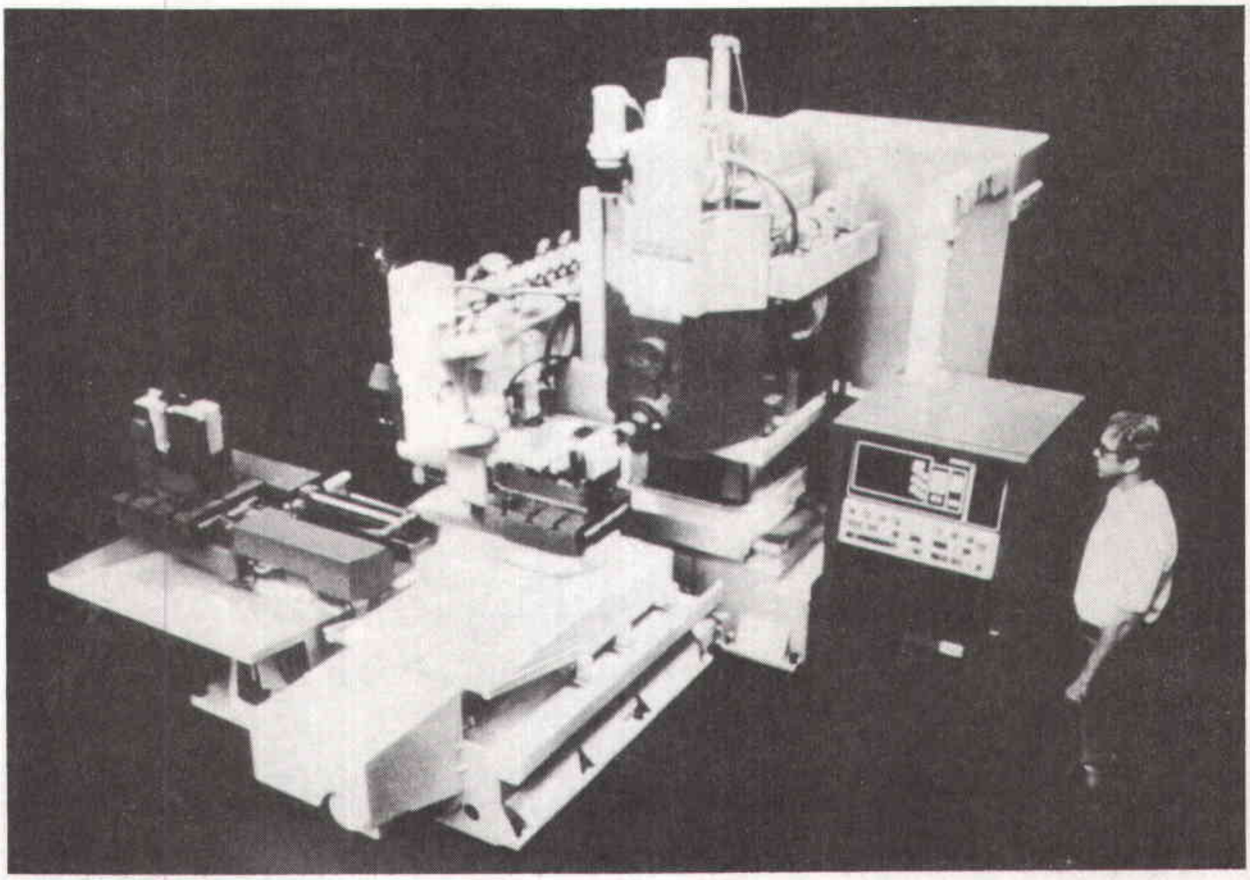


Figure 14

The Social Impact of Robotics and Advanced Automation

Barry J. Brownstein

Mechanization, the replacement of human labor by machine power, began seriously with the Industrial Revolution. Automation - composed of mechanization's production machinery, new materials handling devices, and the control systems that regulate them - evolved first in continuous processes, such as those in chemical production. The application of automation to a variety of other processes, and its human impact, have been the subject of much discussion ever since.

The application of automation in manufacturing began with the production of items such as metal cans which, though discrete in nature, are produced in a quasi-continuous manner. Such automation is normally referred to as "hard" or "fixed," because the production machinery does not lend itself to rapid changeover in order to produce a different product.

Computers, first applied in the industrial setting in 1954 and first used for process control about six years later, have led more recently to advanced forms of "programmable" or "soft" automation that can be applied to the smaller "batch" production runs that typify much of contemporary industry.[1] The industrial robot is an example of this technology.

Although the word "robot" originated only about sixty years ago, it is already difficult to separate emotion from reality when examining its potential role in our future. The Robot Institute of America, a trade association, defines a robot as "a reprogrammable, multi-functional manipulator designed to move material, parts, tools, or specialized devices through variable programmed motions for the performance of a variety of tasks." While these harmless devices have been on sale only twenty years, our fascination and fear of them - or most likely their more capable progeny - has been rooted in our society at least since the Industrial Revolution. Miller[2] suggests that these fears are real and may represent an emotion similar to a master's distrust of his capable slaves, or perhaps a parent's terror or resentment of his growing child. He further suggests that people seem to fear robots in proportion to their perceived power and independence from man, as suggested by audience responses to robots in science fiction films.

Over the past twenty years, the evolution of computer technology has enabled its application to many other types of industrial machinery besides the robot, adding to the flexibility of manufacturing processes. Other such forms of advanced automation include high speed inspection machines and computer-aided-design systems that automate operation beyond mere production, as well as the interconnection of production machinery into flexible, computer-aided manufacturing networks. Slowly but inexorably, these innovations are changing the face of industry and the historical role of people within it. Small wonder that the social implications of advanced automation are being pondered today.

This paper will explore some of those implications, in part by trying to better understand what previous waves of industrial change have done to our society. While each wave of change - and each society changed - has been quite different, taking another look at our past can still give us a better basis to assess ourselves and our future. We will begin by examining the impact of production technologies on industry itself.

The Evolution of Industry

William Faunce[3] structures production technologies into three generic types: pre-industrial, industrial, and post-industrial. Pre-industrial society is characterized by the artisan mode of production and proprietorial organizations, as suggested by the life of an eighteenth century silversmith. Industrial society, on the other hand, utilizes mechanized forms of production and bureaucratic organizations as might be evident in the production of automobiles in the United States today. Post-industrial society, encompassing only about 7 percent of U.S. workers as of 1978, has embraced automated production technology, as typified by workers in a modern, computer-controlled chemical factory.

Table 1 illustrates Faunce's characterization of several U.S. industries according to this system of nomenclature. Since the various production technologies still coexist today, we can examine them to better understand what the evolution in standard practice of the Industrial Revolution must have represented, and thus perhaps better understand what a widespread transition to advanced automation might mean to us in the future. Postponing for a moment the study of possible societal consequences of such a tradition, let us focus our attention on what the new technology might mean to industry.

It can be seen by tracing through the various stages of industrial development that a major theme has been the progressive removal of man from processes, particularly those in which manual actions are interspersed with mechanical ones, or those in which man is caught up in controlling machines. The transition to advanced automation follows this theme; the technologically mature robot is well-suited for replacing workers sandwiched in between machines in industrial processes. The robot stands to change radically the assembly of products, one of the most labor-intensive functions in contemporary industry. Such diverse activities as stitching clothes and assembling electric motors fall into this category.

Computer-aided manufacturing would impact process control at least as significantly as robots would impact materials handling, further mechanizing the steps between a product designer and the ultimate manufacture of his product. This is particularly true for industries in which the product varies often enough to have thus far blocked the onset of mechanization in key steps in the manufacturing process. As over 75 percent of all batch manufacturing in the United States fits this description, significant changes in its conduct would affect "common practice" and thus potentially become an important agent for societal change as well.[5]

The widespread application of advanced automation could profoundly impact the assignment of human labor in industrial production, and thus aid in reversing a trend typified by Henry Ford's plea "I want farm boys."[6] To get a better appreciation for how such production innovations can affect society, let us examine our past.

Social Impacts of Production Technologies

Technology has changed life dramatically since the Industrial Revolution began, in form if not substance. Man's short-range perception tends to filter out many of these evolutionary trends and to view society as a static entity that is continually threatened by change. This viewpoint may explain why the speed at which changes take place affects society's ability to accept it gracefully. Additionally, the complex interrelationships between aspects of a society often provide unanticipated paths along which the society reacts to new forces. These two principles have often come into play in societal reactions to technology.

While not entirely a parallel to today's changing production technologies, the shift of American textile manufacture from the artisan to the mechanized form of production late in the eighteenth century does provide some insight into what can happen when production technology changes. The growth of textile mills in the northern United States placed a great deal of pressure on solving a problem: It took one slave all day to remove the seeds from a single pound of cotton. Eli Whitney's cotton gin overcame this problem, and the production of cotton grew from 140,000 pounds in 1791 to 35 million pounds - an increase of 25,000 percent - in only nine years. As is often the case when a production bottleneck is overcome, the cotton gin helped to highlight the next larger bottleneck - small farms with few slaves - and as a result the U.S. slave population was doubled in just twenty-three years.[7]

Thus the societal impact of the cotton gin went beyond cotton production. A first-order change in the production became a second order change in slavery, and a variety of other interactions in the fabric of society were likewise caused, modified, or catalyzed by the spreading use of the machine. In the words of Roger Burlingame, the cotton gin ultimately "...changed the ethnological, economic, political, ethical, and industrial face of the country. Without it, it is highly conceivable that the issue of the Civil War would never have appeared, that Lincoln would have remained a small town lawyer, that the deeper South would have labored under the smoke-clouds of factories, that jazz music and dancing and Sewanee folklore would never have invaded the world, that the fine old traditions of aristocrats, colonels, hospitality, manorhouses, spoon bread, and juleps would have 'gone with the wind' even more palpably than they did in Miss Mitchell's novel."[8] We will never know for sure.

The cotton gin represented a vertical innovation; one that affected, however profoundly, a narrow spectra of industry. Robots and other forms of advanced automation have characteristics of horizontal innovation, in that the technology they represent could be applied virtually throughout industry. Writers such as Terborgh[9] suggest that horizontal innovation, such as occurred with the changeover to first steam power and later to electricity, tends to have lesser societal impacts. This is in part due to the variation in speed of acceptance of a new technology and in solving the non-trivial technical problems that must be overcome in each of its various applications.

It is impossible to describe in advance all of the interrelationships that could affect a society's reaction to a technology, or to predict when all of the impediments to the technology's application might be overcome. Even if we could do these things, the impact of the technology would still be different on each of the varied societies that simultaneously share our world. Different societies do often react to the same technology differently, again as evidenced by the growth of mechanization in the Industrial Revolution.

Early English factories had a reputation for brutality. People - often children - were "...tied to the rapid, unchanging pace of the machine under the close and often brutal supervision of overseers who were paid on the basis of the amount of work they extracted from those in their charge." These conditions are graphically described in the records of various parliamentary commissions of inquiry.[10] On the other hand, the U.S. textile industry grew up substantially without the miseries of the English system, at least at first. "Spinning schools" were opened to give jobs to the poor, the unemployed, and for children convicted of petty offenses. Sunday School was offered to the chaperoned girls who eventually became the mainstay of the worker population.

This difference in the factory systems may be explained by the simple, "close-to-the-soil", God-fearing nature of American society in the late eighteenth century. It is noteworthy that the more humane American situation to a large degree evaporated when the immigrant, to whom the management could not relate so well, replaced domestic workers.[11] Regardless of the specific interpretations, it is clear that the same basic change in technology affected the two societies differently. This should serve to highlight yet another risk in societal predictions. With that caveat in mind, let us now look at three facets of society - work, leisure, and aesthetics - and postulate what the effects of advanced automation might be upon them.

The Changing Nature of Labor

Few issues raise a more spirited debate than does the potential impact of new technologies on the employment of workers. Likewise, with the exception of those jobs in which automation protects workers from exposure to hazards, no single benefit has done so much to encourage the adoption of advanced automation as has the prospect of decreasing the labor costs involved in production.

In general, the advent of mechanization, with is attendant division of labor, served to produce an elaborate occupational structure with many jobs available that required about the same level of skill. As described by an observer a half-century ago, Henry Ford's 26-mile-long assembly line at River Rouge displayed this trait well. "The worker who puts a part in place does not attach it. The one who puts a bolt in place does not affix the screw, and sometimes even the man who puts the screw in place and the one who turns it are two different workers."[12] As industries move closer to automation, this employment picture changes, reducing the options for the re-employment of displaced workers at the same skill level.[13] Let us examine in more detail the potential changes in employment rate and the nature of work that could result from the application of advanced automation.

It is difficult to analyze the impact of worker displacement due to technology, for it can be offset by simultaneous events in other arenas. For example, a jump in production in response to "world markets" or increased opportunities in burgeoning service industries (which are more difficult to automate) both can serve to soften or even negate the employment impact of advanced automation. In some countries, such as Japan, a major cause of automation is a shortage of unskilled and semi-skilled workers, as opposed to cost-cutting measures. On the other hand, the introduction of advanced automation is being inhibited in Germany by the usefulness of "guest workers" from such countries as Turkey. In such cases, a substantially different societal impact might be predicted. Finally, the impact of changing international centers of production can cause regionalized effects, as evidenced by the return of electronics component assembly from the hands of Far Eastern workers to the new automated plants of Japan and the United States.

The ultimate question is whether advanced automation will in the end reduce opportunities for employment. To the question, "will there be enough jobs?" George Soule[14] answers:

> Technological unemployment has been feared, and even predicted by responsible thinkers, many times since the start of the Industrial Revolution. It has occurred in parts of the economy where sudden changes have not been accomodated without the loss of jobs. But it has never occurred in all industries or lasted long...

Soule goes on to describe how people will buy more products if they have more money, and that it will be some time before an upper limit to such disposable income is reached or the various deprived segments of our society attain a reasonable share of the bounty. Even if that situation is ever remedied, Soule remains optimistic:

> Even if people had all they wanted of things they buy as individuals, there are large unsatisfied needs for things and services they buy as taxpayers. Schools and teachers, roads, parking places, social security, recreational facilities, medical services, slum clearance, housing,conservation of natural resources, protection against violence, domestic and foreign, can barely be provided without unbearably high governmental charges against private incomes. There is much to be done before the whole population is so overwhelmed with goods and services that it can no longer use the labor of all who want work and are fit for it.[15]

In this author's opinion, the long-term impact of automation on overall employment will probably be benign, although industrial employment could conceivably decline. Although factory employment has been part of our society for nearly 200 years, it was not prior to that time, nor is it anywhere ordained that it must be so for all time. The crucial factor in the impact of advanced automation on employment is the form that the transition to widespread application takes, particularly the time it might require. While technological and economic factors can delay or inhibit change, in general the American trend has not been to view the worker as an obstacle to change. In light of the new American appreciation for the world market, even powerful unions see the requirement for automation in this more competitive environment. Such attitudes serve to shorten the transition time, thus increasing the displacement of workers, potentially to levels beyond what might be handled through normal attrition.

In a manner reminiscent of older attitudes towards ecology, the worker today is still often thought of as a product of an external system that will somehow take charge of him once more if he is displaced from his job. What is required is more of a "closed system" view, in which industry, government, and educational organizations plan and take responsibility for aspects of the employment process. This will be especially important if rapid changes in employment patterns take place as a result of the application of advanced automation technology. With the majority of the application of advanced automation technology. With the majority of our species dependent on being connected to our economic system via employment, and the social impacts of unemployment, even a modest amount of cooperation and coordination between those institutions which educate, employ, and protect workers would be beneficial.

The widespread application of advanced automation could lead to a decrease in the number of unskilled and semi-skilled jobs, at least in industry. But what might be the nature of the jobs that would remain? Let us examine the evolution in job characteristics to see if it helps to predict the future.

In pre-industrial times, the worker not only supplied the power to tools and simple machines, but also physically provided the functions of materials handling and control of the manufacturing process. This role of "man as the artisan" is in sharp contrast to that of "man as the machine operator" in the mechanized production mode. In such environments as the manufacture of clothing in America today, even if the power source is no longer the worker himself, both materials handling and process control remain fundamentally human endeavors.[16]

Mechanized production is the environment in which most Americans work today. As described particularly eloquently by Marot sixty years ago, in such an environment, man "...supplements without loss whatever human faculties the machine lacks, whatever imperfection hampers the machine in the satisfaction of its needs. If it lacks eyes, he sees for it; he walks for it, if it is without legs;

and he pulls, drags, lifts, if it needs arms. All of these things are done by the factory worker at the pace set by the machine and under its direction and command."[17] In the words of Georges Friedmann, the assembly line, that symbol of mechanization, is "...in many instances like a signal revealing the present deficiencies of technology, wherever it causes the hand of man to perform highly subdivided operations which mechanization has been unable to conquer."[18] It is precisely these deficiencies to which advanced automation is addressed.

As the handling of materials and process control are changed by the application of advanced automation, the special-purpose machines which have characterized the mechanization stage of industry will be replaced by multi-purpose ones. In such an environment, man often becomes a "machine-monitor" - as typified by today's chemical worker - stepping in only when conditions arise that are beyond the technology of automatic control.[19] Friedmann sees this as the time when "...the worker's last productive movements are entrusted to pinions, gearings, and shafts of metal, total...automation...begins."[20] Clearly this represents a significant role change for at least some of the workers required in a post-industrial society.

In addition to changes in the roles of individual workers, it appears that there will be fewer workers in a given factory, although often the plants may well be elements of a conglomerate corporate structure.[21] Industries in which advanced automation has taken hold have tended towards a removal of class distinctions between white- and blue-collar workers. This is to some extent an extension of the role of the technician in industry today. Such workers often have more job flexibility than many of their contemporaries: "Even today, the production worker who monitors a bank of dials in the control room of an automated continuous process chemical plant has more responsibility, skill, and control over his work activities than the common office worker..."[22]

This view may be utopian, and probably not all workers would share in such an existence. It is likely, however, that some of the causes of worker alienation in mechanistic, division of labor jobs will be ameliorated as advanced automation takes hold and "...man, little by little, retires from the operations of industry, ceasing, as the philosopher would put it, to be the object in order to remain solely the subject."[23]

The Changing Nature of Leisure

After employment, probably the most widely publicized impact of advanced automation is that upon leisure. As factory workers decline in number, society could perhaps be transformed into "...a world of busy, empty factories and busy, crowded shopping malls."[24] Given the power to free themselves from the more mind-numbing aspects of industrial production, how will our descendents occupy their spare time?

Before we address this issue, it is important to emphasize that it is liable to be some time before widespread release from industrial work would occur, if at all. Increased leisure must be more than just a product of a possible decline in industrial employment; it would also require changes in how people are paid. Otherwise, the need to work a certain number of hours would persist, as it does today in non-industrial jobs.

One common conception is that leisure today is at an all-time high with an almost continual decline in working hours since the dawn of history. If we define leisure as that portion of one's time not being spent in exchange for income, an interesting historical pattern emerges. Working hours per year actually peaked in about 1800, when the sixteen-hour factory day led to a working year of nearly 4,200 hours. By 1973, the average was closer to 2,000 hours, and often less. That certainly seems like a downward trend, but what of the years before 1800? In Roman times, almost one-third of all days were festivals, cutting into the working hours. Later, in medieval times, a combination of 141 Saints Days, a 30-day vacation, and the needs of family agriculture led to a working year of only 2,328 hours - not really so different than today.[25]

It is apparent from history that production technology has affected the amount of leisure available. It should also be clear that one's time away from producing income is governed by many things, including religious activities, days of rest and vacation, and personal artisanship, such as is represented by the family-oriented agriculture of the past (which was certainly a necessity at the time). The act of dedicating major parts of one's life to the production of goods for others has not always been part of our lives.

When viewed in this light, it is not obvious that some degree of freedom from industrial activities is either new or bad. The real concern is how the time would be used and its impact on the overall quality of life. Unfortunately perhaps, we are not always prepared for leisure. As stated by David Riesman, "...for many people today, the sudden onrush of leisure is a version of technological unemployment; their education has not prepared them for it and the creation of new wants at their expense moves faster than their ability to order and assimilate these wants."[26]

If we want view leisure as merely unpaid time, Soule[27] sees several uses for it:

- child care and family leisure,
- passive entertainment,

- active home pursuits (gardening, do-it-yourself, etc.),
- participatory sports,
- travel,
- social production (charity, service, etc.), and
- self-education.

As high-sounding as many of these pursuits seem, recent surveys indicate that for better or worse, some 45 percent of leisure is now spent passively watching TV.[28] As Carnegie-Mellon's Herbert Simon ironically notes to those pondering the effects of automation, "If we are worried that people are going to become pathologically involved with their machines and are going to stop interacting with other human beings, then the thing we ought to worry about is not the computer, but TV."[29]

Perhaps a less totally vocational view is needed towards education to help people relearn how to spend their non-income-producing time. As stated most eloquently by George Soule, "technology has mastered the art of saving time, but not the art of spending it."[30]

The Changing Nature of Aesthetics

An often overlooked aspect of life is aesthetics, which can loosely be defined as "taste." Mechanization significantly impacted aesthetics, and one could surmise that advanced automation could do so even more profoundly. Before examining this premise, let us briefly review what has happened to taste over time.

Today we often wax self-depreciatingly about the plethora of poorly designed and poorly made goods we own; this was not always the case. In pre-industrial times, much of what people owned that they themselves did not make - and that was not much - was made by skilled artisans organized in guilds. As recounted by Giedon, "the guilds produced wares of a consistently high standard...Prices were fixed, and were very high in comparison with the hourly wage. Goods were not easily acquired. They embodied human as well as material values, and strong personal bonds attached a man to his favorite possessions."[31]

This situation prevailed until the Industrial Revolution met with machines that could satisfy, in Giedon's words, the "ineradicable wish for adornment, like hunger or love":

> The machines began to pour forth statuary, pictures, vases, flower bowls, and carpets in mass. Simultaneously, furniture became bloated and its forms dulled. There followed a further packing of the room with all sorts of objects called forth by the growing need for adornment. The less costly it became to produce, the more this adornment flourished. Lost it would seem, was man's instinct for quiet surroundings, and for the dignity of space. The same temper pervaded all classes of society. Only the materials and execution vary. The statuary may be chiseled bronze, or, for the less wealthy, cast iron; marble or plaster; china or papier mache; handwrought silver or pressed tin. The process moves on to attack wall and floor spaces; the carpets may be oriental or machine made; the pictures originals or chromolithographs.[32]

The mechanized loom of Jacquard..."freed the designer from the limitations of handicraft and enabled him to realize his every caprice, reasonable or absurd."[33] So too could advanced automation make its mark on our aesthetic future. Computer aided manufacturing could permit exact replication of the brushstrokes of the masters at a fraction of the cost, but to what end? It is difficult to predict.

The aesthetics of the future will probably not be driven by automation, but rather, as is the case with technology in general, by society's use of it. As Giedon summarizes the impact of mechanization, so too can we predict the impact of automation. "Mechanization...cannot be the ultimate cause of poor taste; neither can the mere cheapening of goods...Mechanization is neutral. What matters is how one uses (it). The marks of...taste were already visible...Mechanization merely enlarged these symptoms to undreamed of proportions. The elements lay ready in the man of 1800. It was not mechanization that devalued symbols, but the manner in which mechanization was employed."[34] So it will be for man in the future.

Conclusion

We have examined advanced automation and its potential impact on some facets of future society, often by searching our past for parallels. Futurism has always been a dangerous discipline fraught with humorous errors, even by far more technically astute individuals. Thomas Edison, for example, predicted that his light bulb would revolutionize architecture; homes would be designed with their rooms having windows that faced inward. This would better enable one to catch the rays from the one light bulb that would be burning at the center of the residence. Predictions concerning advanced automation are just as apt to be wrong. We know little of how quickly it will actually spread, how widespread it will ultimately be, nor whatever other human endeavors might interact in its evolution.

Admitting our unknowns, we can perhaps better deal with advanced automation. It is a powerful tool that could significantly impact society in many direct and indirect ways. In the case of some societal areas, such as aesthetics, the best answer is probably to press on as always, being astute enough this year to laugh at last year's fashions. In other areas, such as employment, less of a hands-off attitude would probably be best. Perhaps recent economic history shows our inability to manage large systems, yet the off-cited answers of more education, training, and planning are still the best ones we have to deal with change. Otherwise, rapid change can be disruptive to the point that the long-term benefits of a new technology can be seriously impaired.

Advanced automation will ultimately change our society; our actions now can help decide whether our children will be better for it or not. This paper is dedicated to my three children and their compatriots everywhere who will hopefully spend most of their lives in the twenty-first century: a century whose landscape will be different because of the technologies that we are developing and hopefully will also plan for.

The author wishes to acknowledge the wit, wisdom, and intellectual stimulation provided by his Battelle and Ohio State University colleagues taking part in the Mershon Center's Program in Science, Technology and Government Policy.

FOOTNOTES

[1] See (19), p. 66.

[2] See (16), p. 28.

[3] See (6), p. 216.

[4] See (6), p. 48-49.

[5] See (2), p. 10.

[6] See (1), p. 239.

[7] See (3), p. 164-176.

[8] See (3), p. 170.

[9] See (24), p. 54-55.

[10] See (20), p. 25

[11] See (3), p. 157-162.

[12] See (8), p. 163.

[13] See (6), p. 60.

[14] See (23), p. 56.

[15] See (23), p. 57.

[16] See (6), p. 44.

[17] See (14), p. 4-5.

[18] See (8), p. 180.

[19] See (6), p. 44.

[20] See (8), p. 173-174.

[21] See (20), p. 55-56.

[22] See (20), p. 47-48.

[23] See (8), p. 174.

[24] See (16), p. 31-32.

[25] See (20), p. 26.

[26] See (21), p. 366.

[27] See (23), p. 130.

[28] See (6), p. 76.

[29] See (22), p. 73.

[30] See (23), p. 100.

[31] See (10), p. 334.

[32] See (10), p. 344-345.

[33] See (10), p. 346.

[34] See (10), p. 345.

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Toshiro Terano

Man-Machine Systems

The appearance of industrial robots has signaled a major step foward in automation of manufacturing processes. This is no longer true for only large-scale, mass-production factories, because automation has come to be actively adopted by middle and small-scale factories as well. While it is a fact that this trend presents society with problems in both the economic and employment arenas, these problems are far from new. In reality, they represent no more than another aspect of the very same rivalry with machines that has confronted man ever since the Industrial Revolution.

Machines originally came into being in order to relieve humans of some of the suffering and danger inherent in physical work. When the machines turn out to have socially undesirable effects, the problems may be ascribed either to inadequate forethought on the part of the technologists who developed the machines or to shortcomings in the society which adopted them.

Automation is a technological means by which machines work in the place of man, with the ideal of totally eliminating man from the work process. Automation is thus sometimes conceived of as bearing no direct relation to human beings. In point of fact, however, it is closely connected not only with the people who design, use, and maintain the systems, but also with factory managers, and even with those who purchase the factories' products. In order to evaluate and develop such technical advances properly, it is necessary to consider machines and humans comprehensively, in terms of a man-machine system, and to establish a man-machine relationship in accord with the overall aims of that system. That is to say, technology is not the only issue: machines must also be designed with significant regard for social, economic, and cultural concerns.

In order to evaluate these complex issues, systems engineering offers the technique of assembling as many evaluative perspectives as possible, arranging them hierarchically in a tree graph, and evaluating the issues multi-dimensionally.

The evaluation of industrial automation would not seem, however, to be all that complex a problem. From the standpoint of humanity in general and viewed critically in the long term, the automation of production works to the well-being of man, and one finds no reason to hesitate in its further development. The negative aspects of automation are secondary issues grounded in certain inadequacies of the social structure, which may be separately resolved.

It will be remembered that the technology of automation is in a continual state of advance, having progressed gradually from the very first simple devices to complex systems incorporating computers. Further, one may also note that, over time, the performance of automation has gradually changed from the purely physical to the intellectual. Automation has advanced, as it were, from a state of replacing human actions to one of replacing thought. To illustrate this advance, I would like to introduce here the issues involved in two examples, safety automation, and office automation. Inasmuch as these areas are related to the basic human function of thought, they present more potentially serious effects and fundamental difficulties in evaluation than industrial automation.

Safety Automation

Industrial plants and aircraft are equipped with a variety of safety devices. When dangerous conditions arise, the devices are designed to operate automatically to avoid catastrophe. Safety automation becomes an especially important issue with the increasingly high performance of industrial plants and transportation systems that has meant an increase in potential causes of accidents and more widespread impact of breakdowns.

The issue of the automating of safety, however, exists intertwined not only with technological problems, but also with human problems and questions of organization, cost, and individual perspective as well. As such, the issue is hardly a simple one. The accident at the Three Mile Island nuclear power plant and the recent crash landing of a DC-8 at Tokyo airport (February 9, 1982; 24 dead, 147 injured) both involved a great deal of human error. It consequently may be readily agreed that the matter of safety automation needs to be treated as a problem of man-machine systems. Nonetheless, one will be confronted on this point by two schools of thought on the relationship of men and machines.

The first school of thought would say that because the human operator is unreliable, his errors ought to be overridden by automatic systems. The design of fail-safe and emergency devices is based on this premise.

The second school of thought stresses that one cannot rely on automation no matter how it advances, for no matter how fully a machine may be equipped with safety devices, unforseeable accidents may always occur, and one can never avoid breakdowns in the safety system itself. Under this approach, humans monitor machine activity and take full responsibility for maintenance and inspection. When the monitor sees an abnormality, that person will be able to handle the situation as circumstances require in order to maintain safe conditions. (See Table 1, included here, for a listing of the relative advantages and disadvantages of humans and machines.)

Because the first school of thought conceives of the ideal man-machine system as one in which the predominant position is held by the machine, this approach demands that humans serve the machine in blind obedience. Human intellectual faculties - higher judgment, reasoning, experience, and learning - are entirely ignored and replaced by automatic systems. In the approach taken by the second school, human judgment does take precedence over machine judgment, but with a human being serving as little more than a talisman about the neck of an almost infallible machine. Such a system involves continual stress for the operator and would not be entirely humane.

The problem of safety automation is not simply one of respect for human beings, for even from a purely scientific standpoint, it is far from certain just what combination contributes most to safety. Human abilities and machine functions still compete as intellectual systems.

Office Automation

Next, I would like to take a look at "office automation" as a second example of a man-machine system. There is a strong call today for office automation as a natural next step after industrial automation. Comparisons between the two are often drawn, but the differences are enormous. Within the general organization, the office has come to serve the function of brain, and any attempt to automate the office signifies an attempt to automate human intellectual activity.

In constrast to industrial robots, which substitute for human physical actions, office automation would substitute for the most human of human functions - thinking. As such its potential impact on human society is so great that earlier forms of automation pale in comparison.

A variety of analyses of the functions of offices have been put forward, but the most common view today sees the office as assuming charge of the organization's management decision making. In that respect, when one analyzes operations and data processing in offices, their functions appear as seen in Table 2 (Japan Electronics Industries Association, Report No. 561-182). Regular office work is relatively simple, and the decisions required are not of such very high order. However, when it comes to strategic decision making, work content is no longer predetermined, and high-level, comprehensive decision making based on experience and insight becomes necessary. In planning and forming proposals, moreover, the key ability required is that in the highest of human intellectual activities: creativity.

Office automation devices assist humans in their decision making, but the machines themselves do not possess the capacity to decide. That is to say, this is a typical man-machine system, and here we may consider their impacts on society by dividing them into two categories. The first effect is on the actual substance of office work, and the second with the type of work.

With regard to the first point, it would seem fair to ask whether the dramatic increases produced by automation in the volume of information processed actually results in better decision making. Though any problem in real life is bound to be multi-faceted, as soon as one tries to communicate it to others through any form of information, that problem is certain to become transformed into something unidimensional. Until recently, people in offices working with low volume, incomplete information have attempted to discern the true form of the problems concealed therein, and to a certain degree they have been successful. Advances in information processing by machines mean that humans will have fewer opportunities to see information its original form.

Under these conditions, the human ability to make evaluative judgments may begin to decline, and the proportion of erroneous conclusions may increase. There is absolutely no guarantee that an increase in the volume of information will signal an improvement in its quality.

The second issue involves changes in the type of work itself. With increases in home-based employment, we may expect certain trends to become more and more conspicuous: the integration of home and workplace, increasing employment for the elderly and housewives, the loss of distinctions between side-job and professions, the weakening of human social relationships, the bureaucratization of the office, and dehumanization. One may predict these trends to have enormous impact both on enterprises and on society. Figure 1 represents a "structural model of evaluative indeces" designed for the purpose of comprehensively evaluating such complex effects.

Conclusions

The object of automation is in the process of moving from the simple toward the complex, from taking over human actions to assisting human thought. Accompanying this process is an ever-deepening rivalry between humans and machines. The problems of automation discussed here have a close relation to human thought, and the appraisals and choices they necessitate will be extremely difficult ones.

If we neglect this problem, as if it were simply one of technology alone, the human beings who imagine themselves to be using machines may suddenly wake up to discover that the tables have been turned, that they are being used by the machines. In order to avoid such a situation, we must consider automation in terms of its being a comprehensive system consisting of man (society) and machines (technology). Having clarified what are to be the proper man vs. machine priorities in the system, we must then consider how best to develop, design, adopt, and utilize it.

In order to ensure that man is master of the machines, the people who use them must possess a thorough knowledge of the problem and control of them like capable subordinates. Unless people know what kind of work the machines are doing on the basis of what kind of theory, and possess powers of comprehension and appraisal broad enough to recognize the probable outcome, those machines will simply be black boxes. People will have only two options: to trust them blindly or reject their use outright. Such could not be termed a man-machine system. Rather, what is appropriate for the age of automation is a man-machine system that actually stimulates and sharpens those extraordinary intellectual capacities that only humans possess: creativity, analogical reasoning, imagination, ability to grasp the whole picture, and comprehensive evaluative judgment.

In order to complete such automation, technologists must give greater consideration to human and social questions. How, for example, ought one to apportion the tasks between man and machine, and how ought one to design the interface, in order to ensure that people dominate the machines? Further, what sort of environment is required to stimulate human abilities? Issues such as these call for extensive research on the human factor.

Additionally, the actual machine users must participate actively in the development of man-machine systems and achieve a broad understanding of machine functions. In particular, users must develop the capacity to evaluate critically the machines' informational output to penetrate through to the core of the problem.

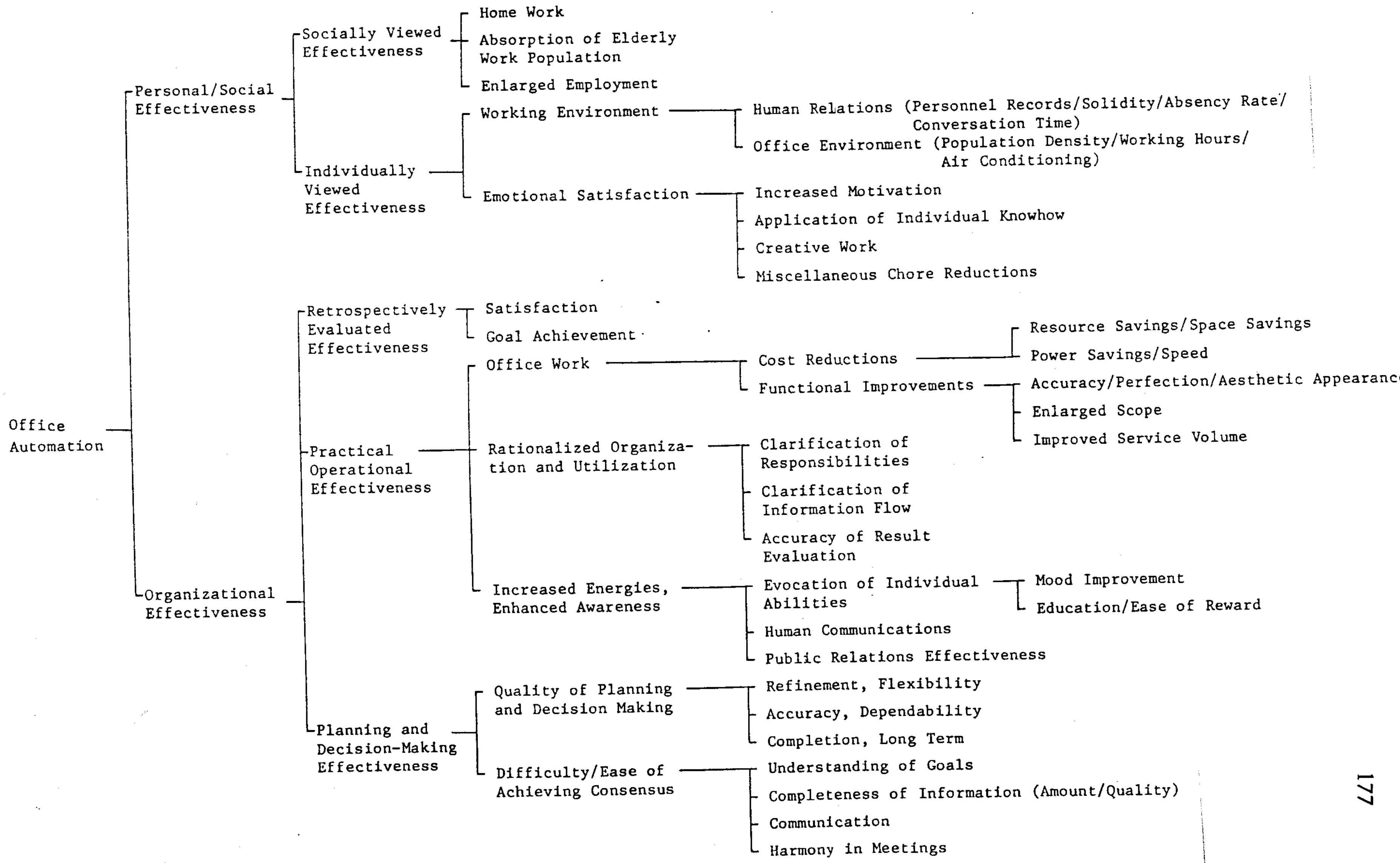
Table 1 Comparison of Human vs. Machine from Safety Standpoint

	Advantages	Disadvantages
Machine	Speed, Power, Accuracy	Single Function, Non-awareness of Own Breakdown/Non-repairing
Human	Comprehensive Judgment Adaptability, Experience, Learning	Fatigue, Habituation, Attention Loss, Willfulness

Table 2 Office Functions from a Decision-making Viewpoint

Division			Independent	Attendant
Organizational Structure			Situationally Responsive, Regulations as Large-scale Framework	Fixed/Systematic, Detailed Regulations
Operational Characteristics	Planning		Long-term, Broad-scope, Complexity, Uncertainty	Mid-/Short-term, Narrow-scope, Simplicity, Certainty
	Resource Distribution		Situationally Responsive	Systematic
	Supervision/ Management		Non-precedent Management, Developmental	General Rule Management, Productional
Decision-making Characteristics	Form		Atypical/Individual	Typical/Organized
	Premise		Value-premised	Fact-premised
	Problem Disposition		Problem Discovering, Creative	Fixed Problem Solution
Object and Informational Characteristics	Environment	Outer	Direct	Indirect
		Inner	Macro-scale Comprehension	Micro-scale, Direct Comprehension
	Information		Time Period Irregularity, Atypical, Comprehensive, Subjective, High Processing Level, Indirect, Uncertain	Time Period Regularity, Typical, Specifically Localized, Objective, Low Processing Level, Direct, Certain
Work Characteristics			Changing Processes, Time Period Irregularity, Complex, Atypical, Situational Adaptation, Variety, Low Volume	Fixed Processes, Time Period Regularity, Simple, Typical, Repetitive, Little Variety, Large Volume

Fig. 1 Evaluation of Office Automation Impact



Ease of Use/Cost/Function

Achiel van Cauwenberghe

The major forces in our economic system, in our social system, are all incentives which push our society towards further automation. Among these forces are increasing energy costs, and increasing prices of raw materials. The same is true with salaries. More stringent environmental regulations and regulations regarding safety conditions also push us in the direction of further automation. What are the advantages of automation? Well, let's say increased productivity, just to be brief, increased product quality, increased safety of operation, more flexible operation, and reduced manpower costs. To be more specific, where automation is concerned, the greatest advantage in order of priority is probably reduced manpower costs; second is increased job quality; third, more flexible operation; and, fourth is increased production control.

In the past, we have seen a very rapid technological revolution in many branches of automation and as far as the closest control instrumentation is concerned, we have had successive waves of automation nearly ever fifteen years. Another generation of instruments is coming from the very decentralized analog instruments, e.g., more electro-mechanical and electronic instruments; but they are more centralized, and decentralization to centralization is a general trend and the largest computer, of course, accentuated this trend.

