Orthobiosis: The Perfection of Man

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My assigned task is to comment on the promise and the menace of futuristic advances in biological research.

This is a hazardous course.

A great deal of recent discussion about "genetic engineering" should be mentioned only to be deplored, for it gives a distorted view of the present status and ultimate purposes of research on molecular biology. Nevertheless, it would be obtuse to deny the ultimate revolutionary importance of developments that bear on the further course of human evolution. By replacing blind fate with human reason, they may place a crushing burden of responsibility for the assignment of goals for man. Many people react with dismay that knowledge is coupled with such a responsibility. Failing to accept it is also a decision, and one that has its own consequences.

This is an old story, one that links Prometheus to Adam. Once man knows that he can know, and that he can judge good and evil, his acts have a moral significance whether he chooses to learn or to deny.

There are other problems, for example of time-scale. Twenty years is a long time in the growth of science, and the fifty years of an adulthood are too long for reasonable extrapolation. In such an interval, *anything* might be possible, even the most lurid titillations that the popular press advertises about humanoids of either mechanical or biological provenience. In refusing to dwell on such extreme speculations, I do not deny the technical possibility of their accomplishment. I merely point out that so much else will have happened in every other sphere of human concern that it would be foolish to concentrate on very specific forecasts. The forecasts will be objectively faulty, and more important, the context in which future events will be judged will have changed more than we can foresee. (In 1920, contraception was a dirty word, and who would have dared discuss voluntary abortion, much less advocate it!)

The critic of "biological engineering" should also be careful to deal with the contemporary aspects of his subject in context, for which reason I prefer the phrase *orthobiosis* (the correction or perfection of life and of man). Orthobiosis is already implemented on a very large scale—constructively,

in the practice of medicine and hygiene; negatively via a global system that ensures that hundreds of millions of underprivileged children will be mentally retarded owing to malnutrition and virus infection. The drastic extension of the average human lifespan during the past century is itself a major orthobiotic influence. Apart from all the changes in the human environment, the quality of a life is very different with the average prospect of 60 as compared to 20 years after adolescence. The side-effects of infant-death control, without the balance of birth control, hardly need to be elaborated. The prospect that death can be postponed, without the means to retard senescence, may be an equally painful technological disharmony of the next few decades.

Some examples of orthobiosis may be unduly traumatic to the layman who has had insufficient experience of human pathology to appreciate the gravity of some of the ills that cry out for help. No procedure could be more intrusive than the surgical modification of sex, and it would hardly be condoned anywhere without the knowledge of the suffering that results from gender-confusion. An awareness of the chromosome abnormalities, chimeras, hermaphrodites and congenital abnormalities that are nature's experiments with man is prerequisite to understanding research in embryology that may lead to interventions in human development. Man's evolution from and biological affinities to other primate species must also be perceived as an objective fact, not a literary allusion. This is not a demand that these matters be left to experts; to the contrary, it is a plea to broaden the base of public understanding for intelligent participation.

The techniques of *biology* cannot be fairly judged without comparing them to those of *education* and of the multitude of other ways by which normative behavior is shaped by the cultural milieu—by just such institutions, for example, as the Nobel prizes and this very series of symposia. The understanding by the reader that the very act of perception both actively alters and is modulated by his own neurobiological structure is another sine qua non for an informed perspective on orthobiosis. (Professor Bruner will speak to this in detail.) This term, then, describes the whole category of influences on the quality of the human organism—an enterprise in which religion, politics, education, medicine and mass advertising converge with the evolutionary endowment of the individual human being.

Antithetical reactions to the concepts of orthobiosis can be expected from various people, depending on their accustomed ways of coping with difficult problems. The scientist asks for more fundamental facts and is sceptical about mere speculations; the philosopher resonates with issues bearing on the nature of man; the legalist may already have proposals for regulation and control. The poet may understand best of all that many of

our discussions of orthobiosis are a metaphor, even a parody of existing institutions. The greatest merit of talking about "genetic engineering" may be the light it throws on the de facto patterns of human evolution; about euphenics for the exposure of the brutally dysphenic effects of our present environment; about sex control to illuminate the disparate value our culture puts on the sexes. It is also important that we understand social control in much broader terms than the compulsions of criminal law. To install a policeman in the bedroom is not a promising approach to questions of population control, whether we think of mere numbers or more subtle questions like "who shall decide who is to be born?"

