DOCUMENT RESUME

ED 132 113 SO 009 698

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TITLE Technology and the Nature of Man: Biological Considerations. An Occasional Paper on Man/Society/Technology.
INSTITUTION West Virginia Univ., Morgantown. Coll. of Human Resources and Education.
PUB DATE Sep 76
NOTE 29p.; For related documents, see SO 009 697-702
AVAILABLE FROM Book Store, West Virginia University, Morgantown, West Virginia 26506 ($1.50 paper cover)

EDRS PRICE MF-$0.83 HC-$2.06 Plus Postage.
DESCRIPTORS Adjustment (to Environment); *Biological Influences; Biological Sciences; Biology; Biophysics; Environmental Influences; *Evolution; Futures (of Society); Higher Education; *Human Body; Human Development; Life Style; Man Machine Systems; Technological Advancement; *Technology

ABSTRACT

This seminar paper explores biological aspects of the man-technology relationship. From man's beginning and continuing into the future, technology is interwoven extensively in the biological fabric of man. Five facets of the biology-technology interaction are examined: (1) technological innovations enabling man to learn about his biological mechanisms; (2) technological influences on man's evolution; (3) technological procedures designed to enhance man's biological capacities; (4) technological byproducts which adversely affect man's well-being; and (5) potential future technological manipulations which may affect man's future biology. It is believed that the future biological development of mankind depends extensively upon the pace and direction of biological technology. Some future technological manipulations which have been predicted involve birth, genetics, prolonging life, medical improvements, enhancing the capacity of the mind, man-machine relationship/combination, and creating life. (ND)

TECHNOLOGY AND THE NATURE OF MAN - BIOLOGICAL CONSIDERATIONS

By

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An Occasional Paper

on

Man/Society/Technology

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Published by

Technology Education Program
West Virginia University
Morgantown, West Virginia 26505

September, 1976

Preface

This paper was presented as one in a series of seminars on Man, Society, and Technology, conducted by the program of Technology Education at West Virginia University during the 1973 summer session. Over fifty individuals, including faculty and students from the university as well as individuals associated with the university through other institutions and endeavors, participated in the seminars.

The seminars were dedicated to a better understanding of the modes of inquiry, basic assumptions, principles, and concepts used by members of various disciplines and professions as they pursue answers to questions concerning the nature of man and technology in relation to the problems and issues associated with ecology, work, theology, law, medicine, politics, education, and economics; and questions concerning values, technological assessment and forecasting.

One overwhelming conclusion was the realization that the complex issues and problems associated with technology are related directly to decisions which are functions of value systems. Values require examination and reassessment. The educated citizen of tomorrow can not be trained as a narrow specialist nor can the humanist remain technologically aloof or illiterate. Education for the future may mean a rebirth of the renaissance man and perhaps a reevaluation of the technologies and humanities and the creation of a new interdisciplinary effort called the "techmanities."

The paper by Lauralee Sherwood, entitled "Technology and the Nature of Man: Biological Considerations," explores one aspect of the Man, Society, Technology equation and provides a beginning for discussions which should lead to more intelligent and effective decision making.

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September, 1976

Technology and the Nature of Man -
Biological Considerations

Lauralee Sherwood

Technology is interwoven extensively in the biological fabric of mankind. It is technology which first set man apart from other biological species in the past, technology which continues to play a dominant role in enhancing and/or degrading his biological qualities of the present, technology which promises to determine extensively the future of his biological existence and technology which has given him knowledge of his own biological mechanisms. Since technology is so intricately involved in the biology of man this paper examines five separate facets of biology - technology interaction as follows: 1) technological innovations enabling man to learn about his biological mechanisms; 2) technological influences on man's evolution up to this point in our history; 3) technological procedures purposely designed to improve or enhance man's biological capacities; 4) technological by-

products which adversely affect man's biological well-being; and 5) potential future technological manipulations which may determine the future biology of man.