Now with the event of the microcomputer we have the possibility of spreading out the control of this automation process, and it is mainly digital and electronic. We see something similar in robotization. Among robots, one can distinguish three generations. We live now, let's say in the second generation. The first generation started in the sixties and contains mainly pick and place robots, noncircuit and early circuit controls, the play-back robot. We can teach the robot how to paint, such as spray painting, or how to weld, and he memorizes that in his memory and then reproduces it many, many times. The second generation which is just started now, is the one that includes intelligent sensors, vision, shape recognition, textile or touch sensing and so on. The next generation will probably be, if one includes artificial intelligence and the possibility of larger computers, the intelligent robotization of the future so that robots can adapt themselves to environments which are nonstationary and changing.

So far as distribution of the wealth is concerned, nearly half or one-third of the robots are installed in Japan. Japan and North America are the leading nations, and then Sweden and Europe. That is the 1980 count of robots, utilizing the same yardstick, the same definition for the robot. Sweden, as a matter of fact, is a special country in the sense that it has the largest robot population per million inhabitants. This is due to the policy of the early seventies and the late sixties. It was chosen on purpose. Most European countries solved their manpower shortage problems during the booming period of the economic revolution during the golden sixties by importing labor from the Mediterranean countries. Sweden did not want to do so. Sweden wanted to develop robots. And consequently, you will see, they have a higher technological development there.

This points to a social problem which I also might try to comment upon. The prospect for further expansion of robots can be deduced from the fact that one percent, let's say or three percent, or five percent of the manufacturing of the workers employed in manufacturing processes would be replaced by robots in the future. How many workers would be replaced? You must divide by 1.5 or

2 workers to be replaced by one robot, then you have some rough estimate of the market and the possibilities of the market in the coming years. This is from now until 2,000.

I would like to add some European flavor to what has been said this afternoon by showing you the use of robots in western Europe. It is said that over fifty percent were used for spot welding in America, I believe. In Europe this percentage is lower, but still the major application is spot welding. It is also may be the easiest application, the task which can be structured most easily. Spray painting is the second most important task performed by robots, followed by injection molding, plastic processing, brass forging, arc welding and assembly, of which there are only a few cases so far, but which is very important for the future. The main industrial sectors in which robots are used are the automotive sector, electro-technical industry, mechanical industry, plastic processing industry, and so on.

What are the possibilities for future improvements of robots. Well, I mentioned a few ones, such as smaller and lighter robots, for increasing loads, cheaper of course, more flexible robots. There will also be robots which have the possibility to recognize patterns through intelligent vision sensors or touch sensors and which have a gentle gripper which means you could use it for the packing industry or textile industry, so that it doesn't tear apart the paper, for instance, or the cloth. These same robots can also be used in industry in the medical sector.

Let us now comment on the social effects of robots. First of all, robots allow us to increase the productivity of industrial processes and this is, of course, the only way to increase wealth. That is, if we produce more on the average we have the possibility of getting better off. Unfortunately, unskilled labor employment will decrease and this means that also there will be a major change from manufacturing employment to the services. This will certainly lead to a restructuring of society in the future. Once more, we will require better education, highly skilled people and some provisions such that those who are unfortunate and less skilled could participate in the wider availability of wealth of the production, the increase of production. This will lead to a kind of social redistribution system which will be different from the one we know now. It is not a shame to say that we live in a dynamic world and the system, the economic and social system, which will be ideal for the year 2000 and later will certainly be different from the one in 1980. More education, the more educated people are, the less unskilled the people are, the more receptive they are to automation and automation even becomes a necessity. You do not find enough people who do want to do the dirty jobs, the unhealthy jobs, the less-skilled jobs, even in European countries where there is a high rate of unemployment - 9 percent or 10 percent of the labor force is unemployed - one still has to import foreign labor for particular jobs. For instance, arc welding. In Belgium we need ever year a few hundred arc welding people imported from Yugoslavia or from other countries which are not at the same level of development. Also, if the organization of an industrialized society is favorable to maintaining people in their jobs, there will be less resistance to automation. This happens for instance in countries like Japan where you have a life-time assurance that you will be employed and you will be cared for in the society in the industrial firm you are working for. Then you have of course, less resistance to automation.

The quality of work is another point one should be very careful with. It is not necessarily true that the quality of work will increase by increasing automation. One has to really be aware of the dangers to the country where termination of a job could lead to a situation where robots will take over. The processes which are easiest to automate might sometimes be the more skilled processes and always the unskilled processes so that what is left for the human operator is sometimes less satisfactory, and they get less job satisfaction. Leisure time, it has been mentioned, will certainly increase. But if leisure time is the amount of time that we do not work for others, then we will need another or a different remunerations system, a different salary system, so that the fruits of industrial automation, of robotization, will be more evenly distributed over the society.

We still have an idea that robots are human-like, even though they do not have to be necessarily copies of humans. It is probably due to the play Chapak wrote in the 1920's where the word "robot" was coined for the first time. But for robots to cooperate with man you could set up a set of rules. They need not be very detailed but should just mention the most important "should not's" in order of priority: you should not harm humans, so it should not be a danger to humans, should obey human orders, and also to protect its own operation, should protect itself. This is the minimum of rules we ought to have so that we can still have the feeling in the future that we control the situation and that the robots do not take over. So let's be optimistic for the future. There are of course some fears, but we can be optimistic. As long as a job will be interesting for man, I believe it will not be robotized. That is the main point. It will only be robotized if it is a dull job, a dangerous job, or an unhealthy job, such as somewhere in a submarine or a nuclear plant task, space manipulation, impossible jobs to do. They are the main possibilities. Man is infinitely superior to the most sophisticated robot and robots will certainly be in the near future still a poor copy of the possibilities of man. It is easier to conclude probably with a saying by Algelberger "...It is far easier to make a robot of man than to make robot like a man."

John Rijndorp

Professor Emori has given us a very interesting glimpse into his philosophy and its implications for man/machine systems. He has made me think of a book by a Dutch philosopher entitled "Establishing a Culture". In this book he summarizes changes in Western living and thinking, science and technology, art and architecture, in the form of the following three phases. In the first place, there is the mythical phase. Here there is no clear distinction between subject and object; between person and universe. The universe is experienced as a whole and explained by a unifying, harmonious philosophy. In the next phase, with the amazing developments of astronomy and physics in the sixteenth and seventeenth centuries, the world become separated from the individual, and philosophy is segmented into an ever growing number of, what we must say, successful sciences. The third phase, which is more or less starting in this century, is a kind of reaction to the second phase. It is called the relational phase. The deficiencies of the separation which becomes apparent in many respects in our society would be overcome by relating subjects and objects in philosophy, and in all science, technology and society. This is called the relational phase. Now I would like to extend this idea by van Fluesen into the topics we are talking about during this Symposium. And in the first place I would like to show how the second phase has affected industry, the university and society.

If we look at the university, we find that the objects, sciences in this case, have been segmented into many different disciplines. And when your subject is humanities, this is more or less the same. People are educated in the university and they go into the enterprise, so you can see the relationship between the two. Two science departments exist, each corresponding to a certain discipline, which are more or less independent of each other, and management is more or less isolated from that in order to try to run the whole thing. There is also the philosophy of work which is called scientific management, which corresponds to segmenting work into smaller and smaller pieces while the human side is concentrated again in management. The result has been what is called alienation where self, the worker, is separated from the small segments of work he is doing.

Now to return to van Fluesen's third phase, which might indicate in what way we can overcome or try to overcome the deficiencies of this present phase. For instance, in projects, be it aero space, or other sectors, the problem of integrating technical disciplines has been solved by systems engineering, where you can say that relations have been built up here but still social disciplines are separate. Now, Singleton, in 1967, has extended the idea of systems engineering into systems economics (that is what he called it). Also, the social disciplines are on the same level, integrated together with the technical disciplines. In fact, at the moment we are in our university operating with some industries. They are paying us money to help them to realize this in actual projects. So what I am talking about is not only his philosophy but also is being paid for by commercial companies. In Japan, the ideal of the quality control circle, as we all know, has been very predominant and we also try now how to realize the same thing in Western industry. Here you can say the workers are integrated and there is relation with management, on the other hand. Another thing which might be very far into the future is the ideal university where humanists and scientists are similarly linked. In our university we try to make a very, very small step in this direction but when you try to make a step you see how difficult it is to get this done. Finally, maybe as a rather far-fetched idea of how we should tackle automation, I think we get the picture which resembles van Fluesen's relation scheme and it looks maybe like this, where the social and technical disciplines are improved together but also the workers, like in Japanese quality control circle, and management. So we have a kind of true or false scheme of relationships. Now, I think it is impossible to return to the original mythical, harmonious static kind of harmony. The world is too complex and we have to live at this second phase, at least that is my feeling coming from a Western country. But what we can try to do is overcome some of the troubles caused by segmentation, and, to return to Professor Emori's more or less final statements, full utilization of each component's inherent functions in these schemes integrated in mutual relations is the only road towards success.

Ichiro Emori

As Professor Brownstein previously pointed out, when there are many social problems, it becomes very difficult for us to even try to identify the problems in order to reach their solution. Especially, when we specialists are encountered with problems, we tend to try to solve the problem within the framework of our specialized field. Within that framework we tend to look for solutions to that problem. However, it is not very easy for us to reach solutions. Specialists' opinions tend to be the art of interpretation. The problem is not only to interpret, but somehow we have to look for solutions to the problems we face. In a way, it has to be a mission oriented approach, especially with regard to social problems since there would be many people involved from different fields. Individually, those individuals will have a field oriented approach. Even if we collect or get many experts from different fields, if the approach we are going to take would be just a multiplication of several field oriented approaches, then we will not be able to adopt a proper attitude toward solution of the problem. Therefore, what we tried to achieve at the first Discoveries Symposium and subsequently was to get specialists together and cast away all the field oriented approaches in order to get mission oriented approaches, and we tried very hard not to look for solutions. So, we tried to first define the problem and identify the problem. That is the reason we thought of definition and identification first. So, with that in view what I would like to tell you today is regardless of whether it is robotics or other fields, as far as the problems that you encounter are concerned with social matters, we should try to cast away a field oriented approach. Rather we should take a mission oriented approach and rather than trying to look for solutions from the very initial stage, what is important is to try to define and identify problems first. And we should try to study those problems slowly and in a steady manner.

The Current State-of-the-Art and Long-Term Implications of Biomedical Engineering

Robert W. Mann

Each of the speakers at this HONDA DISCOVERIES SYMPOSIUM comes with special knowledge and strong convictions with respect to some aspect of "The Social Impact of Advanced Technology." But I would submit that the interface between advanced technology and human health is perhaps the most compelling. All of us, in a very intimate way, are concerned with our personal well-being and, therefore, cannot but have an interest in how advanced technology has impacted the area. Furthermore, the economic cost of health maintenance, driven in part by technology, persistently outstrips the inflationary rise; in the United States in 1981, health costs consumed almost 10 percent of the Gross National Product.

I will attempt a comprehensive overview. Unlike most of my predecessors on the program, I accept with resignation the broad topic assigned by the organizers of this Symposium; thus I will address the current state-of-the-art, with long-term implications, of biomedical engineering.

Scope

My problem in dealing with biomedical engineering is its vast interdisciplinary scope and comprehensive character. Engineering intersects with virtually every arena of biology, medicine, and public health. Figure 1 (1) illustrates some of the conjunctions of traditional engineering fields and disciplines with complementary physiological and medicinal areas. The intensity of stippling suggests the extent of overlap between coordinate areas: engineering on the one hand and medicine and human health on the other. Table 1 (1) organizes comparable information somewhat differently, but again conveys the expansive universe of activity encompassed by biomedical engineering. Beyond breadth, the field is dynamic; Figure 1 and Table 1, only a decade old, predate contemporary areas of excitement, such as computer-aided tomography, nuclear magnetic resonance scanners and genetic engineering.

We can generalize the many specific examples of biomedical engineering identified in Figure 1 and Table 1 into three broad categories of activity, all employing engineering knowledge and technique:

1. Advancing understanding of biological systems in health and disease and the medical practices that address pathologies - that is to say, research.
2. Innovating and implementing devices - diagnostic, medical, and surgical instruments, internal and external prostheses, hospital equipments, etc. - that is to say, design.
3. Developing methodologies to improve health systems delivery - computer-based records and diagnostic procedures, emergency and preventive medical intercessions, environmental engineering, etc. - that is to say, systems analysis.

Educational Aspects

The foregoing examples of biomedical engineering illustrate how superb a milieu it is for demonstrating the engineer's capacity to create predictive models based on natural law expressed through mathematics and to corroborate the models via experimentation. Thus the field becomes a superb foil for exercising the neophyte engineering student's growing competence in analysis and experiment, for biological structure is subject to the same laws of nature which constrain the inorganic world. And the underlying human motivations for doing biomedical engineering are exceptional. Students want to be involved in humane application of technology, and they too are concerned about human health.

Biomedical engineering themes are certainly appropriate as thesis topics and elective subjects at the undergraduate level and as part of degree-granting curricula at the graduate level. A recent survey (2) reports 48 master's and 41 doctoral programs in biomedical engineering in the United States in 1978-79, awarding, respectively, 249 master's and 107 doctorate degrees. The same study reported 37 undergraduate programs enrolling 2,859 students and awarding 464 bachelor's degrees in biomedical engineering.

I consider undergraduate preparation in biomedical engineering inappropriate (3, 4) although the issue is controversial (5). In such programs descriptive and unavoidably qualitative biological, physiological, and medical subjects must inevitably dilute the more rigorous, quantitative physical science, mathematics and engineering science content. Traditional undergraduate engineering curricula are already hard pressed to prepare the engineer adequately. A further complication in biomedical engineering, reflecting the broad coverage of Figure 1 and Table 1, is that the undergraduate biomedical engineering program must somehow make its engineering subject choices from at least several of the traditional engineering fields. Thus undergraduate BME attempts to be both broader in engineering content while at the same time introducing relevant biological/medical information. Four-year undergraduate curricula simply do not have the compliance to adapt without significant loss of engineering rigor. The overriding consideration, certainly of the bachelor's degress, must be adequate engineering preparation or else the further graduate education and employment prospects of the biomedical engineering student is impaired (6). The Biological Engineering Society of the United Kingdom which "certifies" bioengineers does not recognize first degrees in biomedical engineering (7).

At the graduate level, presuming solid undergraduate engineering education, biomedical engineering curricula can be appropriate, particularly for students training at the master's level for specific areas, such as clinical engineering (8) or rehabilitation engineering (9). The superior preparation, of course, is the doctoral program where rigorous graduate engineering education can be complemented with relevant biology/physiology/medicine and culminate in a thesis that advances knowledge, designs and demonstrates new capability, or advances clinical practice.

The approach of biomedical engineering education has enormous potential, as yet almost totally unrealized, in medical education. In 1966, Dr. James Shannon, then Director of the National Institute of Health, tried to interest Massachusetts Institute of Technology in establishing a medical school that would create "a new kind of physician who can exploit the full power of science and technology" (10). Despite the relative affluence of federal support then (National Institute of Health was prepared to commit $50 million to the project), the total estimated cost of the venture, not to mention the political ramifications of creating yet another medical school in Boston, resulted in a demurrer from M.I.T. The focus of those discussions, however, led in 1970 to the creation of the Harvard-Massachusetts Institute of Technology Program of Health Sciences and Technology. The premier educational effort became a biological sciences program which admits twenty-five students each year to a medical-degree program conferred by the Harvard Medical School, but administered and taught, during the two pre-clinical years, by an M.I.T.-Harvard faculty.

Having served on the curriculum committee of this program since its inception, I have been frustrated by the difficulty of introducing into medical education the first-principles approach that underlies the physical sciences and engineering. A virtual dichotomy seems to exist between the rigorous natural law schema for organizing knowledge and the inescapably qualitative, descriptive universe of facts and experience so essential to medical education and practice. Ultimately, I still believe a constructive merger of these two approaches must occur if, for no other reason, the growing importance that scientific knowledge and medical technology plays in the practice of and research by the physician.

But let me move on to the most concrete of my remarks which describe the medical technology that has germinated from engineer-physician collaboration. Whatever the respective differences in their education and experiences and however their alternative styles of research vary, significant biomedical engineering research mandates mutual trust and collaborative sharing between engineer and physician (11).

Biomedical Engineering Product

As outlined earlier, biomedical engineering can occur at any conceivable intersection between engineering and the health sciences. In the time available, and drawing upon my competence to report, I can select only a few such concatinations. Let me elaborate on these to make more concrete the thus-far general discussion.

As my first specific example of the character and effectiveness of biomedical engineering, consider massive burn trauma. The Cleveland Plain Dealer has reported a typical case, "burned over 92 percent of his body" in an industrial accident; the victim is moved rapidly to one of thirty specialized burn centers across the nation. The technology of transportation - jet aircraft and helicopters - makes feasible this centralization of the medical talent and technology essential to survival and recovery. Two immediate problems must be addressed: control of body-fluid balance and overcoming the hazard of massive infection, both normally achieved by the natural skin, now gone. And then the lost skin must be replaced, either by autografts from other areas of the same person - hardly likely in this case - or allografts from a live donor or cadaver, in which case immuno-rejections must be suppressed. Heterografts, primarily porcine in origin, are of short-term value but must be removed prior to rejection, and auto- or allografts substituted.

A collaboration of the polymer scientist/engineer and the dermatologist/surgeon is succeeding in the development of a man-made "skin" that serves better in these severe roles than its natural progenitors (See Figure 2, 12). Synthesized from artificial and natural components, this substitute skin is applied immediately to control the fluid loss and infection problems, but then is naturally integrated into the normal healing process. Thus a rigorous and deliberate biomedical engineering process demonstrates an effective skin substitute of enormous promise - readily manufactured, easily stored and ultimately inexpensive.

Cancer remains a primary cause of human morbidity and death - and a source of great anxiety. Biomedical engineering, through computer-aided tomography and nuclear magnetic resonance scanning, has greatly enhanced the physician's ability to visualize the interior of the body and thus determine the location and extent of tumors. Subsequent X-ray therapy poses the problem of maximizing dose concentration of the high energy radiation at the tumor site while minimizing the exposure of close-by sensitive tissues, such as nerves and internal organs. Relative movement of the radiation source during treatment with respect to the patient can optimize the dosage distribution, but planning the time-varying movement and radiation intensity protocols are formidable. Now a marriage of computer-aided design (13), widely applied in engineering and industry, and data from computer-aided tomography are producing interactive computer-based treatment planning systems (see Figure 3, 14). Via simulation the radiologist can explore how best to relate the patient's anatomy and the kinematics of proposed treatment plans, with the computer displaying the dosage intensity contours at the tumor and in adjoining sensitive areas.

Ultrasound as a means of visualizing the interior of the body is, of course, another product of biomedical engineering that traces its origins back to undersea sonar of World War II. In the synergy of concepts so common in engineering, we now find ultrasonics combined with radiation treatment to enhance tumor remission (See Figure 4). Ultrasonic energy levels higher than those used for diagnostics are focused under computer control so that the localized internal energy dissipation creates hyperthermic conditions in the tumor that then proves more responsive to both X-ray and chemotherapy treatment. In some cases hyperthermia alone has been shown to reduce significantly or eliminate cancerous tumors (15).

An example from my own current biomedical engineering research addresses understanding at the most fundamental level. We are elucidating the remarkable bearing attributes of mammalian synovial joints with the goal of quantifying the role of mechanical factors in the etiology of osteo- (or degenerative) arthritis. The traditional engineering paradigm of creating an experimentally based, mathematically expressed model of the system is followed, but now novel instrumentation and computer-mediated experiments must be devised to record the detailed local and global geometries of components of the human hip joint (16) and quantify the constitutive properties of the soft, fluid-permeable cartilage (17); the much stiffer, but still deformable, pelvic bone support, and the synovial fluid that bathes the joint. The computer model then permits simulation of interrelated solid mechanical, fluid mechanical, thermodynamic and heat transfer phenomena resulting from load carriage and articulation, as in gait (see Figure 5). The predicted pressure and strain distributions, fluid flows, and temperature changes in the tissue must, of course, be corroborated through in vitro experiments (18) and by employing specially instrumented joint implants (see Figure 6, 19). The power of the computer model is that it permits a far wider range of "experiments" than would be feasible with either cadaverous or normal tissue and exploration of the consequences of induced physical factors on possible failure modes: mechanical to the cartilage or mechanically induced biological changes in cartilage cells. Thus various hypotheses on the etiology of osteo-arthritis can be explored. Such computer-based modes have also identified the need for new clinical instrumentation to guide and improve surgical reconstruction of the human hip (20).

Technology is playing an ever more effective role in the rehabilitation of humans who suffer irreversibly physical disfunctions. Substitute limbs following amputation are now servo-controlled via relevant naturally occurring bioelectric signals recapturing important aspects of normal limb movement (see Figure 7, 21). When congenital defects or trauma so impair motor control as to deprive the individual of the capacity to communicate, computer-based interfaces are devised which substitute for the normal modes of speaking or writing (see Figure 8, 22). Technology for the blind and severely visually impaired includes automated braille, direct access to the printed page via isomorphic tactile impressions of ink print and computer-synthesized speech, and enhanced mobility by ultrasonic probing of the travel space before the blind person and presentation of the otherwise visual information via the surrogate senses of audition and the skin (see Figure 9, 23). Vocational illustrations of the application of technology to ameliorate physical handicaps abound. One example is the augmentation of central office telephone switchboards with tactile braille and synthesized speech versions of visual displays that make blind telephone operators competitive with their sighted peers (see Figure 10, 24). The computer is ubiquitous through this rehabilitation engineering research and development (25).

The Biomedical Engineering Industry

Most biomedical engineering research is done in the university environment, but is the results are to achieve practical utilization, technology transfer must occur to industry followed by manufacturing and marketing (26, 27). Although biomedical engineering as an identifiable field is but two decades old, the growth of the industry has been impressive. A little over a decade ago Professor Herman R. Weed, now director of The Ohio State University Bio-Medical Engineering Center, chaired, and I served on, a Task Group on Industrial Activity of the Committe on the Interplay of Engineering with

Biology and Medicine of the National Academy of Engineering. A thorough assessment of the national biomedical engineering industry was conducted that identified less than $1.5 billion of annual product (28). A recent article on the production of medical devices and diagnostic products based on U.S. Department of Commerce survey data estimated more than $13 billion of product in 1981 (29). A comparable study conducted by the federal National Center for Health Services Research compared sales dollars and number of companies for 1958 versus 1977. Sales rose from $997.4 million to $8,060.8 million while the number of companies stayed about the same, 1,356 versus 1,442 (30).

While the approximately ten-fold growth in dollar volume per decade is impressive, the current annual technology product figures must be put into context of the overall national cost for health services. In 1970, Americans spent $75 billion on health care representing 7.6 percent of the Gross National Product, a per capita expenditure of $358. By 1981, that bill rose to $287 billion, 9.8 percent of the G.N.P. and a per capita expenditure of $1,225. Because we concentrate here on biomedical engineering technology, the illuminating comparison is the percent change of total national health cost specifically attributed to technological products: 2 percent in 1970 rising to almost 5 percent in 1981.

Lest technology's share of total cost or percentage of national health care be dismissed as not significant, note that some of the 1981 figure of 5 percent is capital investment in equipment used over and over again, year after year, in the delivery of health care. In each successive year, further accretion of medical technology cascades the overall impact of technology on national health care costs. Over the decade 1966-1976, for example, 20 to 40 percent of hospital costs were attributed directly to the consequences of technology (31). "The measures reflect a higher level of innovation than can be found in most industries of the U.S. economy - the level of patent activity is twice that existing in other industries throughout the U.S. economy." (30) One need only reflect on renal dialysis, nuclear magnetic scanning - more powerful, sought after, and expensive than computer-aided tomography - total replacement of hip, knee, finger joints, technology-laden cardiovascular surgery - pacemakers, triple by-pass, and now, in the time interval between our Conference and preparing this manuscript, the total implantable human heart! Less dramatic, but significant, technological costs accrue in the clinical, microbiological and blood laboratories, in a host of disposables, I.V., syringes, temperature measurements, etc., and now recombinant DNA and monoclonal antibodies. Clearly the future holds more effective and more costly medical resources, and the prospect is for more technology!

To complement our earlier discussion of biomedical engineering education, I would like to express some anxiety with respect to employment opportunities in the biomedical engineering industry. My opinion that there is not a viable market for the undergraduate biomedical engineer is reinforced by others (6), and applies to opportunities in the hospital. A typical comment is that offered by a hospital administrator at an engineering education conference. When hiring engineers for his hospital, he looks first and foremost for eminent engineering qualifications, "the rest can be picked up very easily." Further, it has been my personal experience derived from contact with and consulting in the biomedical engineering industry that there are relatively few places for biomedical engineers per se, even including those who have graduate degrees. Biomedical engineering firms do have employees, usually Ph.D.-level persons, who act as liaison between the company and the physician/hospital for new product identification, development and evaluation. There are, however, relatively few such positions. Most all other engineers in the biomedical engineering industry are hired for their effectiveness in product design and engineering, microcomputer application, or industrial or packaging engineering, etc. - that is to say, graduates of more traditional mechanical engineering, electrical engineering, computer science, and industrial engineering programs.

Academic biomedical engineering research has and will continue to play the dominant role, in my opinion, in creating new knowledge and exploring frontier areas that will create new opportunities for the biomedical engineering industry. Academic settings will include not only the university but also Ph.D.-level BME researchers working on human diagnostic and therapeutic research in hospital environments in direct collaboration with physicians. The identification of specific products and their design and development is an industry function; this is no less true in biomedical engineering than in any other area of engineering.

Health Services Delivery

Biomedical engineering research and industrial activity have profoundly influenced the delivery of health services. Computer-based record keeping and retrieval are classical examples as are systems analyses directed toward optimizing effectiveness and cost in health care delivery, such as those undertaken by the Kaiser Permanente Corporation, leading to the concept of health maintenance organizations. A system of emergency health care is emerging which capitalizes on communications and transportation technology, involves the training of a new class of medical practitioners, the emergency medical technician, and is saving lives and reducing morbidity in acute situations, such as with massive burns discussed earlier, and spinal-cord injury and other technologically induced accidents in our mobile society. Communication linkages via the computer enhance the prospects of improved, more useful epidomiological information, exemplified by such federal efforts as the Center for Disease Control, the Legionnaire's Disease incident, and the attempt at an influenza vaccine. Another dimension of epidemiology is the extent to which our own waste products - chemical, industrial, nuclear - contaminate our environment and produce disease and death, an issue to which the biomedical engineer as environmental engineer is responsive.

Conclusions

Whether viewed from the perspective of the academic or the industrialist, biomedical engineering, to borrow a phrase of Vannevar Bush, "is the endless frontier." A limitless universe of research and education possibilities excite the academic. The innovative products that will flow from industry cannot begin to satiate the human longing for health. The realistic restraint ultimately must be cost. As an extension of the earlier cited G.N.P. data, studies indicate that by 1990, the United States will be spending $750 billion annually on health care - more than the entire current federal budget - 11.5 percent of the then G.N.P. and $3,057 for every man, woman and child in the United States.

Reconciliation of, on the one hand, the opportunities for enhanced health care via technology and, on the other hand, the staggering costs will constitute a central socio-political drama for decades to come. Although it would be presumptuous to predict outcomes, certain generalizations seem apparent. On the one hand, a moratorium on the advance of technology seems unlikely.

Science and technology have their own imperatives, and when their outcome is coupled with the human propensity for life and health, imposing stagnation sounds impossible. One way to illuminate options, or rather the distribution of options, is to classify the technologies of medicine into diagnostic, therapeutic, and preventative. The therapeutic technologies address the management of illness, and in limiting, extreme cases extend survival without cure, placing a high cost burden on the system without generating compensatory benefits. Advances in diagnostic technologies also pose dilemmas in that to the extent new, enhanced procedures yield unsatisfactory answers, these generate the rationale for additional, ever more sophisticated tests. Whether the additional costs warrant the search, in part, depends upon therapeutic possibilities.

In contrast to the above, prevention, including early detection and rehabilitation, offer potential for real cost containment or reduction. The classical examples in the 1940s and 1950s were the elimination of diphtheria, tuberculosis and poliomyelitis. Much of the current excitement of biotechnology is the hope that our ever-growing understanding of genetic and developmental processes will lead to genetically engineered therapeutic processes that will follow detection with cure. Only time will tell, but in the meantime, biomedical engineering in all of its manifestations will continue to prove a very exciting area.

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Table 1

Biomechanics	Transport mechanisms	Simulation	Instrument development	Therapeutic techniques	Health care system	Environmental engineering
Properties of tissues Stress-strain relations Viscoelastic properties Tensile strength Compliance Contraction--relaxation Damping	Mass--transfer Hydrodynamics Diffusion Active transport Secretion Excretion Digestion Absorption	Mathematical modeling Systems Sequences Interactions	Research tools Physical meas. Chemical comp. Microscopy Isotope	Physical therapy Surgical instruments Respiratory treatments Radiation therapy	Organization Medical economics Longrange planning	Pollution Air Water Noise Solid waste Human fertility Population control
Biomaterials Support materials Artificial joints Bone substitutes Artery—vein substitutes Dialysis membranes Nonthrombogenic surfaces Artificial skin	Energy transmission Electromagnetic waves X-ray Ultraviolet Visible light Infrared Microwaves Radiowaves Mechanical waves Subsonic Sonic Ultrasonic	Biological models Comparative Anatomy Physiology	Clinical instruments Neurology Cardiology Respiratory Gastrointestinal Genitourinal Musculoskeletal	Monitoring Intensive care Surgical, postop Coronary care Ward supervison	Methods improvement Support functions Service functions Nursing Facilities design Medical care	Aerospace Environment control Closed ecologic systems Physiological adaptation
		Bionics Sensors Networks	Diagnostic data Automation Chemistry Microbiol. Pathology Multiphasic screening	Artificial organs Sensory aids Heart-lung mach. Artificial kidneys Artificial extremities Arms Legs	Operations research Optimization of laboratories Support functions Personnel Processing Scheduling	Underwater Compression effects Heat conservation Communication
		Control system analysis Neural controls Neuromuscular Autonomic Visceral organs Glands Temperature Blood pressure Hormonal Controls Metabolic controls Psychological responses	Computer applications Data processing Analysis Retrieval Diagnosis		Cost-benefit analysis Cost accounting Evaluation of results Beneficial economy	

TABLE 1

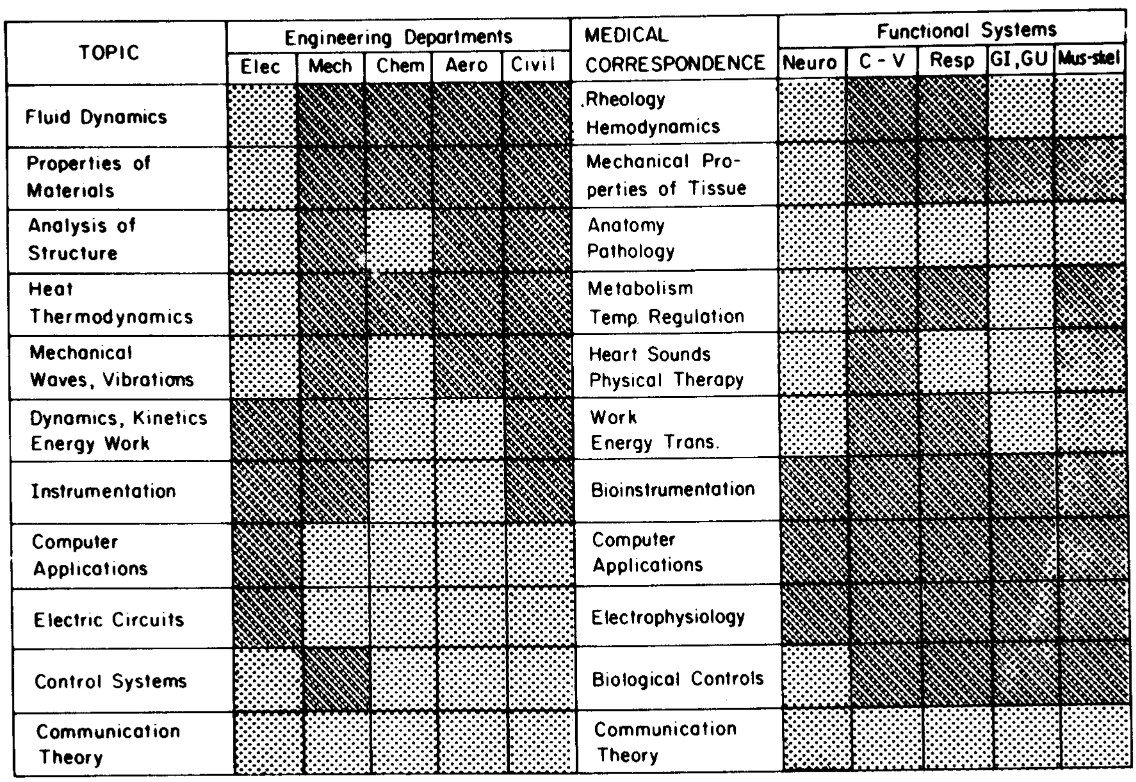


FIGURE 1

Relating Engineering Specialties to Health Aspects of Organ Systems of the Human Body

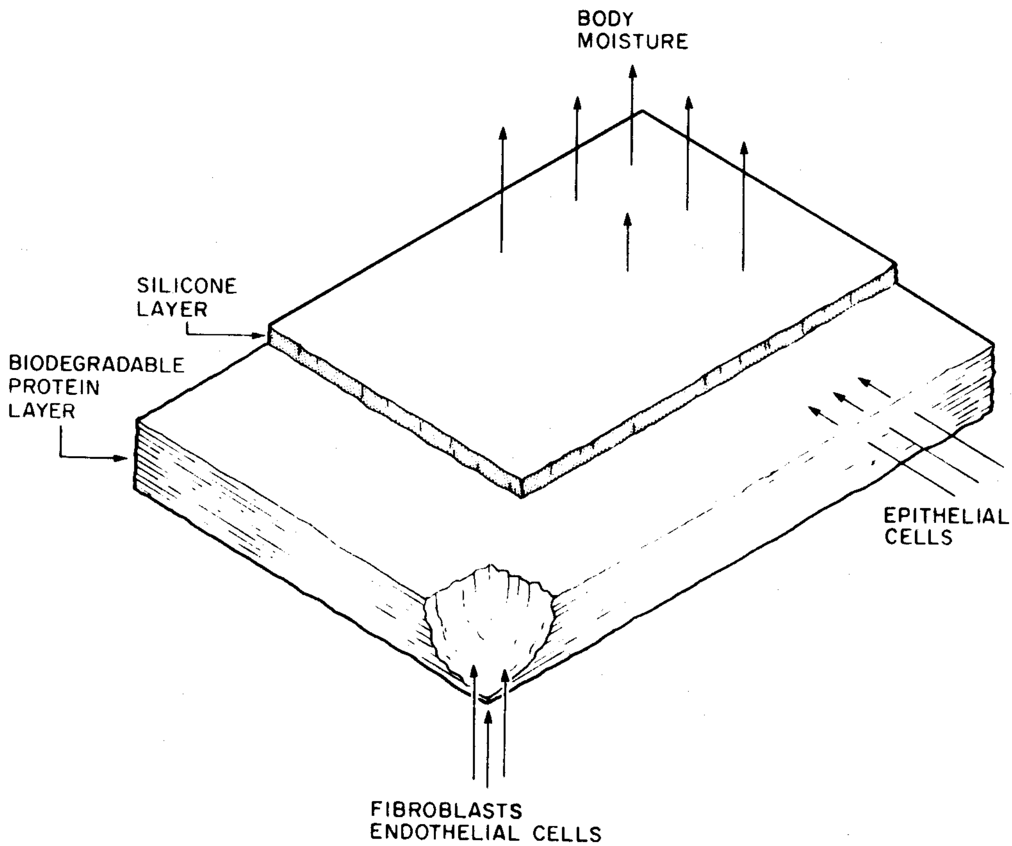


FIGURE 2

The Structure and Function of "Artificial" Skin

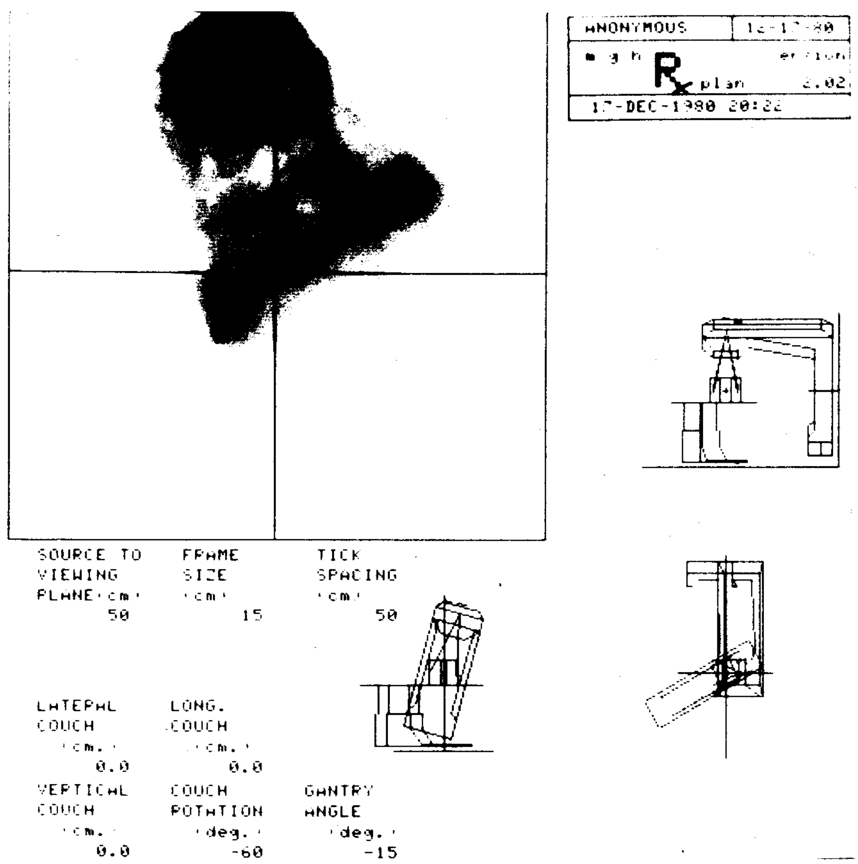


FIGURE 3

Computer Graphics Display of Interactive Skin Planning Process

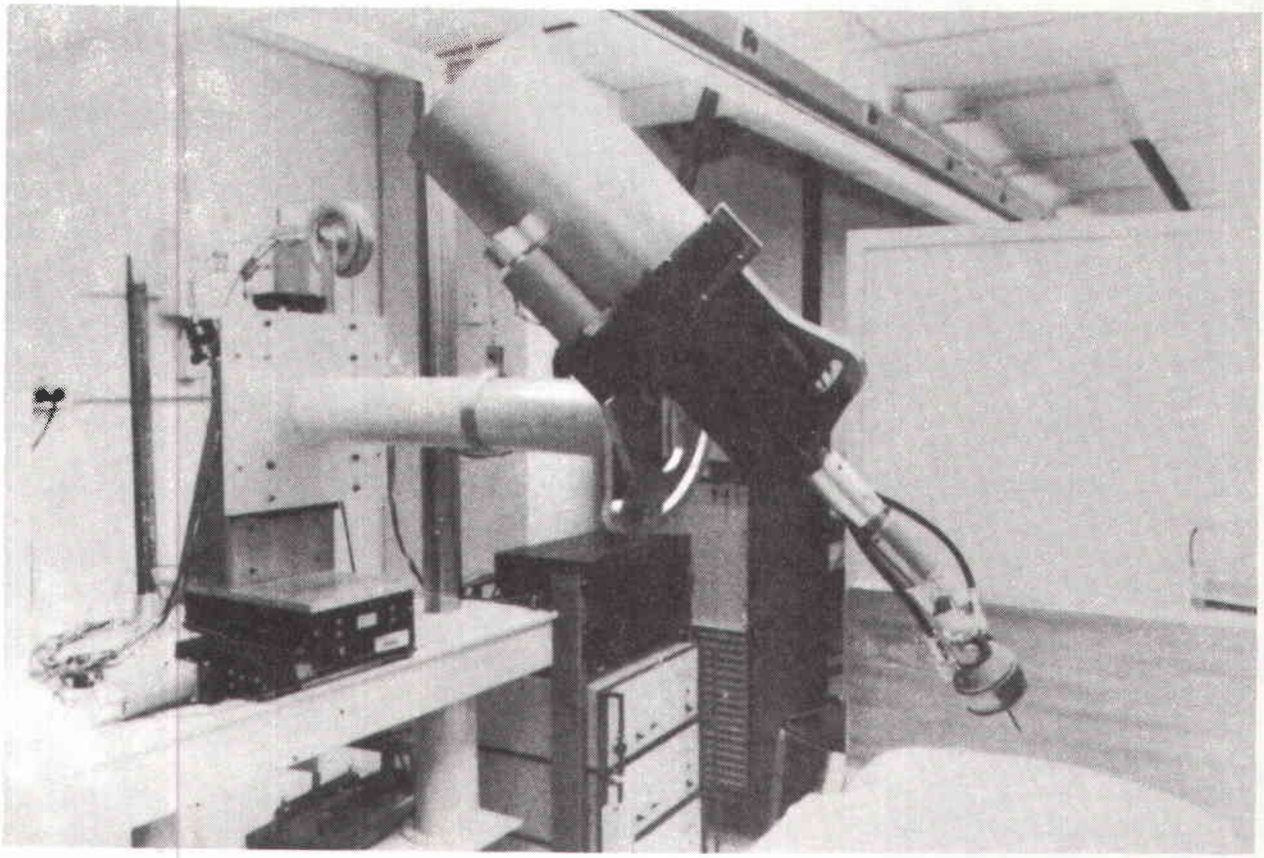


FIGURE 4

Apparatus for Inducing Hyperthermia in Cancerous Tissue via Computer Controlled Focussed Ultrasound