Value judgments inevitably play an important part in the implementation of any programs of orthobiosis. Applied genetics in particular is so laden with religious implications about the nature of man that some question the morality of even investigating the scientific bases of human nature, just as others challenge the basic commitment of western culture to scientific enquiry. This was once called the work of the devil (as in the Faustian legend); the counter-cultures today denounce science simultaneously as a toy of the intellectuals and a tool of class oppression. Since Galileo (or might we say, Prometheus) the Establishment has also feared the revolutionary impact of objective scientific inquiry on the mythologies which sustain the status quo.

At this symposium we have been taxed to make an explicit formulation of a pro-scientific ideology. In general, I have been very leery of such enterprises, and particularly of any claims that a particular ethical system can be validated by a direct application of scientific reasoning, i.e., that morals can be proven by science. Attempts to base ethics on evolutionary biology have been conclusively criticized by Simpson and Dobzhansky[1] as examples of circular reasoning: "How do you prove from what we know of evolution that human individuality is more important than human society? And yet we do feel that individuals should not be sacrificed for attainment of social ends."

Ideology, furthermore, tends to degenerate into a set of wooden formulas susceptible to self-serving rationalizations of the ideologists' established pattern of conduct. It is beyond doubt that more human misery has been inflicted in the name of public ideals, myths, gods, and altruistic interventions, than through the sum total of private venality. Furthermore, the individual ego-ideal is often quite unconscious. The complexes that reconcile the ego-ideal with professed ideology, on the one hand, and actual behavior, on the other, are even more obscure and self-reports about them most unreliable.

Few of us here have digested the vast literature on ideology and on value systems from the different standpoints of religion, economics, history, pol-

itics and psychology. It is delightful to contemplate the creation of the perfect slogan which might mobilize the disorganized efforts of the rest of the world and perhaps even provide a convincing personal cause. In practice, we know that any group of intellectuals needs little license to produce a number of precepts which is some higher power of the size of the group. The "end of ideology" then comes forth as one of the major ideologies of the current era.—The sources of "moral character and moral ideology" are, nevertheless, amenable to scientific investigation as illustrated by the studies of Lawrence Kohlberg[2] on the stages of their development in children. The capacity to defer gratification, which he emphasizes, can be translated as a measure of the scope of the personality. This can, as most religions teach us, be extended in space (empathy or vicarious gratification) as well as in time (investment for larger, future goals).

Science relates to ethics in many ways more defensible than claims on its behalf for ultimate verification.[3] Logical argument can expose inconsistencies within and between posture and behavior. It often brings unwelcome news about the consequences of an action that we might prefer to ignore. (Unfed children will starve to death even if they live in Biafra or India.) Technology which creates many ethical dilemmas can also make for evasions of others: the American ethos has taken pride that an overall glut in total production might soften the inequities of the relative distribution of wealth. If kidney machines or artificial hearts can be made cheap enough we can evade the problem of choosing "who shall live?" now thrust upon us. We already face so many difficult moral decisions that we ought to be glad of any we can defer and keep our strength for the others.

This cautionary preamble still does not deter me from casting a tentative vote in the direction of evolutionary humanism. Julian Huxley was, I believe, an accurate reporter in suggesting that self-admiration was the most pervasive of human ideologies, and that no serious scientist doubted that evolution, in the large, was *good progress*. Even the cynic must respect his own uniquely human capacity for cynicism; the physicist for physical cerebration; the biologist can add an informed wonderment about the actual process of evolution itself and its culmination in man.

At one time I may have scoffed at the efforts to dignify evolutionary humanism as a religion—but the very convening of this session persuades me that Huxley was quite right in his perception of the depth of the religious instinct. If we distill the convergent essence of the beliefs of scientists, we probably will not go far from the doctrines he suggested in his manifesto upon the founding of UNESCO,[4] the working hypothesis of a scientific, evolutionary humanism in which man is dignified as "the sole trustee of further evolutionary progress".

My main complaint about humanism is the quibble that we do not quite know how to define a man (i.e., to identify which bodies are inhabited by souls). No other religion has solved this problem much better. The biologists at least face a more manageable debate on where to divide a concensual line, knowing that life and death, human and animal, are regions on a continuum. My quibble is then a sectarian dissent, not basic schism.