Technology to Learn About Our Biological Mechanisms

Technology has given man the tools with which to critically and objectively examine the very process of life itself. Up until the seventeenth century man could understand only superficially about the biological processes which he could grossly observe. He knew nothing of the cellular, chemical and molecular processes underlying these gross observations. From the discovery of the microscope in the seventeenth century on, however, man has been developing new and ever more sophisticated techniques for exploring further and unraveling the mystery of "what makes us tick". Instruments have not only expanded the scope and sensitivity of man's senses, such as enabling him to see objects smaller than could be detected by the naked eye, but instruments also reveal phenomena and forces to which the body has no sense receptors, such as electric charge which is vital in the understanding of brain and muscle function. Furthermore instruments can provide the objectivity and reliability so essential to research and control. What could not be known yesterday because there was no way of measuring it can easily be known tomorrow through new technology. In fact faith in our technological capabilities has led some scientists to the conclusion that it is only a matter of time before we understand completely and can duplicate the life process, as recently declared by Professor J.D. Bernal, (Taylor, p. 188).

"Life is beginning to cease to be a mystery, and becoming practically a cryptogram, a puzzle, a code that can be broken, a working model that can sooner or later be made."

Implicit in the acquisition of knowledge about our biological mechanisms is the ability to manipulate these mechanisms, for better or for worse.

Technological Influences on Man's Evolution

The fabrication of tools is sometimes regarded as a sign of the achievement of human status. Upright posture is also considered to be a characteristic which differentiated early man from other primates. Undoubtedly these factors played interacting roles. According to Comfort the sequence of progress of the early emergence of man would be (Comfort, p. 54)

"- partly erect posture - power to use tools - fully bipedal stance - better tools - premium on higher intelligence - further progress. It now looks as if this is correct: The tools came first, and the power to make them may have influenced the process of evolving human structure and human abilities from a much earlier stage than had been thought."

Thus it might be said that technological capabilities, i.e., the use of tools and the increased mental capacity which it implies, together with the erect posture, are important biological distinctions of early man. Based upon a process of natural selection the populations that survived were those that contained genes ensuring efficient tool - making and tool - using as well as physical stamina, cunning and endurance.

These first men who based their existence primarily upon their ability to hunt gradually gave way to the Neolithic farming way of life. The history of man's development after the Neolithic is too complicated

to be followed here. With the discovery of the smelting ores and the making of bronze and later the discovery of iron, the inventive capacity of the human brain soon began to release the stream of new technological aids to life that has increased until today. New sorts of tools were invented to assist with living by enhancement of some function that men previously performed with their unaided powers. As the tools were perfected, symbolic communication about them was developed, leading to new language forms such as those of logic and mathematics. Also more subtle religious and philosophical concepts appeared. The groups of people that were able to take advantage of such developments survived at the expense of their neighbors. Education, conformity, and restraint must have been important factors, as well as inventiveness and physical strength. The power to discover and use new tools with which to get a living and to fight were increasingly necessities for success and survival. All such capacities undoubtedly involved subtle changes in the features of the two major control systems of the body - the nervous system and the hormonal system, but unfortunately we know almost nothing about the inheritance of such capacities and can at present only speculate as to how it operated to determine the present developmental stage of human biology.

As with all other species, man is continually evolving, but at the present time the selective forces which act on him are in many ways different to those which acted on him early in his history and those acting on other living creatures. The great difference between man and other animals in this context is that natural selection for the lower animals still depends almost exclusively upon "survival of the

fittest" in the natural environment, to which they must make the necessary biological adaptive modifications, while man is in a position to modify or adapt his environment to suit himself. Clothing, the introduction and improvement of agriculture, heated and air-conditioned housing, the adoption of sophisticated means of transportation, modern medicine and surgery - these are some of the technological means whereby man can and has adapted to the earth's environment without undergoing biological adaptation. Man alone with his technological achievements has been able to inhabit and survive in literally every niche of the land, from the tropics to the arctic, and, to a limited extent now but undoubtedly a greater extent in the future, from outer space to the ocean's depths. However, there is no evidence that the operation of natural selection has been entirely suspended or bypassed. It probably continues to operate in the new zone of adaptation into which man has moved, namely the new environments which he is creating in the process of controlling the natural environment. Perhaps those best adapted to survive the stresses of modern living and our polluted environment will be those who survive to pass their genetic stamina to future generations.

Technology to Improve or Enhance Man's Biological Capacities

In many direct and subtle ways technology has improved or enhanced our biological capacities. We are better nourished, healthier, and have greater life expectancies today thanks to our technological achievements particularly in the areas of agriculture, medicine, and sanitation.