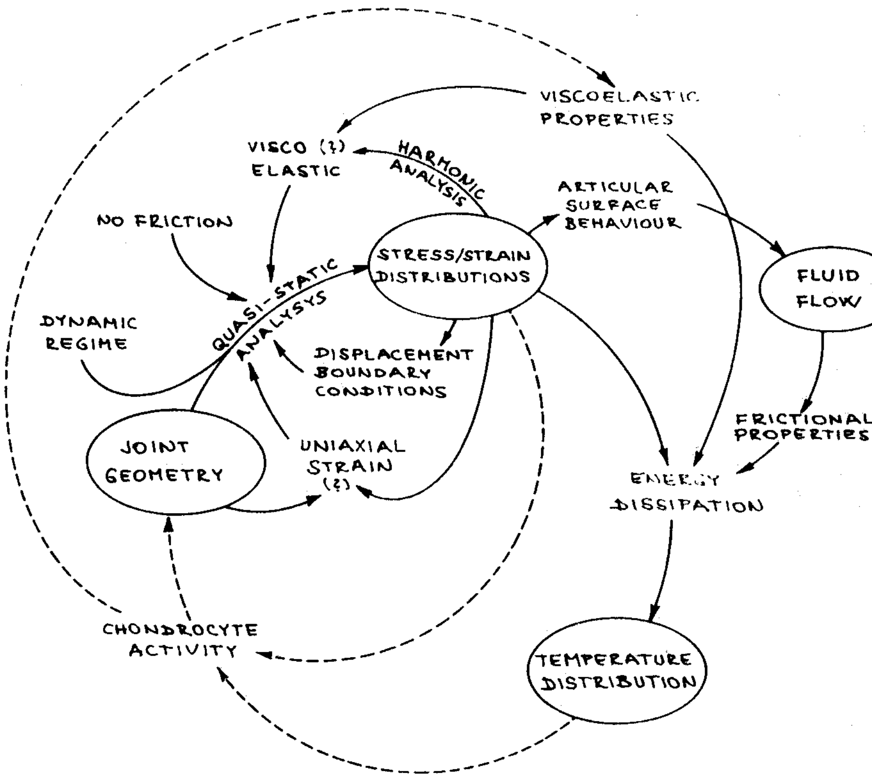


FIGURE 5

Schema of the Interrelated Variables and Consequences of Mechanically Induced Factors in Mammalian Synovial Joints

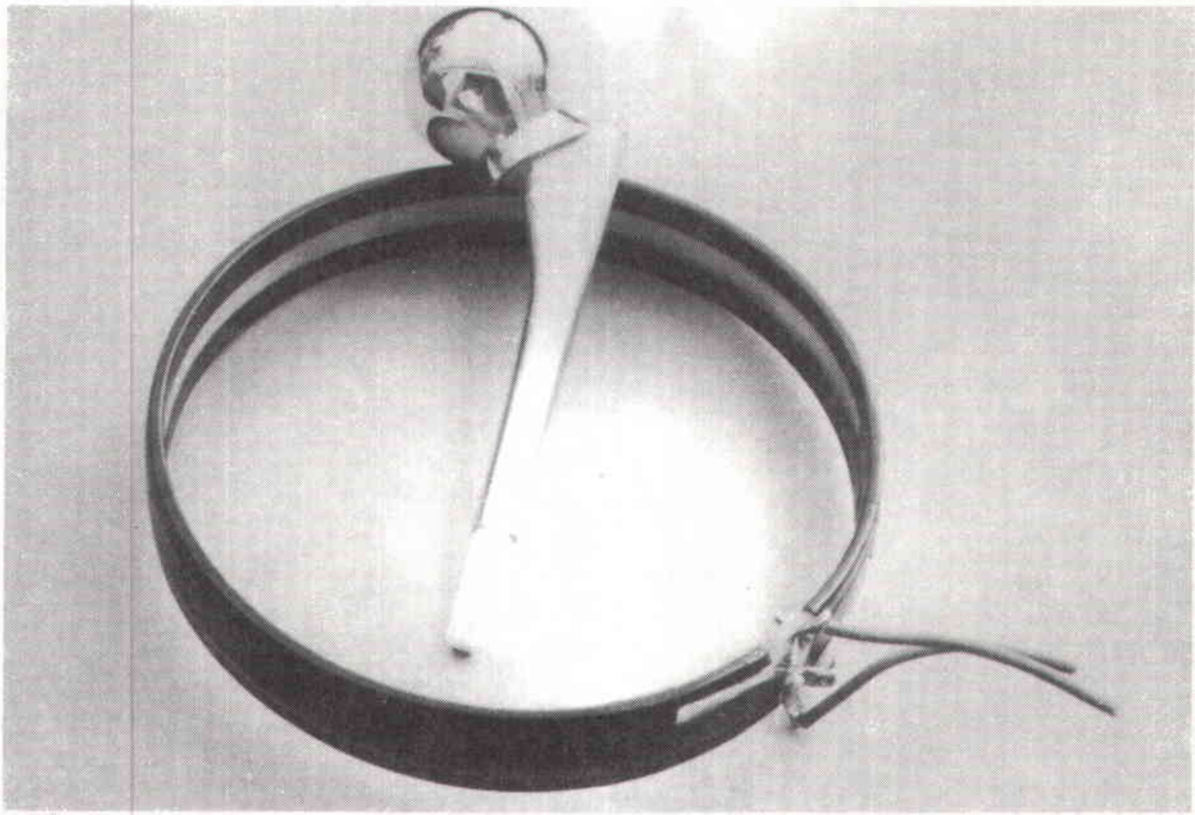


FIGURE 6

An Orthopaedic Implant for Hip Joint Reconstruction with Pressure Sensors, Telemetry and Antenna for Measuring Articular Cartilage Pressure Distribution *In Vivo*, Together with Radio-induction Power Loop

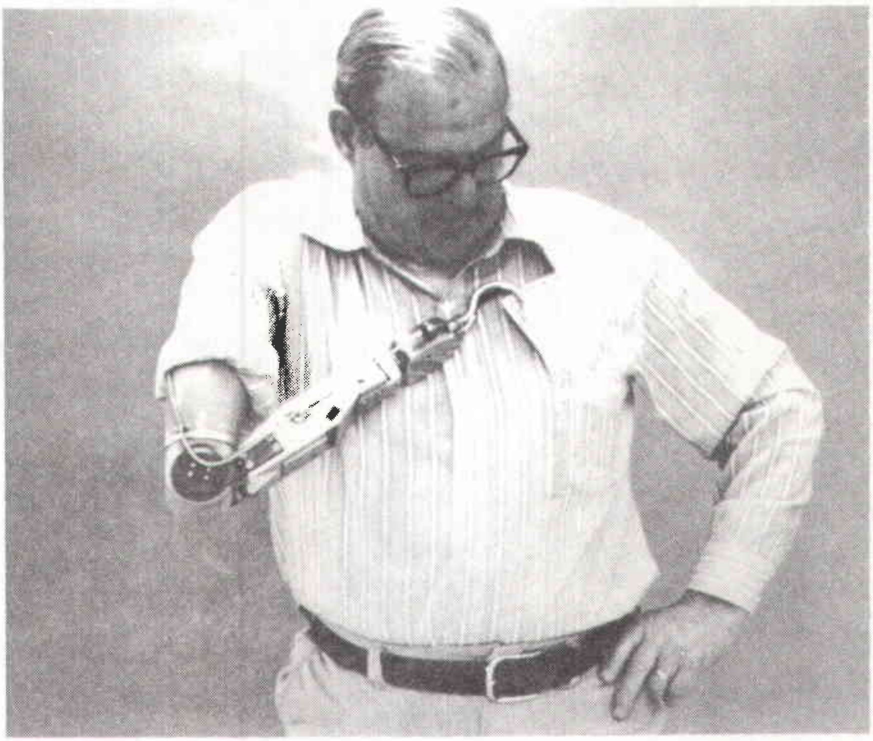


FIGURE 7

Upper-extremity Amputee Wearing Myoelectrical-servo-controlled Boston Elbow (cosmetic forearm cover removed)

FIGURE 8

The M.I.T. UNICOM--A Microprocessor-based Communicator for the Non-verbal Person which Accepts a Range of Inputs Adapted to the Operator's Manual Capacity and Produces Graphic Message Dsplays Appropriate to the Input Control

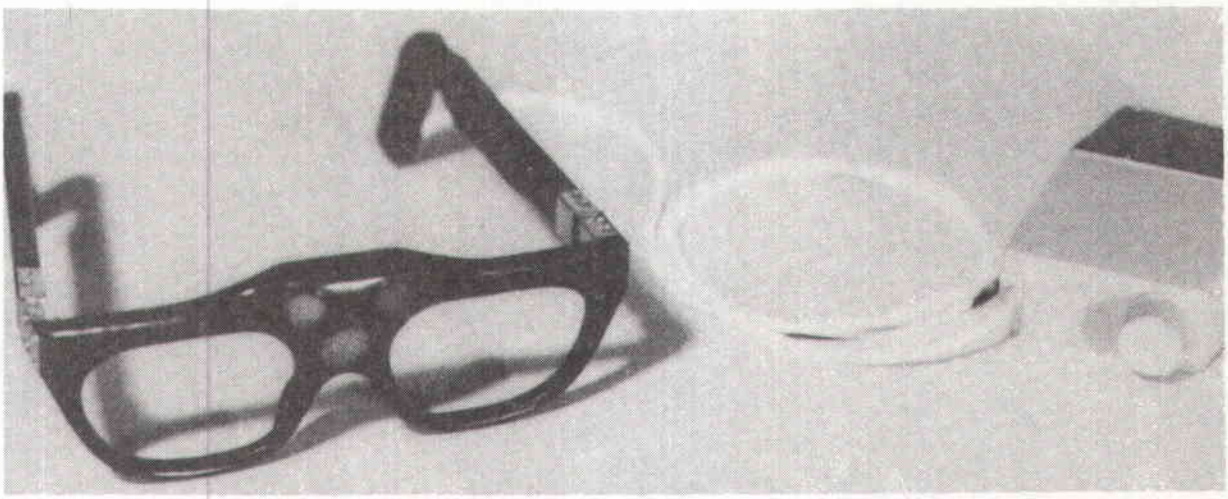


FIGURE 9

The Sonicguide--Ultrasonic Transmitter and Receivers in the Eyeglass Frame Detect Objects Before the Blond Wearer and Present Audio Cues of Range, Azimuth and Texture to the Person

FIGURE 10

The M.I.T. Braille-supplemented Traffic Supervisory Position Switchboard Under Evaluation by Blind Operators at Southwestern Bell Telephone

A Multivariate Analysis of the Relation Between Health and Social Indicators

Toshiyuki Furukawa

The life expectancy at birth in Japan has now equalled that of Sweden, Norway, Netherlands and Denmark, which have long been regarded as "long-life countries" whereas Japan has not.

The overall state of health in any country, ordinarily represented by some statistical items such as expectation of life, mortality, infant mortality or birth rate, is often considered to be very intimately related to the level of development, which is measured traditionally by income per capita, gross domestic production, illiteracy rate and so on. Actually, the economic situation and cultural circumstances have strongly affected the demand for healthy living by individual people and the supply of health services by the government or private groups. But the interaction would not be clearly explained by a few relationships between socio-economic and health indices, as the indices do not show the whole socio-economic level or health level. In order to improve this feature of the indices, many reports have been presented and other indices proposed, which are devised to show more precisely the level of health or economic state or cultural situation. It is regrettable that many of these new indices have not yet been adopted in statistics in some countries and, furthermore, that comparisons of international statistics become difficult because of differences in data collection and analysis.

In this report, the analysis was based on the 60 indices of socio-economic conditions and public health in 66 countries of the world. The purpose of the study was to take a general view of the interrelationship between socio-economic level and health status in a given country and to evaluate the characteristics of the country from the view of biostatistics and national statistics by some mathematical analysis of these variables. The methods used were correlation analysis, principal component analysis and cluster analysis. Many suggestions were obtained by comparing the transition of the countries and the variables during the latest decade. Before concluding the study on the relationship between socio-economic and health indicators, we reviewed the literature that referred to the mathematical analysis with a similar aim.

Source Data

The data were collected from a yearbook edited by the Statistics Bureau of the Japanese Prime Minister's Office (generally for the years 1975 and 1965).

The selected variables were those usually described and referred to in papers analyzing similar data. There were up to 60 items as follows: expectation of life in males and females, population, population density, birth rate, death rate, infant mortality, area, cause of specific death rate (cerebrovascular disease, heart disease and tuberculosis), index number of gross domestic production (GDP) per capita, national income per capita, estimated circulation of daily newspapers per 1,000 inhabitants, expenditure on social security per GDP, electric energy production per capita, percent of dwellings with flush toilet, number of radio receivers per 1,000 inhabitants, energy consumption per capita, percent of dwellings with tap water, number of daily newspapers, caloric intake per capita per day, protein intake per capita per day, number of criminal offenses, number of television receivers per 1,000 inhabitants, number of students by sex (college or university), economically active population (male and female), number of scientists and engineers, public expenditure on education as percent of GNP, production of scientific books, railway transport traffic (net ton-kilometers and passenger-kilometers), civil avaition transport (net ton-kilometers and passenger-kilometers), international sea-borne shipping (imported and exported), population employed in wholesale and retail trade, number of mail services, number of telephones in use, total value of exports, total value of imports, annual attendance at cinemas per inhabitant, percent of the population in agriculture, number of unemployed per 1,000 inhabitants, Engel's index, external trade dependency (export and import), illiteracy rate, population per physician, population per hospital bed, population per car, total expenditure, total revenue, marriage rate, divorce rate, percent of paved road, population employed in public and civil service, and latitude.

We investigated as many countries as possible which had data on a life expectancy. The following 66 nations were chosen: Japan, Afghanistan, Israel, Iraq, Indonesia, Democratic People's Republic of Korea, Republic of Korea, Saudi Arabia, Sri Lanka, Thailand, China, India, Turkey, Nepal, Pakistan, Burma, Philippines, Vietnam, Malaysia, Iran, United States, Canada, Puerto Rico, Mexico, Argentina, Colombia, Chile, Brazil, Venezuela, Peru, Ireland, England, Italy, and Austria, Netherlands, Greece, Switzerland, Sweden, Spain, Czechoslovakia, Denmark, Federal Republic of Germany, Democratic Republic of Germany, Norway, Hungary, Finland, France, Belgium, Poland, Portugal, Yugoslavia, Rumania, Algeria, Uganda, Egypt, Ethiopia, Kenya, Zaire, Sudan, Tanzania, Nigeria, South Africa, Morocco, Austrailia, New Zealand, and the Union of Soviet Socialist Republics.

Correlational Analysis

The 60 variables collected in the 1970s were studied by correlational analysis. Some of the countries had not reported some indices; for example, national income per capita was not revealed in East European countries or the Union of Soviet Socialist Republics. To avoid the influence of these missing data in the analysis, we used the pair-wise method of analysis. That is, in calculating a correlation coefficient of a certain pair of variables, only the information of the countries where both variables existed was used in the analysis.

In the second section of this paper, we demonstrated that the most critical factor contributing to the development of life expectancy was not the improvement of medical technology or medicine but the rise of the social and economic level of the nation.

The results of our study, however, presented rather more intricate relationships than those suggested by the above conclusion. We found many indices that showed a high correlation with life expectancy, such as nutrition (calorie intake and protein intake), education (number of students given higher education and illiteracy) and information (circulation of daily newspapers), and they demonstrated higher correlation coefficients than that of national income per capita which was in turn related more strongly than population per hospital bed and population per physician to life expectancy (see Table 1). Pertaining to the mortality rate, we also found a complex structure; however, population per hospital bed and population per physician showed high relationships, whereas infant mortality rate demonstrated much the same pattern with that of life expectancy, namely, it correlated highly with nutrition level, education level and information level of the nation. As to the birth rate, it seemed to have a closer relationship with the poor nutrition level and low economic level and was unlikely to have high correlation with population per hospital bed and population per physician.

For further investigation, we present some results of cross tabulation analysis, which is one of the most basic, but suggestive, methods of descriptive epidemiology. The variables used as health indices are: 1) life expectancy at birth (male); 2) mortality rate; and 3) birth rate.

Relationship Between Life Expectancy at Birth and Socio-Economic Indices

The national income per capita is, naturally, high in the developed and industrialized countries and very low in the developing countries. Accordingly, the cross-tabulated graph with expectation of life and national income per capita showed the exponential-like curve (see Figure 1). So, it is very probable that the correlation coefficient was lowered even though there might be a consistent relation between these two variables (r=0.735). From this graph some points are worth noting. From a general point of view, it can be said that the higher the national income is, the longer the expectation of life becomes, with the prolongation of the life expectancy dramatically increasing as the national income per capita rises to a level of $1,500; thereafter the curve shows a gentle growth with the increase of national income per capita. From the extrapolation of this graph, it would seem that the expectation of life would reach the 80's in the near future, but then would remain at that level for a long time. However, a few countries with oil fields or diamond fields (e.g., Saudi Arabia, Republic of South Africa, Iran) show a short life expectancy compared with the countries of the same level of national income per capita. On the contrary, some of the countries (e.g., Japan, Sri Lanka, Netherlands) show a higher life expectancy than other countries of the same level of national income per capita. It is thought that a radical increse of national income in those countries where the expectation of life is comparatively short could bring an unbalanced social and political situation. The latter countries, where the expectation of life is comparatively longer than the same level countries, seem to be "intensive," namely, in their small area with comparatively large population, resources and capital are at a high density.

In the relationship between life expectancy and population per physician, the dispersion of the developing and developed countries is distinct. The difference of the level of population per physician causes this situation (see Figure 2). It can be said that there exist two types of countries that show shorter life expectancies than those of the countries with the same population per physician. One is the group where economical growth happened so quickly that many hospitals or educational systems were constructed and the number of physicians has increased, but the common sense or customs of the inhabitant remains undeveloped and the modern medical system has not functioned effectively. In these countries, it seems that the expansion of health education and improvement of health beliefs bring about the rise in life expectancy. The importance of the change of health beliefs is mentioned in Miyasaka (1973). The other group contains those countries where the social and economic system is already developed and a modern medical system is used commonly, but some other factors, which might be social stress, food customs, or severe natural circumstance, restrict the prolongation of life expectancy. The assumption, noted also in other studies, that the economic level, extension and repletion of medical facilities, and increased number of physicians are not the most critical factors of improvement of the expectation of life is thought to be supported by these results.

Circulation of daily newspapers is a useful index which shows the flow of information and/or knowledge level of the nations, namely, social and cultural level. The relationship was also an exponential-like curve (see Figure 3). Of course, the multilingual countries would have a greater circulation number compared with monolingual nations in the same socio-economic level, and the low life expectancy of the Union of Soviet Socialist Republics or India for the number of circulation of daily newspaper could be explained by considering that these countries are typical multilingual nations.

The above three graphs followed a kind of exponential- or saturation-curve and the correlation coefficients are thought to be lowered because of the non-linearity. The relationship with calorie intake per capita per day was different (see Figure 4). We found a crude linearity particularly among developing countries. Toyokawa (1975), investigating the relationship between various food intake, national income per capita and life expectancy, mentioned that sugar, meat, eggs, milk and dairy products are consumed roughly in proportion to national income per capita, and cereals are in crudely inverse proportion. As noted before, the life expectancy has a strong relationship with national income per capita; consequently, the linearity obtained in Figure 4 is thought to be an adequate result. But it is noticeable that Japan and Sweden show long life expectancy for their relative low level of caloric intake, and that the Union of Soviet Socialist Republics, Argentina and Republic of South Africa indicate rather short life expectancy for their relative high level of caloric intake.

Relationship Between Mortality and Socio-Economic Indices

It is normally thought that the mortality rate has an intimate relationship with the number of medical facilities and staff. The cross tabulation with population per physician and population per hospital bed is shown in Figures 5 and 6. There have been some reports on the mortality rate as a health index; for example, it indicates a high score in developing countries where the infant mortality rate is high as well as in developed countries where the infant mortality rate is low but the number of deaths of advanced age is high. However, the graphs showed some marked features. Some of the countries with oil fields demonstrated a relatively high mortality rate for their number of medical staff or facilities (e.g., Saudi Arabia, Nigeria) and Vietnam showed the same tendency. These countries indicated a similar trend in the relationship between life expectancy and socio-economic indices. We also found some countries where the mortality rate is low and the medical facilities are fairly well settled, but the expectation of life is short (e.g., Republic of South Africa, Mexico). It can be said that different factors operate in the reduction of the mortality rate and in the prolongation of the expectation of life.

Relationship Between Birth Rate and Socio-Economic Indices

The population explosion in the developing countries is a world-wide and serious problem in these days. In order to study the relationship with social level, it was plotted against illiteracy rate and caloric intake (see Figures 7 and 8). Both of these two graphs show the linear relationship, particularly in the relation with caloric intake. There are several countries where the illiteracy rate is low but the birth rate indicates a rather high score (e.g., Philippines, Thailand). It is said that there exists a close relationship between the birth rate and religion or customs of the inhabitants that is not easy to change by means of education. So, a reason for the deviation of the countries in Figures 7 and 8 could be related to national customs or religion. In the Republic of South

Africa, the birth rate is rather low for its high illiteracy rate. This could be caused by the insufficiency of the data sampling in the birth rate of colored people.

Factor Analysis

Factor analysis is one of the methods to investigate the interrelational structure of multidimensional data space constructed by original variables or observations. It transforms given original variables into a new set of composite variables or factors that are uncorrelated (orthogonal) to each other. The algorithm searches for the best linear combination of variables to explain more of the variance within the data space than any other linear combination of variables. So the first factor accounts for the most variance in the multidimensional space. The second component ranks next to the first component in explaining variance and concomitantly is orthogonal to the first component, i.e., the second component would elucidate the proportion of the variance not accounted for by the first component. Similarly, subsequent components are defined.

In the analysis of the computed results, it was found that the influence of the number of population was so strong that the result of the analysis was much distorted. Therefore, the variables that were thought to be directly influenced by the population size are divided by its population.

The new variables used are the following 55 items: expectation of life (males and females), population, area per capita, number of physicians per capita, calorie and protein intake per capita per day, index number of GDP per capita, national income per capita, expenditure on social security per GDP, expenditure on education per GNP, cause of specific death rate (heart diseases, tuberculosis, cerebrovascular diseases), number of hospital beds per capita, birth rate, death rate, infant mortality, estimated circulation of daily newspapers per 1,000 inhabitants, illiteracy rate, revenue per capita, number of television and radio receivers per 1,000 inhabitants, number of telephones in use per capita, number of criminal offenses per capita, economically active population ratio (male and female), electric energy production per capita, energy consumption per capita, number of cars per capita, number of mail traffic per capita, enrolled students in higher education (male and female), population (agriculture and fishing field, wholesale and retail trade field and public and civil service field), percent of dwellings with tap water, percent of dwellings with flush toilet, traffic per capita (railway transport and civil aviation transport of passengers and goods), total import value per capita, total export value per capita, number of scientists and engineers per capita, number of production of scientific books per capita, divorce rate, paved road rate, number of unemployed per capita, annual attendance to cinemas per inhabitant, marriage rate, Engel's index, international sea-borne shipping (tonnage imported and exported).

The years for which data were collected are generally 1975 and 1965, which were assumed to represent the 1970s and 1960s. If the data were not observed in 1975 or 1965, the data investigated in the nearest year to 1975 or 1965 were adopted. However, if there were no data during the periods 1961-1970 and 1971-1980, the variable was assumed to be a missing value. According to a change of political system or war, a few countries changed territory or names during the decade. We analyzed the countries unless the change was exceedingly significant for the analysis. Vietnam is omitted for this reason.

With the correlation coefficient matrix obtained from the data, factor analysis and cluster analysis were carried out as presented in the next part of the paper.

Factor Analysis of Data from the 1960s and 1970s

The contribution of the first component was over 40 percent in both eras, 44.2 percent in the 1960s and 48.5 percent in the 1970s. The second and third components are 9.3 percent and 8.1 percent in the 1960s and 8.4 percent and 7.4 percent in the 1970s respectively. In order to analyze the meaning of each component, variables that showed high factor loadings with the component are helpful. In the result of the 1960s, the first component received positive contribution from national income per capita, number of television receivers per 1,000 inhabitants, energy consumption per capita, number of cars per capita, life expectancy (male and female), death rate of heart disease, number of hospital beds per capita and percent of dwellings with tap water; but it was negatively affected by agricultural population ratios and mortality due to tuberculosis.

The estimated circulation of daily newspaper per 1,000 inhabitants and students enrolled in higher education (male and female) affected the second component strongly and positively, and the death rate of cerebrovascular diseases and the economically active population ratio (male only) influenced it negatively.

In the third component, traffic per capita of railway transport of passengers, economically active population ratio (female only), index of GDP, divorce rate and marriage rate affected positively and percent of dwellings with flush toilets, area per capita, total export value per capita and illiteracy rate showed negative effect.

It would be easy to think the first component as the level of development or "richness," whereas it is a little difficult to explain the second, third and other components.

Transitions of the Countries During the Years 1960-1980

Because it is often helpful to plot the individual scores on a graph to identify the meanings of the factors, using all the data from the 1960s and 1970s, a factor analysis was conducted.

The contribution of the first component was 44.8 percent, equally high as with the results of principal component analysis of the individual data from the 1960s and 1970s. The contributions of other components were very small, for example, 9.2 percent in the second component, 6.6 percent in the third component and 4.8 percent in the fourth component. The first component received a positive contribution from variables including the number of cars per capita, national income per capita, number of telephones in use per capita, amount of mail per capita, expectation of life of females, percent of dwellings with tap water, number of criminal offenses per capita, caloric intake per capita per day, and number of hospital beds per capita, whereas it was negatively affected by the population ratio of agriculture and fishing, birth rate and Engel's index. The second component was positively affected by total export value per capita, annual revenue per capita and illiteracy rate, while it was negatively affected by of GDP per capita, per capita transport of passengers by rail and annual attendance at cinemas per inhabitant.

The trends of the transition of the countries were obviously different among developed communist countries, developed free countries, oil producing countries and developing countries in the other area (see Figure 9). The most apparent movement is one from the left lower (fourth quadrant) to the right upper (first quadrant) that is shown chiefly by developed, free countries in Europe and North America. Almost all of these countries were located at first in the fourth quadrant and then moved toward the first quadrant. Some of the other countries such as Saudi Arabia, Argentina, South Korea, South Africa, Japan, Peru, Venezuela and Puerto Rico also showed the same trend of transition. The developed communist countries, e.g., East European countries and the Union of Soviet Socialist Republics were grouped together but their movements were not the same. They were located and moved within the fourth quadrant. There were two types of transition trends, one was from the lower left part to the upper right part, and the other was the almost horizontal one or descent one. The former included Yugoslavia, Rumania, Hungary and the Union of Soviet Socialist Republics, while the latter group included Poland, Czechoslovakia, and the German Democratic Republic. It was noticeable that the behavior of Japan is similar to that of developed free countries; however, the location is the same as that of the communist countries. The third group represented the developing countries and was located mainly in the second quadrant. The transition trends were complicated among these countries. However, there were distinct movements, one from the lower right part to the upper left part as in the cases of Saudi Arabia, Peru, Venezuela, Mexico and Brazil. The other trend was almost vertically downwards as shown by Indonesia, Turkey, Pakistan, Thailand, Iraq, Nigeria, Tanzania, Zaire, Ethiopia, and other African countries. The remainder moved almost horizontally as in Chile, Malaysia and Algeria.

Briefly speaking, South American countries showed the same trend as that of West European and North American countries, whereas the African countries and Southeast Asian countries showed a different kind of movement. Considering the variables contributed highly to the first component and the distribution of component scores of the countries, it seemed that the first component indicated the "richness" of the countries that could be measured by the national income per capita, namely "money." From a similar point of view, the second component is thought to be the "affluence" of information and various consumer goods. When the national power was measured by the amount of gold, the money, of the country, almost all of the world countries showed development at the same rate, of course including the developed countries during these decades. Therefore, the qualitative difference of development among the countries seemed to be dependent on the second component.

The affluence of information and consumer goods is thought to be supported not only by the economic power of the country but also by the culture, education, industrialization and living standard. The behaviors of the East European countries and the Union of Soviet Socialist Republics could be explained from this point of view, i.e., in these countries, where the richness as the whole country was improved, the wealth of each person in consumption was not so remarkably enriched. Some of the oil-producing countries, represented by Saudi Arabia, showed extremely high development along the second component axis, which could be accounted for by behavior in such countries where many modern facilities have been purchased and brought in during the period. Japan is also showing curious behavior. It might be imagined that Japan, located in an upper position like other developed, free countries, showed more drastic movement along with the same trend. The fact is the location of Japan is the same as that of the communist countries on the graph and the trend of movement is the same as that of the free countries. One reason might be the population growth in Japan, which is rather high compared with other developed countries. Hence the development of the affluence of information or consumer goods are thought to be denied by the growth of the population. The same kind of behavior could be found in the southern European countries (Portugal, Greece, Spain and Italy) and South Korea. In some of the East Asian and African countries, population growth is affected so significantly that the effects of the improvement of the national economies was negated.

Cluster Analysis

Cluster analysis is also one of the methods for investigating the interrelationships among variables. Its most exceptional characteristic is its grouping of variables with reference to their similarities as defined arbitrarily by the analyzer.

In this study, similarity was measured by the correlation coefficients of variables pair-wise deletion. The variables used were the same as those of the factor analysis.

The results in the 1960s and 1970s were shown as two dendrograms respectively (Figures 10 and 11). The results were similar to each other, and the clusters seemed to show similar patterns. The first group in the 1960s was composed of life expectancy, calorie and protein intake per capita per day, number of physicians per capita and expenditure on social security per GDP. The corresponding group in the 1970s also included the same variables as well as number of hospital beds per capita, estimated circulation of daily newspapers per 1,000 inhabitants and death rate due to heart disease. This cluster included national income per capita, number of telephones in use per capita, number of cars per capita, number of television receivers per capita, energy consumption per capita, population ratio of civil servants, percent of dwellings with tap water and flush toilets, number of offenses per capita and mail traffic per capita. This cluster seems to denote the service and information factor. The feature is strengthened in the 1970s, namely, the factor of service, consumer goods and information. The other clusters were rather small compared to the first and second clusters. However, it is noticeable that the last cluster was composed of mortality, infant mortality, birth rate, Engel's index, death rate due to tuberculosis and the population ratio of agriculture and fishing. This cluster also related to population size. The index of public health was also included in this cluster. Because we used the correlation coefficient as the measurement of similarity, the first and the last cluster are thought to show contrary behavior. Since there exists only a small difference between the two clusters, however, major change could not be found. Hence, the characteristics of the variables are thought to be unchanged during the period.

From the results obtained, the meaning of the variables has not changed, but the characteristics of the countries have changed drastically during the decade. It would be adequate to analyze the movement of the world countries with the same variables.

Review of the Literature

Many studies have dealt with the problem of health status and socio-economic situation. Studies of the correlation between socio-economic indices and mortality started with an investigation of the European, mainly English and French, experience in the nineteenth century. Before long, some other health and socio-economic indices were reported and the data on developing countries became available. Then several cross-section analyses between developing and European countries were made. More recently, studies have reported on factors such as the socio-economic correlates of specific causes of death by an analysis based on time-series data and the estimation of longevity. I would like to review briefly these various kinds of studies.

The early studies were mainly concerned with the causes of the decline of mortality that were observed in Europe in past centuries. The principal arguments emphasized the role of income per capita in the development of health standards. The dominant conclusion was that the improvement of the environment under the influence of the growth of industries strongly correlated with the reduction of infectious diseases as the cause of death (e.g., Eversly, 1965). Certainly direct factors that reduced the mortality were the influence of the improvement of living conditions, the development of effective medical practices and the decrease of the fear of famines by the development of agricultural knowledge, but the base of thse improvements was thought to be the raising of the socio-economic level in the given country.

There have also been between country comparisons including data on developed and developing countries. Grosse (1979) analyzed the relation between health and population in developing countries and noted that poverty and low income per capita were not the same. An example of this existed in the State of Kerala in India and in Sri Lanka. He also insisted that health service provision of personnel, facilities and sanitation facilities could not fully explain the variations in levels of expectation of life, whereas social factors such as infant feeding practices, personal hygiene, fertility behavior and nutrition seemed to be more critical. Ohadike (1979) investigated mortality differentials and their correlates in Africa and noted the role of the standard of living and of the distribution of health services. Hashmi (1979) mentioned that a simple correlation analysis showed that mortality was highly sensitive to some economic variables as well as to the state of medical and public health services.

There have been more specific studies pertaining to the developed countries, which have analyzed the socio-economic correlates of some health indices including not only mortality levels but also mortality levels classified by specific cause of death or life expectancy or incidence of specific disease. Wuensh (1979) presented the results of a canonical correlation analysis between socio-economic features of counties in Belgium and death rates by cause of death. It was concluded that the first factor of the independent variables seemed to reflect predominantly lawlessness, prosperity, housing and to a lesser extent, medical consumption, education and income level. This factor correlated mainly with a group of causes composed of stomach cancer, suicides and to a less extent, of other digestive system diseases, pneunomia, cancer of the rectum, cirrhosis of liver and ill-defined diseases. Investigating the increase in the total mortality for 15- to 24-year-olds in the United States in the 1960s, Waldron and Eyer (1975) concluded that the rise of the mortality rate was due to the doubling of suicide and homicide and an increase of divorce among parents, increased alcohol consumption and associated family problems, increased illegitimate pregnancy and a relative decline in income for young people as compared to their parents. He also mentioned that the contributing factors to the rise in suicide was a trend toward greater social isolation due to increased parental divorce and decreased marriage among young adults. Analyzing French data, Villin (1979) noted that excess mortality in the less privileged social categories seemed to be due either to genuinely social diseases such as tuberculosis, alcoholism, suicides, and transport accidents, elimination of which depended not on the progress of medicine but merely on the modification of social structures and behavior, or to diseases that contributed much to an increased total mortality, for example, heart disease and cancer, whatever the social class, and which accounted for a substantial proportion of excess mortality in the least privileged advanced age group. The effect of socio-economic factors on the development of health status was also emphasized by some other authors. Karisto et al (1978) studied to what extent excessive morbidity in the Finnish population could be explained by socio-economic factors. In their reports, it was said that a clear connection between education and health as well as between occupation and health was observed. However, only a small part of the difference in morbidity between Finland and the other Scandinavian countries could be explained by variances in demographic or socio-economic structure. Knowles (1980) analyzed the relation between development and health status using life expectancy as the principal measurement and concluded that life expectancy was most strongly associated with literacy, and water and sanitation played an important but much smaller role as explanatory variables, with Gross National Product (GNP) per capita adding little more. Carvajal and Burgess (1978) investigated the socio-economic determinants of fetal and child death in Latin America and noted the role of household income, mother's education level and labor force participation and of migration as well as the incidence of extramarital relations. Concerning the cause-specific studies, the rise of mortality from coronary heart disease has been investigated with geographical and ecological elements, for example, living on the plains or in the mountains (Maede, 1979), and smoking and alcohol (Teraeslinna et al., 1971). A time-series analysis of changes in mortality was presented by Land and McMillen (1980) using data from the United States during the period of 1946-1979. They mentioned that changes in the age structure of the American population had substantial impact on changes in mortality rates for diseases of the respiratory and circulatory systems as well as on deaths due to cirrhosis of the liver, accidents and violence. They continued that the infectious and parasitic diseases seemed to be more intimately related to public health expenditure per capita than to improvements in the general standard of living. Increases of the level of cigarette consumption per capita had a serious impact on the respiratory system's mortality, whereas the level of mortality due to the generative diseases was positively affected by a rise of liquor consumption per capita and negatively influenced by an increase in health care utilization. The levels of maternal and infant mortality rates were positively related to a rise in fertility rates and negatively correlated to those advances in health care services associated with hospital birth. They also emphasized the role of the business cycle on the mortality rate of cardiovascular, accident and violence.

Several reports were oriented more to health and economic policy. The relationship between nutrition, population, health and socio-economic level is related to the political situation of the country. Gish (1979) analyzed the possibility of planned improvements in health and concluded that in the Third World improved health was not primarily a matter of providing medical systems but rather a broader question requiring a better understanding of the nature of underdevelopment itself. It would remain impossible to alter significantly the health status of the world's poorest people so long as it remained impossible to deal seriously with existing social and property relations.

In Japan, Akiyama et al. (1973) analyzed the changes in mortality and its incidence using cohort analysis and cited the influence of the development of socio-economic level. Toyokawa (1975) investigated the relationship between income per capita and food supply per capita per day such as beans, vegetables, sugar, and meat. Hatano (1981) discussed the relationship between the socio-economic level, mainly life style and customs, and life expectancy.

In this paper, we reported the results of correlation analyses using data from the 1960s and 1970s, we investigated the variation between countries by the method of factor analysis and examined the interaction of socio-economic and health indices by means of cluster analysis. We also showed change in the variable clusters and the variations by countries due to differences over the observation period of about ten years.

Conclusion

In order to analyze the relationship between health status and socio-economic indices and the transition of the countries in the world during the period from 1960 to 1980, studies 66 countries using about 60 indices of socio-economic and public health conditions were made using correlation analysis, factor analysis and cluster analysis. In the discussion, other analyses of the link between public health and socio-economic situations were reviewed, and it was noted that the improvement of health in a country is related not only to the development of medical and health facilities and resources but more to the growth of the social and economic level of the country.

The result of a correlation analysis supported the above presumption and suggested the presence of more complex relations between the socio-economic and public health indices and health status in a country. That is, whereas the increase of national income per capita certainly affects the prolongation of life expectancy, the growth of information such as the expansion of daily newspapers, telephones, radio and television seemed to affect the promotion of health status much more.

The principal component analysis confirmed the results of the correlation analysis and related conclusions. Although the principal components from the 1960s and 1970s data were not distinct, the movements of the countries during the decade helped explain the meanings of the components and the characteristics of the other countries. The first component was much larger than other components and indicated the economical "richness" of the country, which was shown by the loading of indices related to economics and industrial level of the country such as national income per capita, population ratio of agriculture fishing, number of cars and telephones in use per capita, and birth rate. West European countries and North American countries, the so-called developed countries, located generally in the positive part of the first component and Africa and Asia, e.g., the developing countries, moved in the negative space of the first component. The other components were relatively small so that it was difficult to analyze the meaning of the components from the indices which loaded on the component. But the movement of the countries were distinct, especially in the case of Saudi Arabia, Western Europe, Canada, United States, Argentina and Japan. We assumed this second component was the "affluence" of information and consumer goods. Because we used the index values per population, there would be several countries where the growth of the socio-economical level and health status was actually lowered by the increase in population, as in, for example, India, Indonesia and some other developing countries. The improvement of economic status due to oil exports was remarkable during the period, as represented by the extreme growth of Saudi

Arabia; however, there could be found several examples of imbalances in socio-economic growth in the country. Furthermore, there appeared confusion, annoyance and difficulties in other developing countries, where the economic power of the country was low but many consumer goods and facilities were induced.