In recent years, man-baiting has become a fashionable literary sport—all our troubles come, we are told, from man's implacably hostile and aggressive character, inherited from his animal ancestors. I know too many good men to accept such a generalization about man. If the trouble were merely in man's genes, we would have a relatively easy task assigned to us, and a full license for the practise of eugenics. We must not overlook the vastness of his task, the perfection of a culture to colonize the whole planet, with no tools other than his wits.

One failing still stands out. Our imperfect solutions aggravate every problem. In contrast, the computer memory can be totally erased; its task is hardly altered by successive iterations, and programs can then be gradually perfected. We must always build on the sins, mistakes and hatreds of every step on the way.

I may, then, summarize my conception of evolutionary humanism with the conclusion that it depicts *man as the historical animal.* Our evolution has reached the point that progress is far more a function of our traditions and our social forms than our biological functions. As part of the world-mind,[5] with a unique consciousness of past and future, each individual should be less jealous of the life of his own body, and more protective of every other one, than a purely zoological ideology would encourage.

Molecular biologists are often slapped with a red herring, the imputation that they degrade man into a mere machine. We do in the main insist on "mechanism", mainly as a reaction to the pessimists who have disparaged and who discouraged research on the frontiers of biochemistry.[6] (The recent elucidation of the mechanism of DNA replication counts for more than all the verbiage that has ever been expended on this debate.)

To insist on the inherent inaccessibility of other processes, like the brain or feeling, to analyses of mechanism remains as much a mistake as to boast of accomplishments whose realization is still remote and may never be complete at the hands of finite human intelligence.

The attribution that man is *merely* anything is merely an idiosyncratic misanthropism.

In the rapture of self-exaltation, many humanists may nevertheless forget that evolution is a continuing process.

The perfectibility of man and the corollary of his present imperfection,

should stand out as one of the most precise implications of the evolutionary outlook.[7] We should be optimistic (and humble) that our posterity will progress beyond our capabilities, even for moral judgment, to the same degree as our own proudly proclaimed emergence from apedom. We have then one precept about values—that we ought to guarantee that there will be a posterity, and that we take care not to foreclose the options available to it. The ravaging of the earth, of primitive peoples, of our wild life, of one another, and even our carelessness about the planets, are our cosmic sins.

This humility supports the policy of pluralism—that the state must not intrude in the intimate lives of citizens except for the most inescapable needs of public order. This principle must be renewed and reinforced to stem the temptations of totalitarian exploitation of techniques of biological engineering, just as the constitutional protection of free speech is the only defense against mind control by the techniques of communication engineering.

"Orthobiosis" has the etymologically obvious meaning "right living". Before discussing orthobiotic innovations—the possibilities of human improvement from new knowledge of molecular biology and genetics—we ought reflectively to ask "what are man's real problems in biological perspective?" We do better to look for solutions to real problems, if we can, than invent problems for our new tricks and techniques.

Uppermost is the avoidance of war, or rather the positive promotion of world harmony and economic development and integration. These are manifestly not problems of biology, at least not human biology; for the political reaction would engulf any effort at biological change. (What could be more hostile than to attack a neighbor with a pacificatory virus? For the tanks would surely follow!)

Economic productivity, especially in tropical and semi-arid habitats, clearly does have a biological basis about which we know very little. The potential for biological innovation in tropical agriculture is now hinted at by the "green revolution" of recent years. These improvements in wheat and rice strains were brought about rather traditional methods; modern molecular genetics is just now being discovered by plant breeding specialists.

The escape of world population growth rates, a byproduct of modern medicine, is a well documented threat to the survival of the species. It is primarily a problem of self-aggravating poverty, i.e., failure of economic development, rather than of the technical potential for food production. Proposals for biological solutions, e.g., by the use of environmental sterilants (antidotes by prescription requiring a license to bear a child) are, fortunately, pure fantasy. Quite apart from the political problems of obtaining public

acquiescence to such schemes, they could never be guaranteed to be safely reversible so as to avoid sterilizing the species.

On the other hand, the present patterns of growth and urban concentration and poverty, are ideal for fulminating epidemics of virus diseases[8] that may spontaneously solve the population problem in the harshest way imaginable.

Poverty, hunger, pestilence, pollution are beyond doubt the further problems that this generation must face, or there will be no posterity. No one of us here would hesitate to abandon every other commitment if he knew any effective route to answer their challenges—and I offer my deepest respect to men here who have had the wit and the power to make important contributions in these spheres. But the paths are tortuous, and the main problems are unabated.