Agricultural technology has steadily been improving our nutritional

status up until now. Through the use of pesticides, crop rotation, modern farm equipment, soil management, selective breeding, etc., we are now able to produce more food on less land than ever before. Through special processing, packaging, shipping, and storing of these agricultural commodities we are able to enjoy an abundant supply of a wide variety of even seasonal foods throughout the year. Even though man undoubtedly has or can develop new methods for improving the food supply tremendously, recently fears have been expressed that severe food shortages await man in the future if the population explosion does not level off concomitantly. Hopefully man has the wisdom, ingenuity, and stamina to cope with this crisis or world-wide famine would certainly lead to the biological degradation of man just as it has facilitated the biological improvement of man in the past.

One obvious influence of improved nutrition is the so-called secular trend which is the term used to describe the tendencies toward greater size and earlier maturity. If we look at the statistics which have accumulated over the past 150 years or so, we find that at any age the children of today are bigger than their earlier counterparts were. One only has to visit a museum and examine the dimensions of the armors and costumes to be aware that the average American male of today is much larger than were the medieval knights. Evidence also indicates that boys and girls are becoming sexually mature six months to two years earlier than did their parents; in fact on the average sexual maturity is now reached almost three years earlier than it was a century ago.

The change in size first became noticeable in prosperous industrial countries such as the United States. At first this difference was

thought to be of genetic origin, but evidence has accumulated which indicates that the secular trend has been caused by environmental factors, most notably improved nutrition. Comparative studies between off-spring of emigrants to the U.S. and their kin who stayed in the homeland revealed an astonishing difference in size between the groups. In all cases, the American-born children were by far the tallest. With industrialization in other countries the same trends of increased size and earlier maturity are being evidenced. Under normal conditions, the growth of the modern child in the Western world is not interrupted by seasonal nutritional deficiencies, as was the case in the past and as still occurs among most nonindustrialized people. The general availability of milk, of vitamin sources, as well as of a great variety of food permits a well-balanced diet and consequent uninterrupted and rapid growth throughout the year.

Good nutritional status also improves our mental capabilities and our general disease resistance. Other achievements in the field of medicine and surgery have continued to prevent or cure disease and improve the biological health of man. Many of the disease problems of the past have been conquered through health science technology. Infectious diseases which were at one time the biggest killers of man are limited now thanks to antibiotics, immunizations, and improved hygienic measures. Parasitic infestations likewise can be eliminated for the most part by appropriate drug therapy and hygiene. Awareness of nutritional diseases and appropriate additions to the diet have brought the decline of rickets, scurvy, and so on. Complications of pregnancy and birth defects have decreased with improved prenatal care.

Techniques are available now for even giving transfusions to the fetus in utero. People with metabolic disorders such as diabetes mellitus can lead relatively normal lives with provision of their metabolic deficiency, insulin. Surgical procedures and prostheses can remove, repair, replace or improve diseased or destroyed parts of the body. Amputees need no longer hobble around on a wooden stump. Techniques have been developed which pick up and amplify nervous impulses or signals from the severed end of the nerve and then use these signals to activate an artificial limb, thereby making a machine directly and sensitively responsive to the nervous system of a human being. Strides are also being made in the areas of mental health and nervous disorders. Children with phenylketonuria once were destined to be mentally retarded, but now with close dietary regime low in phenylalanine these children develop normally. Sufferers of Parkinson's disease characterized by severe tremors have received relief by treatment with L-dopa which replaces a deficient chemical in their body.

With the decline of infectious diseases which were responsible for high infant and child mortality, there has been a concomitant rise in chronic and degenerative diseases as the population age has increased. Medical personnel are making strides now toward bringing these diseases under control. Intense research is on-going to determine the causes and cures of cancer, cardiovascular disorders, and collagen disorders such as arthritis. Meanwhile efforts to abate these diseases continue. Coronary care units with intensive continuous monitoring of heart attack victims by a vast armamentarium of equipment saves many lives. Artificial pacemakers restore the normal rhythm of the heart when the

biological pacemaker is destroyed by disease. Early diagnosis with new technological skills, surgery, irradiation, and chemotherapy offer hope for cancer patients. Even for those who have vital organs beyond repair, such as chronic kidney disease, hope has come in the form of renal dialysis and organ transplant.