Because the meaning of each variable did not show significant change during the decade in the results of the cluster analysis, comparison and analysis of the countries using the same indices could be undertaken. The transition of the countries from the 1970s to 1980s could be analyzed with similar indices and it would be interesting to check the impact of the oil crisis or other political changes in developing countries. The prolongation of the life expectancy and the growth of national income per capita and population size are also important in the prediction the health and social situation of the next generation.

TABLE 1. CORRELATION COEFFICIENTS BETWEEN THE IMPORTANT SOCIO-ECONOMIC AND HEALTH INDEXES.

	Expectation of life		Death rate	Birth rate	Infant death rate
	Male	Female			
National income per capita	.735	.762	-.426	-.793	-.674
Population per hospital bed	-.579	-.578	.608	.490	.664
Population per physician	-.714	-.678	.768	.578	.380
Illiteracy rate	-.829	-.846	.731	.778	.513
Circulation of newspapers	.762	.777	-.483	-.797	-.590
Calorie intake per capita	.824	.864	-.527	-.902	-.607
Protein intake per capita	.795	.833	-.520	-.871	-.525

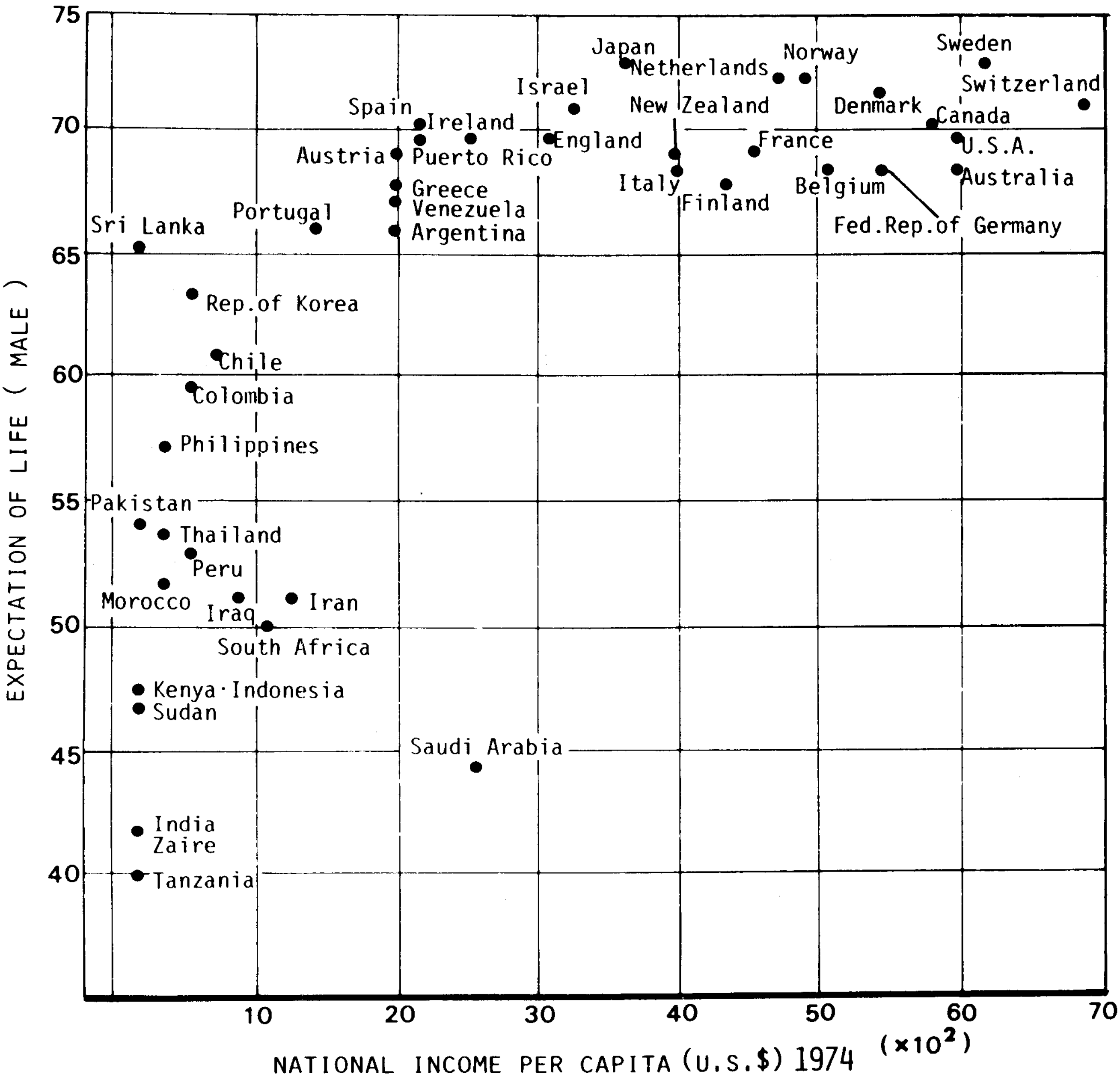


FIG. 1 RELATIONSHIP BETWEEN EXPECTATION OF LIFE (MALE) AND NATIONAL INCOME PER CAPITA. (N = 44, R = 0.735)

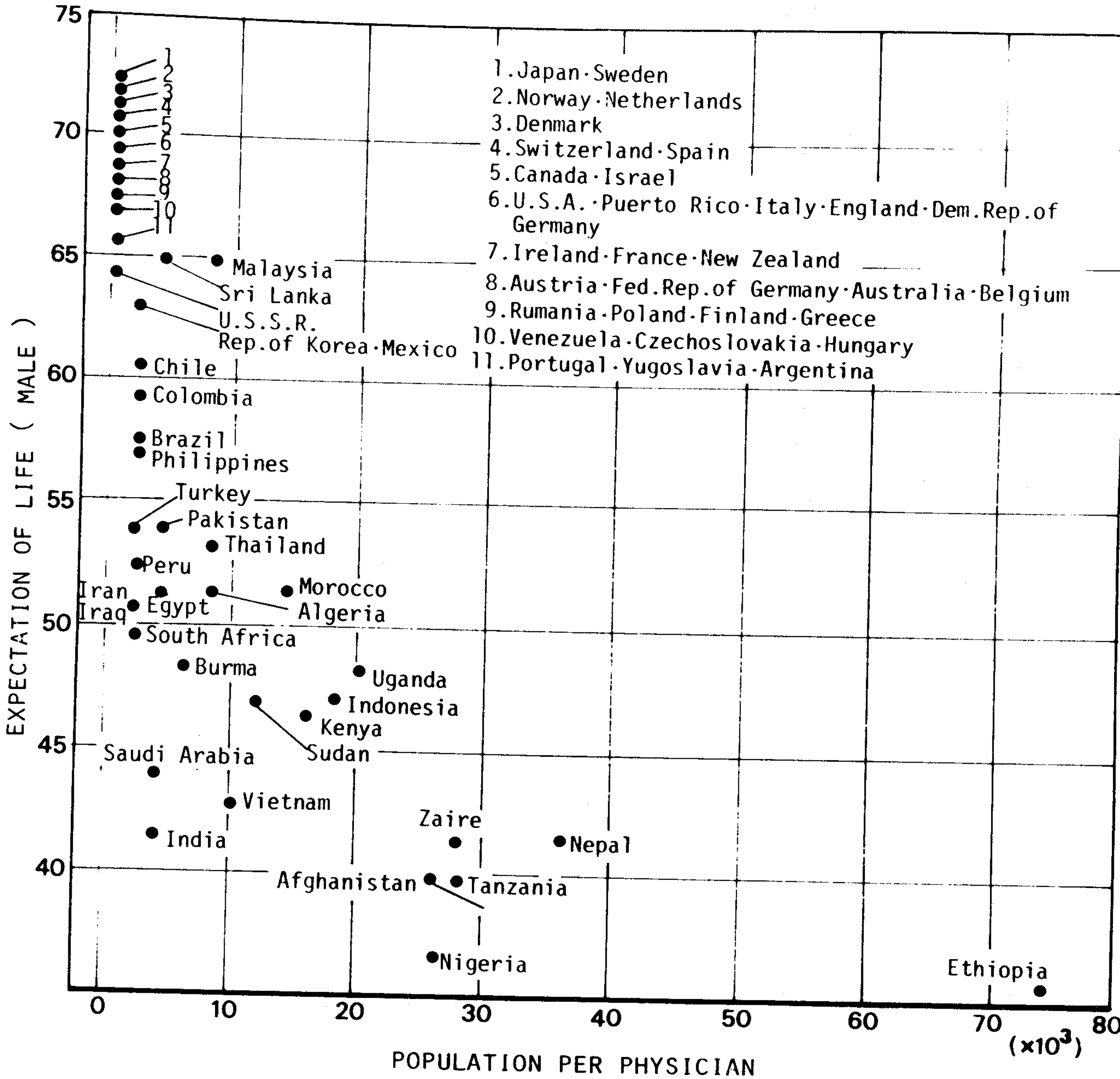


FIG. 2 RELATIONSHIP BETWEEN EXPECTATION OF LIFE (MALE) AND POPULATION PER PHYSICIAN. ($N=64$, $R=-0.714$)

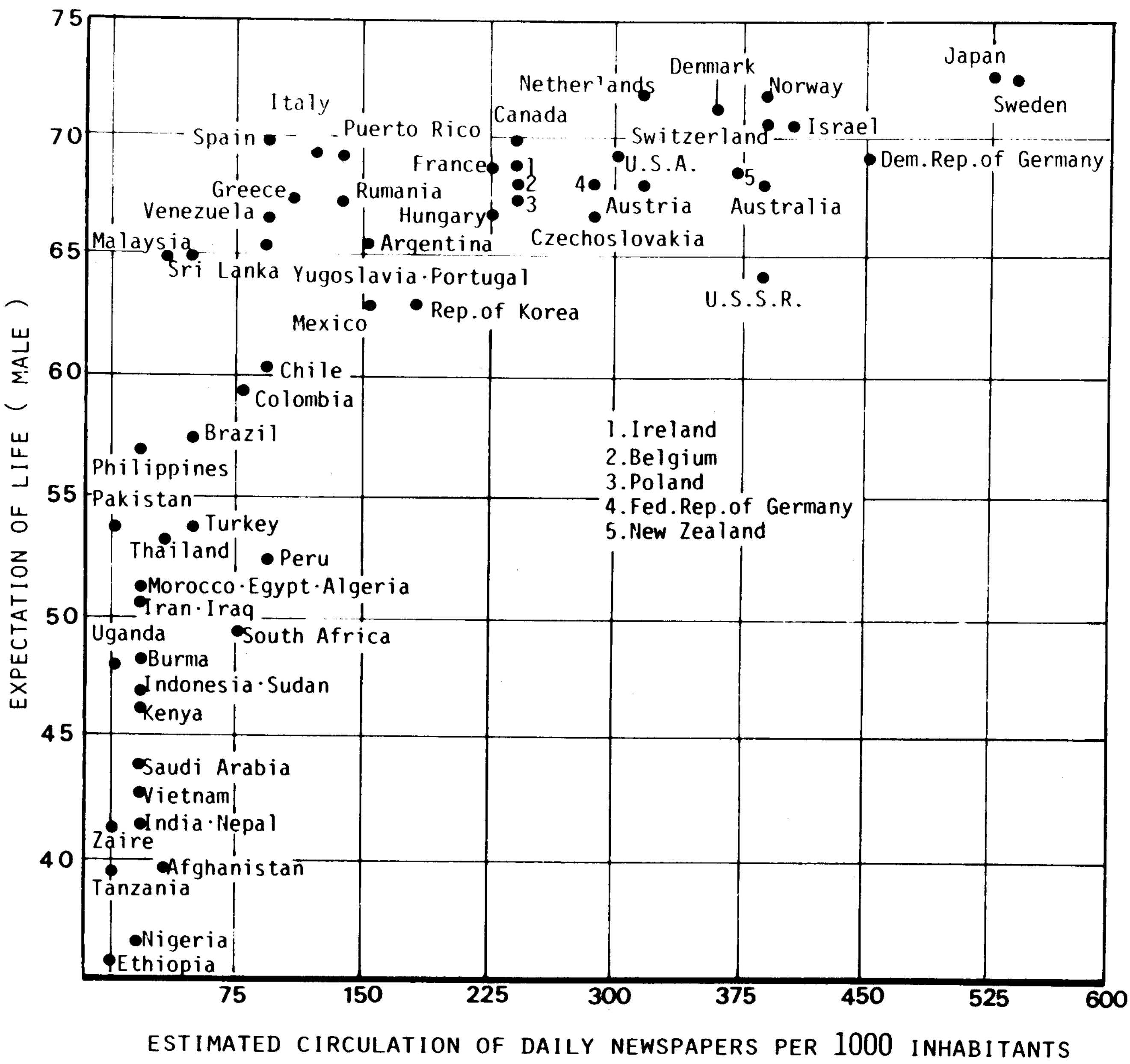


FIG. 3 RELATIONSHIP BETWEEN EXPECTATION OF LIFE (MALE) AND ESTIMATIED CIRCULATION OF DAILY NEWSPAPERS PER 1000 INHABITANTS. (N=63, R=0.762)

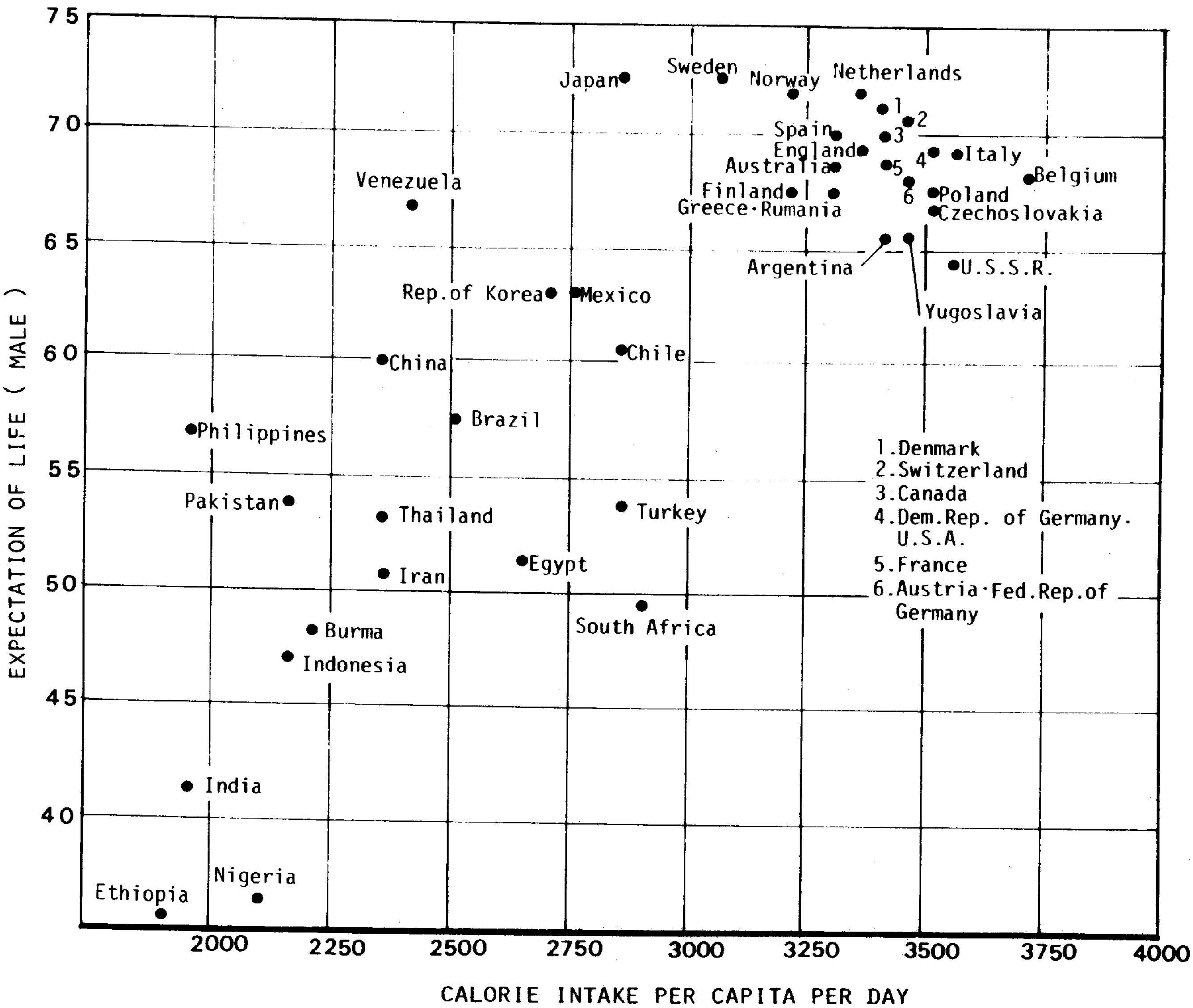


FIG.4 RELATIONSHIP BETWEEN EXPECTATION OF LIFE(MALE) AND CALORIE INTAKE PER CAPITA PER DAY. (N=43,R=0.824)

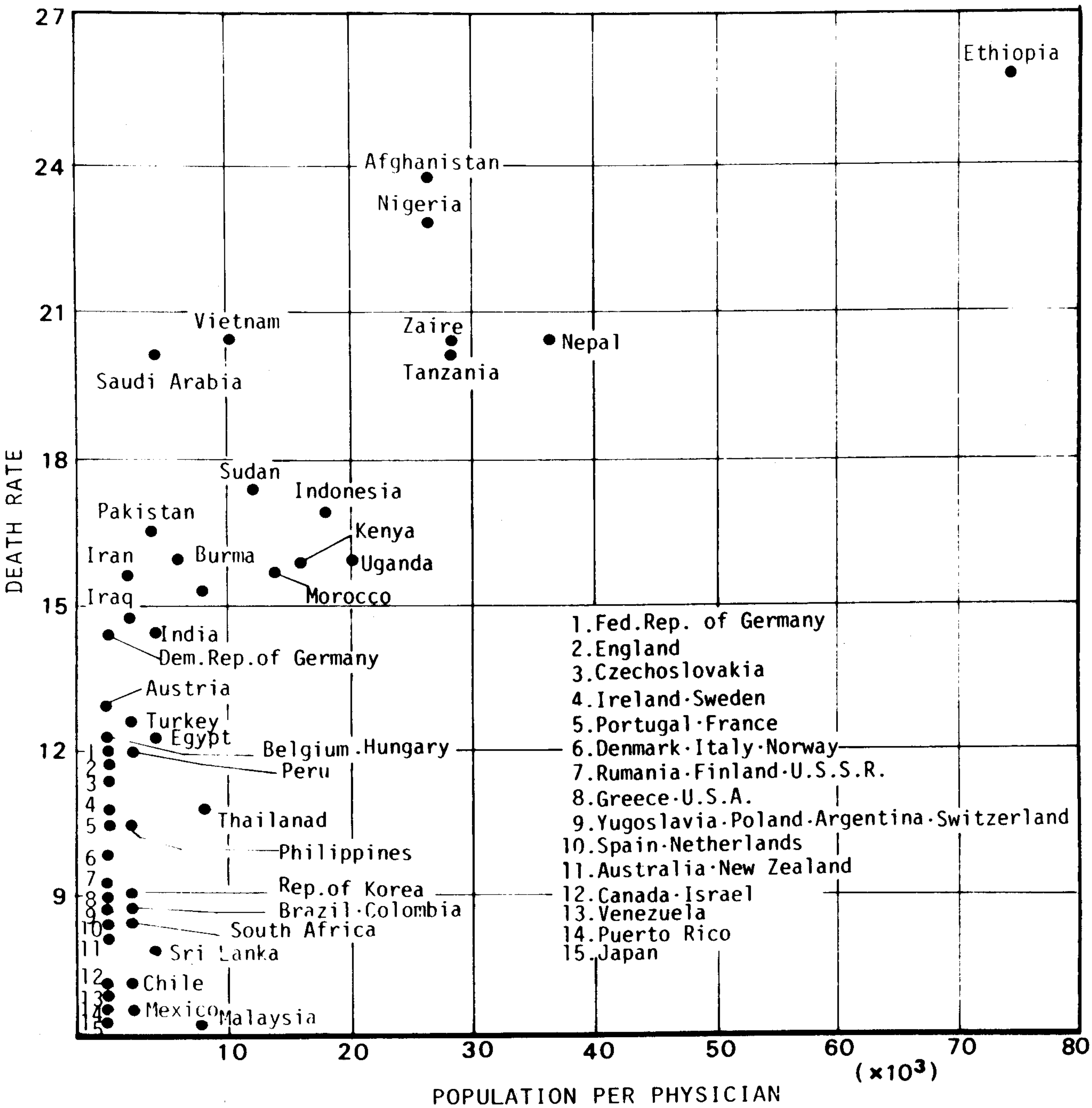


FIG. 5 RELATIONSHIP BETWEEN DEATH RATE AND POPULATION PER PHYSICIAN.
(N = 64, R = 0.768)

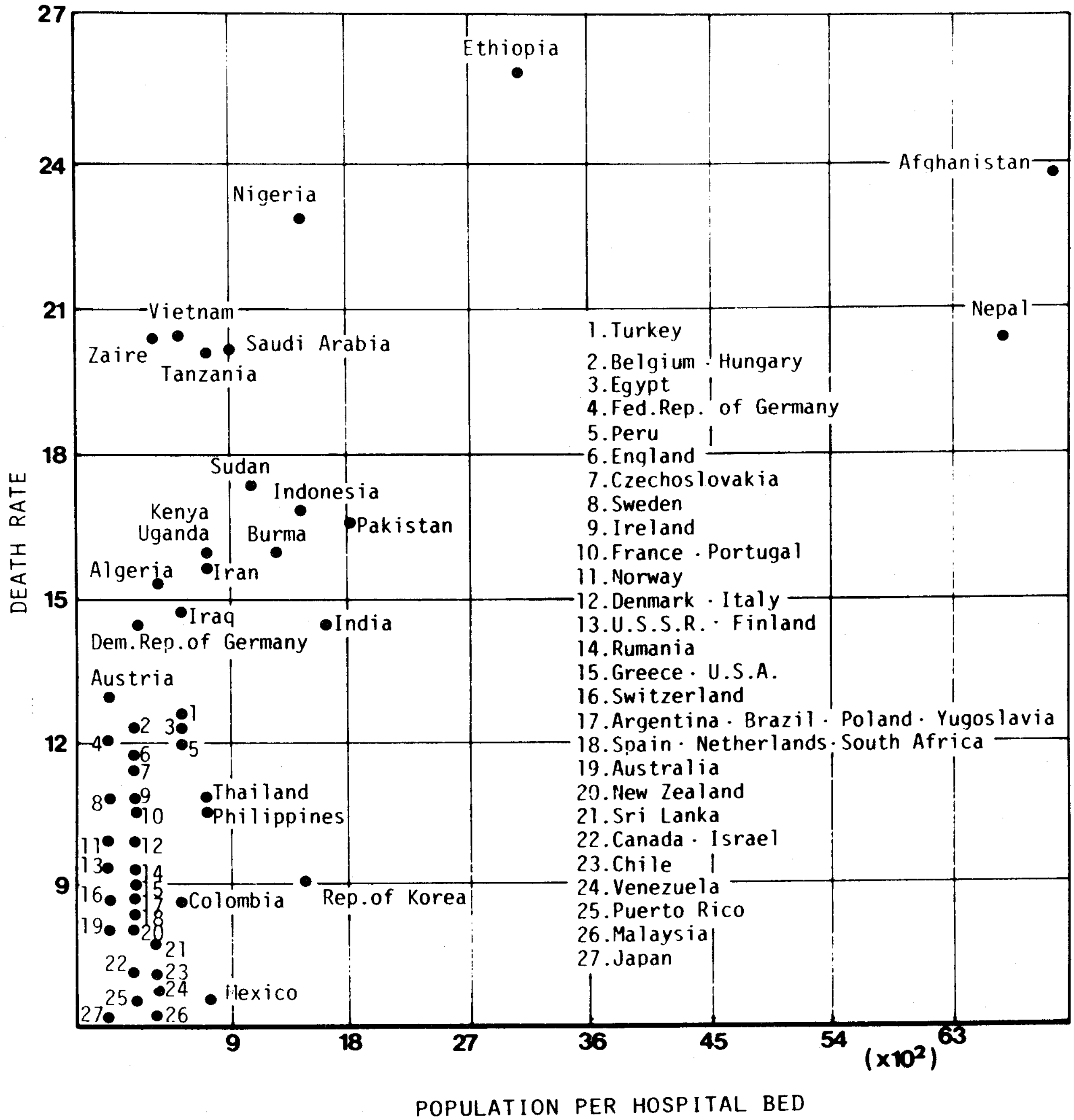


FIG. 6 RELATIONSHIP BETWEEN DEATH RATE AND POPULATION PER HOSPITAL BED. (N = 64, R = 0.608)

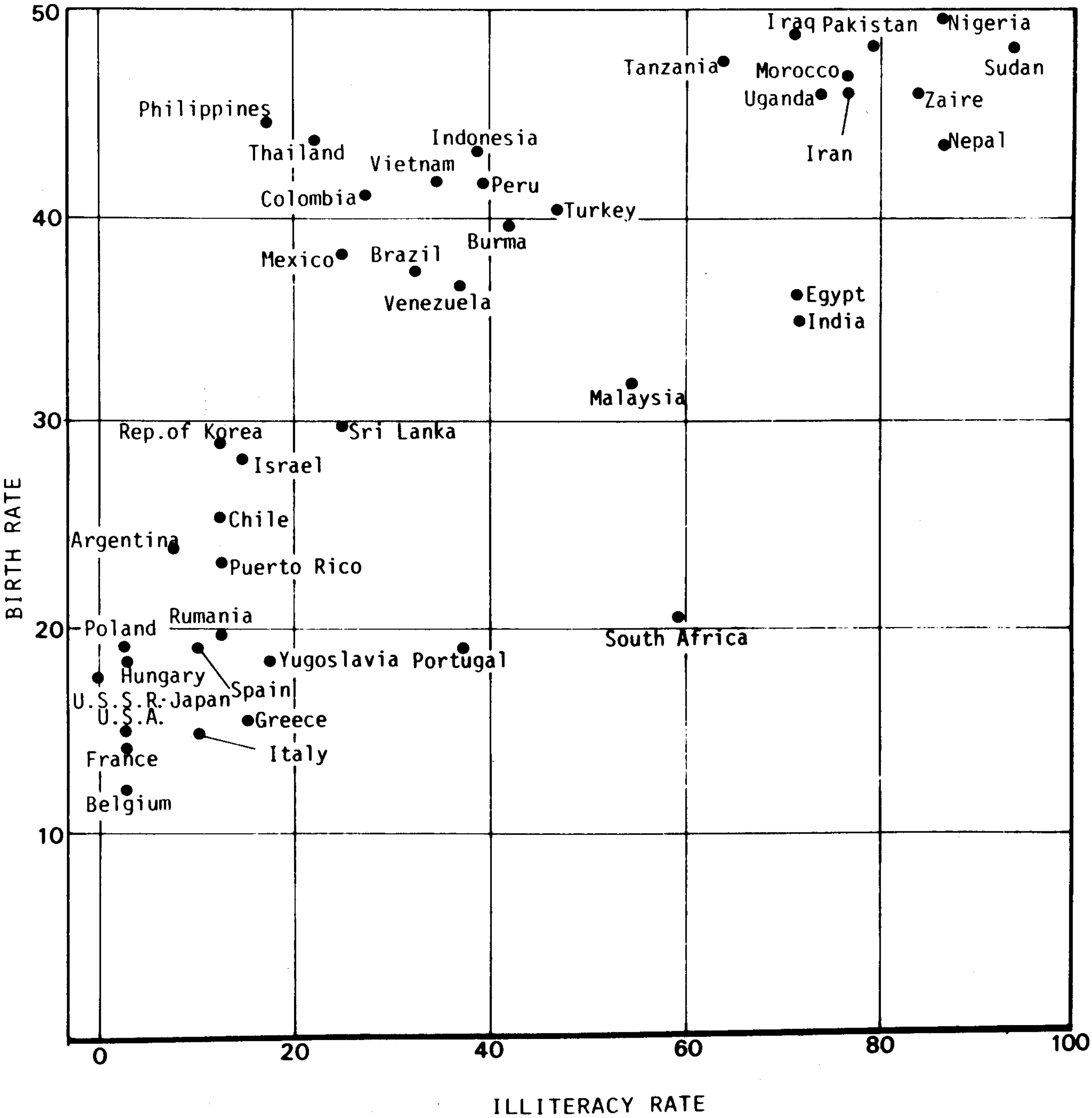


FIG. 7 RELATIONSHIP BETWEEN BIRTH RATE AND ILLITERACY RATE.
(N = 45, R = 0.788)

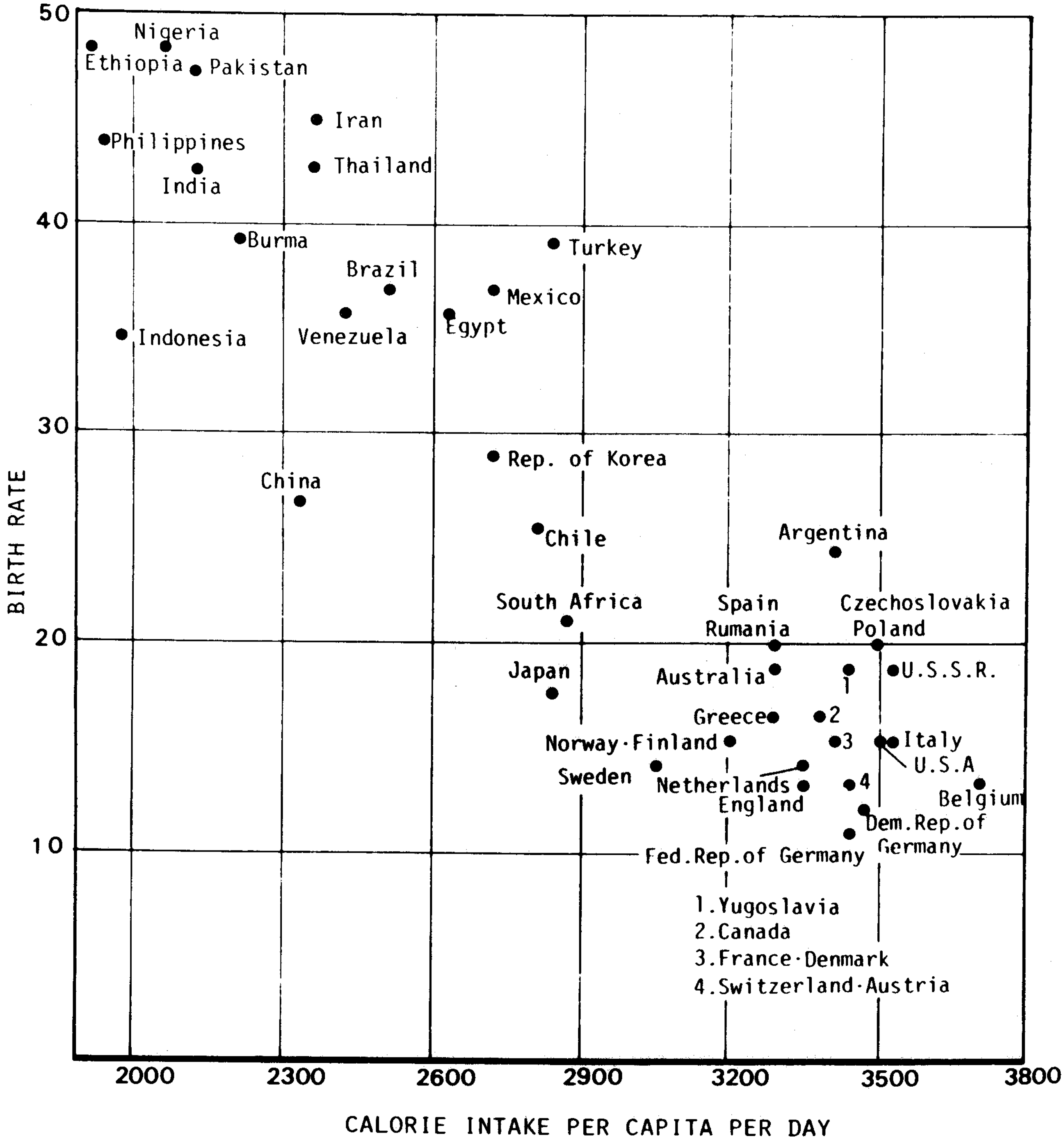


FIG. 8 RELATIONSHIP BETWEEN BIRTH RATE AND CALORIE INTAKE PER CAPITA PER DAY. (N = 43, R = 0.902)

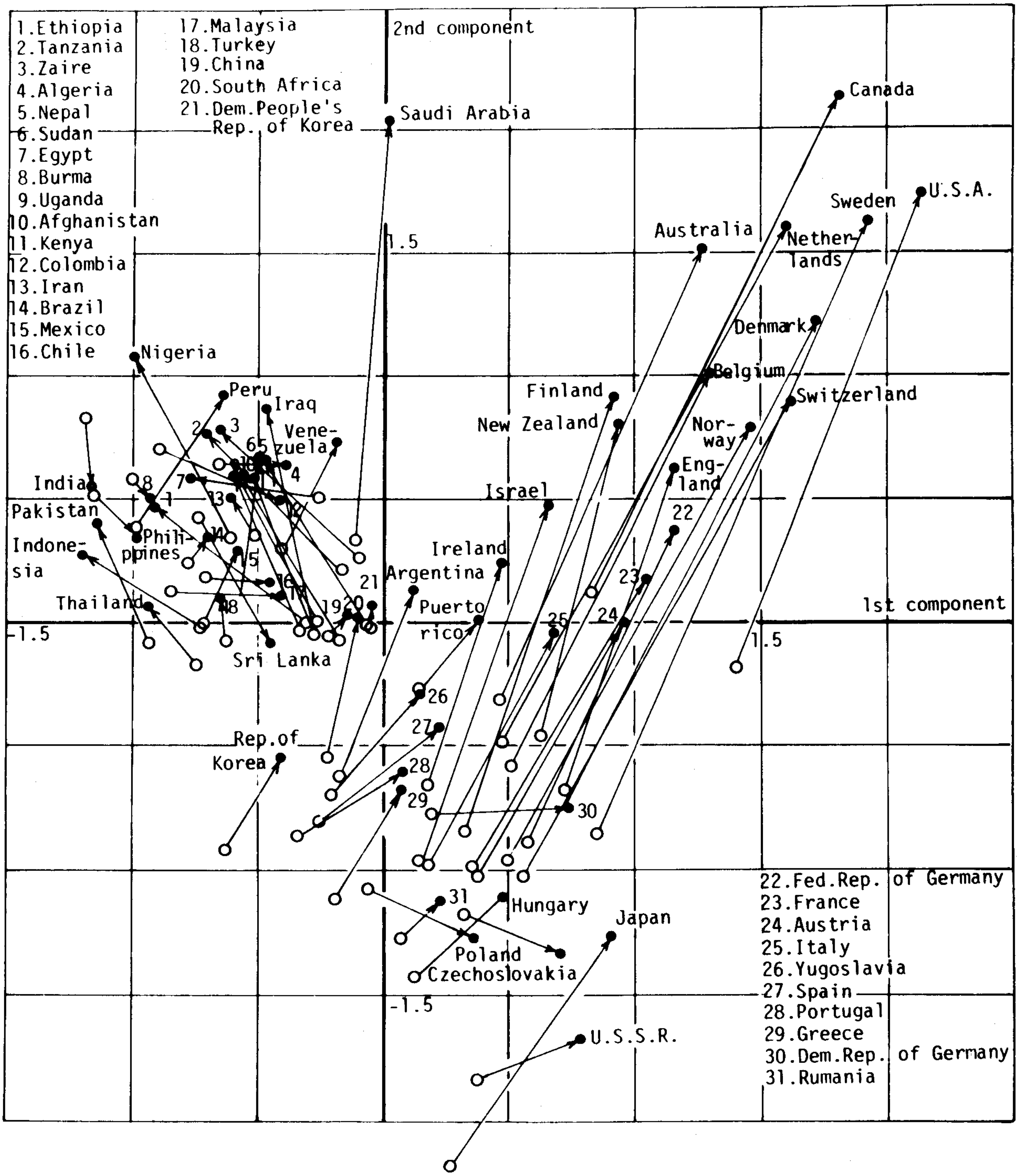
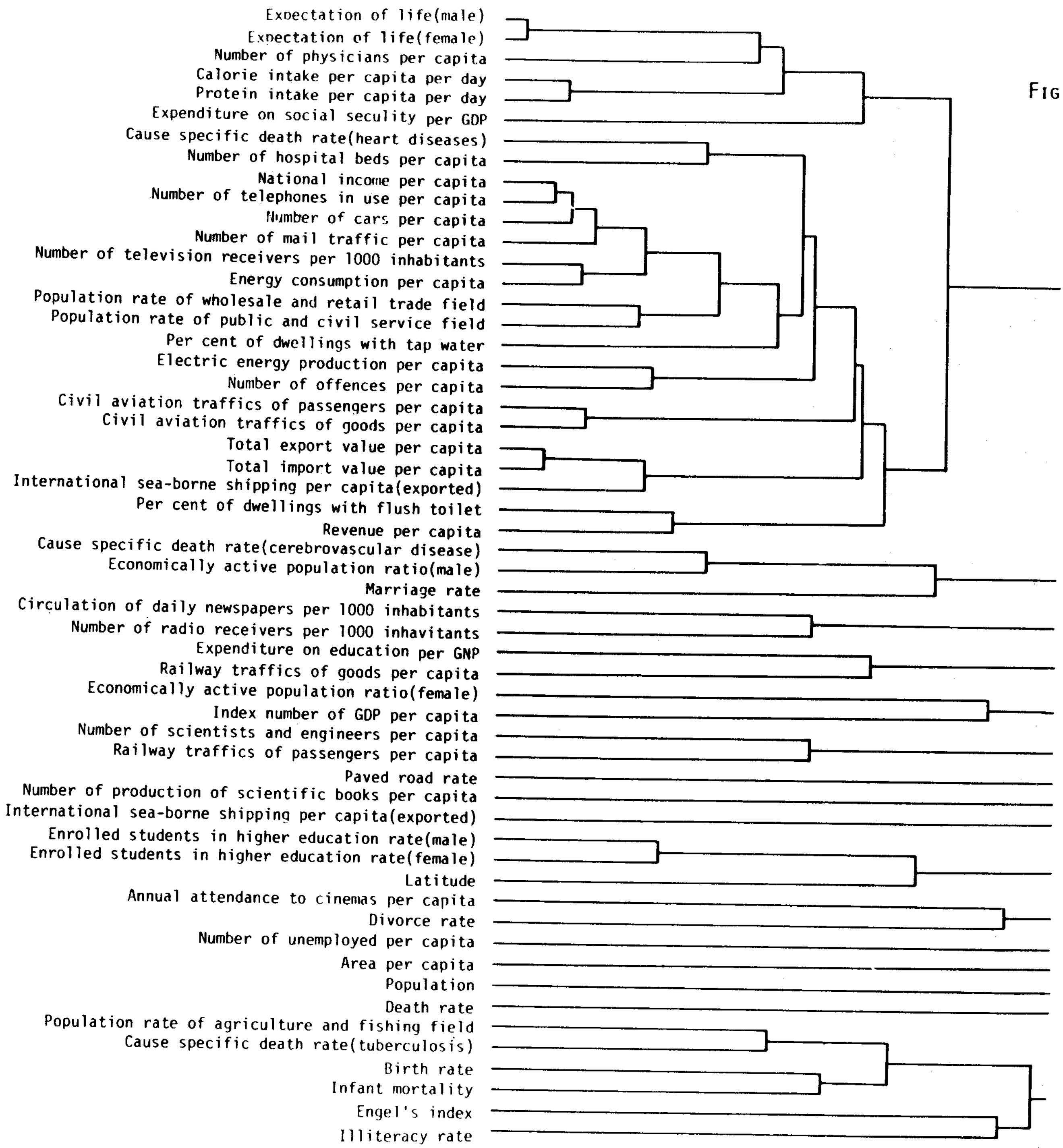


FIG. 9 TRANSITION OF 65 COUNTRIES DURING THE YEAR 1961 TO 1980.