Certainly it would be short-sighted to redirect all our resources into the panaceas for instant relief of global problems. We need to maintain constant vigilance that our remedies do not have side-effects as portentous as the original disease—consider the history of DDT as a rather stark example.

Basic scientists who have worked in the genetics of bacteria and viruses believe that these discoveries have ever growing importance for the prevention and healing of serious human diseases. We live, in the present era, in an incompletely justified optimism about having "conquered infectious bacterial disease" as the fruit of the development of the antibiotics. However, viruses are in general still beyond the reach of antibiotic therapy. Even bacteria, believed to be under firm control with antibiotics, are continuing their own evolution and continue their assaults upon human health with renewed vigor. In the long run, only our continued vigilance over bacterial evolution can justify our hope of maintaining a decisive lead in this life and death race.

However, whatever pride I might wish to take in the eventual human benefits that may arise from my own research is turned into ashes by the application of this kind of scientific insight for the engineering of biological warfare agents. In this respect we are in somewhat the same position as the nuclear physicists who foresaw the development of atomic weapons.

There is, however, a crucial difference. Nuclear weaponry depends on the most advanced industrial technology. It has then been monopolized by the great powers long enough to sustain a de facto balance of deterrence and to build a security system based on non-proliferation. Nuclear power has thus, ironically, become a stabilizing factor tending to reinforce the status quo in parallel with established levels of economic and industrial development. Germ power will work just the other way.

The United Nations Study Report on chemical and biological weaponry

has summarized some infectious agents that have served as points of departure for the development of biological weapons. Any knowledgeable virologist could suggest many more. I will not repeat these technical details, nor will I bludgeon you with the horrible diseases that some of these agents provoke. I will also leave to your own conscience the burden of moral judgements about using these kinds of weapons. Most civilized people would be repelled by the thought, but perhaps no less by exposure to the human realities of any other form of warfare. Overriding such comparisons should be the grave moral issue in a policy that risks the lives of a world of innocent bystanders. Fortunately, these concerns actually converge with our self-interest in calling for a halt to BW before it becomes established in the arms-traffic of the world. (This discussion of BW was written from the standpoint of a U.S. citizen just prior to President Nixon's announcement (Nov. 25, 1969) of the U.S. renunciation of BW.)

My main fears about BW are to do with the side-effects of its proliferation 1. as a technique of aggression by smaller nations and insurgent groups and 2. by the inadvertent spread of disease.

If the great powers could actually protect the secrecy of their BW work I would be much less alarmed. The chance of BW ever being used in a major strategic attack is essentially negligible in the face of the nuclear deterrent. The suggestion that we need BW or CW weapons for specific retaliatory purposes in order to deter their use aims at a ridiculous kind of precision. Will our deterrent missiles have to follow the same trajectories as those that might potentially attack us? Will they have to be launched at the same time of day? Will they have to have the same mix of explosive energy and radioactive fallout? If we are attacked with anthrax strain B27 must we reply with anthrax B27?

On the other hand, if I were a Machiavellian adviser to a would-be Hitler I might indeed advocate a considerable investment in biological weaponry as a desperate approach to the cheap aquisition of great power even if at a very great risk. And, of course, the first thing I would do would be to plant my intelligence agents in the existing BW establishments of the high-budget powers in order to get the necessary scientific information at the lowest possible cost.

However, if I were patient I would not bother to do even that. No security system, no counter-intelligence system in the world expects more than a delay of 5 to 10 years in the leakage of vital information. We do not have, and I presume do not contemplate, security reservations like war-time Los Alamos for the containment of BW research. If a high level activity is to be maintained there will be frequent turnover of personnel. It is unreasonable to expect a tighter security barrier here than has pre-

vailed in any other area, given the problems of reconciling security with a free society. Besides these channels for diffusion of information, there are also bound to be Pueblo-like incidents, and finally calculated leaks in the budget competition of the services. The American people might be the last to know. But we can hardly rely on more than a ten year delay between many important discoveries in BW research laboratories and their availability to hostile and irresponsible forces outside.