These are just a few examples of the many marvelous ways technology has served the medical profession to repair or improve the biological capacities of man. With continued improvement in methods of prevention, diagnosis, and treatment, most people are optimistic that the majority of human ailments may be brought under control. In fact there are groups of people so optimistic about the capabilities of applied science that they have formed societies and paid sums to insure that, at death, their bodies will be preserved by freezing, on the assumption that medical science will be able to thaw them out and restore their defective parts at a future date when the answer to their therapeutic problem has been solved.

Adverse By-products of Technology

Technology is increasing at an exponential rate and while it is true that technology has unquestionably improved our lives and our standards of living, there have been unintended adverse by-products; technological innovations frequently bring with them potential hazards. In using technology, we are forging a two-edged sword and in most cases the undesirable edge of the sword has been unsuspected, unforeseen, subtle and often delayed before it strikes. In many applications we lacked a sufficiently broad background to envisage all of the negative implications. We have been forging ahead with our vision focused only on the positive edge of the sword because we have had a limited

ability to comprehend the repercussions of our technological arrogance. Many examples substantiate the fact that we must be cognizant of potential harmful effects of technological innovations and learn to balance the good with the bad.

The first area of adverse side effects which comes to mind in these days of the impending ecological crisis is environmental pollution. Air, water, noise, radiation and solid waste pollution are all marking their effects upon man's biological well-being. Some of these effects are immediate, but more seriously probably are the latent effects which will show up subtly later as disease or as genetic alterations. For instance although for the most part inhabitants in areas of heavy industry and traffic appear day by day to be making a successful adjustment to massive air pollution their bodies are paying a subtle toll. While they continue to function effectively for the time being despite the presence of irritating substances in the atmosphere they breathe, the linings of their respiratory tract are registering the insult, undermining the normal defense mechanisms of the lung. Each exposure leaves its mark and eventually the cumulative effects of the irritants result in delayed pathological manifestations, primarily in the form of irreversible pulmonary disease. Epidemiological studies indicate that chronic bronchitis, emphysema, and lung cancer take twice as heavy a toll in polluted urban areas compared to relatively non-polluted rural areas, even ruling out the factor of cigarette smoking.

One further factor compounds the pollution problem and that is the phenomenon of synergism. A common example of this is found between two types of air pollutants - sulfur dioxide and carcinogens (cancer - causing substances). If the levels of sulfur dioxide and

a carcinogen in polluted air are both doubled, the resultant hazard is much more than doubled, because sulfur dioxide inhibits the lung's normal self-protective mechanisms and makes it more susceptible to the carcinogen. In synergism therefore the over-all effect of a complex biological insult is always greater than the sum of the effects of its separate parts. This is why new threats to our biological well-being often arise in the course of gradual, quantitative changes in the level of exposure.

Even more subtle changes in the biological fabric of mankind occur in the case of genetic mutations which are known to occur for instance in exposure to radiation. Recently it has been intimated that chronic exposure to some chemicals may also produce alterations in the genetic make-up of future generations.

In addition to the pollutants in our atmosphere and water, we are continually being exposed to an ever increasing variety and quantity of chemicals from other sources - for instance pesticides; food additives such as artificial sweeteners and preservatives; household items including the astounding number and diversity of products under the kitchen sink, in the bathroom, and in the garage; and drugs. In addition to drug abuse, even "normal" drug therapy can lead to adverse, sometimes life - endangering reactions.

For the most part we do not know the effects of most of these chemicals in the body. Furthermore it would not even be sufficient to examine the effects of each type of molecule individually, because within the body interactions such as synergism may and probably do occur. It is possible although not yet determined that some of these agents to which man is now inadvertently exposed will cause serious disease, shortening of the life span, decreased fertility, or deleterious

mutational changes in genes. Such possible effects may be numerous yet difficult to discover. To illustrate this fact witness a few of the "mistakes" we have already made.