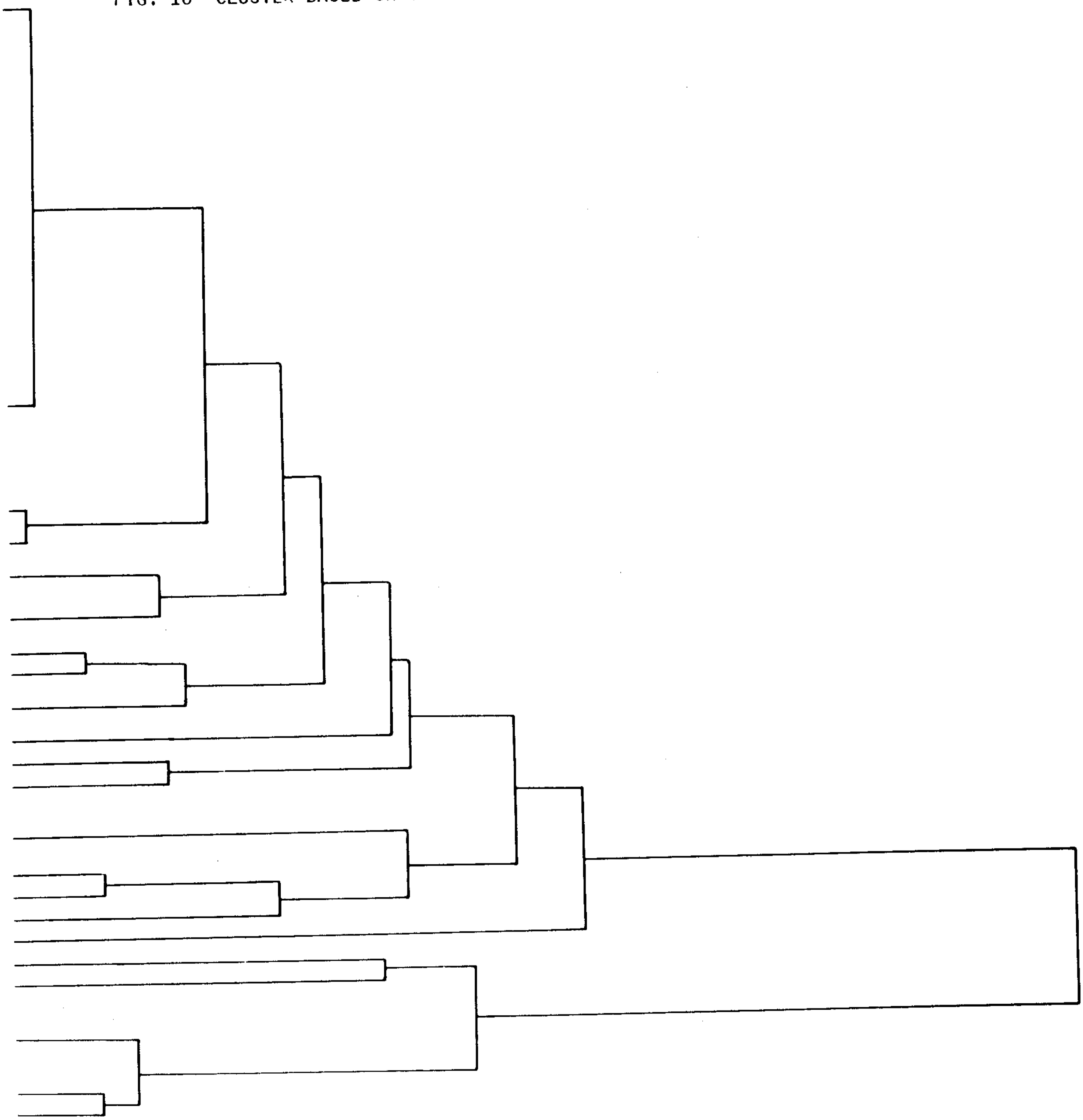
(THE FIRST AND THE SECOND PRINCIPAL COMPONENT PLANE)



Expectation of life(male)
Expectation of life(female)
Number of physicians per capita
Calorie intake per capita per day
Protein intake per capita per day
Expenditure on social seculity per GDP
Cause specific death rate(heart diseases)
Number of hospital beds per capita
National income per capita
Number of telephones in use per capita
Number of cars per capita
Number of mail traffic per capita
Number of television receivers per 1000 inhabitants
Energy consumption per capita
Population rate of wholesale and retail trade field
Population rate of public and civil service field
Per cent of dwellings with tap water
Electric energy production per capita
Number of offences per capita
Civil aviation traffics of passengers per capita
Civil aviation traffics of goods per capita
Total export value per capita
Total import value per capita
International sea-borne shipping per capita(exported)
Per cent of dwellings with flush toilet
Revenue per capita
Cause specific death rate(cerebrovascular disease)
Economically active population ratio(male)
Marriage rate
Circulation of daily newspapers per 1000 inhabitants
Number of radio receivers per 1000 inhavitants
Expenditure on education per GNP
Railway traffics of goods per capita
Economically active population ratio(female)
Index number of GDP per capita
Number of scientists and engineers per capita
Railway traffics of passengers per capita
Paved road rate
Number of production of scientific books per capita
International sea-borne shipping per capita(exported)
Enrolled students in higher education rate(male)
Enrolled students in higher education rate(female)
Latitude
Annual attendance to cinemas per capita
Divorce rate
Number of unemployed per capita
Area per capita
Population
Death rate
Population rate of agriculture and fishing field
Cause specific death rate(tuberculosis)
Birth rate
Infant mortality
Engel's index
Illiteracy rate

FIG. 10

FIG. 10 CLUSTER BASED ON THE 1960'S DATA.



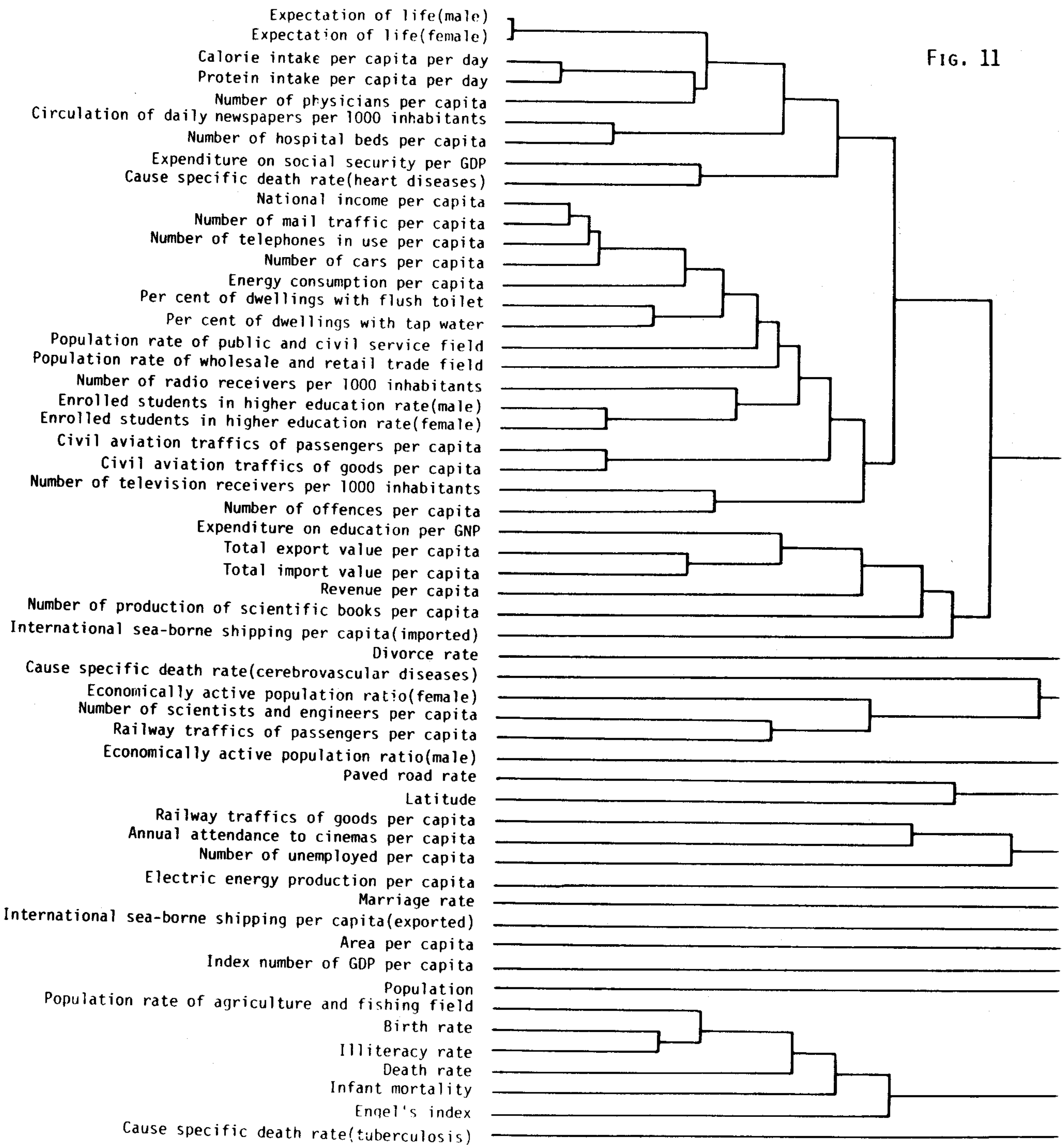
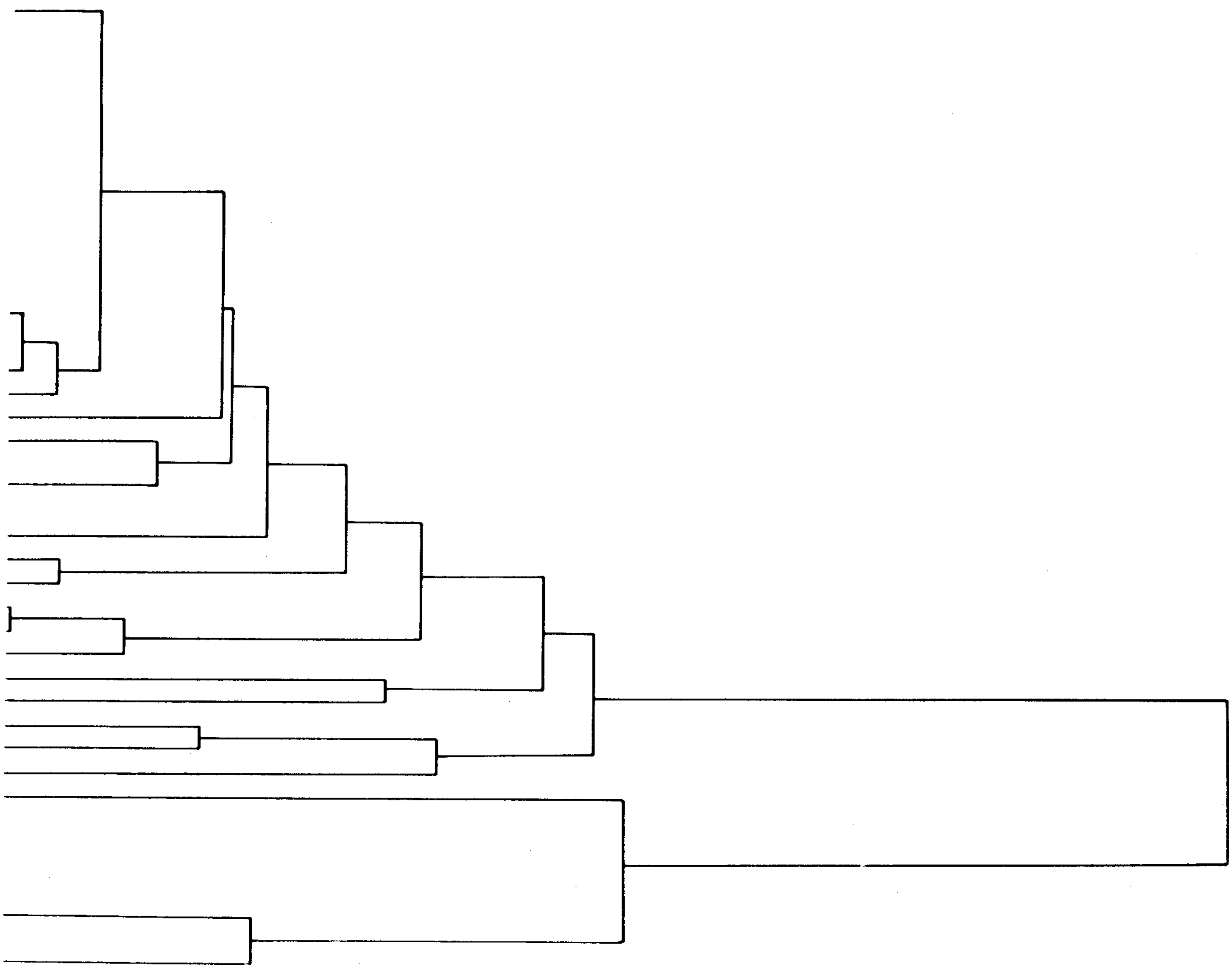

Expectation of life(male)
Expectation of life(female)
Calorie intake per capita per day
Protein intake per capita per day
Number of physicians per capita
Circulation of daily newspapers per 1000 inhabitants
Number of hospital beds per capita
Expenditure on social security per GDP
Cause specific death rate(heart diseases)
National income per capita
Number of mail traffic per capita
Number of telephones in use per capita
Number of cars per capita
Energy consumption per capita
Per cent of dwellings with flush toilet
Per cent of dwellings with tap water
Population rate of public and civil service field
Population rate of wholesale and retail trade field
Number of radio receivers per 1000 inhabitants
Enrolled students in higher education rate(male)
Enrolled students in higher education rate(female)
Civil aviation traffics of passengers per capita
Civil aviation traffics of goods per capita
Number of television receivers per 1000 inhabitants
Number of offences per capita
Expenditure on education per GNP
Total export value per capita
Total import value per capita
Revenue per capita
Number of production of scientific books per capita
International sea-borne shipping per capita(imported)
Divorce rate
Cause specific death rate(cerebrovascular diseases)
Economically active population ratio(female)
Number of scientists and engineers per capita
Railway traffics of passengers per capita
Economically active population ratio(male)
Paved road rate
Latitude
Railway traffics of goods per capita
Annual attendance to cinemas per capita
Number of unemployed per capita
Electric energy production per capita
Marriage rate
International sea-borne shipping per capita(exported)
Area per capita
Index number of GDP per capita
Population
Population rate of agriculture and fishing field
Birth rate
Illiteracy rate
Death rate
Infant mortality
Engel's index
Cause specific death rate(tuberculosis)

FIG. 11

FIG. 11 CLUSTER BASED ON THE 1970'S DATA.



Genetic Engineering: Current State of the Art and Long Term Prospects

A. M. Chakrabarty

Genetic engineering is the deliberate modification of genes of prokaryotic or eukaryotic organisms to produce a useful product, that is to cause a permanent change in the hereditary make up of a cell to cure an inherited disease, i.e., to make the cells grow faster, and become resistant to harmful chemicals or environmental factors. Recently, considerable attention has been drawn to the development of techniques that allow stable incorporation of genes from the prokaryotes and eukaryotes into other prokaryotes and eukaryotes through use of bacterial plasmids, phages or defective animal virus genomes as vectors (1, 2, 3). In this short article, I would like to deal mainly with the techniques of recombinant DNA, and the application of recombinant DNA technology in the biomedical and pharmaceutical industries, where considerable progress has already been made. The potential application of genetic engineering techniques in agriculture, food processing, chemical and energy-related industries and in genetic therapy has been evaluated before (4, 5) and will not be discussed here.

Methodologies of the Recombinant DNA Techniques

The recombinant DNA technology allows the incorporation of a fragment of DNA containing several genes from prokaryotes or eukaryotes into a vector that could be a bacterial plasmid, a phage genome or a defective plant or animal virus genome. The chimeric DNA can then be introduced into an appropriate host tht could be either bacterial, yeast, plant or mammalian cells. Hybrid vectors consisting of both animal virus genome and bacterial genetic segments for appropriate selection purposes have also been used (6). Usually the host cells are quite specific for the respective vectors, although vectors capable of replicating both in bacterial and mammalian cells have also been described (7).

The first step in combining the vector DNA and the foreign DNA is to isolate them in pure states. For higher eukaryotic organisms, where the DNA may have intervening segments (introns) that interrupt the continuity of a functional gene, the functional gene is obtained in the form of complementary DNA (cDNA), by isolating first the messenger RNA (mRNA) and subjecting the mRNA to reverse transcription by avian myeloblastosis virus reverse transcriptase followed by DNA polymerase I and S1 nuclease treatment. The addition of polymers of homologous deoxynucleotides to the 3'-OH end of the resultant double-stranded DNA with the use of the enzyme deoxyribonucleotidyl terminal transferase allows the formation of the desired gene with a polydeoxynucleotide homologue (poly dA for example, a homopolymer) at the 3'-OH end. The vector DNA is then linearized by treatment with a restriction endonuclease and a second homopolymer (poly dT for example) that is complementary to the one present at the 3'-OH end of the cDNA is introduced at the 3'-OH end. The vector with a poly dT tail and the cDNA with a poly dA tail are then mixed and annealed to form a heterogenous population of hybrid DNAs. Transformation or transfection of the host cells with such hybrid DNA selecting for the appropriate character of the foreign DNA or the vector (or insertional inactivation) will allow the recovery of host cells containing the cloned foreign DNA.

An easier and often used method of cloning foreign genes is by restriction of the enzyme treatment of the vector and foreign DNA followed by ligation of the fragments by E. coli or phage T4-induced ligase. A large number of restriction enzymes can be used to eliminate the probability that the foreign gene may have a site for the restriction enzyme and therefore can be inactivated when cloned. Precaution must be taken to use only those restriction enzymes where the enzyme-induced cut in the target gene will not interfere with the biological activities of the gene(s) to be cloned or the replication, maintenance or the selectable characters of the vectors. Efficient ligation in this instance depends upon the staggered cuts introduced by the restriction enzymes. The cohesive termini can be joined by H bond formation during annealing at low temperature, which is then covalently closed by the ligase.

A third, and rather infrequent, method of joining the vector and foreign DNA is the flush-ended joining catalyzed by phage T4-induced enzyme ligase. Such enzyme-catalyzed ligation is inefficient and the yield is poor. Because the DNA fragments do not need any cohesive termini, it is a very useful method for combining DNA fragments that do not have protruding ends, such as fragments produced by restriction enzymes that make flush-ended cuts or fragments produced by two different restriction enzymes having different single-stranded ends. Such single-stranded regions can be removed by digestion with S1 nuclease and the DNA fragments joined by this method.

Application of the Recombinant DNA Technology

The ability to introduce DNA from any source to bacteria, yeast, or mammalian cells and their continued replication and functional expression allows the production of entirely novel compounds by such cells. The initial observation that eukaryotic genes are not functionally expressed in bacteria prompted the construction of expression vectors, that allow expression of eukaryotic genes in bacteria (8). Thus production of many pharmacologically-active animal proteins, whose synthesis is stringently regulated in animal cells, in bacteria may allow such proteins to be used in health care industries and medicine. Similarly replacement of a defective gene from the chromosome of an animal, including human beings, with a functional counterpart may help in permanently curing many instances of hereditary genetic defects. The simplest applications obtained to date, however, relate to the elaboration of protein products in bacteria that are normally produced by animals in very small amounts. Notable among these are somatostatin, insulin, human growth hormone, interferons and a variety of viral surface antigens as vaccines. In addition, the successful insertion of foreign DNA in mammalian germ line cells, their continued propagation and the tissue-specific expression of such genes may open up possibilities of not only breeding agriculturally important animals, but also of their application in the area of human gene therapy.

Production of Somatostatin and Insulin

Somatostatin, a small polypeptide hormone of 14 amino acids, used in acute pancreatitis and insulin-dependent diabetes, is the first hormone to be produced by a genetically-engineered bacterium (9). Instead of the usual methods of isolation of a gene, the somatostatin gene was synthesized chemically from its known amino acid sequence, using those trinucleotide condons that are known to be favored in E. coli. An additional methionine condon was introduced before the first amino acid condon to facilitate cleavage of the polypeptie by cyanogen bromide. Because somatostatin does not have any methionine residue, the cyanogen bromide treatment does not cleave the polypeptide any further. The syntheic somatostatin gene fragment was cloned in a hybride pBR322 vector containing the EcoR1 fragment of plac5 which retained the lac operon control region and most of the lacZ structural gene. The orientation of the lacZ fragment containing the somatostatin gene was found in some cases to be such that the proper reading frame for these two genes was maintained. One colony having such a cloned gene produced a hybrid β-galactosidase-somatostatin polypeptide during growth in the presence of an inducer of the lac operon. Such a hybrid protein did not demonstrate radioimmune activity before cyanogen bromide treatment, but demonstrated considerable activity after cleavage.

The method of chemical synthesis of a eukaryotic gene for cloning in bacteria overcomes many of the inherent problems associated with gene cloning in bacteria (10). Total synthesis of a gene gives directly the exact desired sequence, the coding sequence and the non-coding sequence can be designed at will for prokaryotic expression, restriction sites can be built in or removed, and introns deleted. It also bypasses the need for isolation of the specific gene or the mRNA, and allows a study of the effect of selective addition or deletion of nucleotides (or trinucleotide sequences corresponding to specific amino acids on the proteins) on the biological activity of the polypeptide product.

An essentially idential chemical synthesis method was also used for making insulin by E. coli. Insulin, which is used extensively for diabetes treatment, is a polypeptide with two chains, A and B. The immediate precursor of insulin, called proinsulin, contains the two insulin chains A and B, connected by another peptide C. The translation product of insulin mRNA is not proinsulin, but a polypeptide containing a signal peptide of about 23 amino acid residues on the amino terminus of proinsulin, called preproinsulin. During mobilization of the entire preproinsulin molecule through the endoplasmic reticulum, the signal sequence is cleaved producing the proinsulin molecule. During subsequent processing, the C peptide is eliminated from the middle, producing the insulin molecule.

In the chemical synthesis of the insulin gene, the genes for human insulin, the A chain and the B chain, were designed from the known amino acid sequences of the human polypeptides. The genes were then separately fused to E. coli lac Z gene on the plasmid pBR322, which on propagation in E. coli produced the A chain and B chain polypeptides as β-palactosidase hybrid peptides. Because human insulin has no methionine residues in the amino acid sequence, the A and B chains could be obtained by cyanogen bromide cleavage of the hybrid polypeptides. After the separate production and purification of the A and B chains, active human insulin was obtained by in vitro formation of the correct disulfide bonds between A and B chains (11 and 12).

A different method for insulin production utilized the ligation of the cDNA copies of rat preproinsulin mRNA at the unique PstI endonuclease site of the plasmid pBR322 that lies in the region encoding amino acids 181-182 of penicillinase (13). The ligation of the cDNA copy of the rat insulin mRNA into the penicillinase gene of the plasmid pBR322 led to the formation of hybrid DNA molecules that were functionally expressed to fused proteins carrying the antigenic determinants of both insulin and penicillinase. Such fused proteins were secreted into the periplasmic space, enhancing the yield and ease of isolation of the insulin molecules (13).

A third method of insulin production has utilized the total synthesis of a 277 base pair long sequence that includes the DNA sequence coding for human proinsulin (10). The human proinsulin DNA sequence was derived from the known amino acid sequence by use of the genetic code, and utilizing the knowledge of the rat proinsulin DNA sequence.

Production of Human Growth Hormone

A combination of chemical synthesis and cDNA cloning has been used for production of human growth hormone. Human growth hormone (HGH) is a protein consisting of 191 amino acids with a molecular weight of nearly 22,000. It is essential for linear growth, and is also deemed effective in the treatment of other disorders including bone fractures, burns and bleeding ulcers. Because the growth hormone is species specific, the only source of HGH used to be human cadavers. The production of HGH in E. coli by the application of recombinant DNA technology has provided an inexhaustible source of this very important protein. A 77 base pair fragment containing coding sequences for HGH amino acids 1-23 was synthesized chemically. A 512 base pair fragment obtained by cDNA cloning of the HGH mRNA and containing the coding sequences of the rest of the molecule (amino acids 24-191) was then ligated to the 77 base pair fragment and the entire segment was cloned in E. coli with an expression vector pGH6. On transformation into E. coli, the recombinant molecule allowed production of a protein that had growth promoting activity as potent as authentic pituitary-derived HGH in hypophysectomized rats (14). The bacterially produced HGH also had the same activity as the pituitary-derived HGH in promoting tibial growth in rats. Recent clinical trials indicate high potency of the bacterially-derived HGH in the treatment of human patients.

Production of Interferons

Interferons are a family of proteins which are believed to have antiviral and possibly antitumor activity (15), inducing viral resistance in target cells and inhibiting tumor cell proliferation and modulating immune response. Human interferons have been grouped under 3 major classes: α , β and γ . The α-interferons (IFN- α) are encoded by a family of genes consisting of a dozen or so of non-allelic member (16) and are derived from leykocyte cells. Interferon β (IFN- β) is produced mostly by fibroblast cells and resembles IFN-α in virus-induction and acid stable properties. Both of these interferons have been purified to homogeneity and partial amino acid sequences were determined. IFN-γ , on the other hand, is generally produced in cultures of lymphocytes exposed to various mitogenic stimuli, is acid labile and does not cross-react with antisera prepared against IFN-α or IFN-β. The antiproliferative effect of IFN-γ on transformed cells has been reported to be much higher than that of IFN-α or -β, suggesting its effectiveness in cases of neoplasia, such as the antitumor activity mouse sarcomas (17).

The cDNA cloning of both IFN-α and IFN-β has been accomplished (18 and 19). The bacterially-produced IFN- α preparations have variously been demonstrated to protect squirrel monkeys from a lethal dose of encaphalomyocarditis virus infection (20). Another IFN- α preparation, $\alpha 2$, made by cDNA cloning in E. coli has also been shown to have comparabe effect as the buffy-coats leukocyte interferon in protecting rhesus monkeys from vaccinia virus infection, but had much fewer side effects, at least in the rhesus monkeys (21). The prospect for successful clinical trials of bacterially-made interferon for protecting human subjects against certain viral diseases therefore appears good. Another interesting development is the total synthesis of a 514 base pair fragment of double stranded DNA coding for human interferon-α1 (22), which is functionally expressed in bacteria such as E. coli or Methylophilus Methylothrophus (23). Since hybrid interferons formed by cleavage at a common restriction site allowing fusion of the N-terminal sequence from one gene with the C-terminal sequence from another are now available, a large pool of synthetic interferon fragments will allow the convenient synthesis of a variety of hybrid interferons. Thus, in addition to a range of natural IFN-molecules with their different pharmacological properties, a large number of hybrid interferons with a different set of properties may soon be available for antiviral and antitumor activity tests.

The cloning of the immune interferon (IFN-γ) has recently been accomplished (24). The cDNA sequence for IFN-γ codes for a polypeptide of 166 amino acids, 20 of which appear to constitute the signal peptide responsible for secretion of the interferon. The human genomic IFN-γ sequence appears to have one or more introns, in contrast to IFN-α or -β, which contain no introns. Expression of this DNA sequence in E. coli and cultured monkey cells gives rise to a polypeptide having identical acid lability and SDS- sensitivity properties and the same immunological properties as authentic IFN-γ. Future clinical trials with such bacterially-derived interferon preparations will be very valuable in evaluating its antitumor properties.

Production of Vaccines

The Recombinant DNA technology offers exciting opportunities for vaccine preparation in abundant quantities and low cost because of the bacterial production of surface antigenic proteins against a large number of viruses. Normally vaccines are prepared from attenuated viruses grown in cell cultures (25). Such a process is not only expensive, but it is also hazardous because of the pathogenic nature of many viruses. Because vaccine production requires only the surface antigenic determinants of the virus, any method that selectively allows the propagation of only the surface antigens instead of the intact virus in bacteria, is very valuable for a continued supply of the vaccines. The recombinant DNA technology has been employed to generate surface antigenic determinants against such viral diseases as hepatitis B, foot and mouth disease, influenza, etc. Some forms of hepatitis and hepatocellular carcinoma (liver cancer) are caused by the virus hepatitis B and a vaccine, produced from the 22-nm particle form of hepatitis B surface antigen (HBsAg), has been found to be effective in clinical tests (25). Such a vaccine has, however, been derived from the sera of chronic carriers, and is, therefore, obtained only in limited quantity at high cost. It has been possible to clone the genes for both the core and surface antigens of the hepatitis B virus in E. coli (26). Only small amounts of such antigens are normally produced in E. coli. Using an expression vector that employs the 5'-flanking region yeast alcohol dehydrogenase I as a promoter, the cloning of the HBsAg gene in the yeast saccharomyces cerevisiae has led to the production of the antigenic proteins that assemble into particles similar to the 22-nm particles secreted by human cells (27). These 22-nm particles are known to be about 1,000 fold more immunogenic than the unassembled HBsAg protein. Thus, not only complex structural features such as the 22'-nm particles can be produced in simple eukaryotic hosts such as yeasts, but microbial production of such viral particles of high immunogenicity emphasizes the value of such particles as potential vaccines against hepatitis B infection. The complete absence of intact hepatitis B viruses and/or human proteins in such preparations eliminates the possibility of secondary infections or auto immunity problems as a result of the vaccine.

Another disease for which vaccines would be tremendously useful is foot and mouth disease. This is a viral disease affecting cloven-footed animals such as some domestic and wild ruminants and swine. Although vaccines are presently available, the disease is widespread in essentially all the continents except Austrailia and North America and conventional vaccine preparation methods are somewhat ineffective because several strains of the virus cannot be grown to a titer high enough to provide sufficient antigenic mass for effective vaccination, as well as the fact that the virus is unstable, particularly below pH 7.0, so that the vaccines must be stored under refrigeration all the time. Improper inactivation of the virus has also caused problems in vaccination in the past (28). It is therfore highly desirable to use the antigenic determinant of the surface proteins, particularly the protein VP1, which is known to cary the eptitopes inducing neutralizing antibodies. The gene corresponding to VP1 has been cloned in E. coli by several groups (29 and 30) and the gene has been shown to be expressed functionally in E. coli to produce the VP1 protein with neutralizing activity against the virus. The prospect for the development of a cheap and effective vaccine against foot and mouth disease virus thus appears good.

Application of the recombinant DNA technology has also allowed nucleotide sequences of various genomes, including the genes specifying many of the surface antigenic proteins, to be determined from which the primary amino acid sequence of VP1 and portions of others such as HBsAg have been deduced. Using computer analyses of the amino acid sequence and physical arrangements of major surface antigenic polypeptides obtained from different viral serotypes and measurements of immunogenic activity of enzymatically or chemically-derived fragments of these polypeptides, it is now possible to predict the portions of the polypeptides that may retain the antigenic specificity (31). Such short polypeptides may then be synthesized chemically, coupled to carrier protein, and used to elicit antibodies against target viruses or toxins. Synthetic peptides eliciting antibodies against hepatitis B viruses in mice after a single injection (32). Similarly, chemically-synthesized peptides corresponding to two different regions of the VP1 polypeptide of foot and mouth disease virus have been shown to produce high levels of a serotype specific virus neutralizing antibody in cattle, guinea pigs and rabbits (33). A single innoculation of one of these peptides (141-160 peptide) protected guinea pigs against subsequent challenge with the virulent virus. Production of vaccines against other human viruses such as the influenza virus also appears to be feasible in the near future since cloning of the major antigenic determinant of such a virus in E. coli has demonstrated functional expression of such a gene to produce the haemagglutinin in E. coli cells (34).

Future Prospects for Genetic Engineering

It thus appears that application of genetic engineering techniques has been and will continue to be very useful in making valuable drugs and pharmaceuticals that have only been obtained in limited quantities and at high cost by conventional techniques. Obviously, such applications are not limited to only drugs and pharmaceuticals, but can be extended to areas such as agriculture, energy, heavy industry and chemicals, and possibly to permanent cures of some inherited genetic diseases (4). It should be emphasized that although this article has dealt with only those areas where techniques in genetic engineering have been used for practical purposes, the real thrust of this technology has been in enhancing our knowledge of the basic sciences, mainly in the area of understanding the molecular and genetic basis of eukaryotic gene structure and expression. Such understandings will inevitably help in our attempts to apply this knowledge in problem solving. For example, the application of recombinant DNA techniques has allowed the introduction of genes from one animal species to another, leading to the production of important biological proteins in novel animal cells. The complete chromosomal mouse β^{maj} globin gene, including its intervening and flanking sequences, has been cloned in the monkey virus SV40. The mouse gene is transcribed, processed and translated in infected monkey kidney cells to yield mouse β-globin (35). Similarly, the human β-interferon gene has been cloned in mouse fibroblast cells which produces the human β-interferon protein under the same regulatory conditions, i.e., the protein is inducible by poly (I), poly (C) (36). Essentially identical expression of human interferon β1 gene has also been observed in mouse and rabbit cells (37). Thus various human and animal genes are now known to be expressed in other animal cells. What is exciting is that such foreign genes are not only functionally expressed, but the cloned genes can be transferred into germ-line cells with subsequent transmission of that gene to offspring. Thus rabbit β-globin gene has been introduced into the germ-line of mice, where such DNA was found in one case to be integrated in the middle of one of the homologues of chromosome 1 (38). The rabbit β-globin gene sequences were also found to be transferred to the progeny on mating. Similarly fertilized mice eggs injected with cloned human β-globin genomic region demonstrated the preservation of such sequences in adult cells. Such sequences were also found to be transmitted to the progeny, again confirming that it is possible to introduce entirely foreign DNA to animal cells for maintenance and transmission as a heritable character (39). If cloned foreign genes are found to be functionally expressed in a correct temporal and tissue-specific pattern, it would not only raise exciting possibilities of introducing functional genes to alleviate the genetic deficiencies in human suffering from in born errors of metabolism, but it would also open new ways of breeding agriculturally important genetically superior animals.

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C. William Birky, Jr.

Being a geneticist, I'm going to address Dr. Chakraberty's talk and I think first of all that his talk illustrated that in a certain sense, genetic engineering and gene-therapy techniques are very much like any other kind of technology. The more powerful the technology, the more efficient it is, the more control it gives us over our environment and, in this case, possibly, over ourselves as well. Also, the more potential there is not only for good but also for evil or for bad effects as well. In this sense, I don't believe that recombinant DNA technology, genetic engineering, is vastly different from anything else. We faced this sort of problem when we brought in atomic energy. We faced the same sort of problems with the beginning of the industrial revolution.

Now, genetic engineering and gene-therapy techniques, especially as applied to human beings, do in some people's minds raise some new kinds of ethical issues. These are raised primarily by medical applications to man. Suppose, for example, that we have a person who has sickle trait or sickle cell anemia and we wish to cure that person of the disease by altering one of his genes and changing it to the normal gene or substituting the normal gene for it. In a certain sense, I don't see this as being really very different from heart surgery where we change the person's heart to cure a disease, or neurosurgery where we operate on the brain to relieve a persistent pain or something of that sort. Surgery also was criticized by people. Some people said, "Well, when you go in and operate on the brain, you are violating the person's soul." Other people said that for heart operations or bowel operations or wherever you happen to believe the soul resides.

In his keynote speech, Dr. Atsumi suggested that when we change a person's genes, we are somehow violating that person's integrity. This comment has been made very often - many people have suggested this. I don't see a person's integrity as residing any more in the person's genes than it does in his brain or his heart or his big toe, for that matter. A person's integrity - if there is any meaning to that term at all - is a function of the individual as a whole and operations on genes, in this respect, are not really very different from operations, modifications of any other part of the individual.

There is perhaps a little bit different problem when we talk about altering the genes in the eggs or the sperm so that we are now affecting not just the individual himself or herself, but we are also affecting that individual's descendants. My colleague, Dr. John Burnham, mentioned to me the other day that we hold our genes in trust for our descendants - for our children and grandchildren - and it behooves us to be very careful with that trust and what we transmit to them. That is quite true.

We also hold our environment in trust for our offspring and for our grandchildren and our great-grandchildren, and many of us feel very strongly that we should try not to pollute our environment and preserve it in good shape for them. This does not mean, however, that we don't touch it. This does not mean that we go back to the age of Rousseau and return to nature.

In fact, it is perhaps instructive to ask what happens to an altered gene in a person. How long is it actually going to affect that person's progeny? To begin with, if you alter a gene in a person, establishing a new gene in an individual, and that individual now has two children, there is one chance in four that he will not transmit that gene to any of his descendents - it will, in effect, die with the individual. Population geneticists can calculate about what would be the average lifetime and fate of a gene. The majority of all new genes, whether they would be human-made or arise by mutations, disappear from the population in time. And of those, if you have a population on the order of 150 million people, one can estimate that the average lifetime of a gene that is going to disappear is something on the order of twenty to thirty generations. Many of those genes, of course, will disappear immediately. Very rarely, a newly introduced gene will spread in the population and affect large numbers of individuals - in fact, it could spread to the entire population. The probability of that happening in a large population is less than one percent and may in this population be as small as one in one hundred and fifty million.

So, in general, it is instructive to stop and think a little about what population genetics can tell us about the fate of new genes. Hopefully, if we think something about this, and try to transmit this information to the public and consider it, we will be less frightened of the prospects of gene therapy and genetic engineering. Hopefully, the public as a whole will be, too. Put it in its proper perspective, I think it is not that different from other aspects of technology and medicine.

Robert McGhee

As an engineer, I am, of course, accustomed to working in the narrow and very concrete worlds of mathematics and physical science, and I have never ventured professionally into the arts or into the humanities. I feel somewhat uneasy with respect to my participation in this symposium, as was also expressed by Professor Araki, but for the contrary reason that I am overly acquainted with technology and have thought too little about its social implications. What I would really prefer to do then, if I had my own way, would be to pick out some very specific aspects of one of the speakers' presentations and ask him some very detailed questions about mathematical models, experimental methodology, component characteristics and so on. However, in the spirit of the Discoveries Symposium, and being inspired by Professor Mori, I would like to at least begin by raising some general issues, especially relative to Professor Mori's presentation.

First of all, there are obviously two distinctly different sides to human nature: the physical side and the spiritual side. One is inherent, the other is the product of experience and culture. It is generally acknowledged, even in the West, that man's spiritual revolution is incomplete and in fact that every man must travel his own independent path of development if he is to realize his full potential.

The question I wish to raise is the following: "Is it not also true that man's physical evolution is incomplete?" After all, we were all brought here by some kind of mechnical conveyance because our own limbs were not capable of moving our bodies with sufficient comfort and speed to permit us to assemble here. Does this not represent a type of prosthesis which extends our physical capabilities far beyond our natural range? We are meeting inside an air-conditioned and artificially lighted room with electronically amplified voices. Does this not reflect weaknesses in our bodies that were overcome by artificial means? Today we are more and more assisted by computers in dealing with vast amounts of information. It this not because of the physical organization of the human mind which suits it poorly to the processing of numerical data? Is the digital computer not yet another prosthesis to compensate for the inadequacy of our neuro-network hardware in this respect?

If you are willing to accept these ideas, then why should we be apprehensive about robots? Are they not nearly the next logical step in our physical evolution - as Mr. Reinfeldt characterized them, the physical extension of the digital computer? We have a saying in English that dog is man's best friend. Isn't it possible that robots may displace dogs? After all, the root of the very word robot implies subservience and service. I believe this possibility to be particularly applicable in the field of physical rehabilitation where the symbiosis of man and machine is especially close. Evidently, a person wearing an artificial limb or brace constitutes a single system that is partly human and partly mechanical. We tend to take for granted all that has been achieved in this area of medicine and frequently fail to note the great improvements in health care which have taken place in this field in recent decades. I myself believe that research in robotics will have a profound effect on artificial limb design in the future. And I am personally committed to working in this direction.

Yoichiro Murakami

In considering the role of discussant, it might be my obligation to mention the contents of the presentations of our three preceding eminent speakers. Because my academic background is the history of philosophy of science, I am not qualified to discuss the contents of the presentation in technical detail, so all I can do is look at the problem from a different point of view than medical experts. I would like to make a very brief comment not on what our speakers said but what they did not mention. The impact of advanced technology on our society can be discussed from various points of view even if we confine ourselves to the medical aspects. What I am going to point out here is an impact of advanced technology as a whole on civilization: psychological, in other words, an information medium on the mental - not physical - the mental health of the members of our society.