As a matter of prudent self-protection, BW research laboratories in the U.S. and the U.K. have pioneered in the technology of containing dangerous microbes. I have great respect for the technical capabilities of the senior civilian management of these laboratories. They should be credited with the outmost diligence in protecting both their personnel and the surrounding community. They have also published a great deal of their work in the engineering of such protective facilities and this experience is unquestionably of great value in public health work. For example, the British laboratories at Porton were acclaimed for the safe handling of the very dangerous Marburg virus upon its first outbreak in Europe two years ago.

In spite of these precautions, disease organisms have nevertheless escaped from time to time and inevitably will do so in the future. Such escapes already constitute a breach of security. They also compromise public health, which is further complicated by keeping civilian physicians in ignorance of potential agents that might fulminate into large scale epidemics. The intentional development of virulent strains resistant to conventional antibiotics obviously worsens the problem. We simply have no way of assuring ourselves that a BW development activity will not eventually seed a catastrophic world wide epidemic that ignores national boundaries.

On the immediate horizon are modern developments in molecular genetics. These undoubtedly point to the development of agents against which no reasonable defense can be mounted. Because of the uncertain danger of retro-action, such agents are hardly likely to be used in consequence of any rational military decision, but would obviously play into the hands of aggressive insurgence and blackmail.

Finally, even the publication, albeit as a positive contribution to humanity, of the technology of safe containment insidiously helps solve a problem that might have hindered a potential insurgent from dabbling in BW.

The problem of containing infectious agents being manufactured and stockpiled in large quantities, or tested in the open air, is a much more difficult technological challenge; and it is encumbered with even more official secrecy than the laboratory work. The main effect of security has not been to deny information to an enemy but to protect an establishment from both destructive and constructive criticism at home. In this case, more

open constructive criticism would be crucial for assurance that procedures for containing microbes are well conceived and correctly implemented.

BW agents for use against man can be expected to be far more capricious than any other form of weapon. For any strategic purpose they are essentially untestable since large populations would have to be held to an uncertain risk. With nuclear weapons we can at least be confident of the laws of scaling. The destruction of targets can be calculated from simple physical measures like the energy released. Nothing comparable to this can possibly apply to BW agents. For this reason again the United States and other nuclear powers have absolutely nothing to lose in disavowing their use in war. Our continued participation in BW development is akin to our arranging to make hydrogen bombs available at the supermarket.

Microbiological research must be expanded in programs of public health research for defense against our natural enemies. In fact, the public health bureaucracy has refused to give prudent thought to the recurrence of major pandemics of human disease, be they of spontaneous or human-intelligent origin. Perhaps this is simply a consequence of their sense of futility about mobilizing the necessary measures of global health needed to protect the species. If we add to already urgent concerns the spread of dangerous diseases from large foci of infection established by BW attack, the prospects become even gloomier.

Our self-interest as human beings urgently calls for the institution of improved measures of world public health and of international controls on the development and use of BW agents. Research related to BW perhaps should continue; but it is of the first importance that this be fear-reducing rather than fear-generating, for the latter can only lead to mutual escalation of anti-human developments.

It is difficult at this stage to detail the texture of new agreements subsequent to our ratifications of the Geneva protocol. We cannot suddenly impose unilateral decisions on the international community; but no other issue can evoke such a unanimity of world opinion. New agreements probably should include (1) public legal commitments against secret BW research; (2) the establishment of central, international laboratories to monitor the occurrence of threatening organisms and to help develop generally available means of protection against them; (3) a legal system to protect the freedom of information and communication of data on disease organisms to such central authorities; (4) a general acceleration of research and health services to minimize the incidence of infectious disease, particularly in underdeveloped countries. No situation could be better designed for the evolution of serious new viruses than the existence of crowded, underfed human populations in which foci could develop and spread with a minimum of

medical control; (5) treaty commitments on BW analogous to the nuclear non-proliferation treaty; (6) pre-agreed sanctions by the civilized world against the release or development of BW agents, clearly invoking international law against such "offenses against mankind" as akin to war crimes.

If political wisdom can dispel the threat that molecular biology will be harnessed to the task of global suicide, the most important challenges to applied biology are (1) monitoring and managing the threats of world-wide epidemics from the spread of old viruses and the evolution of new ones even worse; (2) world nutrition; (3) the understanding of the human consequences of environmental degradation; and (4) efficient ways of assessing side effects of drugs, food additives and substitutes and other consumer products of vital importance in a crowded world.