1) The association between cigarette smoking and lung cancer has taken decades to become recognized.
2) Thalidomide was given innocently as a sleeping pill until later it proved to cause deformities in babies of a large percentage of pregnant women who were critically exposed.
3) Defoliating preparations sprayed in huge amounts on the forests and croplands of Vietnam have now been found to induce birth defects in laboratory animals and may be the cause of increased birth defects among recently newborn Vietnamese babies.
4) One little known story is that of polyvinyl plastic. In the 1950's the plastic industry developed new types of flexible, synthetic materials with good wearing properties known as polyvinyl plastics. At once they found a ready market in automobile upholstery, so that within a decade nearly every American car was upholstered with the new plastic and almost everyone came in contact with the material. Many people noticed that a slippery, transparent film occurred on the steering wheel and windows of such cars on hot summer days, but tolerated the situation. Another ready market for the new plastic was in hospital blood banks where polyvinyl equipment replaced glass equipment for the storage and transfusion of blood because it was unbreakable and flexible. Later a new sometimes fatal phenomenon tagged "shock lung" was noticed in wounded soldiers in Vietnam after transfusions of long-stored blood, but the condition was not correlated to the transfusion process itself at the time. Then in 1970 a researcher at Carnegie

Institution's embryology laboratory was having trouble with an experiment. Upon investigation he discovered that plasticizer was leaching out of the polyvinyl containers into his culture medium, killing the embryonic cells with which he was working. Further studies demonstrated that the plasticizer in the polyvinyl plastic also readily enters blood stored in such containers, and that the plasticizer activates histamine release and causes blood platelets to become sticky and clot, which is probably the premise for "shock lung". Plasticizers have also been found in some foods, which are often packaged in polyvinyl-coated containers. Human exposure to plasticizers also includes plastic toys and water hoses and the new "wet-look" plastic garments.

According to Commoner the plastic story should remind us of our ignorance - (Commoner, p. 231) "that we are hardly aware of the potential hazards from hundreds of similar substances that have so quickly become ubiquitous in our environment. It warns us that the blind, ecologically mindless progress of technology has massively altered our daily environment in ways that may, much later, emerge as a threat to health. Unwittingly, we have created for ourselves a new and dangerous world. We would be wise to move through it as though our lives were at stake."

Besides the pollution problem and the chemical insults in our environment, there are other adverse spin-offs of our technological achievements. Foremost among these is the rapidly changing pace of life brought on by technological advancement, resulting in the many stresses, uncertainties, and novelties which are continually barraging mankind today. Man's entire biological mechanism is aimed at ensuring a constant "internal environment" in the face of a changing external environment. This concept of constancy in the internal environment is referred to as homeostasis and indeed

physiological adaptations occur continuously to maintain this homeostasis.

We have two lines of defense to maintain homeostasis in the face of stress. The first line of defense is neural which depends upon the activation of the sympathetic nervous system which immediately prepares our body for "fight or flight" in emergency situations. The heart starts to beat faster, blood pressure is raised, blood is diverted to the skeletal muscles, and the body tenses as it prepares to handle the impending situation. Such a response is advantageous in the face of a physical threat such as those encountered by early man when dealing with predators and enemies. But if the sympathetic nervous system is called into play because we are stressed by worry and competition on the job, tension at home, struggling through a traffic jam in an over-heated car, etc, the response which would have been advantageous in the case of physical stress is inappropriate and may be deleterious in the face of these emotional, psychological or social stresses.

Continued stress may bring into play the second line of defense, endocrine, wherein the hormone cortisol is released from the adrenal gland into the blood to be circulated throughout the body. Cortisol alters carbohydrate, fat and protein metabolism within the body to make available a ready pool of materials to be used in the repair of damaged tissues or to be used as immediate sources of dispersible energy. Once again such a response is appropriate if actual physical trauma is being incurred but is harmful if the stress is not of physical origin. According to Rene Dubos (p. 340, Toffler) - "There is

absolutely no question that one can overshoot the stimulation of the endocrine system and that this has physiological consequences that last throughout the whole lifetime of the organs."