As you know well, certain chemical substances can induce the symptoms of mental diseases such as schizophrenia. Let me cite as an example an experimental report by Dr. Utanako, a former professor of psychiatry of the University of Tokyo and one of the leading scholars in that field in Japan. His report says that the continuous daily dosage of a certain amount of hydrochloric amphetamine to Japanese macaques may cause all symptoms of schizophrenia but another experiment done by Professor Ito Etaha, an eminent pathologist of the University of Osaka, and his colleagues teaches us that the informational, not material environment, can produce the very same effects among the Japanese macaques. Ito's group tried to prepare an informationally isolated environment for some newborn babies of Japanese macaques by separating them from their mothers at the very moment of their birth and keeping them within the individual cages as strictly isolated as possible. The baby apes were fed by automatically controlled milk machines and the keepers made it a custom when they had to come close to the cages to cover their faces by veil for fear that the apes should read various emotional expressions on their faces. The results were remarkable. The apes brought up in this way show the same symptoms as the drug I had formerly mentioned could induce. These two experiments mean that, in certain conditions, both physical substances or physical chemical substances and informational environment or milieu equally result in the mental alienation of macaques.

Of course, those were the cases of monkeys, but we can learn some lessons from them about human cases, particularly in the light of fully suggestive research. This research was carried out by Dr. Noda, a young and active Japanese psychiatrist, who investigated psychotic situations in Papua, New Guinea, for years. As you know, Papua, New Guinea, is a typical place that has been exposed to the influence of modern science and technology but the degree of the exposure varies from place to place. Even now, the exposure in the highland villages is not so much as in the shoreside villages because the pace of propagation of modern science and technology is very gradual in penetrating from the seaside to the mountain district. According to the observations of Dr. Noda, the ratios of the numbers of schizophreniac patients to the village populations apparently correspond to or co-relate with the extent of the exposure of modern science and technology. Dr. Noda told me that what mostly impressed him in Papua was the fact that he could find no patient of forty and above at all among the mountain villages.

Of course, we could be drawing a hasty conclusion from him from this observation, but what we are able to speculate is modern science and technology as an information medium or cultural climate may, I said, may, sometimes play a destructive role to the mental health of human beings. This might sound trivial when we count various favorable effects in medicine that have been and will be produced by advanced technology, but I can't help the feeling that we are strongly advised to take the other side of the coin, or rather the third side of the coin into consideration as well, so that we may realize the harmonized society that Dr. Atsumi impressively proposed in his keynote lecture.

Eduardo Caianiello

As you may know, Prometheus had a brother whose name was A-Prometheus. Prometheus means, from its Greek root, somebody who looks ahead. A-Prometheus, the brother is somebody who looks behind. And all questions to promethean people usually come from a-promethean people. I prefer to stay away from this context and propose, trying to enlist myself among the promethean people, a model for criticism. This motive came to my mind when just on the day that I was leaving Italy, I received the proofs of a paper which is going to appear in Cybernetics and Systems, made in conjunction with a colleague of mine who is an electro-chemical engineer. We had been working so much on communications aspects of the nerve system in animals that we had completely forgotten the other aspects, the energetics, of it all. So, it was our intention to see if we could possibly propose a model - a model is just a tool for provoking thought, it is not a description of reality - which would account both for the energy consumption in human beings or animals and for the communications aspects of it. We know that the brain, especially the outer part of it, is a big consumer of oxygen, out of proportion to everything else. We also know that if the supply of oxygen is stopped for a few seconds in the brain, death follows. But if the same happens in other parts of the body, there are permutations, other reactions which do not involve oxygen, which can function when we get needs for bursts of energy. But, without oxygen, the brain dies. Can there be a mechanism which accounts for both aspects: one, the creation of an almost static potential difference throughout the body, and two, whenever energy is released, strong energy consumption. Just think of the automobile. Batteries and things you need for turning on your radio exist. A similar mechanism exists in nature: that is the fuel cell. The standard battery, the electric battery, produces energy in the same way. The fuel cells have something that can be alkaline, say hydrogen on one side, something like oxygen on the other side and electrodes in between; as soon as continuous operation is stopped for a second, everything fades away. Under this assumption, we should find a possibly comparable mechanism. Suppose then that there are as many annodes as there are nerve endings. Suppose that from the electrical engineers point of view, forgetting all they know about communication, nerves and fibers are just electrical conductors. They have to be insulated. They are. And oxygen, which is one of the reactants, must be fully protected before it can reach the terminal goals in which the action has to take place. It is. It is incorporated into hemoglobin and when it meets with glucose, the reaction takes place. Glucose can be manufactured in many ways. So the overall picture is that of annodes distributed all around the body wherever there are nerve endings, and a central cathode which maybe should be the melangial variety, wherever there is a need for a continuous flow of some fluid to bring to appropriate nutrients. The role of the cerebrial spinal fluid has been and still is, I believe, to be merely mechanical, e.g., something into which the brain flows. Perhaps this underestimates the ability of nature. Perhaps, I say perhaps because I don't know any better, it is through this medium that the brain acts as the unique cathode so that the fuel cell mechanism is able to function. Suppose now what I said sounds to a degree similar to truth; we might discover some interesting consequences. Suppose something goes wrong in our neural connections, then what we need is just a by-pass. And this might explain, notably because there are many Japanese in the audience, in a very simple way what some think acupuncture undoubtedly does. It is said that we lose a hundred thousand neurals per day; these figures vary by factors of ten to a hundred according to the author you cite, but there may be no harm at all. Under stress, the brain, out of necessity, is jury-rigging something in the nature of organization; when a permanent circuit is established later on, elements which were used may be discarded. So, to throw out surplus neurals may just be a natural way of the functioning of the brain. What about yoga practices? Well, most of yoga is based on breathing techniques that increase the amount of oxygen that goes to the brain. So, the benefit one might derive from it may be attributable to the same cause that I am suggesting as the basis of this model. What is recharging a battery, for instance? Well, restoring fuel, sleeping. And what about the effects of alcohol? Well, ask engineers who deal with fuel cells. Alcohol leakage short circuits everything. Finally, I will say that some anesthetics such as ethelyn and psycopropolene are very reasonably produced. They may have exactly the same effect. Indeed, they are always used in conjunction with oxygen to counteract the excess of the possible negative action. Altogether you may feel that we were just forgotten, that engineers need some potential difference in order to talk about electricity which would be on the order of a million volts, no more than that. But without that, it would not make sense to talk about requiring the nerves to function differently as a means for exchanging information. This is the point I want to make. It is very easily digestible; to go further is not my job because I am a theorist. If true, it may well have bearing on the subject of the presentation which was human health.

Social Implications of Advanced Computer and Communication Technologies

David K. Hsiao

What Are the Advances in Computer and Communication Technologies?

The advances in computer and communication technologies are characterized by cost reductions, performance gains and capacity increases in hardware. For example, the complexity of the hardware that fits on a fixed-size chip doubles every year. In addition, the cost of a chip declines 28 percent with each doubling of manufacturing output. Chip storage quadruples every two to three years while the price per memory-bit declines 30 percent every year (see Figure 1).

- Semiconductor complexity doubles every year.
- Semiconductor costs decline 28 percent with every doubling of manufacturing output.
- Memory chip storage quadruples every two to three years.
- Memory bit-price is declining 30 percent every year.

Figure 1 - Semiconductor Technology Advances

There is a similar trend in the advances of magnetic disk technology used for mass storage. For example, the packing density of the disk is tripled or even quadrupled every five years (see Figure 2).

- Disk technology advances are realized by packing more bits in the same area.
- Current trend is triple or even quadruple the packing density every five years.
- Disk evolution also takes place via new product classes with different characteristics:
  - Moving-head disks,
  - Winchester disks.

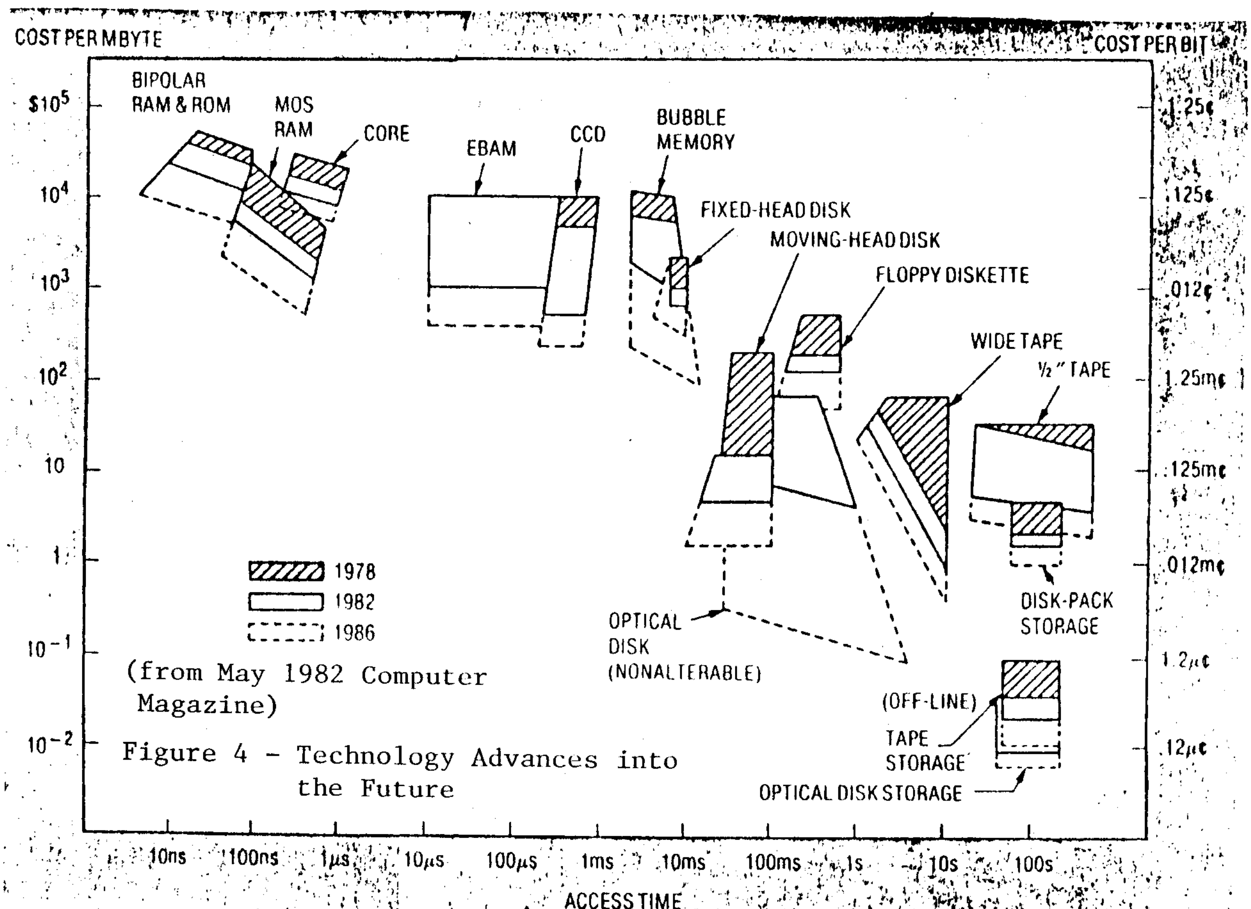
Figure 2 - Disk Technology Advances

In communications, the cost is no longer proportional to the distance of transmission. In fact, long-distance communications is expected to be cheaper and more efficient than short-distance ones. Furthermore, the distribution of computing power into either local or regional computer networks is becoming cost-effective (see Figure 3).

- Long-distance communications will be cheaper (may even be cheaper than short-distance ones)
- Local networks will be cost-effective and in vogue (e.g., the Ethernet development).

Figure 3 - Communication Technology Advances

Despite constant inflation, high-cost of production and general depression in manufacturing and production elsewhere, computer and communication technologies tend to dissolve the inflation constant, reduce the production costs even in depression (see Figure 4).



(from May 1982 Computer Magazine)

Figure 4 - Technology Advances into the Future

In addition to hardware advances, there are also software advances in computer and communication technologies. The presence of software in computer and communication systems enables the systems to be flexible and effective. By flexible, it is meant that the computer and communication systems are no longer designed narrowly for a specific application. Instead, with the help of software they can be flexibly adapted to cover a broad range of applications. Such flexibility can also be accommodated rather quickly. By effective, it is meant that it is easier to tailor a computer and communication system for intended applications and user requirements by employing new software on existing and new computer and communication hardware. Recent advances in software engineering allow the design and production of software packages and systems as an engineering endeavor. In other words, we begin to have the right tools to design, specify, and produce programs in a systematic and verifiable way so that the programs produced are the programs intended. We also have better handles on the performance and reliability of the software. The change of program production from an art to an engineering discipline permits us to build more sophisticated and more diverse computer and communications systems (see Figure 5).

- Hardware - Cost Reduction, Performance Gains and Capacity Increases
- Software - Engineering Methodologies, Program Sophistications and System Flexibilities

Figure 5 - Characteristics of Computer and Communication Technology Advances

Because of the advances in hardware and software, computer and communication systems are in widespread use, both for fun and work. Unlike other industries - such as the automobile industry where the product, namely automobiles, are focusing on a particular area of utilization, i.e., transportation - computer and communication affects many areas of human activities, both for work and fun. Because they are fun, they can reach us at the early stages of human development. Whereas an automobile driver must be at least 16 years old, computer games can be played by children in kindergarten. Computer and communication systems also affect our work. Not only do they change the way we work, they also alter the nature of the work itself. The question is whether the advances in computer communication will have a continuing and more profound impact on our fun and work in years to come. This question is closely related to the question of whether the hardware and software advances in computer and communications have reached their logical and physical limitations. If they have reached their limitations, then their impact on our fun and work will not be important. On the other hand, if they continue to advance in terms of cost reductions, performance gains, capacity increases and sophistication, then the impact will be more profound; it may even be overwhelming. As a technologist and scientist, may I say that the advances in computer hardware and software and in communications will be such that the future prospects of utilizing these advances for fun and work will be exceedingly promising and rewarding.

The Nature of Computer and Communications Technologies

The impact of the computer and communications technologies are not due solely to their advances in cost reduction, performance gains, capacity increases and sophistication. The profound impact on all walks of life and the widespread applications to fun and work are also due to the nature of the computer and communications. Unlike other modern discoveries - such as petroleum, a source of energy for consumption - a computer and communication system serves as a means of information and control (see Figure 6).

- It is not a mere source of energy for consumption.
- It is a means of information and control.

Figure 6 - The Nature of Computer and Communications Technologies

Because of the important role of information and control in all phases of human endeavors, the impact of the computer and communications technologies is keenly felt. It is through the acquiring of information, the processing of information, the utilizing of the processed information and the controlling of acquired information that a modern organization can forge ahead. For the first time, the information becomes a source of "energy" for "consumption." Unlike other energy for consumption based on physical resources such as minerals, the information as a source of energy for consumption is based on knowledge and expertise. By utilizing knowledge and expertise, the modern organization views a computer and communications system as a data utility to provide effective use and control of its knowledge and expertise. Without the accumulation of knowledge and expertise, modern organizations cannot survive. Computer and communications systems are the most effective and rapid means for control and communications. Consequently, every modern organization can be considered as a central data utility, although different organizations tend to utilize certain types of data, accumulate certain knowledge and develop certain expertise with its own computer and communications system (see Figure 7).

A computer and communications system is to be viewed as a data utility to provide effective use and control of its knowledge expertise.

Figure 7 - Data Utility

From this point of view, computer and communications technologies are also the most effective and rapid means to advance knowledge and expertise for modern organizations (see Figure 8).

Rapid and Effective Utilization and Control of knowledge and expertise are the requirements of a modern organization.
Computer and Communications systems can meet the requirements.
Figure 8 - The Requirements of a Modern Organization

Impacts of the Computer and Communications Technologies on Our Ways to Accumulate Knowledge and to Develop Expertise

The use of computer and communications systems for the accumulation of knowledge and for the development of expertise has altered the traditional preparation of knowledge and development of expertise. For example, the use of computer-aided instruction and telecommunication-based conferences has prompted computer-driven and self-paced studies. The absence of face-to-face lectures and in-class lecturing tends to create a university without walls and instruction without classrooms. Furthermore, with continuing reduction in cost, gains in performance, increase in capacity and sophistication, the computer and communications system for instruction will reach far and wide. The traditional roles of teachers, instructors and professors will change. Instead of one-to-many, direct instruction by educators, computer- and communications-based educational systems will consist of mostly message-oriented interactions between systems and students, and between instructors and the systems. For the first time, computer and communications systems will become the media by which materials for instructors are developed by the experts. They also will become a resource of knowledge-based systems for instruction. Finally, they will be active around-the-clock for drill and practice, for learning scenarios and for intelligent exercises by the students.

Learning and instruction via computer and communicationsn can provide a lifetime of continuing education. Thus, homes become campuses; experts in one discipline may become students of another discipline. The delineation of teachers and students will not be clear; the difference between a formal and informal education may also become fuzzy.

Similar to learning and education, computer and communications systems will impact our working schedule and habits. A computer and communications-based organization commonly has terminals or even small computers at the workers' homes. Because these computers or terminals are in turn connected to the central computer through a communication network, the home becomes an extension of the office. It is entirely possible that some of the most productive work is done in the home, particularly if the work involves decision making. Working habits may also change because it will be difficult to maintain the traditional nine-to-five office schedule since the necessity to go to the office becomes rare. With electronic files, word processing facilities and electronic mail at the hands of the workers via their terminals at home, perhaps more flexible working schedules and habits can be developed. Such flexibility can affect the workers' mobility and concentration. Although professionals may change companies and employers, they would not have to be relocated, because electronic access to different parts of the United States or even other countries is rather straightforward. All one needs is the support of a computer and communications system (see Figure 9).

With the availability of computer and communications systems, perhaps the routine work such as payroll and inventory may be taken over by these systems. This tends to make human workers available for more intelligent and challenging work. One can no longer find comfort in one's routine work;

- Computer-driven and self-paced studies
- University without walls
- Classrooms without instructors
- Homes as campus
- Experts vs. students
- Informal vs. formal education
- Specialization vs. generalization

Figure 9 - Preparation for Knowledge and Development of Expertise

instead, modern workers will have to find excitement in one's non-routine work. One such non-routine work and new challenge is to make sure that computer and communication technologies are properly utilized for doing all phases of routine work so that they become electronic slaves of the human masters. Otherwise, we may become the slaves of electronic systems. The ultimate goal is to utilize computer and communications systems to provide data utilities for the accumulation of knowledge and the development of expertise for human users. In other words, computer and communications technologies should impact us so that we will gain intellectually (see Figure 10).

- Homes as office extensions
- Flexible work schedules
- Modes of working
- Workers' mobility and concentration
- No routine work
- More challenging work

Figure 10 - On Being Experts

Social Implications of Advanced Computer and Communications Technologies

Speculation on the social implications of advance computer and communications technologies can best be left to the social scientists. As a computer and communications scientist and technologist, my speculation on social impact has its built-in bias and narrowness: I think computer and communications technologies will impact us profoundly. They may represent the most important industrial revolution that will elevate us from doing routine and tedious work. They will further prompt us to become well-learned individuals. And finally, they will force us to sharpen our minds and intelligence. I think our society will be more democratic if information sharing and control can be readily distributed and widely disseminated. Knowledge and expertise will be more easily developed by a larger number of people rather than restricted to a few. Although the educational process and training will be less formal, specialization will be more easily accomplished by using electronic means. Home work-station and other computer communication means will enable a person to change jobs without relocation. It will be easier for individuals to change careers through electronic, self-paced retraining and education. The mobility of workers from the countryside to the city, from the North to the South, from inland to the coasts and from one continent to another may not be necessary because we could reach there electronically. Perhaps we will have more intelligent, better educated, and better trained workers distributed all over. Perhaps there will be few companies and organizations in the traditional sense of having an army of full-time workers. Instead, workers with the computer and communications means may serve many companies and organizations as experts very much like a consultant to several organizations. For the first time, the centers of activities and the focus of the work will be individuals rather than organizations (see Figure 11).

- Implications will be early and profound through fun and work
- Implication will affect both large and small organizations
- Implications will change the structure of organizations and society

Figure 11 - The Social Implications of Advanced Computer and Communications Technologies

In the future, society may consist of faceless and sexless individuals behind the computer and communication means. They will relay messages, perform work and utilize information without revealing themselves personally and directly. We may even insist that our electronic slaves, namely, the computer and communications systems, pay taxes in addition to doing the routine work for us. Thus, we may be able to replace the human income tax with an electronic slave tax. We may even use computer graphics to do our drawings and computer communications systems to display and market our drawings. Such a drastic and far-reaching impact on society will be difficult to envision at this point, because the advances in computer and communications technologies have just begun. The most important question I would like to ask is whether the technology advances and their impact on the society produce a more humane society of the future.

Computer Technology, Skill and the Structure of Work

Harley Shaiken

At first glance, there appears to be an enormous contrast between the Chrysler Corporation's Jefferson Avenue plant, an aging assembly facility built in 1907 on Detroit's now deteriorating east side, and the John Hancock Building, a gleaming glass and steel skyscraper near one of Boston's poshest neighborhoods. Inside, however, new forms of automation, based on computers and microelectronics, are being used to transform both. At the Jefferson Avenue plant, robot welders perform 98 percent of the welds on new car bodies automatically, while at John Hancock, word processors and other electronic office technologies are laying the basis for a restructured office. The exploding technical capabilities of these new machines and systems combined in many cases with their plummeting costs are extending automation to every sector of the economy.

The rate of introduction, despite the current weakness of the economy, promises to be very rapid. General Electric, for example, predicts that by 1991 the annual market for factory automation will be $29 billion.[1] Predicast, a Cleveland-based consulting firm, projects the 1990 market for office automation at $16 billion a year.[2] While there is little doubt that the workplace is being profoundly altered, the real questions concern the nature of the transformation, the social cost involved, and who will pay these social costs.

The widely held expectation is that a dazzling array of new occupations and skills will accompany the introduction of computers in the industrial workplace. Although some boring and undesirably jobs may be eliminated, the argument goes, others will be substantially upgraded. The need for manual skills will be replaced by the demand for intellectual skills. Instead of machinists, for example, industry will require computer programmers. The structure of management will also change. The provision of timely information about production through new electronic methods will permit better and faster managerial decision making. The minimization of human input in production itself will result in more predictability and greater efficiency.

This rosy view of the future is challenged by a darker vision: the creation of a pyramid of skills that concentrates a few creative and meaningful occupations at the top while the rest wind up with fewer skills and subject to new forms of monitoring and electronic control. David Rockerfeller, chairman of the Chase Manhattan Bank, hardly America's premier social critic, has underscored these apprehensions by predicting that present forms of automation may lead to a "two-tier society, with satisfying and well-rewarded work for some, while the rest are left to grapple for unskilled jobs."[3] Not only will skills be eroded, but managerial control will be increased in an increasingly authoritarian workplace.

Microelectronics and computer technology, however, do not mandate a more hierarchical work structure with fewer skills. Instead, they offer a number of critical choices: increased work autonomy or extended managerial authority, enhanced human input or the elimination of human decision making, a wide distribution of skills or a concentration of skills. Unfortunately, rather than exploring different technological alternatives and the ways in which they affect people, the assumption is made that there is only one "best" way to develop technology and considerable efforts go into adjusting workers to the result. It is therefore inadequate to discuss only the "effect" of computerization: the "purposes" the technology is designed to serve must also come under scrutiny. This paper will begin by exploring some of the goals that inform the design of new manufacturing technologies today and then look at the consequences of these approaches on skills, the quality of life on the job, and the structure of the workplace.

The final report of the Machine Tool Task Force, a two and one-half-year project funded and guided by the United States Air Force, offers an important insight into the design criteria of new technology. The five volumes of the report are filled with brilliant technical insight and valuable engineering detail. The assumption is made, however, that increased productivity and profitability will flow from a work environment in which all variables are eliminated. Because human participation is certainly a variable, one of the central conclusions of the study is that machines should be designed to "reduce operator involvement." One way to achieve this is to "simplify controls to allow use of lower-skilled labor" and to "approach unmanned operation."[4] The report recommends that industry should:

> Reduce the skill levels required to operate or maintain certain machine tools (or to plan the manufacture of a part), an approach already practiced by some of the technically more advanced companies. This can be done by using more automation, and substituting computers for people in executing certain decisions or operations. (emphasis in the original)[5]

Some managers go beyond this and view automation as a substitute for good labor relations. In other words, if a worker doesn't show up on Monday, you can be sure a robot will. Iron Age Magazine, a respected journal, described a survey of managers in the metal working industry concerning flexible manufacturing systems (FMS), a highly advanced and integrated form of computerized metal working.

> ...labor's role in manufacturing, particularly as regards control over production rates and product quality, is being thoroughly reexamined. Workers and their unions have too much say in manufacturer's destiny, many metalworking executives feel, and large, sophisticated FMS's can help wrest some of that control away from labor and put it back in the hands of management where they feel it belongs.[6]

Now there are certain hidden costs to developing technology in this direction whether in the factory or in the office. There is a moral cost. When technology is used to fracture skills and increase control over work, human beings become diminished rather than enriched by change. But there are also some very real economic losses. Perhaps a new term is needed to describe them: counter-productivity. By counter-productivity I mean the design and use of technology in a way that fails to realize the full productive potential of that technology. In the case of computerization, it's quite easy to mask counter-productivity, because the gains of robots or word processors are most often compared to the conventional systems which they replace. Given that they are more capital intensive, their productivity excels. A more accurate way to measure productivity would compare the actual use of a system to what its potential might be, both in terms of improving production and life on the job.

I would like to examine three examples of counter-productivity, resulting from a contradiction between the potential of computerization to expand human input and a social organization of work that seeks to limit human input. First, a use of computer-aided design (CAD) that severs the designer from the realities of production; second, a deployment of numerical control (NC) that removes most decision making from the worker; third, the "office of the future" in which work is monitored and paced electronically.

Let's first look at computer-aided design. With conventional design methods in manufacturing, the process is, by nature, interactive. A designer who draws a part must take that drawing down to the shop floor, explain it to the machinist, listen to the machinist's input and, in general, interact with the working environment. The nature of the process itself requires some interaction between the designer and the realities of the shop floor. With computer-aided design, however, it becomes possible to model a design within the computer itself. As a result prototypes often do not have to be built to test various design alternatives. The design can even be converted into instructions to guide a machine tool and these instructions can be electronically transferred to the shop floor. The temptation is to accept the computer model in place of the reality of the shop floor. The two are not the same. When computer-aided design is used to enhance a close relationship between the designer and the worker, it expands the possibilities of production. But, computer-aided design as the replacement for that interaction poses some real dangers. It becomes very easy to lose the feel of making things, the intangible know-how that only comes from close contact with the realities of production as they take place.

An example of this loss of feel occurred in a British aircraft factory. A young designer, using the latest in computerized equipment, designed an igniter for a gas turbine engine. The igniter was then made on a computerized machine tool. It was a brilliant design, but somewhere in the process the decimal point was moved accidently one place to the right. The computerized instructions came down to the shop floor, and the worker involved built the igniter according to the specifications. The only problem was its size: ten times the projected design. When the worker carried it up to the young designer in the shop office, the designer looked at it and did not immediately notice any problem with the part. It sounds like an impossible story, but I'm assured by one of the designers involved that it actually happened. While this might be particularly outrageous, errors of an analogous nature that are only 10 percent off might not be discovered. How do these become compensated for once the designer becomes severed from the realities of the shop floor?[7]

The second counter-productivity concerns the use of computerized machine tools. When a computer program rather than the machinist begins to control the machine tool, it becomes possible, though not technically mandated, to make the operator a monitor rather than a participant in production. The result is hardly the skilled and creative jobs that computerization promises. In the '60s when numerical control machining was first introduced, it was widely hailed as transferring the nature of machining from a manual occupation to an intellectual one; transferring the nature of work from people who use their hands to people who use their heads. And certainly the possibility exists for designing numerical control in a way that could fully utilize the talents and abilities of the machinists. But, consider a report from the Machine Tool Industry Research Association in England, an industry body that has studied the impact of numerical control on the machinist. "The operation of some NC machine tools has already become mere machine minding and operator concentration is difficult to maintain. Boredom can lead to loss of concentration and thus to increased risk of accident."[8] The boredom leads to more than risk of accident. Those systems that build out human input are incapable of using the creativity and skill that only human beings can bring to the production process. In fact, in order to compensate for boredom and lack of operator involvement, it becomes necessary to design more and more complex machines in order to replace the few remaining human functions that exist. The increased complexity can lead to increased unreliability. Because human skills atrophy under these circumstances, when the skills are needed they may not be there. Donald Gerwin, a professor of business adminstration at the University of Wisconsin, who has studied computerized manufacturing systems, summarized the problem:

> ...System designers, in their haste to develop smoothly functioning systems free of human variability have committed the tragic flaw of overlooking the simple fact that humans are also critically important sources of control for system variability. It is time to recognize this and give greater consideration to the design of transitional systems where humans and machines interact rather than to the design of increasingly complex, less reliable technology where humans merely cope.[9]

And finally, the third counter-productivity, monitoring and pacing in the "office of the future." There is a central distinction between the use of computers to gather information and using computer technology to pace work. An example of the latter is the increasingly used method of monitoring the number of keystrokes a typist makes in real time, as the person is typing. This transcends just the information about productivity that is required in any operation and becomes a vehicle for determining the pace of the work itself. Ironically, there is an efficiency loss associated with this. Studies at the University of North Carolina, for example, point to the fact that when work is paced electronically, the error rate increases. Depending upon the application, increases of from 40 to 50 percent up to 400 percent were reported. Moreover, for the same amount of work, workers who are paced electronically perceive the pace to be faster than those who are able to pace themselves. Under externally paced conditions, errors increase after 10 minutes, according to these studies, while under self-pace conditions, they only increase after one hour.[10]

Using technology in an authoritarian way can degrade the quality of life on the job. A 1979-80 study of women who operate video-display terminals at Blue Shield in San Francisco discovered a startling level of stress. The stress ratings of these clerical women were higher than any group of workers the National Institute of Occupational Safety and Health has studied, including air traffic controllers. Those interviewed also showed high levels of depression, anxiety, and fatigue. Eye strain or muscle strain were reported by 80 to 90 percent. Is the problem the technology itself? Hardly. When the clerical VDT operators were compared with "conventional clericals" and professionals using VDT's, the study concluded: "The pattern emerging from the results clearly indicates that the clerical VDT operators report the highest stress level, the professional operators report the least amount and the clerical workers who do not use VDT's fall in between. This suggests VDT use is not the only contributor to job-stress elevation; job content must also be a contributor."[11] The professionals exhibited less stress, in part, because they were able to use the VDR as a tool, with more control over the pace of work and more autonomy in decision-making than the clericals.

Underlying the issue of counter-productivity is the fear of technological displacement. When powerful labor-displacing technologies are introduced during periods of slow or stagnant economic growth, the same output can be produced with far fewer workers. Computerization makes this problem especially acute because all productive sectors of the economy are simultaneously impacted. The argument is frequently made, however, that unless industry introduces new technology very rapidly, it will not be able to compete in an increasingly competitive world market. That argument may be true, but it is incomplete. It does not address what happens to the livelihoods of those people who are displaced in the process of becoming competitive. Unless this social cost is addressed, it does not go away but becomes more difficult to pay the longer it festers.

The automobile industry illustrates the severity of the employment crisis. Currently, there are a quarter of a million people unemployed at the major producers on an indefinite basis and, when the supplier industries and dealers are factored in, the total is close to a million people out of work. The rapid introduction of robots into the automobile industry could, in fact, freeze a considerable amount of that unemployment into the system. General Motors alone has announced that it plans to purchase 20,000 robots in the next ten years. According to GM, the average robot today displaces 1.7 workers in a two-shift assembly plant, and 2.7 workers in a three-shift manufacturing plant. This is on a net basis after all the people that are required to maintain and install the technology are factored into the equation.[12] The potential exists for forty thousand or more people to be displaced as the result of this one technology. What does their future look like? Extremely grim since other areas are being automated as well.

The extent to which workers perceive innovation as translating into unemployment is the extent to which a natural and legitimate resistance to innovation develops. The issue is not stopping the development or introduction of robots, but developing those social programs that can effectively deal with displacement prior to that displacement taking place. It also means linking the introduction of new technologies to social gains for those who are affected and for the larger society.

In conclusion, the rapid computerization of the work place promises real benefits. But these benefits will not be realized automatically. Within the workplace, the danger is using a 19th century form of work organization to cope with what is very much a 20th century technology. Outside the work place, the failure to develop those mechanisms capable of dealing with displacemnt could make automation a threat rather than a benefit. Ultimately, the technology surely can be designed and developed in a way that utilizes the skills, the creativity, the talent, and the experience of human beings. There are risks associated with these new directions, but anything less may not be up to the challenges we face.

FOOTNOTES

1 Barnaby J. Feder, "GE Offers Data Link to Improve Automation," New York Times, March 31, 1982.

2 Alice M. Greene, "Office Automation Continues to Attract Manufacturing," Iron Age, March 23, 1981, p. 123.

3 Quoted by Barry Rohan, "Rockerfeller Sees Dangerous Split," Detroit Free Press, October 7, 1980, p. 36.

4 Machine Tool Task Force, Technology of Machine Tools; Lawrence Livermore National Laboratory, University of California, Livermore, Ca., Vol. 2, p. 20.

5 Ibid, Vol. 1, p. 17.

6 Raymond J. Larsen, "Taking the Labor Out of Manufacturing at Cincinnati Milacron," Iron Age, September 28, 1981, p. 104.

7 New Technology: Society, Employment and Skill, Council for Science and Society, London, 1981, p. 41.

8 Albert E. DeBarr, "Safety, Noise, and Ergonomics of Machine Tools," Technology of Machine Tools, Vol. 3, p. 8.17-7.

9 Melvin Blumberg and Donald Gerwin, "Coping with Advanced Manufacturing Technology," paper delivered at conference on QWL and the 80's, Toronto, Canada, August 30 - September 3, 1981, p. 12.

10 Beith, B.H., "Work Repetition and Pacing as a Source of Occupational Stress," paper presented at the International Conference on Machine Packing and Occupational Stress, March 1980, Purdue University with NIOSH (West Lafayette, Indiana).

11 Quoted by Judith Gregory, Testimony for 9 to 5, National Association of Working Women, New Technology in the American Workplace, Hearings by the Subcommittee on Education and Labor, U.S. House of Representatives, Committee on Education and Labor, June 23, 1982, p.15.

12 See Harley Shaiken, "Trauma in Detroit," Technology Review, August 1982, p. 74.

Social Values, the Schools and Advanced Technology: What Has Posterity Ever Done For Us?

Kevin Ryan

The year 2000 is a handy and round referent. The child who is born today will be in the high school graduating class of the year 2000, eighteen uncertain years from now. While the present is clearly a predictor of the future, exactly which bits of our present hold our future is a source of some controversy.

The futurist writings that I have consulted in preparation of this paper seem to be enormously preoccupied with advanced or high technology. One of the most striking things about the terms advanced technology and high technology is that they are so charged. They trigger off a wide set of reaction among artists, scientists, scholars, and social seers. There tend, however, to be two kinds of reactions: the dark vision of our high technology future or the light vision. Advanced technology sets off in the mind's eye visions of sugar plums or visions of chains. The new technology is conceived of either as a benevolent genie we are about to let out of the bottle or as a malignant sorcerer's apprentice run amuck.

The Positive Vision

The positive vision of high technology suggests that we are in the midst of a cultural sea-change. We are going through the painful process of leaving one paradigm for experiencing and reacting with the world and entering a new one. Right now we are at the focal point of cultural shift similar to the time when we moved from feudalism to capitalism. Our current confusion and uncertainty is to be expected. But fear not. We are at the dawn of a great new day or what

Yoneji Masuda calls Computopia (1980).

The revolution that started with radio, television, and the transistor is quickly giving way to the industrial robot, the interactive home computer, an explosion of satellite communications and soon onward to the push-button marketplace, to the silicone chip library, and to Alvin Toffler's "electronic cottage," (1980) where the great majority of people work at home at their own pace, at tasks well suited to their skills and in an environment with an ideal balance of work and play. The health of our possessions, whether our trusty home robot or the roof over our head, will be carefully monitored by our computer. So, too, will be the health of our bodies. No more long waits in the doctor's office to be followed by the embarrassment of probing fingers. A quick scan, and we will be told nicely and privately to cut down on the gin and get more exercise.

More important, though, is that our electronic cottage will be a cathedral of learning. It will contain a teaching faculty that would make the combined resources of Harvard and Johns Hopkins appear puny. It will have the riches of the Library of Congress available at a fingertip. But more than just a great storage bin for information, it will have all of this in a very interactive mode. The electronic teacher will know exactly what the pupil already holds in his head and exactly how he holds it. Our computer will know how best the student has learned in the past and just how much practice he needs on new material for maximum retention and application. The new teacher will do all of this and make learning exciting and appealing in a way that only Pac-man seems capable of doing now.

To those who scoff at such a dream, Lewis Branscomb of IBM recently reminded us that education, as we currently do it, is enormously labor intensive.

"The per pupil cost of pupil education in the United States has been rising at 10 percent each year compounded over the last 10 years...whereas for the last 20 years the cost of computer technology has been dropping at a rate of about 25 percent a year (1979, p. 9). When the two cost curves cross, the revolution will be on us.

The Dark Future

The dark vision of the future provided for us by high technology comes in two versions. One is the nuclear version that says between now and the year 2000 we will have used high technology to deliver destruction and death to each other. This vision suggests that we are unable to measure up to high technology - that we, as a species, have not evolved far enough to manage the fruits of our hands and minds. It suggests that we were unable to transcend our primitive past. Whereas once our warlike and aggressive instincts could be exhausted by the sheer physical demands of chasing our prey all day across grassy savannahs and by the other chores of survival, now our excess energy and passion are turned toward those we decide are our enemies. Therefore, while part of our brain is able to bring about the glories of the sonnet and silicone chip, the other part, long ago programmed to be afraid of the unknown and to protect oneself against what might be threatening, wins out. In this future, then buttons are pressed and the curtain lowers, at least on the modern world as we know it.

The second version is not quite so brutal, but perhaps more brutish. Roberto Vacca calls it a "coming dark age" of hopelessness. Instead of being freed by our advanced technology and enabled to fulfill our potential as individuals and as a species, we use what C. S. Lewis call "that hideous strength" of our advanced technology to become enchained and enslaved. The technology that in the past has increased our food supplies and energy sources has also turned on the birth spigot. Having passed four billion people in 1975, we are still, in a real sense, in high gear and head for between 6 billion and 7 billion in 2000 (Shane, 1981). But while technology has turned on the birth spigot, it cannot keep up with the flow. We cannot keep up with the hunger in the Third World. We cannot keep up with the educational needs and demands of people in the Third or the Second or even the First World.

But most important, for this dark scenario, we cannot keep the secret of our riches from the bands of urchins roaming the streets of Rio or Calcutta or Los Angeles. Through the very miracles of our technology, they know about our lives. They know about the good foods, the good wines, the leisure and the rest. And they do not understand why they do not have it. They do not understand about capital formation, or the work ethic or prerequisite skills. They understand that the life they see on the television and the film screen looks satisfying and comfortable. They know that theirs is not. They do not understand deferred gratification or discipline, but they understand unequal distribution of wealth. Their intellects have gone untrained, but their passions are raw. This is not some new, strange scenario. We have seen it in the blood baths of the French Revolution and the sweeping away of czarist Russia. Still we fool ourselves into thinking that what the restless and sullen masses want is a new deal. And while we busy ourselves trying to extend benefits of the new technology, they rise up and demand a totally new order.

Leaders who urge temporizing are swept away. Leaders who promise the New Jerusalem and clean waters are born aloft. Our leaders in the First World cannot satisfy their demands and desires. Threatened with overthrow, the only reasonable alternative becomes control. The awesome power of advanced technology is turned, then, towards manipulation and control of the world's masses. The dream of the flowering of mankind becomes, in reality, the pacifying of mankind.

A major part of this technological control will be providing the modern equivalent of the Roman bread and circuses. Huxley's Soma will come in two forms: one, as an actual part of our regular diet, and two, as part of our family-on-the-wall TV world. Here the Soma will be in the form of soap operas and soccer, and a continuing array of mind-diverting and mind-dulling activities. Thus, advanced technology has led us into a gray, Orwellian half life.

Three Assumptions

In addition to these bipolar visions, I have found in the writings what I believe are three assumptions upon which a world of advanced technology is based. The first is that there will be a future. A second assumption is the existence of a stable, orderly society; and the third is the existence of a work force with the skills and values to develop, produce, utilize and maintain advanced technology. The first of these, a future, depends on luck or guile or prayer or possibly all three. In any event, the existence of a future is an assumption that goes unexplored here. The second and third, a relatively stable world order and a work force up to the challenger of advanced technology, go to the core of this paper.