The progress of science would in fact be paralyzed if its practitioners took an all-or-nothing approach in the selection of problems for attack, and the patient exploration of the possible must be weighted at least as dearly as the pursuit of iconoclasms.

In this light, there remains some justification for saving some of our energies to deal with some longer range problems like those pertaining to man's evolutionary future. These are also very immediate in the context of family life, which counts for an important part of human concerns, even while the storms of geopolitics rage.

The doctrine of pluralistic choice dominates my own prescriptions for ethical policies in the general field of human reproduction. This is in part an attempt to evade the external imposition of moral principles on others; but it is also a constructive attempt to preserve the fluidity of human options in facing rapid change in the physical and socio-technical environment. For example, the time is not far off, we hope, when soldiering will be an obsolete profession and commitments by martial states to combat-adapted genotypes would be grossly malfunctional. Almost every other aspect of human value, except the elusive one of intellectual breadth and flexibility, is subject to the same reservation, which undermines the utility of any comprehensive long-term eugenic schemes beyond the minimization of undoubted defects. Even here we may expect ironic discoveries, for example, that some "defectives" are the most amenable to specific treatments with drugs or hormones that will more than restore "normal" capabilities. Certainly we must be quite cautious about plans to "eradicate" *genes* which make defective homozygotes (like cystic fibrosis) before we understand the biological advantages of the heterozygotes that supposedly maintain the gene in the population. The target of such programs should be the disease itself, the immediate cause of human distress.[9]

"Individual choice" faces an inevitable paradox in this field: whose choice, and when? For the child does not make himself—in many different ways he is the creature of his parents and of his culture. The newborn cannot have decided by and in whom he was conceived, and carried, and to rely upon his choice about his early care would stand as criminal neglect. The parents must undertake the systematic manipulation of their child's development—presumably in his own interests, and certainly constrained by many realities of their particular culture. We call this, without irony, the *humanization* of the child, for his acculturation is as indispensable to his human functioning as is the biological substratum that makes it possible.

There are many compromises here, in different styles, between the varying interests of the community and of individual families; which change from one polity and time to another. I propose that parents assume the same kinds of responsibility in their wider orthobiotic choices as they now do in the education and family discipline of the child. Indeed, they cannot rationally be separated from one another. The traditions of political freedom that minimize the intrusion of political and religious sectarianism in the schools are precisely those that can protect the autonomy of the family at home.

This approach is not free of patent ethical hazards—we must condemn excesses of paternal authority, but within broad limits the children themselves will find more effective remedies than we would have the sophistication to apply by legal sanctions.

This discussion can only begin to open the issue of the meaning of manipulation. The generation gap shows how urgently we must work on our confusions, even before we face new problems of conscious orthobiosis.

The technology of orthobiosis differs from medicine only in its greater breadth. Medicine is usually thought of as a *reparative* rather than *constructive* art, but this simply reflects an arbitrary definition of abnormal and diseased. Thus, in the field of mental health, we see an unlimited range of sources of distress that the therapist will aim to relieve; nor can we find any sharp boundary between mental health and education. Medicine is also abutted by nutrition and physical exercise, the traditional arenas of domestic orthobiosis, whose importance to health is being rediscovered by contemporary medicine.

In fact, biological engineering is merely speculative medicine—as theoretical promises are realized, they will and should be assimilated into the framework of medical practice. This is important to insure not only technical competence but also the ethical tradition of commitment to the needs of the individual patient.

For the sake of orderly classification, orthobiosis can be classified into

eugenics, euphenics or *euthenics,* depending on whether the target for improvement is the DNA of the germ cell(s), the somatic characteristics of the individual, or the environmental scene. Eugenics implies an influence on the genetic endowment of future generations; euphenics does not. As far as euthenics is concerned, this paper will concentrate on those aspects of the environment that most directly influence the characteristics of the individual. Plainly, genes, soma and environment are intimately connected through channels like natural selection, environmental hygiene and economic opportunity.

Especially with respect to psychotropic influences, euthenics is the input, euphenics the output of the same process. I can speak with less authority on these most important forms of human manipulation (education, mass communication, language, the popular arts, explicit psychotherapy, and all the subtleties of group behavior). For that reason only, an undue weight of my remarks will be a technical exposition of processes which may have only ancillary importance. These are, however, compressed in tables I and II, with a few additional notes.