Let us examine the implications of one of these biochemical manifestations as an example. Changes in lipid or fat patterns of the blood during stressful situations is one such factor which has been studied extensively. It has been shown that non-physical stressful situations release fats which are not used metabolically. This may account for the fact that atherosclerosis (fat or cholesterol deposits along the lining of the blood vessels) seems to be correlated with frequent and prolonged stressful situations. Coupled with this is the fact that decreased physical exertion which accompanies our sedentary jobs (let the machines do the hard work) also results in increased cholesterol levels and a greater propensity toward cardiovascular disease. Furthermore technology has provided us with a diet high in meat, milk and milk products, and eggs, all dietary sources of cholesterol which were not as widely available in the past. Thus increased stress, decreased physical activity, and increased cholesterol intake are all factors which may increase blood cholesterol, predisposing to atherosclerosis, a forerunner of heart attacks, and all of these factors may be attributable to our technological society. Thus by stepping up the pace of scientific, technological and social change, we are placing increasing demands upon our body to adapt, and we are paying the price of adaptation by tampering with our chemistry and biological stability.

We do not know the optimum level and optimum cycle frequency for the various stressors that we are exposed to, and we know very little about the physiological cost of making an adaptation to any given stressor. A meager attempt to start quantitating the relationship between need for adaptation and disease has been made by Dr. Thomas H. Holmes at the University of Washington School of Medicine. He created an ingenious research tool named the "Life - Change Units Scale", which made it possible to crudely qualify the rate of change in an individual's life. By extensive studies and correlations he showed that the rate of change in a person's life - his pace of life - is closely tied to the state of his health. His research established that (Toffler, p. 330)'"alterations in life style' that require a great deal of adjustment and coping correlate with illness - whether or not these changes are under the individual's own direct control, whether or not he sees them as undesirable. Furthermore, the higher the degree of life change, the higher the risk that subsequent illness will be severe. So strong is this evidence, that it is becoming possible, by studying life change scores, actually to predict levels of illness in various populations." Thus changes brought about by technological innovations whether desirable or undesirable clearly can affect the biological status of man.

Several other adverse technological by-products might be mentioned briefly to indicate the diversity of effects that have occurred. For instance accidental injury and death are among the leading causes of morbidity and mortality. Many of these accidents occur through the improper use of modern technological conveniences, such as factory equipment, automobiles, ingestion of cleaning agents, etc.

Another monumental problem today, that of population explosion, is partially due to applied science which provided antibiotics, immunizations, DDT control of the mosquito vector of malaria etc., to

decrease tremendously the death rate of the children of the world, who then survived to reproductive age to hasten the population explosion. To a lesser extent techniques which have led to an increased life span have contributed to the population explosion.

One area which has tremendous implications for the future gene pool of man is euphenics, or the science of controlling diseases of genetic origin, so that the sufferers of these diseases live to reproductive age and hence pass their defective genes on. For example, juvenile diabetics when treated satisfactorily with insulin enjoy relatively normal lives and can reproduce whereas in the past they did not survive to reproductive age. There can be no doubt whatever that the survival to reproductive age of patients with severe juvenile diabetes will lead and has indeed already led to a steady increase in the number of new cases of severe diabetes in the younger age groups. Another example is the mental retardation of congenital phenylketonuria which can be averted, as indicated earlier, by a rigid dietary restriction of phenylalanine, but the genetic defect remains and can now be passed on where in the past the victim would have spent a subnormal life of institutional confinement. As medical science probes further and finds the answers to more and more of such diseases this could lead to a deterioration of the future genetic pool of man.

The most awesome of the adverse effects of technology on man is the threat of complete extermination of Homo sapiens in two possible different ways. Foremost of course one thinks of the threat of a widespread nuclear holocaust with lethal levels of fallout over all inhabited regions gradually killing those who survived the initial blasts.

In the event that there were survivors two other threats to the integrity of our biological species would exist. First food chains would certainly be disrupted by world-wide fallout and long-term rise in radioactivity, making it a clear possibility that man might be unable to find sustenance. Secondly in addition to the deleterious effects of chronic irradiation to their own bodies, the survivors would suffer genetic damage from radiation - induced mutation, resulting in future generations of abnormal offspring.

Extinction of man is possible in another way unrelated to the nuclear threat. Man has evolved to this point by adapting to his environment or by adapting his environment to suit his needs. But now that the environment is changing at such a rapid pace through technological innovation, will man as a species be able to continue to adapt rapidly enough? Thoday defined the survival of the fittest by saying that (Potter, p. 47) "the fit are those who fit their existing environments and whose descendants will fit future environments." Dobzhansky points out that (Potter, p. 48) "no biological law can be relied upon to insure that our species, man, will continue to prosper or indeed that it will continue to exist. However man is the sole product of evolution who knows that he has evolved and who is capable of taking steps that might help to insure survival."