Advanced technology is a fragile thing. One of the more sobering lessons of the Vietnam War was how ineffective our advanced military technology was against a guerrilla army and an agrarian society. We apparently dropped on tiny North Vietnam many times the equivalent of the bombs dropped in World War II, but we seemingly did little damage. On the other hand, the effects of a fraction of that same bombing on New York or London would be devastating. As we saw a few years ago, one burned-out transformer can cripple New York City. What would an old-fashioned hand grenade do to the core of a large information bank? What would the now available suitcase-sized nuclear weapon do to a regional communication center and its power sources? What I am suggesting is that contrary to earlier America or to many of the other countries in the world, an advanced technological society is enormously vulnerable. And this fact has not been lost on terrorists. In France recently there have been three attempted bombings of computer centers (Nova, 1982). While there may never be any adequate protection against terrorism, it does seem to flourish among those who feel a deep sense of injustice, and where there are large groups who feel disenfranchised or cut off from the sources of power and influence in the society. So the maintenance of a society that is free of deep civil unrest and extensive crime is a basic necessity in order to develop and exist with advanced technology.

The third assumption speaks to the skills and values of the citizenry. Advanced technology requires advanced people, people capable of learning complex skills. Implicit in that assumption are the qualities of self-discipline and intelligence. It requires people who are able to work together harmoniously, a far different skill than that required of the lone farmer tilling his homestead. And the advanced technological society demands these people in large numbers, much larger than we currently are capable of producing, as a glance through the want ads will confirm.

Underlying these latter two assumptions is the need to transmit to the citizens of our technological world, and particularly our year 2000 graduate and his fellows, the values needed to maintain a stable society and to be effective participants in an advanced technological society. There are some fundamental attitudes and human dispositions that people must have if we are to achieve the promises of high technology. On the other hand, the pleasure-seeking, undisciplined escapist will have little contribution to make. An individual unable to cooperate and lacking impulse control will be a burden rather than an aid. An individual with no sense of loyalty or honesty or without a sense of excellence will be a severe social liability.

What I am suggesting is that high technology is built on the values of people and further, if we are to achieve the benefits of a high technological society, they will flow from the values that we are teaching the young today. And it is to this issue, the teaching of values, we now turn.

Transmission of Values

A dozen or so years ago, the United States was in the middle or a very divisive war, the Vietnam War. In the midst of all the carnage, misdirected good intention and angry debate about our involvement in that war, there was one frightening, attention-getting and sobering statement, a statement that very quickly riveted the attention of the "older generation." The simple declaration, "Don't trust anyone over thirty," sent a tremor through the society. It was perceived by many as a statement of rejection. Something on the order of "You've got it all wrong. You've botched it up. We who will be inheriting this land cannot look to you for guidance." While hindsight and the recent addition into the corporate world of Jerry Rubin and other student radicals would suggest that it was a temporary rejection, it was still quite frightening. Our authority as parents, as teachers, as business and civic leaders was being undermined because our values were being rejected.

Values are very fundamental human preferences. They represent what we think "ought to be" and what "we want to be." Values are basic orientations to social life and to work and to the world in general. Shared values are also the common denominators and the glue that hold a community together. Shared values are the basis for our living together in harmony. Values are both personal and social. Attack a man's values and he may go for your throat. If a nation's core values are eroded, it may go down the drain.

The issue of our social values is of critical importance. A few years ago the economic historian, Robert Heilbroner wrote in the first chapter in his An Inquiry into the Human Prospect (1980), and a most depressing prospect it is, of the widespread pessimism that has engulfed the American people. He listed a number of causes for this pessismism from the explosion of violence and street crime to shocking assassinations but then concluded that "perhaps even more important among these topical causes of our pessimistic frame of mind has been yet another development in the recent past - the failure of the present middle-aged generation to pass its values along to its children," (p. 13).

We are not born with our values. They are transmitted to us. Sometimes the process is quite conscious. Sometimes it is quite unconscious. But it is going on rather intensely from our first consiousness onward. I do not think it is too much to say that while our primary concern with our year 2000 high school graduate is his health and physical safety, our next greatest concern is with his values. Literacy and formal education are enormously important, but they can come later. Dominant values - whether "good" or "bad" - in our life take root - or do not take root -during our youth.

The Family

There are three institutions that have major responsibility for transmitting a society's values to the young: the family, the church, and the school. My own research suggests that there is all but complete consensus that the family has the primary responsibility for values transmissions (Burkholder, Ryan, and Blanke, 1981), the church a second, but very closely followed by the school in third place. But while there is great consensus in the primacy of the family in values transmission, the family has been undergoing some very real changes in recent years.

Most of these changes in the family would appear to weaken a family's capacity to transmit its values. Whereas two generations ago, only the father left the home - often a farm or a shop - to work, this generation has seen the mother leave also the home. In 1970, 40 percent of married women worked outside the home. In the 1980 census, 51 percent reported working outside the home (Hacker, 1982, p. 39). According to The Urban Institute, the projection is that by 1990 more than two out of three married women will be working (Smith, 1979, p. 14). Also, the trend has been increasingly over the last decade for married women with children to enter, or often return, to the labor market when their children are younger and younger (Hacker, 1982, p. 39). What this means, quite simply, is that first the father and then the mother have less and less time to spend in face-to-face communication with their children. Now when the child comes home from school at four o'clock, instead of talking to Mom, he tunes in on "General Hospital." More about television later.

Another threat to the family is its break-up. Between the 1970 and 1980 census there was a striking increase in people "who were separated or divorced or no longer living with their former mates," (Hacker, 1982, p. 37). The number of men in this category rose by 122 percent, with a parallel figure for women

79.4 percent. The sexual discrepancy derives from the fact that when divorced and separated women have children they generally get custody. Given that arrangement, these women fall into the category of "single heads of families," whereas their former husbands are classed as "living alone," (Hacker, 1982, p. 37).

A major result of all this divorce is what is called "the single parent family." Not only has the job of care and value transmission of the children now fallen to one parent, but so have many other chores. Now, one parent, typically the mother, has a full-time job, plus all of the household chores from meal preparation to getting the car fixed. She has very little time for parental guidance and connecting with her children.

Another family trend is for smaller families. What this often means is that few children have the good example, help and support, and value transmission of older brothers and sisters. Then there is the mobility of the Americans with one out of five households moving each year. What that often means for the children in the family is moving away from grandparents, from uncles and aunts, and from long family acquaintances; in effect, moving away from the family's back-up system, the people who care enough to correct your behavior, keep you on course and give you a sense of belonging.

In addition to these trends are two factors identified by sociologist James Conant (1981): the first, that increasingly parents find their recreation outside of the home, away from their children, and, the second, that there is little opportunity for a child to contribute to the work of the family, as in the case of a farming family or a family grocery store. What all of this suggests is that there is relatively little face-to-face communication for value transmission in the American family. Add to that the fact that the average American home has the TV set on for six and a half hours a day (Moody, 1980, p. 4) and we have real questions about the modern family's instructional power.

The Church

The church not only speaks to our connection with our Maker, but it is also a meaning maker. It deals with not only who we are but what we ought to do. Particularly in this latter area, what we ought to do, it is directly involved in the teaching of values.

However, the exact place of religion in American society is difficult to judge. I have often thought that if a visitor from outer space came to gather data on our society, landed in a motel and only had TV as a source of data, our extra-terrestrial social scientist would have a very curious view of Americans, particularly as it relates to religion. The visitor would observe the heroes of our TV shows, people like Lou Grant, or Hawkeye from M.A.S.H., Captain Furrillo of Hill Street Blues, or, if there were reruns, Mary Tyler Moore, have no apparent spiritual life. They are all caring, involved and admirable people. Also they belong to no church and seem totally untroubled by ultimate questions. In effect, our "ideal citizens" live admirably without God. Religion does, however, make the news occasionally, usually in one of two forms. The first is a report of a group of religious people who have formed themselves into a pressure group to keep another group from doing what they would like to do. Second, we see the television report of some poor deranged creature being hauled off after shooting up the local pizza parlor. Which he did in response to the direct command from a voice emanating from the glove compartment of his pick-up truck, a voice that claimed to be the Almighty. What our outer space visitor would see, then, is that religion is very much at the fringe of society, and it plays little part in the life of the society.

One hundred and fifty years ago this year Alexis de Tocqueville visited "outer space" from France and reported in Democracy in America:

> America is still the place where the Christian religion has kept the greatest real power over man's souls...the religious atmosphere of the country was the first thing that struck me on arrival in the United States. The longer I stayed in the country, the more conscious I became of the important political consequences resulting from this novel situation.

Contrary to the image emerging from mass communication, the "novel situation" is still very much alive in this country.

Last year the Connecticut Mutual Life Insurance Company commissioned Research and Forecasts, Inc. to "probe the basic beliefs and core values of a diverse sampling of Americans," (Preface). The intention of the study was to provide them "with useful insights on how people make decisions and how people ascribe values to their actions and aspirations," (Preface). The study was an enormously comprehensive one. They held 2,018 hour-long interviews with 1,610 randomly selected individuals. In addition, they sent to over 4,000 leaders of business, law, education, government, the military, the media, religion, and science an eight-page questionnaire covering the same issues as the interviews. In all, 1,762 leaders responded. The researchers reported they were quite surprised by what they found. This is reflected in what they have titled their report, "The Impact of Belief." At the beginning of the report they write: "In investigating major aspects of American life...one factor that consistently and dramatically affects the values and behavior of Americans is...the level of religious commitment," (p. 6). The report goes on to say, "The impact of religious belief reaches far beyond the realm of politics, and has penetrated virtually every dimension of American experience," (p. 6). This study found that while 44 percent of the American people report attending church frequently, 74 percent or almost three out of four Americans describe themselves as religious. An equal number (73 percent) say frequently that God loves them, and nearly all Americans (94 percent) say they experience this feeling at least occasionally. Over half (57 percent) of the public report they frequently engage in prayer (pp. 17-18).

Using a behavioral index of religious activities and of the experience of religious feelings, the study attempted to measure the depth of individuals' religious commitment. They report that slightly over one out of every four Americans can be termed "highly religious." The report claims that they identified "a comprehensive and powerful group of Americans, approximately 45 million strong, as intensely religious and (the study) demonstrates that religious Americans are likely to vote often and to become highly involved in their local communities," (p. 7).

In a section titled "The search for equilibrium" the authors of the study speculate about their data. They suggest that "one reason so many Americans may cling to religion in the United States is that it provides some measure of order in their lives, some restraint on the cultural injunction to pursue happiness, or in some cases hedonism, to its furthest limits. They believe that people have so many opportunities and choices - from different consumer products to mobility to changing one's marital status - that it is not irrational for Americans to consider themselves overwhelmed by freedom," (p. 11).

Encouraged to be self-centered and "overwhelmed by freedom," Americans continue to cling to what Daniel Bell refers to as "the anchorage of religion." Bell has recently stated, (1976) "What holds one to reality if one's secular system of meanings prove to be an illusion? I will risk an unfashionable answer: the return in Western society to some conception of religion," (pp. 28-

29).

It would appear then that religion is a resilient force in the transmission of values and advanced technology and all its changes may be the handmaiden of even more profound religious revival.

Schools

It is very easy for Americans, in particular, to overlook the great accomplishments of their educational system, especially pre-collegiate education. Our methods of education have been a major U.S. export during the last sixty years. We have been quite successful in developing a system of schools that take the great majority of students through the 12th grade. And in the United States, nine out of ten children attend the public schools, and they have been continually credited as being bulwark to our democratic traditions and structures. Recently there has been a rising tide of criticism aimed at our public schools. Perhaps rising tide is a bad metaphor. I have been a public school teacher or professor of education for twenty-three years now, and the tide has only gone one way: up. What change there is is in the content of the criticism. Fifteen years ago, in 1967, the criticism was that the schools were not relevant to the social realities of the day. Nor were they helping to solve some of our most acute national problems, such as racial inequalities. The new waves of criticism are aimed at the schools' poor academic training, particularly in math and science (about which more will be said later), and in the transmission of the kinds of social values society needs and Americans prize, values such as a sense of excellence, respect for private property, respect for law, willingness to work hard, and the capacity to defer gratification, and a sense of civic responsibility and service. While I do not have a scintilla of evidence to support this statement, I believe that behind the back-to-the-basics movement of a few years ago and the current efforts to bring prayer back into the public schools, is the perception among a large part of our citizenry that the schools are failing to pass on traditional American values.

However, there can be little doubt that Americans desire the schools to be involved in moral and values education. Both in 1975 and again in 1980 the Gallup Poll organization interviewed a national sample on whether or not they thought "the public schools should teach morals and moral behavior." To the astonishment of many educators, 79 percent of the American people in both years, 1975 and 1980, were in favor of the schools taking such an active role in moral and values education. Incidentally, in 1980, 84 percent of the parents who had children in public schools were in favor (Phi Delta Kappan, 1979, 80). However, this was not the perception of the public school teachers and administrators. The reason for this is, I believe, the fact that first, teaching is a short-term occupation for most and, therefore, there is a disproportionately high number of people in their twenties and early thirties in the teaching profession. This means that the great bulk of teachers in our public schools came into teaching after 1967, fifteen years ago when our sense of a national consensus on values was most contested. In general, it was the time of the new morality, and teachers were just as much affected by the value uncertainties as everyone else. It was a time when we emphasized value differences, rather than the value commonalities.

One of the most significant residues of that focal moment in our history is that the role of the teacher has been recast. In the past, teachers both taught skills such as literacy or the solving of quadratic equations and also saw themselves as value transmitters. In effect, they were surrogate parents, society's agents for passing on the positive values needed for individual excellence and social cohesion, values such as responsibility and self-discipline.

What I am suggesting is that in the last fifteen years teaching has been defined in the minds of new teachers as a much more technical task, the transfer of skills, and that the role of value transmitter has slipped away. For one thing, there is very little emphasis on the value dimension in teacher preparation. On the other hand, the idea of "indoctrinating" children with society's values or "inculcating" values is viewed typically with repugnance. The little attempt at values education there is in the school is to help children clarify their own values or engage in debates over moral issues (Ryan, 1981). The idea of the school teaching that certain values are better than others and that certain moral stances are intellectually superior to others or that students "ought to" feel certain obligations to their fellow citizens makes many educators feel very uneasy.

In the last fifteen years in our society, there has been an enormous shift in our perception of ourselves as social beings. We have spent much more time emphasizing our value differences than our shared values. More dramatic is the shift in emphasis from civic responsibilities to individual rights. In a recent issue of Daedalus (1981) Gerald Grant reports how this shift has not been lost on the young. A new student entering the Boston public schools would, Grant writes, "be handed 'The Book', a 25-page pamphlet detailing student rights, with less than half a page on student responsibilities," (p. 141). He then goes on to describe how the pamphlet details an elaborate and exhausting process that teachers must go through to discipline a child and how many "protections" are built in to the system for the student. Grant reports an incident he personally encountered while doing his study.

> A female teacher was still shaking as she told us about a group of students who had verbally assaulted her and made sexually degrading comments about her in the hall. When we asked why she did not report them, she responded, 'Well, it wouldn't have done any good.' 'Why not?' we pressed. 'I didn't have any witnesses,' she replied (p. 141).

This vignette dramatizes the current situation. Our schools have become officially value neutral and the traditional moral authority of the teacher has been reduced to a narrow, legalistic authority.

Changed Priorities

What I have been suggesting is that the two of the three institutions to which we have traditionally given the transmission of our positive social values have fallen on hard times. They are, in effect, weak teachers. And they reflect a change in society's priorities. Where once America was described as a society that was child-centered to a fault, we now seem to be erring in the other direction. As we have become increasingly narcissistic and consumer-oriented and older and grayer as a people, children have become seen as more of a nuisance and we are less and less willing to invest in them either personally or institutionally.

A recent nationwide survey on the hopes and fears of Americans, (Watts, 1981) found a rather surprising change in attitude from an earlier survey, completed seventeen years earlier in 1964. At that time "aspirations for their children" was the second most frequently reported personal hope, second only to "better or decent standard of living." Some 35 percent of the people mentioned it. In 1981, only 8 percent reported it. The same percentage hoped for a good job; congenial work. The overall percentage of Americans, then, who expressed the hope that their children succeed and be happy is less than one-fourth of the 1964 level (p. 40). And this is not an isolated finding. Four years ago the

Yankelovich firm found that the American consumer ranked cars above children as ingredients to the good life (Watts, 1981, p. 39). In 1980, Louis Harris in studying working families found that "the majority of family members agreed that today's parents were not as willing to sacrifice for their children as their parents in the past," (Watts, 1981, p. 35).

Television

Before moving away from the issue of the values transmission to the young, let me turn very briefly to a new force in the lives of children, a new technology that has begun to raise some very serious questions. One basic fact is that "the typical American child now watches television for more than 30 hours a week. That's more time than he spends with his parents, playing with his peers, attending school, or reading books," (Moody, 1980, p. 4). Neil Postman has reported that "television appears to shorten the attention span of the young as well as eroding, to a considerable extent, the linguistic powers and their ability to handle mathematic symbolism. It also causes them to be increasingly impatient with deferred gratification." Postman calls television "the first curriculum because the high school graduate has spent more time watching television than attending to his school lessons (16,000 vs. 13,000 hours)." He is also concerned with what he calls the disappearance of childhood. And that "television is opening up all of society's secrets and taboos, thus eroding the dividing line between childhood and adulthood and leaving a very marginized culture in its wake," (U.S. News and World Report, p. 43). In effect, the transmission of values does not seem to be going on in the home or the school, but is coming right through the glowing tube in the living room. And what is so striking about television is not television's ubiquitousness, but that it is so much with us and we know so little about what its true effects are.

The Schools as Teachers of Skills

A society does not live by values alone. We need schools to develop not only good citizens, but skilled workers, managers, and decision makers. To keep our current technological society going and, certainly, if we wish to participate in an advanced technological society, our nation needs to graduate from its elementary, secondary and higher education institutions people who are competent in mathematics and science. Exactly what competence in mathematics and science means is difficult to define. However, if we in the United States compare ourselves to our allies and training partners in Japan or our not so friendly rivals in Russia, the current situation is downright frightening. Starting the mid-'60s and surprisingly unnoticed until two years ago, the Russians have made an extrordinary improvement in their teaching of science and mathematics, not only in the quality of their graduates, but the quantity, particularly their secondary graduates (Hechinger, 1980, C4). While all Soviet students are required to take chemistry, physics, biology, and advanced mathematics, including calculus, in American secondary schools, science and math enrollments and achievements are falling. This leap in technological education is sending a rich flow of young people into Russian industries and armed forces with the educational background to steadily strengthen the country's technological base (Walsh and Walsh, 1982, pp. 13-17).

Professor Michael Kirst of Stanford recently completed a study for the Japanese Ministry of Education of that country's educational system. Kirst concluded that Japan is much better equipped than the United States to produce workers for the economy of the future, requiring high levels of math, science, and technical skills. For instance, Japanese students bound for college take trigonometry and the majority take courses in physics, chemistry, biology, and earth sciences. Only 5 percent of high school students in California, a state deeply involved in advanced technology, take trigonometry. The University of California requires only one year of science and two years of math for admission (Kirst, 1981, p. 707).

In recent years educational researchers have been reporting on studies that have found that the variable of student's "time on task," the amount of time the student is engaged in academic work, is directly related to the student's achievement. The implications of the time on task variable and of the the facts that the Japanese school year consists of 225 days as compared with 180 days in the United States, and that Japanese children report they do more than twice as much homework as their American counterparts, should be quite clear to us (Walsh and Walsh, 1982).

Two other bits of data. The National Center for Educational Statistics reports 1981 survey data on science and math courses taken by high school seniors. Only 37 percent of all U.S. high school seniors have taken chemistry; 19 percent have taken physics; and 8 percent have taken calculus. And further, not only have our Scholastic Aptitude Test scores been declining for the past 15 years, but the percentage of students who take the Achievement Tests for Advanced Placement in College was down 40 percent between 1972 and 1979 (Walsh and Walsh, 1982).

In the midst of this dreary, discouraging picture of our current performance in the public schools supporting advanced technology,we also have the great problem of unequal distribution of effort. By this I mean simply that the good science, good math, and the computer literacy programs are concentrated in a relatively few school districts, school districts serving the affluent. The children of the working class and the poor are rather systematically shut off from these opportunities. Thus added to the gap between ourselves and a number of leading technological countries in the world, we have a growing gap of technologically educated haves and have nots at home.

There is, I believe, an even more serious problem. For even if we have a change of will and put in place new, future-oriented mathematics and science programs and even if we have the students eager to take them, we are lacking the vital ingredient: the teacher. Amid high national unemployment and a surplus of teachers in many curricular areas, there is a shortage of science teachers of crisis proportions. Recently Dean Harry Lustig of City University of New York was interviewed in The New York Times (April 6, 1982, pp. 21-22) and reported that 22 percent of the high school mathematics teacher teaching posts in the country are vacant and that 26 percent of the posts that are currently occupied are taught by people who are not certified or are only temporarily certified to teach mathematics. Beginning salaries for mathematics teachers are about $13,000 or so a year. Starting salaries for computer programmers are $23,000 to $24,000 a year. Lustig asserts that anybody who "can master enough math to be a math teacher certainly can master enough to be a computer programmer." He claims the situation is even worse in the physical sciences where industry continually draws away from science education the few students who are taking those courses. He went on to say that

> at the highest level - scientists, doctors, research engineers,etc. - we have for a long time been ahead of the rest of the world. But the

> signs are that this is no longer true. More and more of the basic research, more and more of the basic inventions are already being done in other countries... If we go to the next level, the technicians, I think we are even worse off. We are failing to produce enough low-level and middle-level personnel with sufficient scientific and technical knowledge to be able to do the job. After all, the Three Mile Island incident was caused basically by unskilled or untrained or uncaring technicians (p. 22).

It is not simply that we have a huge differential between the pay of a science teacher and the kinds of positions he or she can command in industry. We have also made the teaching profession unattractive. First, there is no reward for the specialized training of a science or mathematics teacher. He or she receives the same beginning salary as a new kindergarten teacher. And they usually have to put up with a very permissive school environment that arms them with very little authority and provides them with very little respect. It is little wonder that last year in the entire state of Connecticut there were zero graduates produced equipped to teach high school science. In Minnesota, in the entire state, there was one (New York Times, April 6, 1982, p. 22). In Ohio where there are 50 colleges and universities training teachers, the 50 institutions together projected graduating only seven earth science teachers in 1981. How many were attracted into industry instead of teaching is unknown. Taken together, then, the few students taking a soft science and math curriculum, plus the drying up of the supply of mathematics and science teachers is a major handicap for a country that wants to participate, let alone lead, in the advances in microelectronics, robotics and computer information systems.

Conclusion

In summary, let me suggest that barring a devastating war, the world of advanced technology will come. Democratic capitalism is a bully engine to bring together talent and resources to develop the potential in the electronics, robotics and computer fields. Whether the United States will participate in the this new world of advanced technology is the question I have been exploring. The data that I have looked at and presented suggests that we will not be among the leaders. The data suggest to me that we have decided at some level or other to spend our capital today rather than invest it for the future. As the current saying goes, "What has posterity ever done for me?"

This conclusion may very well be wrong. America has been characterized as a resourceful and competitive society. But it does appear that since World War II we as a nation have been slightly drugged with our material success and our world leadership. We seem to have forgotten a truth that our founding fathers knew and that the waves of immigrants that built this country knew. That is, that our national institutions, from democratic government and economic system to our families and our schools, are made institutions. They are not inevitable. They are not permanent. They can slip away from us. The theologian and social thinker, Michael Novak, has recently written in The Spirit of Democratic Capitalism, "Societies are not like the weather, merely given, since beings are responsible for their form. Social forms are constructs of the human spirit," (1982, p. 20).

All of us need to realize that what we have has evolved to us out of a different moral climate. It was all built when there was a different answer to the equation, "How much freedom and luxury do I deserve and how much responsibility and service do I owe?" We need to see in searing clarity that our participation and that of our high school graduate in the year 2000, in the coming world of advanced technology depends directly on the transmission of knowledge and values we are doing now and in the immediate future. Even in the brave new world of advanced technology the ancient truth holds: We will reap what we sow.

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Gen-Ichi Nakamura

I specialize in corporate strategy among the business management areas. Let me comment on "The Social Implications of the Advanced Technology" from the business management viewpoint, particularly from the "corporate strategy" viewpoint based upon my limited experiences and observations of Japanese business realities.

Contrary to the technological forecasting for the 1980s made in the Japanese business world in the late '70s, the first quarter of the '80s has seen remarkable development of various technologies in Japan as well as in major Western countries. As a result, leading Japanese corporations have been required both internally and externally to change their own corporate strategies in a sophisticated way to be well-aligned with the sophisticatation level of the technologies they have developed either independently or jointly with other companies and/or organizations. My impression with corporate strategy in this decade is that the above-described tendency will be be much more accelerated in the years to come.

Now, let me focus on several aspects of this tendency.

First, the more sophisticated advanced technology becomes, the more top managers will be required to have sophisticated capabilities especially in the area of advanced technology. The first quarter of the 1980s has seen the birth of an increasing number of new Japanese presidents with technological backgrounds in several advanced technology industries. This new phenomenon, in turn, has aroused them to develop their capabilities in other functions such as marketing, finance, industrial relations, etc., so they will be able to acquire "balanced eyes" at the corporate level.

Second, the more sophisticated advanced technology becomes, the more sophisticated must be the approach to gaining social acceptance. One small example is the growing public confusion of nuclear power generation with nuclear power armament. The confusion has been supported by opposition movements against possible nuclear war. To dispel such misunderstanding, major electric power companies have become more and more sensitive toward relations with government, the public, and the local community.

Third, the more sophisticated advanced technology becomes, the more important effective management will become, including the training of workers on the floor in terms of their abilities and values. One small example is again nuclear power generation. A couple of years ago, an unfavorable event took place in the Tsukuga Plant of the Japan Nuclear Power Generation Co., in the Kansai area. The leakage of an undesirable output from the generation process was reportedly caused by a careless operation at the rank-and-file worker level, not by the highly advanced manufacturing process per se. This accident resulted in accelerated opposition to the continuing operation of the existing plants of other electric power companies as well as to the construction of new nuclear power stations, and has brought about a longer construction period of ten to twelve years or even to fifteen years, up from six to eight years in the 1970s. A small error in the implementation process, even in some other company, led to a huge increase in construction cost.

Fourth, the more industrial robotics will be introduced in factories in various ways, the more sophisticated corporate strategy will be required to handle the alignment between technology, new business development, and human resource education, so that employees who will possibly be transferred to other jobs will be trained properly. In connection with this, the time horizon and/or the period of developing corporate strategy will become longer and longer in the "age of unpredictability," to use the coined work by Dr. Mike Kami, because the human resource education strategy, among others, requires the longest lead time. By the same token, some corporations will be required to deliberately slow down the speed of advanced technology development, either to balance the speed of development of interdependent strategies at the corporate level or to "cover" the investment in existing facilities.

Fifth, the more sophisticated advanced technology becomes, the more sensitive must be awareness toward foreign counterparts or toward more co-operative efforts with them, to abate possible or probable conflicts between foreign countries resulting from the technology's of its promising future. One remarkable example is the case of Fujitsu Fanuc Co. that has already established a technology exchange contract with Siemens in West Germany. They have also recently decided to establish a joint venture corporation with General Motors' in Michigan for research and development, and manufacture and sales, of industrial robots by integrating the technological expertise of the two corporations into the new production at a higher level of performance. In other words, the new principle of co-existence or cooperation and competition, or the new trade-off between them in advanced technology industries, will become more and more important between foreign advanced countries.

Sixth, as the advanced technology brings about and accelerates change in industrial and economy structures, advanced countries will have to transfer willingly some of their less advanced technology industries to developing and less developed countries following the principle of the international division of labor, (although such companies will go through painful experiences). In this context, Japanese attitudes at government, industry and company levels must change toward those countries, including Asian countries.

Let me conclude that the more sophisticated the advanced technology becomes, the more sophisticated approach companies in question will have to take in terms of developing well-aligned corporate strategies, new social awareness and new principles of co-existence, co-operation and competition. Also longer strategy formulation horizons piercing through the foggy environment for the rest of the 1980s.

Julian Gresser

I would like to pose some basic questions summarizing lessons of the environmental movement in Japan in the early Fifties and Sixties and then to speculate on the significance of the so-called information intensification policies of the Japanese government.

In the post-war era, economic growth was predicated on certain basic assumptions that economic growth itself was good and that technology would successfully address the problems of dislocations caused by economic growth. As a result of this precipitous move for industrial development, there began to occur in the early Fifties strange episodes of some pollution-related diseases. Many of you may know Minamata disease, "itai-itai,"that can induce poisoning, and various pulmonary disorders and which results from sulpher oxide and nitrogen oxide exposure. The victims of these maladies formed a movement that, at first isolated, increased to become a national movement as the victims confederated. What is important for today's discussion, in my mind, was the attitudes and the values of the movement. They were that it was regarded as immoral to develop industry to the extent that this industry directly affected human health. It was regarded as immoral to impose serious risks of physical damage on human populations. Companies that operated in this way, it was believed, had a moral duty to investigate the consequences of their activities, to inform the exposed populations, to employ the most advanced technologies to control this pollution irrespective of the cost of introducing these technologies, and if necessary, to shut down operation if adverse consequences could not be averted. The movement, as I said, became a national phenomenon and gave great force to the diffusion of these values.

What happened historically was that the victims, after years of struggling with industry and government, gave up the historical methods of dispute settlement, namely mediation, and turned to seek an absolutist universalist determination of the justice of their cause by turning to the courts. In four famous pollution trials, the courts espoused the victims' grievances and recognized that the grievances were justified by law. Despite the fact that in many cases or in a number of cases causation was from a scientific perspective unproved, the courts held that causation as a matter of law was determined. In some cases, although there were many polluters and although the victims had great difficulty in demonstrating that the source of pollution could be precisely and in scientific terms attributed to a single source, the courts held in these cases that collective responsibility was essential and that the polluters would themselves have to bear the burden of disproving the arguments of the defendants. I think what is important to point out in this context was that underlying the courts' decision was a fundamental judgment about science and essentially the ecclesiastical aura that attended scientific statements and judgments. For years, for example, the polluters had used science as a weapon to oppress victims, had used the uncertainty of causation and the lack of clarity in responsibility as a way of delaying, as a way of frustrating the victims' claims. What the courts essentially were holding or suggesting was that there is nothing absolute about science. Often science masked very basic political judgments in a technical vocabulary that sought to perpetuate an existing status quo, an existing and unfair allocation of society's benefits. What the courts were attempting to do was to reallocate and to readjust the social balance.

Now what is intriguiing for present students of industrial policy in this country as well as in Japan, is that, despite the fact that as the result of the courts' decision, imposition by many industries of the most stringent environmental standards, and, inauguration of a system of imposing broad emission charges on polluters to compensate victims of pollution, Japan continued to surge ahead in its economic development. As we are seeing today, the consequences of this drive for economic health would really seem to suggest that the current methodology of the present administration in the United States deserves to be carefully scrutinized. Environmental protection and economic development, control of energy resources and productivity and competitiveness are not somehow antithetical choices. Indeed, the Japanese record, as suggested by the OECD conference in the late Seventies, suggests that these two are indeed harmonious objectives.

Now one can look at the record of the environmental era and try to scrutinize Japan's existing "Pollyanna" policies of information industry intensification. Indeed, in the late Sixties and early Seventies, particularly with the oil shock, Japanese decision makers were faced with a difficult set of choices. How was Japan to proceed with the pressing task of economic development and at the same time secure a stable source of energy, control pollution and educate their people? The solution to this set of dilemmas was the policy of information industry intensification...

To move increasingly to higher value-added information intensive technologies, you could skirt the pitfalls ahead and proceed with the job of economic development. What is interesting is that this emphasis on high technology, which was the core of information industry intensification, in many ways was tilted away from this balance because high technology came to be viewed as an absolutely strategic and critical industry. It was strategic not in the sense that we in the United States tend to use the term to connote military applications, but strategic in the sense that these industries were regarded as critical, not only in that they would be swiftly growing important sources of foreign exchange and would support new industries in the future, but also because they would increase the competitiveness of mature industries (such as automobiles) and industries in decline (such as shipbuilding). Therefore, they make more difficult the problem of balancing social costs with social benefits that the petroleum industry and other industries of the Fifties and Sixties imposed. But indeed it was essential to the argument for information industry intensification policies that the development of these industries would address these social problems. And, indeed there is some basis for support or recognition of the logic of the Japanese government's argument that the introduction of high technology, the automation of the work place, would indeed reduce pollution costs in cases, that the introduction of automation, of various forms of telecommunications, will indeed indirectly affect the use of energy resources and indirectly in some cases reduce energy costs and thereby provide stimulus to productivity.

So there is, as I am trying to suggest, some basis for the argument for information industry intensification through high technology as a continuation of this balancing of social benefits and costs that grew out of the environmental movement in the history and legacy of the court decisions of that period.

However, as we step back and look at the present policies, it seems - particularly in light of today's discussion - that they really have not adequately grappled with the social consequences of information industry intensification. I don't know of any intensive, in-depth inquiry in Japan as to the economic or social consequences, for example of the computerization of Japanese society. Of course there are studies, but I don't think - at least I do not know from my own experience - there is profound grappling with the policy of vocation. Rather there is an effort to try to develop either through guidance, e.g., ministerial guidance, or legislation an appropriate allocation of the benefits and costs of this move to promote this technology.

Genetic engineering is another example. The Ministry of International Trade and Industry, the Science of Technology Agency, and the Ministry of Education, have now several times weakened the guidelines applicable to research in genetic engineering and still have not developed in detail a set of guidelines applicable to the manufacture of new products through genetic engineering. Certainly there is very little discussion in government agencies of the ethical implications of genetic manipulation, particularly with respect to humans. One can make the same argument as it applies to robotics or the development of Japan's nuclear industry, the aerospace industry, etc. It is as though the lessons of the past have been completely forgotten because, perhaps, the necessity presented by the environmental movement is gone, because the environmental movement itself has become institutionalized - it has essentially become its own church and, therefore, the stimulus to decision makers is gone yet the problems remain.

I might conclude by observing that there is a curious phenomenon that is developing now as a result of information industry intensification in Japan and the pressure that it indirectly places upon the United States. We see often the conflicts in trade between Japan and the United States, but less well observed is another problem, mainly the race to introduce high technology because of the competitive edge it gives the country that moves faster. To the extent that Japan increasingly introduces robotics technology, for example, in the short run it will reduce production costs, and thereby user industries gain an edge over

United States' competitors. This, of course, as was told to us today, places great pressure upon the automobile industry and other users in the United States. To the extent that the United States is less well equipped, however, to deal with the social ramifications of the introduction of this high technology, it really places the United States decision makers and communities in a terrible bind. Thus it seems high technology has placed Japan and the United States locked together like two titans each trying to secure an advantage over the other and yet perhaps each injuring the other along the way.

Relationship Between Technology and Socio-Political System

Socio-political system, in this comment, means either a capitalist system or a socialist system. Although communication technology is neutral in its nature, it has a different impact in the two systems. We must start our discussion by pointing out the historical fact that a capitalist system preceded a socialist system, and capitalism has developed along with the modern technological developments that are fundamentally based on the Industrial Revolution at the end of the eighteenth century. F. Engels points out that, despite the prevalence of the poor working class in all periods of history, the proletariat who support their own life only by selling their labor have grown only after the Industrial Revolution. Thus, from the first step, modern technology and modern capitalism have developed together by helping each other.

Then, what is the relationship between modern technology and the socialist system? Should socialism reject a modern technology that is the most important cause of producing a proletariat? Once again Engels has said that rejection of large-scale industry in modern society is impossible, and that a new social organization, which controls large-scale industry is needed. This new social organization is to be incarnated into a socialist system. In this sense, machine and technology should be transferred from a capitalist society to a socialist society. This is eloquently reflected in Lenin's statement: "Communism is Soviet power plus electrification of the whole country." Lenin, moreover, gave special subsidies to studies in radio technology, and he emphasized the importance of radio by calling it a newspaper without paper and distance.

It is now clear from these facts that modern technology has been used and developed positively even in a socialist society. As technology is neutral in its nature, it can serve not only a capitalist society, but also a socialist society. Highly advanced technology, however will engender different impact among the two socio-political systems, because this technology would function in a different social context. In order to clarify the impact of modern technology, the following three aspects would be important: massification, socialization, and de-ideologization.

Massification Caused by Modern Technology

Developments of communication technology have shortened the distance between power elites and the masses. (As a result of this, elite and mass influence direct each other.) Even the power elite will be restrained by responses of the mass, as the masses will also be restrained by the power elite's responses. Thus, democracy becomes mass democracy, and old despotism becomes totalitarian dictatorship. Generally speaking, dictators usually neglect the response of the masses, but the totalitarian dictatorship, whose power is based on mobilization of the masses, cannot be stable without taking the masses' responses into consideration. In this sense, totalitarian dictatorship may be called a mass dictatorship. Politics, whether it be democracy or dictatorship, has become mass politics due to development of communications technology. This is the massification of politics in present time.

Socialization Caused by Modern Technology

Developments of modern technology provide us a convenient and pleasant daily life, but at the same time they require dependency upon public facilities. With regard to water supply, we dug our own wells in olden times, but now it is supplied by public water service. As for light, we used candles or lamps in olden days, but now it is supplied by the electric company. The situation is the same with transportation and communication. If we consider older societies where life facilities were supplied by individuals or the family as a "personalized" society, we may call the present society where life facilities are provided by public organization a "socialized" society.

In this socialized society, we can enjoy a convenient and pleasant daily life; but at the same time, we have to be cautious about the vulnerability of the society. Modern convenient facilities are easily damaged by accidents, and that damage is easily distributed to wide areas by highly dense communication technology.

De-ideologization Caused by Modern Technology

The three important components of information society may be television, the private car and computer. Socialist society, which is basically founded on control of information, is initially hesitating to introduce these information media, which contribute to the free flow of information. Television in the Soviet Union is formally defined as "the strongest weapon of ideological indoctrination of the mass," but ideological television programs are too boring for audiences who watch the shows at home where they can feel at ease. So it is necessary for television to become an entertaining media. It is symbolic that television became prevalent in the Khrushchev era that was characterized by de-Stalinization and de-ideologization.

Private cars are still very scarce in the Soviet Union, despite its production ability. As a private car can go anywhere at anytime, the police cannot detect people's mobility so easily. This may be one reason why private car production has been restricted to a lower level.

As for computers, when cybernetics - the basic theory of a computer - was first introduced to the Soviet Union in 1953, the socialists said that it would be pseudo-science that would serve millionaires and imperialists, and it would be an inescapable fate for cybernetics to die along with the decay of imperialism. But after a few years, Soviet authority changed its attitude to cybernetics completely and now hastens to develop it. This seemed to be influenced by American developments. Soviet authority, however, still faced the dilemma that a computer easily produces an overflow of information that is basically contradictory to the characteristics of a socialist society based on control of information.

The three important information media, television, private car and computer, are functioning to open the socialist system and in that sense, they function as a de-ideologization of society.

Fred Margulies

Being concerned about the social implications of advanced technology, we have to deal with two major approaches: The typical approach that tends not to care about man and society being affected by careless and thoughtless implementation, and, on the other hand, the shallow but effective slogans of the job-killer effect.

Let me deal with the employment problem first. Over the last decade we have been confronted with a rapid advance of technology taking place under the headline of micro-electronics. At the same time, we have been witness to a steep increase in unemployment figures - more than thirty million in the OECD area alone - and figures are still rising. No wonder that people blame technology as the job killer. Yet, two events taking place at the same time need not necessarily cause the causallink between them. We remember the happy Fifties and part of the Sixties when equal advances of technology were accompanied by continuous full employment - at any rate in European countries. And on the other hand, we remember the world crisis of the Thirties when a hundred million lost their jobs without anything such as computers or robots about. Technology alone can thus not be held responsible for development that is about to repeat all the follies of the Thirties when one part of the people were starving because they had not enough food while another part of them were starving because they had produced too much food. The same is happening today. Our crisis is not caused by over-production but by under-consumption. World steel capacity, for example, at present is at eight hundred million tons per year. The world's need for steel is estimated at a minimum of fifteen hundred million tons. That is twice the present capacity.

Yet this capacity is only used to some seventy percent, and all over the industrialized world we hear moaning about the steel crisis. If technology is to take the blame, it is for the fact that all of our computing power, all our mathematical knowledge, all our complicated and sophisticated algorithms have not been able to remedy our economic system. The simple equation that increasing production power should be matched to the increase in consumption needs of this world remains unsolved. As scientists and engineers, we should feel responsible for these facts.