These examples have served to demonstrate that technological advancement has created numerous problems which must be dealt with. If sound preventive procedures are not soon devised in parallel with technological advances (Taylor, p. 220) "Science will begin to be seen in a very disenchanted way, as the bringer of gifts which too often end by cancelling their own benefits ... Instead of asking 'Will this provide us with something we can export or at least sell?' the question will become 'Will this create for us problems which will nullify any advantage?'"

Potential Future Technological Manipulations

The future biological development of mankind depends extensively upon the pace and direction of biological technology. A wide diversity of techniques will be developed which will have profound influences even within our own lifetimes. The following predictions are among those possibilities cited most frequently by experts in the field. The list is neither exclusive nor inclusive; undoubtedly not all of these predictions will be realized, while on the other hand breakthroughs in areas totally unconceived of today may radically change future progress and efforts.

1. Birth Technology

a. Artificial insemination - This technique has already been used with success in humans, mainly to overcome sterility. It is usual to distinguish between fertilization with sperm from the husband (AIH) or from some other donor (AID). The next breakthrough here might come through the use of sperm frozen and preserved for prolonged periods of time. Mothers-to-be might choose sperm from men with particular traits which they desire to have in their children, or a man could conceivably sire a child after his death.

b. Egg-transfer - Another biological technique which may have an impact on the family before the end of this century is egg-transfer wherein fertilized eggs are transferred from one female to the uterus of another. This might benefit infertile women who cannot conceive normally, but would have no difficulty in carrying a baby to full term in the uterus.

c. Controlled sex determination - If it became possible to differentially inactivate male-determining or female-determining sperm either in the male or after intercourse in the female reproductive

tract, or to separate the two populations of spermatozoa in vitro and inseminate with one or the other, a couple could be assured of the sex of their child.

d. Embryo transplants and embryo cultures - Frozen embryoes completely labelled as to sex, eye color, probable size at maturity and probable IQ, may at some future date be purchased by a woman for implant in her own uterus. An even more distant possibility is the development of a system to raise embryoes outside the human body, or Huxley's "test-tube babies".

2. Genetic

a. Genetic engineering (eugenics) - With new knowledge about the structure and nature of coding of the DNA molecule within the gene which determines the genetic characteristics of an individual, tremendous possibilities exist for gene deletion, gene insertion, or gene surgery for subtle or dramatic alterations. The implications are awesome. Changing the genetic constitution of man would be a tremendous responsibility. We know too little about for example the physiological basis of human intelligence and its inheritance. We have no basis to predict what would be the best genetic structure for the future. Furthermore we would run the risk of breeding out good characteristics unwittingly in attempts to breed in another. And what do we do with the "mistakes"? They can't be discarded as one might do if manipulating the genetic characteristics of a variety of corn for instance.

b. Genetic duplication (cloning) - Another genetic maneuver of the future might be the exact genetic duplication of an individual. At this point it is possible to take out the nucleus of an unfertilized frog egg which contains only one half of the genetic information necessary for an individual, that from the mother, and replace it

with a nucleus from a body cell of another individual which contains complete genetic information. The resultant egg will develop into an exact genetic copy of the donor of the cell. Used wisely this technique might be beneficial for instance in agriculture, where herds of "instant champions" could mean a large percentage jump in meat production over the whole world. The prospects of applying the same technique to humans is frightening. Who could phantom a "herd" of Hitlers for instance? Most of us probably still adhere to the old adage, "Variety is the spice of life".

3. Prolong life - According to Dr. Alex Comfort, the director of Britain's Medical Research Council Gerontology Group (Taylor p. 94) "there is the real possibility of a breakthrough affecting either human vigour at high ages, or the human life span, or both". Increased life span with decreased vigor, or a situation in which physical age is arrested as mental age continues to decline would be undesirable possibilities of tampering with longevity. Another form of control which has the support of many gerontologists is the selective prolongation of the period of life which is the most socially productive, so that an individual would remain at his peak for a longer period of time rather than merely prolonging the senescent days.

4. Medical improvements

a. New methods of diagnosis - such as comprehensive automated clinical biochemistry, new drugs, new medical and surgical equipment all promise to improve the status of our medical care.

b. Replacement parts

1) Transplantation of organs - has met some success already and undoubtedly will reach new horizons in the future as more complete immuno-suppression is achieved. The limiting problem here will be the source of organs for transplant.

2) Artificial organs - offer an alternative hope to organ transplant. Probably the first such device will be an artificial heart. Already there are by-pass machines which can take over the function of pumping the blood through the circulatory system during cardiac surgery, but machines of this type at the present are too large to be placed within the body. Once technology achieves functional machines of appropriate size artificial replacements for some of our vital organs will be a very real possibility.

3) Organ culture - is an even more radical alternative, wherein organs could be grown from embryonic tissue in whatever quantities required. Cell and tissue cultures are now well-developed techniques; organ culture is the next logical step even though technical difficulties are presently hindering this line of progress.

4) Regeneration - of new parts is still another means of restoring body function. Lower animals have regenerative capacities; for example lobsters can regenerate claws, and newts can regenerate whole eyes and optic nerves in a few weeks. Perhaps this ability to regenerate is simply turned off somehow in higher organisms, including man, but perhaps might be turned on again by some application of embryonic fluids or tissue inducers or neural excitation. Obviously a man losing a finger or a foot would greatly prefer growing a new one to using a mechanical prosthesis, no matter how sophisticated the device might be.

c. Control of pain - has been accomplished to a degree already through anesthetics, analgesics, etc. but the future promises more. Both from the electrical and chemical angle man's power to control

pain is becoming steadily more absolute. Before very long most if not all forms of pain will be in principle controllable and control methods will become simpler and more reliable. It is speculated that everyone may have his own portable pain - control unit to be used in case of mischance.

5. Enhancing our mental capacity

a. Increasing intelligence

1) Use of drugs - which prolong thinking time and enable a person to marshal the facts he knows, though they cannot tell him what he does not know, is one avenue of increasing intelligence.

2) A recent discovery of a factor controlling nerve growth opens another possibility for raising intelligence provided treatment could be given in the fetal stage or the earliest weeks of life.

3) Since the brain consists of two symmetrical halves, one of which is dominant, it might be possible to exploit the reserve capacity of the non-dominant half of the brain to increase mental capacity.

b. Memory control - including transfer of knowledge chemically from one individual to another and memory erasure are probably areas which will preoccupy future scientists once the nature of memory is more thoroughly decoded.

c. Control of moods and emotional states - through the use of drugs is already upon us today and is being extensively abused. Discovery of new chemicals and further experimentation will undoubtedly lead to wider use of mind-controlling drugs, but hopefully under more rigorous guidelines than exist at the present.

6. Man-machine relationships - Man and machine in the future may very well take on what we would consider today to be bizarre relationships, ranging from "man-amplifiers" to "cyborgs" to "ectopic brains".

a. Man-amplifiers - are conceived of as machines which when worn improve upon or amplify our own biological capacities. Work on a 'muscular system' which will outdo human muscles is already in hand, with preliminary designs calling for a man-amplifier to be able to support half a ton on either hand.

b. Cyborgs - the abbreviation of cybernetic organism, is the term coined for the speculated hydrids of men and machines where the two are so intermixed as to be virtually indistinguishable. The essential difference between the man-tool relationship and cyborgs is that the communication between the cyborg components would be two way. Not only would the machine receive instructions from the man but also would inform the man of conditions it is encountering.

c. Ectopic brains - or "brains without bodies" is an even more radical concept which is visualized as a brain maintained in a metal body living indefinitely until overtaken by its own senility. Such a development if it ever were to occur is undoubtably a century or more away.

7. Creating life

In their search to discover in detail how living things work scientists may learn how to create life. Man has already made a virus, the lowest form of life, by placing the appropriate components together and allowing them to assemble themselves. The next step is most likely to come from attempts to build the structures within

the cell, followed if successful by synthesis of a living cell. Creation of a living cell capable of feeding, metabolizing, excreting, and equipped with some kind of irritability or sensitivity to the environment would be a fantastic achievement! The creation of life would be the ultimate technological control over biological processes.

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