But unemployment is not the only cause for the wide-spread resentment and fear with respect to technology. It is widely enforced by the daily experience of employees on whom computer systems have been imposed. Working in an organization setting designed by Taylor eighty years hence, as we have just heard in the preceding speech, their jobs are fully cemented and fractionized by applying to technology of today and tomorrow painless scientific management. Now automatons are further degrading and alienating man who is thus losing his personality and his personal relationship to his work. This not only spells degradation of man but also wastes one of the most precious resources of our economy and of our society: human brain power. The waste is a two-fold one because we not only make more use of the resources available, but we also let them perish and dwindle. Medicine has been aware of the phenomenon of atrophy for a long time. It denoted the shrinking of organs not in use, such as muscles in plaster. No research supports the hypothesis that atrophy also applies to mental functions and abilities. If Taylorism ever was justified at the beginning of this century, it certainly is not fit for the technology and the people of our times. Present technology is characterized by the growing importance of man in spite - why, even because of - automation and computerization. Division of labor, separation of thinking and doing, man is an appendage of the machine - these principles of Taylor are no longer in accord with the new technology. The more complex a system is, the more it is dependent on intellect, creativity and the human ability to make decisions. The dream of the machine working without man will never come true.

Equally important changes have taken place since Taylor's times with respect to the work force. Workers and employees have become the majority of the population only in industrialized countries. Their organizations have become more powerful and influential. Labor unions are, as a rule, not outlawed and persecuted as they were eighty years ago. They have become an intricate part of political and economic life. Workers and employees have raised their level of education. They are more self-confident. They are aware of their personal profession and economic value. Thus, resistance is growing against inhuman working conditions. When material need has to some degree and for some period of time been overcome, mental gloom expressed in lack of challenge and content of work is all the more present. Thus, technological needs and human aspirations meet in the search for new patterns of worker organization and for new relationships between man and machine.

Any machine offers a certain amount of perfectionism in its particular field. But because of that quality, it is incapable of creativity. Operating strictly logically, the computer will amplify human intelligence but will equally amplify human un-intelligence. Man is, on the other hand by definition, not perfect, faulty, and makes mistakes. But this is a supposition to his creativity. The perfection of a machine is restricted to the built-in formalism of its performance while the content and meaning of work originate from and terminate with the human being. Just as the best quality TV set has no influence on the quality of the program, just as perfect grammar and syntax cannot prevent a speech from being empty and meaningless, the same will happen even with a perfect computer. Only permanent control and correction will prevent the contents from rotting and meaning from being distorted. While the machine will render best results if it is adept at applying a strict and well defined routine, man has to be given space for applying his own discretion wherever it is possible. In fact, by the way, that the Japanese management has, to a considerable extent, realized these possibilities and is consulting workers about the application of new technology wherever this is possible is to my mind one of the most important factors of their success.

The philosophy behind these suggestions is based on two assumptions. One maintains that technology is not deterministic. That its direction, its application, and its consequences for man, for the economy and for society are not pre-designed. For every technical or organizational problem, there exists a multitude of alternative solutions, each one having its merits with respect to different criteria. Thus technology, rather than restricting human traits to applying the one best way the experts suppose to have found, opens up a wide range of new options to both designers and users. So far, however, there are very few cases where these options are being used. Design of jobs is usually aimed to compensate for human shortcomings. Sometimes it is also intended to prevent future disadvantages. Both targets are valuable and important, but the third equally important component of job design has been neglected widely up to now. That is what has been for us called prospective design: the conscious implementation of possibilities to apply human choice when using automated equipment when structuring one's own job, when deciding on work content and work sequence, and so on, thus allowing for development of one's own personality. This certainly cannot be achieved by erasing one rigid work system by another one. What is needed instead is the replacement of rigidity by flexibility, the offer of new options and a wider range of activities and decisions to everybody in accordance with new technology. Experiments with an implementation of alternative work organizations carried out over the last ten or fifteen years have proved that flexibility may be increased, options may be extended, job satisfaction may be enhanced, while technological needs and human aspirations need not be contradictory to economic considerations - though they ought to have autonomy.

The second assumption therefore implies that every technological change requires corresponding changes in work organization, in working conditions in the allocation, in the flow of information, in decision making and many other things. Where this is neglected, new technology fails to live up to expectations. The blame is then put on the technology, while it really needs to be found in the conservative spirit of the respective user, thereby the economic and social system as a whole. It is not sufficient to accept man as part of the man/machine system just because all attempts have failed to design systems that will work without man. It is not sufficient to have the operator in the maintenance scheme be equal to any other part that has to be maintained to keep the system going. We ought to realize that each and every progress in science and technology was incurred by man in order to serve man. It must never become an end to itself, lesst people might ask the question, as they increasingly do, "Why do we have to have all this? Why should we be dominated by forces over which we have obviously lost control? Let's stop this vicious circle and get off it as quickly as possibly."

There is a loss of faith in science and technology when we witness the many threats to our civilization, and to combat it we have to prove in everyday life that alternative ways to apply technology will not only help avoid hazards and disadvantages such as unemployment, loss of qualification, gradual monotony stress syndrome, but will go far beyond that by improving the material and the spiritual quality of life for all of us. If technology and society do not match, it is completely wrong simply to place the blame on technology, though this seems presently very much in vogue. It is much more appropriate to adapt our society to meet these new technology demands: for example, a non-Tayloristic work organization, a selective approach to technology because not everything that is possible is also desirable; institutions to allow for participation of users in all decisions; the priority of national economy over micro-economic considerations. Above all, we have to perceive man's role in the man/machine system as that of the master with the machine designed, selected and implemented to serve man. This has become the real challenge of our time. Scientists and engineers, I believe, should consider it their privilege to guild into their work considerations about man and society.

The first session dealt with the contemporary revolution in the intersecting fields of communication and information processing. Dr. Morimi Iwama opened the discussion by describing the technological roots of that revolution. Solid state technology is the foundation. Micro-miniaturization is putting hundreds of thousands and maybe soon, even millions, of circuits on chips that are the size of a nail. This leads to declining costs per circuit and it speeds up processing. The difference in efficiency that used to exist between large computers and micro-computers is disappearing.

The kind of sophisticated communication switching and processing that this development makes possible was illustrated by Dr. Iwama by reference to an echo suppresser that once would have required a room full of expensive equipment and is now a small box used in the thousands in telecommunications networks. Solid state developments, together with progress in transmission by such means as satellites and optical fibers, are making all sorts of novel communications services possible. Among these are video-text and video-conferencing.

Micro-electronic processors for example, make it possible to compress a TV picture to three milli-bytes per second that could be handled on four pairs of wires instead of cables or optical fibers. That led to the second presentation by Dr. Lawrence Roberts who examined the implications of the simultaneous availability of larger band width, as in optical fibers, on the one hand, and then compressor techniques, such as those that Dr. Iwama had described, on the other hand. These are alternative technologies for achieving the same goal of providing people with all the communications capacity that they need. But these two approaches are in contradiciton in the sense that if compression is cheap and easy, there is less need for band width. And if band width is abundant and cheap, there is less need for compression.

Dr. Roberts, therefore, examined the usage, cost and technical parameters of the communications system, as it exists, so as to make some estimates of what the results of the trade-off between band width and compression are likely to be in the future. That enabled him to make some forecasts about the nature of the telecommunications system of the future. Dr. Roberts did not see much demand for video beyond entertainment - and that tends to be delivered in other ways, such as over the air or on cable systems. On that assumption, the probable development of compression leads one to conclude that 60 to 100 kilobyte channels, which can be put on wire pairs, can handle the requirements of offices as well as homes. This presumes that the voice, which will be 98 percent of the traffic, will be sampled and then handled by packet switching. Packet switching of the voice will perhaps cost one-third as much as circuit switching. Where large capacity is needed, as for example on the multiplex trunks or for computer-to-computer communication, local microwave and optical fibers will be used. But often, there may not be enough traffic to justify a fiber. If indeed it turns out that there is large scale demand for video point-to-point, that would of course change these projections that I have just summarized.

Dr. Charles Csuri then excited and entertained us with examples of computer graphics. These represent a vastly different kind of communication and of information handling than most of what people do today, which were the basis of many of Dr. Roberts' estimates. So if these became widespread, they could greatly increase communications capacity requirements. Dr. Csuri displayed samples of computer graphics work done by his students and by other groups around the country. We watched buildings being derived on the screen from blueprints and being moved around the landscape. Perhaps most impressive was a skeleton who managed to walk across the screen in a most life-like fashion.

The four discussants Messrs. Darwin, Pellegrini, Araki and Moody, focused on the human constraints on the use of technologies that the speakers had described. Professor Pellegrini emphasized the importance of acquiring a new computer literacy. Machines in the past have processed matter and energy; now they transform information, too. Other panelists emphasized the need for designing information systems to meet the consumers' desires and needs and emphasized that this is something much too rarely done. Professor Araki noted the resistance of many humanists to technology. But he himself made a strong defense of the relationship of these two and of the usefulness of computers and communications technology in humanistic education.

The question period also focused on what human beings wanted and would use out a panoply of options that electronics is making possible.

Thomas Sheridan

This is a report on robotics and automated production controls. Professor Mori, you recall, began the session by showing us a beautiful film and outlining what he called "the 12-link chain of dependent origination" - twelve developmental steps which characterize man's struggle with the inherent contradictions of life. And similarly, he pointed out the steps of his fruitful use of technology. The principal message, in wonderful Japanese perspective, concerned the impact of robotics in helping man contemplate and come to grips with himself.

Mr. Rehfeldt then provided a contrasting perspective of American pragmatism. Robots, he claimed, are not in the image of the film "Star Wars." They are here and now; they are simple programmable machines doing specific industrial tasks to increase productivity and product quality and to reduce costs.

Mr. Brownstein then recounted historically how robots have replaced people in hazardous and undesirable jobs. But he reminded us of the dark clouds of unemployment and empty leisure. He pictured what we want to avoid: the computerized robot efficiently stamping out millions of cheap statues of Elvis Presley with the human worker as a mindless button-pusher symbolic of the worst of what might be meant by productivity. The robot can and must be directed toward more fulfilling forms of production and the enhancement of human leisure and aesthetics.

In the discussion, Professor Terano emphasized the need for people in systems to provide safety and understanding, to cope with unpredictable events, and to be supervisors of the computer. The automation, he claimed, must function as a "gray box," in his metaphor, rather than a "black box," to be partially observed and controlled by man rather than left to operate completely autonomously.

Professor Rijnsdorp then portrayed for us the progression from the mythical subject-in-object stage of the early culture to the present subject-apart-from-object stage of the technological culture. He called for a multi-disciplinary, multi-perspective approach in integrating man and machine.

Professor van Cauwenberghe then reinforced the pragmatic view of robots, citing what we can expect shortly, and indeed, what is already existing in university laboratories in terms of new visual and tactile capabilities in robots, and asserting a one-for-two replacement factor, one robot replacing two men. He hoped that jobs that people want to do will not be replaced - and I must say I hope so, too.

Professor Emori, finally, urged us not to be premature in defining and trying to solve social problems raised by robotics. We need time to observe and to think hard about these problems - they are difficult problems, they are going to take some considerable effort.

Now, I think what this comes down to is that we must face certain facts about the current situation in looking ahead. Robots are very fashionable just now. At my institution, and I'm sure it's true throughout the nation and the world, every second engineering student wants to do robotics. It suddenly has caught the public's fancy. But what we are really witnessing, in my view, is a continual, gradual evolution of automation: computers, sensors, actuators and the systems and control theory to put them together with human beings to do useful jobs.

The so-called artificial intelligence community has probably promised more than it has produced and it seems is now recovering from a small gap in credibility. Some problems, such as chess playing and speech recognition, have seen much more progress. Others, such as simple two-handed coordination at the level of a two-year-old child, we hardly understand at all. In practical applications, robots have done very well in spot welding, in paint spraying and certain other very specific well-defined jobs. But these are easy tasks. We might call this skimming the cream off the top of the milk. We are still very far from robot capability for general purpose assembly.

Lastly, let's face the fact that sophisticated technology down through history has been associated more with military activity - with making war -than with activities of human caring - with making peace and love. Is robotics to fall in line with this infamous tradition? I hope not, but I think herein lies our greatest challenge. The next Discoveries Symposium certainly has much work to do.

Herman Weed

Our session carried the title "Advanced Technology and Human Health." We looked at three basic areas: the direct application of technology and health care - bio-medical engineering; at the social effects of technology on such things as world indices - birth rate, and the potentials of genetic engineering - be it good or bad.

In the area of technology and health care, Dr. Robert Mann commented very specifically on both the use of bio-medical engineering and upon its extreme rapid growth in the period of ten to twenty years that we have recognized it as a profession. I believe he quoted the number, a growth of ten times in ten years. Both Dr. Mann and other studies have indicated that the progress of technology in our health-care delivery, at the moment at least, appears to be more limited by costs, by knowledge, by an understanding of how to apply, than by technical limitations. It appears that the near future will see the effects: some of the major advances of non-hospital medicine, self-diagnosis and therapy; of artificial organs; of support for the handicapped, such as controlled muscle stimulation, blind readers and controlled prosthesis; advances in ultrasonic and radiation therapy, and even perhaps a new look at physiological systems.

In the area of social effects of technology on health indices, Dr. Furukawa presented data that very simply said, "Countries with higher per capita income, thus generally more technology, demand more health care. People live longer; they have fewer children; they have lower mortality rates." In other words, there is an effect. The effects are seen in an older population, changes in the final causes of death, perhaps even in the definition of death, the need to employ a new generation of handicapped, and perhaps a needed change in some of our education - in particular engineering and medicine. New knowledge, new problems to solve, a new understanding.

In the area of genetic engineering, Dr. Chakrabarty presented the tremendous potential. Perhaps this is indeed the next technical revolution, comparable to computers, to transistors. We should see the possibility of genetic therapy - a whole new world of cure for diseases that are of the genetic direction. The relatively inexpensive synthesis of drugs is also a great concern. We have the possibility of the designed human, of the surrogate birth. The potential is there. Some of the things we are concerned about are, in fact, already being done. The questions: Are we crossing a forbidden evolutionary barrier: Who should decide? Is genetic change different from brain surgery, from an artificial arm, from nuclear energy? The future appears to hold a continued rise in the use of technology in direct health care - walking paraplegics, artificial hearts, livers, pancreas, computer diagnosis - limited primarily by cost and imagination of how to use the technology that we have. The social changes are going to result in an older and different population, but with continued demand for ever-increasing technology and health care limited primarily by dollars. There is a new potential in genetic engineering, perhaps the next step in technology, a first chance at some of the genetic diseases, perhaps cancer, with the question, "Who should decide?"

Bradley Richardson

The entire theme of this Symposium has been the social impact of advanced technology. This theme was addressed most concretely yesterday afternoon in Session Four, but the main theme was interwoven in comments made by speakers and discussants throughout the program. I think there was widespread agreement by everyone who took part in the program as a speaker, as a discussant, as a chairperson or as a participant in the audience, that people are important and that we are addressing rapidly changing relationships between the way we do things and the way we as people live and behave.

Originally, when we talked about this particular theme in the fall, I wondered what society is and how we would break it down intellectually, conceptually, into manageable components that we could then address as being contributing factors to the induction of new technology or could be factors upon which new technologies have an effect of either a positive or negative kind. In the discussions, inductively, I believe, we emphasized the many different relevant dimensions of society, each one discretely and specifically enough so that basically we have a handle on what we are talking about. We mentioned human values, both as a contributing system to the sustenance and support of the development of high technology and also as a property of individuals and societies that might somehow be changed in some instances, or might be used as a basis for evaluations of social policy decisions to be made with regard to genetic engineering, the use of robots to replace workers and other applications of technology that have major consequences for society as we know it. We discussed individual psychology in the area of motivation in the work-place, and also there was some mention of the possibility that computer graphics may ultimately change some aspects of our psychological responses to images conveyed via the electronic communications media. We, of course, discussed human health. There was mention of environmental safety, and of the question of pollution. Leisure was mentioned at several points as an important aspect of human behavior and allotment of time. Class relationships were mentioned on at least two occasions. There was discussion of power at the workplace and how technology might alter certain patterns in management relationships. There was mention of the organization of work itself - of how people do jobs and the way they are allocated to jobs. There was mention of ideology, broad social theories, and some discussion, at times, of the economic base upon which an advanced technological society might be founded.

It was quite clear that there were different timetables involved in the impact of different emerging technologies on people. Certainly the computer revolution is upon us, whereas the genetic engineering revolution - as was just mentioned - may come later and in a more piecemeal way. Parts of it are already here, but some of the impact, as I understand it, may be somewhat later.

There was also, I think, implicit discussion of the variations in scope of impact of different technologies. Certainly, computers and communications were emphasized as the advanced technological revolutionsn that would be affecting the most people at the earliest stage. I think some aspects of scope weren't too explicit, but we got the sense that perhaps other aspects of advanced technology would be more selective in their impact, whereas, the communications revolution and the related computer revolution, if you will, are going to have very broad consequences.

In the session yesterday afternonon, specifically Session Four, three speakers addressed the questions of the social base needed to project an advanced technological society, and also the social cost and social benefits of such a society. Professor Ryan of The Ohio State University addressed the issue of social base most directly, largely from an American perspective, but I think from a perspective that has analogues in both European and Japanese societies today even though it was particularly centered on some social changes going on in this country. Changes in the home and in marriage practices, and the decline in the effectiveness of schools as places where the values that hold society together and motivate people to work and to learn were seen as critical negative factors that might undermine some of the support which society could provide for an advanced technological revolution. We are all aware of the things that are going on, impressionistically at least, in the area of value change, and I think we all could react sympathetically with Professor Ryan's comments. Also, in the American case - and perhaps here the comments were more specifically applicable to the American case than to Japan, and probably to some extent to Europe - we heard that there were unbelievably low levels of new teachers being produced in the critical mathematical and scientific areas upon which a new technological age would depend. Related to this, we have seen an enormous shortage of engineers in this society. Engineering schools, are not producing engineers at satisfactory rates that would enhance, support and stimulate rapid development of the promised advanced technological society.

Other speakers addressed themselves to the social cost and benefits of advanced technology, particularly in the area of computers and automation at the work place. Professor Hsiao was the most optimistic and saw the computer ultimately as functioning as a slave for man and relieving man of many troubling physical tasks, which would then permit many people to become consultants rather than workers and to lead very flexible lives, therefore having not only more time perhaps for leisure, but time to fit leisure into their own individual lifestyles, if you will.

Professor Hsiao also suggested that the development of computers will soon make faculty members redundant - which wasn't something I welcomed personally. Harley Shaiken took a much more qualified view of the implications of computers and mentioned several aspects of the effects of automation on work and motivation which he thought were negative. Automation could lead to boredom, inattention, and greater errors in performance of work tasks. Electronic pacing in the automated office could lead to stress and mistakes, and also to greater control. Computer-assisted design could remove the designer from the object of his design efforts to the point that he might make very serious and undetected mistakes. Professor Margulies, one of the discussants, went on to comment that, in effect, advanced technology could produce even greater alienation from work (in the traditional Marxian sense) than had occurred in the first industrial revolution.

Professor Shaiken argued strongly that advanced technology will come, and that our most critical concern is to determine how it will be used and to examine the issues of its introduction thoughtfully. Particularly critical in the introduction of advanced technology, to its effects on people, and also to the reactions from different social and political groups, is the presently very weak condition of the American and European economies. While advanced technologies are available and emerging at a very rapid pace, there may be resistance to their acceptance, because of the very negative economic conditions that we are now in. This resistance might not come or might not be so intense if conditions were different. That may have a kind of structuring effect on how quickly and in what ways we digest new technology. This has led to concern by many people participating in yesterday's panel and in other parts of the program regarding the need for creative social policy-making. Some people have argued that a sufficiently creative social policy will come out of decisions made by industries, other have emphasized the role of union movements and some have suggested that governments can play an important role. But, as Julian Gresser mentioned yesterday, Japan, which some have taken as kind of a model of effective social and industrial policy-making, has itself not addressed some of the social problem questions that we have brought up. In other words, the current emphasis in Japan is on high technology and very rapid development of high technology without consideration of some of the social issues that we have raised. Moreover, in other countries with less integrated political systems, matters of this kind are being raised in only a fragmented way. So the real world does not provide us with encouraging examples of creative decision making.

Several people have suggested to me that we might move from yesterday's discussions and from our general thematic discussion to suggestions of an agenda for 1983's Man-Tech Discoveries Symposium to be held in Great Britain. Some people have suggested that we formulate a specific charge for that symposium. Accordingly, I have suggestions for some points that might be addressedas a sequence to what we have discussed here. The Discoveries Symposium is an on-going process, and a year's time will permit, more research, and more thoughtful consideration of issues raised here which could then be addressed there.

It has been suggested that we might look more carefully at the probable scale of displacement in offices and workplaces which will result from automation, in other words, more could be done to actually study the problem using examples and techniques such as Harley Shaiken mentioned yesterday. Advanced technology is moving into industry, people may need a lot of retraining and it may be possible for us rather quickly, on the basis of some of our discussions here, to move to measurement of some of these needs in a systematic way. Similarly and relatedly, the nature of the social and educational base needed to implement a highly technological society remains a subject of great concern. I think Professor Ryan's comments about our poverty, if you will, in the secondary school area were particularly poignant and pointed, and we need to keep this topic on the agenda. It may have implications for other societies as well as our own. The ethical and legal problems suggested by genetic engineering will be a continuing topic that may be addressed in the future as the Symposia advance from stage to stage. And, indeed, as the technologies themselves are changing rapidly, by next year we may have a new agenda of things to say about, for example, developments in the area of computers.

Finally, we did leave some things out in our discussions of advanced technology and human society. This was in part conscious - these are matters that we discussed in the organizing committee and in Tokyo last fall. I would like to mention them briefly because these could also be agendas for future Symposia. They are certainly areas of relevant social policy concerns.

First, we haven't decided whether this is going to be a middle-class social revolution - a technologically induced middle-class social revolution - or whether poor people, the poor stratum that exists in our country, in Britain, and in various places around the Mediterranean, and certainly other places in industrialized society, will be allowed to participate. How deeply will the impact of advanced technology go in society is the question. How far will different aspects of high technology penetrate, how much can be afforded? I hear people saying that we will all have home computers in a decade, and yet having just purchased one, I find it really very difficult to imagine that everyone will be able to afford one, even though the price may go down. This is, of course, a rather trivial example. But, in reality, many people in this country and many people in other countries can't affort many products of the first industrial revolution. We really haven't considered this issue.

We haven't talked very much about the relationships between the northern and the southern countries. Will the advanced technological revolution broaden the gaps and create a richer or a least different, northern society still separated from the less-developed countries of the world? Or, as Professor Chakrabarty has mentioned and others have suggested, will advanced technology ultimately have some beneficial effects for problems of production and crop management in Third World countries? Another open-ended question, if you will, for future Symposia: we talked a little bit about economics in our original planning, and we had hoped to have a session on economics as a kind of technology of social management and prediction. Specifically, will societies, the advanced ones that we have been talking about, have enough money to pay for advanced technology in the increments that we have projected to be available and desirable in some of our discussions here? Will the financing be available? Also, other economic parameters exist, such as the disruption caused by economic downturns, which can produce very different scenarios of social and political reactions to advanced technology than we might project if times were good. Economics count, and the spin-offs from economics to the political world count in designing a multi-variable picture of the future.

Finally, we haven't said a great deal about politics. Politics has been an important ingredient or non-ingredient, depending upon the situation, in the economic development of both advanced and less advanced countries, and it seems very reasonable to project that the nature of political leadership, the degree of pluralism in particular countries, and the degree of stability and instability in particular political environments will all be critical factors to the induction of advanced technology. What we are suggesting here is simply that advanced technology has to be seen in the context of its total environment, that the world is complex, and that there are many issues and factors that will affect how things will turn out which we have been unable to address here.

Dr. Harold Chestnut

We have heard a number of different ways in which advanced technology is bringing up a stepped-up automation effort in robots, and a stepped-up communication computation control effort on information for industry. In a way you might think that this is a new problem, but in reality we have had changes in automation and in information handling before so that we really do have an experience base with the past with changes of this sort before. Some of these changes have been quite smooth and others have been quite abrupt and have been quite dis-harmonious. There have been in many cases - like containerized shipping, electronic typesetting - long and costly strikes before new technologies were able to be brought into being. On the other hand, in the case of something like numerical control, this was sort of an evolutionary thing. It was tried first in one place and then another, and it came in quite smoothly. Consider automatic pilots in steering aircraft. We had pilots, co-pilots, and navigators before - we still have them. On the other hand, their job is greatly improved by virtue of having the advantage of automation to help them. However, although there are similarities in the past, I think the present situation may be considerably more severe because of the speed and the magnitude of the changes that are proposed, and in fact are underway, and also the breadth and scope of the effects of the change. And further, as was mentioned, we have a present base of unemployment within the world that is quite high, and the general measure of industrial production is not forecast to change very greatly in the years ahead; so a number of situations emphasize the need for considering this social impact of advanced technology. And despite the fact that we may have many people unemployed, it is pretty clear if you look from the point of view of employment requirements, that many people with special skills are not available. So in many cases, there will have to be educational programs to bring these new technologies into widespread use.

As we look at what is happening, it is apparent first of all, that much work on a world-wide basis is being placed on advanced technology. Furthermore, the plans for the future include rapid change and major magnitudes of this change, the sort of thing that we saw is taking place in micro-electronics, VLSI. Contrary to the prices of everything else where the prices are going up, in electronics, in this high technology area, in many cases the prices are going down, performance is going up. It's just different than anything else. And this is especially true in the field of computers, communications, and control. Another emphasis taking place world-wide is the automation of work, and it is being applied in several industries, not only energy materials, but especially robotics and plastics. So there is a great deal of effort in the field of automation.

Further, if we look at change as being something that takes place in different ways, we can look at three different stages of change. The first is essentially doing the same thing but in a different way - using new methods, new technologies. If you think of computing that stage was in early days in the mid-Forties where people were able with relays to perform arithmetic functions. They were not doing anything new or different, it was just a different method of doing things. On the other hand, with the advent of electrical computation, the arithmetic functions were done much more rapidly and more effectively. This could be described as a second stage, of change and new performance. The third stage - and this is a stage that I think we are with the current advanced technology - is we are doing something that is different and better, and it's really an emphasis on the new applications. For example, the use of computers for airline reservations was something that a normal computer in the past was not considered to do. When we talk about advanced technology in this present Symposium, it seems to me we have been emphasizing this advanced technology, and it is bringing in new applications that are going to have an impact on the way people do their work.

The third idea that is present here is the idea that changes affect people in different ways. Occasionally we would hear a speaker say "Well, advanced technology is a terrific thing and we think this is going to be a brave new world and we are all for it." On the other hand, people who are concerned with unemployment said, "It's a bad thing, we have plenty of people who are unemployed already." So it is clear that if we look toward the people who are causing the change, this advanced technology may be an exhilarating experience. However, from a social point of view, we also have to consider the people whose lives are changed adversely by the technology. People may lose jobs, they may lose status, they be required to uproot their family and move. For these people, advanced technology does not have the same meaning as for the people who like it. On the other hand, if you look at society as a whole, people use the service and benefit from it. For example, management users are less emotionally involved, and they view automation and advanced technology in a favorable light. And as we consider the social impacts, I think we have to look at it from those many different points of view, and that is part of the opportunity that we have had here during this symposium.

So, in a way we said we looked at automation before, but what is different in the foreseeable future? First, the time for change is considerably shorter. The effects will be more quickly apparent. World-wide television, broad communications, air travel - all of these facilitate change, and many of these changes are going to be apparent in the three- to five-year period. Not by any means all of them, but there will be significant changes in the relatively near future. Second, the magnitude of change is greater. There are world-wide implications. There are several countries involved, and in many cases the balance of trade may be at stake. Interestingly enough, occasionally there are joint technical efforts between companies in different countries that are taking place. And furthermore, national technical competition is involved, and I have a feeling that to a certain extent, some of the excitement and drama that was associated with the efforts in the space race may take place here in the field of advanced technology. Furthermore, as we look at robotics in particular, it will be affecting several blue-collar activities such as welding, painting, and in the future perhaps assembly, and it will be taking place in several industries - transportation, perhaps discrete parts manufacturing - so we are not talking about a single change in a single industry, but rather a broad change in both handling information and automation of the work in several different places. In other words, you may be able to put out one or two fires; but when there are a lot of them, you require a different strategy. This revolution being proposed in information handling affects many offices and many organizations in different industries large and small. We may be talking about millions of people and tens of billions of dollars involved in a five- to ten-year period. So, whereas frequently the typesetters or the stevedores might have had a critical problem, it really wasn't necessarily felt on a world-wide basis, I think that the advanced technologies we are talking about here may be of that world-wide character.

Another thing I think that is extremely important, that was brought out here, is that the workers would like to be a more important part of work planning. If these changes are to take place and to have the support of workers, it is highly important that the quality of working life, the quality of work circles and so on, be incorporated in this social change that we are talking about. So, it is clear that changes are underway. As I see it, a number of steps should be taken now in a number of different quarters - in industry particularly because much of advanced technology will affect industry, but also government, universities, labor unions - all should try to anticipate these problems and to get plans underway for avoiding the difficulties of some of the past transitions with automation.

Efforts should be made to identify the adverse effects of changes and the effects of social cost should be included in these cost-benefit analyses. I think the experience in Japan in connection with the environment - and to a certain extent, here in the United States - is something we should look to, because I think that in the case of the environment there has been a successful effort to bring in the cost of doing business to improve the environment to be included as part of the overall cost of the product. Another of the steps to be taken is to get worker participation in the change process, and we have had a number of examples explained where that was taking place. Another of the steps should be to provide education needed to make for successful change and for retraining people who will need help. And we may need some newly educated system-people to bring into being these vast changes that are being proposed. Along that line, I think it is important that we try to bring in people who will be responsible for the success for the change in addition to the technical people who are associated with bringing about the advanced technology.

At this time, I would like to try to look at some of these social implications of advanced technology. My impression is that advanced technology will continue to make rapid progress and over the next three to five years, that we will see significant breakthroughs. Electronic communications, computing, control - all have projects underway which should be resulting in successful applications in this relatively short time-frame. Robotics, automation, health care are underway. Materials manufacture is another area, and certainly educational aids, such as we saw with computer graphics, can be brought about in a relatively short time-frame. In order to accomplish this, we definitely need more education for people to develop, build, use, service and maintain the technology to make automation more useful for the people it serves. We also need, in a social sense, to create an environment that is tolerant in accepting change and innovation. We must foster a public attitude receptive to change. More than support for technical research and development is needed. In fact, tolerance by the total society for change -including those people who might be put out of work by change - is necessary.

It was interesting to me that in our laboratory, where we developed some of the first automatic elevators, we were among the last ones to have human elevators. It was simply a bargain with the union and the company that as long as those operators were available for work on those elevators they had a job. So we were some of the last to have automatic elevators. And this has been true in a number of industries.

Incentives and benefits must be provided for people who will suffer from the loss of work, and we must try to provide motivation for people who will be displaced from work to become eligible to work at new jobs. These jobs may not be quite at the comparable level, but I think with taking a proper time perspective and providing incentives and benefits, the transitions can be made.

I think one advantage of this Discoveries Symposium is that it brought out the fact that different effects of advanced technologies may take place in different nations and in different cultures. In other words, as we look at the various countries of the world it is clear that they have different constraints and different boundary conditions. And I think that by considering problems on an international basis and an interdisciplinary basis we are indeed fortunate.

A last item here is that we must strengthen the role of social scientists and/or engineers in helping to bring about some of the tasks noted. We have worked and talked considerably about the advanced technologies, but it isn't quite clear with technologists as the introduction of the new technologies take place. Although the major social impact of advanced technology will be felt over the next five to ten years, there is still time to do something to lessen the blow when it occurs. But we must anticipate the necessary changes, and I hope that the proceedings of this Discoveries Symposium will provide people who weren't here an opportunity to catch the flavor and the ideas that were expressed here.

In the past few months I have been asked to speak on the subject of eco-technology as a result of my becoming identified with the Honda Prize. People have said, "What is eco-technology, and how can we learn more about it?" Many people are interested in learning more on the subject, and I think to an extent that the Honda Foundation and these Discoveries Symposia can bring eco-technology as a word into more widespread understanding. This is highly desirably. It is interesting that many of the people that I have spoken to seem to agree that the benefits of technology in the field of food and health are well worthwhile. In other areas they question some of the effects of technology. And I think some of the data that were brought out here in terms of extending people's life expectancy through the advantages of higher economies and ones that are brought about through the use of automation will be very useful in that regard. Perhaps at a Discoveries Symposium the subjects such as Brad Richardson mentioned, can be tied more closely with that of eco-technology, and people from various countries could describe eco-technology as perceived and practiced in their various countries.

Gunnar Hambraeus

We have been given the grand tour of the very perimeters of science and technology in these few last days. We are deeply impressed by the force and the speed of technological change and we share the hopes and missions of our speakers: that the immense potential benefits of new development will be realized and that the misuse, the risks will be avoided. But at the same time I feel a great curiosity as to where all of this will lead us.

This earth on which we live is around four billion years old, give or take a few years. Life in some form has been around at least one thousand million years. Man - homo sapiens - can be traced back about one million years and organized society appeared about ten thousand years ago. But for nine thousand eight hundred years, progress was rather slow. In his history of the English speaking peoples, Winston Churchill remarks that the comforts of his own childhood home were in no respect superior to the amenities of the Roman villas in the year 200. Practically all our industrial technology and most of the things we use in our daily life are of this century. Most of us here can remember homes without radio and TV, a time when things of synthetic materials and plastic were unknown, and when long-distance travel was for the few only.

There were times, even after the Second World War, when eminent men pronounced the end of discoveries and innovations. How wrong they were. Solid state physics and a new molecular blood biology are the most glaring examples of signs where new vistas are being opened by every step that they proceed. Living in the present and occupied with each our own niche, we seldom realize the magnitude of technological change on this globe. Perhaps we need to go into space to get the right perspective. To an imaginary observer on the planet Mars, Tellus has in a few decades become the strongest radio star within sight. And this is a man-made radio star.

Where, then, will this rapid revolution lead us? Can we, in the real sense, direct our future? As scientists, we strongly defend our right to pursue our research anywhere that our studies might lead us - to go hunting for the treasures of knowledge like the Princes of Serendip and to discover the unexpected and the unsought. Yet I was very impressed by the observation of Dr. Fawcett that so much of our knowledge remains idle when in fact the needs and potential benefits of its applications are so obvious. To his list of negative bonds in energy, locomotion, pollution, critics could add food spoilage. During a recent visit to the Soviet Union I found that up to forty percent of the milk of the Soviet dairies went down the drains. I could mention pest control, environmental protection, and of course man's mistreatment of his own body in food, drink, and drug abuse.

Now, the complete freedom of basic science is an illusion. There might still be a few disciplines where expenses are modest and the availability of outside grants is not critical. In most areas, however, the directions of fundamental inquiry are determined by review committees, research councils, and foundation boards, whose combined wisdom is not always totally unbiased. I'm not convinced, for instance, that future generations will acclaim our present very heavy investment in big science. The application of knowledge, on the other hand, is largely determined by market forces. The earnings potential of technology foreseen will determine the volume and speed of development. The examples that we have discussed in our sessions are all driven by projected substantial gains. There seems to be an insatiable appetite for more information and entertainment in the world. Robotics will make possible much more efficent use of our productive investments and will speed inventory turnovers. Price, elasticity of health care, is absolute. As Dr. Mann said, there is no connection whatsoever between the ordering of medical-technical supplies and the paying of the bill. Also, the expectation of business opportunities in genetic engineering are very high. There is little wonder that progress in all these fields is extremely rapid.

In discussing the harmonious interplay between humanity and technology, it is important that we learn more about the forces behind the engineering evolution. As I just said, the market expectations play a leading role. But markets here must be interpreted in its widest sense, including public and political demand. Bio-engineering may be, as Dr. Mann pointed out, a multi-billion market. Possibly, however, compassion towards the sick and infirm, as well as fear of our own ultimate fate, may be driving the public to support medical research in general, and bio-engineering as part of that. Where, on the other hand, there develops a fear of a new technology, the market vanishes, regardless of what economic gains that this technology might offer. This is, of course, what has happened with nuclear energy in this country. We have many examples to show that public opinion manifested in political action will create markets where none existed before and vice versa. Environmental protection technology, road safety device systems, are positive examples. Water fluoridization and food additives show the other side.

Two of our sessions were devoted to new technologies that could be said to be in the balance. Their acceptance by our industrialized societies may to a large extent be dependent on a superior psychology of introduction and continuous information effort from our side. It has been rather interesting to observe in our deliberations the different attitudes to these new technologies from the three continents represented here. Where the optimism on the Japanese side is very obvious and stimulating, the Europeans have generally been inclined to note difficulties and obstacles, with the Americans somewhere in the middle. As a participant of an earlier Discoveries Symposium, I can discern, I think, a slight movement of our American friends from the positive to the negative side.

Our session yesterday afternoon was extremely illuminating. From the rosy world of the expectations of David Hsiao we were thrown headlong into the dark foreboding of Harley Shaiken. Finally we were rudely awakened by Kevin Ryan's report on the state of American schools. His lecture, though, made some of us from Europe feel that we are not quite alone in this world. It is obvious that our technical revolution means substantial changes in our society - we have all said that. Also, as Dr. Shaiken said, the new technology, like the apple at Eden, is for good or evil.

Possibly a super computer could adapt the benefits and losses in a set of different scenarios to optimize the welfare of a nation. The difficulty, however, is that the people who will gain are usually a different group from the losers. Even if the gains seem, on the total, substantially greater, there are already and will be the fears of groups of people caught in the transition. It is true that our robots will relieve manual workers from toil, discomfort and risk. It must not be denied, however, that the robots also will take over a great many jobs that are now handled by humans. If something threatens my job, I fight back. Actually these and similar reflections on for instance, office automation, the new information media and the effects of bio-engineering, leads me to the conclusion that it is not the actual technologies as such, not the products and systems which are our main problem. It is not even the transitions, though they can be both rapid and brutal. It is rather the expectations and fears, the maneuvering and tactics, the struggle for anticipated benefits and for privileges and power that are the Scylla and Charybdis of the great technologies of the future.

We had scare-hysteria over nuclear power and recombinant DNA. Stocks in giant companies starting research on genetic science have soared years before any useful products were created. Labor unions in western Europe have persuaded the common market to enact laws on co-determination with regard to decisions on new technologies. The reflections here seem to depend here on the society where they appear. Actually, the optimism of the Japanese seem to me to stem from the basic stability of their society. In Europe and, perhaps in the United States, governments and authorities have lost a lot of the trust of the public. And this makes the common man very unsure of his future and makes him resist change.

Well, this brings me to the message on my conclusions. We of this Symposium have been briefed on some active sectors of science and technology frontier. We discern great changes, opportunities and promises, but also obstacles and threats. We are convinced that if well utilized, the new conquests could bring better life in the homes and in the workplaces for most - if not all - people. Technology, however, has to be handled with care. It is up to us here to bring the message to the public, to the media, to the decision makers, to the politicians and to force them into a dialogue and to make them understand what has happened, what could happen and what should happen.

In all of this scientific and technological evolution or revolution, there is one invariant, at least on our time scale, and that is the human being in all its fragility and splendor. All is folly and wisdom. The longings, dreams and ambitions of this tiny, thin-skinned, naked child of an ape have brought us modern world. There is no end to the wonders to come, but our compassion, foresight and wisdom have not increased, at least not in proportion to knowledge. Our philosophy of today is not very superior to that of ancient Greece and our great religions stem at least from medieval times. Possibly, the new information technology can assist us to make wiser decisions for the future. In contrast to many speakers here before, I see no limits to artificial intelligence.

It would be tempting to speculate on new intelligent species of creatures created out of genetic engineering. If we keep up the present speed in research and development where will we be in one hundred years, in one thousand years from now - even ten thousand years is a very short period in the life of mankind and in the life of this earth. I doubt very much, however, that humans will ever give up the decision making to machines or to other creatures.

Thus, I come back once more to responsibilities of our group here. The discourse here must not end today. We cannot rest content, passively just recording what is happening in technology and society in the world around us. We have a mission, we have to set out, each on his and her own, on a crusade to inform, convince, persuade and indeed force industry, commerce and government to use the fire of Prometheus to the good of all mankind. That is my interpretation of eco-technology.