My purpose in this exposition is to share my expertise with a wider community, so that the issues of orthobiosis may be ventilated, understood and rationally decided. I hope this caveat is unnecessary, but it comes from weary dismay at having advocacy for wide and intrusive applications thrust at me for the sake of a critic's rhetorical shorthand. I do however advocate responsible, carefully thought out, and humane experimentation.

Euphenics. This term was coined[1] as a counter-slogan to eugenics, to parallel the antinomy of phenotype and genotype. It was intended to suggest that new knowledge of molecular genetics would be as powerful for medicine as for direct genetic intervention. In fact, euphenics is simply medicine, stressing the outlook on this as the modulation of developmental processes towards the restoration of health, or some other optimum.

As indicated in table I, euphenics is widely practiced already, but with few exceptions, its purpose is the restoration of normal health. Those who would seek super-normal nutrition are likely to be labelled food-faddists, insofar as an "optimum" nutrition has already been assimilated into our norms for health. Nearly the same applies to education, although a wider variety of styles is practised in the privacy of the home nursery than in the public schools.

We know less than most people think about the norms for fetal and newborn nutrition. The former are a matter of current controversy. The prevalent style of emphasizing control of the pregnant mother's weight and fluid accumulation has been sharply attacked by Brewer[10] as neglecting the

Table I. *Euphenic (and dysphenic) influences on human nature by period of life.*[26]

The entires in the table refer to important (□) or incidental (●) influences having particular impact on the stage indicated.

The table emphasizes effects that are likely to persist for long periods after the evoking stimulus is removed. The "euphenic" effect is, in many cases, figurative, and may be implied mainly by the remedial measures taken to prevent or repair injury.

Form	Fetus		Prem.	New Born		Youth	Adult	Age	
Growth of brain									
Dysnutrition		□	□	□	□	□			
Specific regulation (hormones)*	□	□	□	□	□				
Induced tolerance to grafts	□	□	□						
Teratogenic drugs, radiation & infections/prophylaxis	□	□	●	●	●				
Induced abortion/therapy for threatened abortion	□	●	●						
General control of organ differentiation with inducers and repressors**	□	□	●	●	●		●	□	●
Surgical repair of congenital and other defect			□	□	□	●	●	●	□	□
Transfusion; organ transplant			□	□	●	●	●	●	□	□
Critical dietary (MSG) & hormonal (estrogen, steroid) triggers				□	□	□	●			
Hypoxia; oxygen poisoning				□	□	●				
Sensory stimulation					●	□	●			
Virogenic therapies**			□	●	●	□	●			
Vaccination						□	□	●		
Dietary & hygienic habits established						□	●			
Psychotropic & other drugs, including addiction & other side-effects							□	□	●	
Hormonal, surgical mod'n of sex							□	□		
Artificial organs						□	●	●	□	
Environmental pollution	□	□	□	□	□	□	□	□	□	
Sonic habituation; deafness							□	●		
Psychodynamics & psychotherapy			?			□	●	□	●	
Popular culture; music			?			●	□	□	□	
Education; letters; arts						□	□	□	●	
Propaganda						□	●	●	□	

* Known from animal experiments, but not observation on man.
** Speculative possibilities under laboratory investigation in animals.

fetus' need for protein. Nor do we have the faintest idea as to the level of early nutrition that would sustain the best vigor of the fully developed youngster, in mind or in body. Now ancient experiments have shown that rats lived longest when somewhat "undernourished" with respect to calories; experiments like these are rare in man, for the political system tends to produce kwashiorkor (protein malnutrition) instead.

Recently, Olney[11] has shown that newborn mammals can be altered by large doses of MSG (monosodium glutamate) with lifelong effects. The furor that these findings have raised with respect to formulas for baby foods may obscure the deeper interest of the finding. Evidently the neonatal

hypothalamus can be injured by otherwise non-toxic doses of a normal nutrient, with subsequent failure of appetite regulation. This suggests that a wide range of nutrients can influence the setting of chemosensors that signal important homeostats. Few other compounds have been studied so far. There is little doubt, however, that our styles of baby-feeding have amounted to considerable, if unconscious, developmental manipulation.[27]

Hormones. The most potent regulators of organ development and function are the "hormones". We now have substantial information about the natural systems involving such organs as the gonads, secondary sex apparatus, thyroid and adrenal, and have some insight into the regulators of the muscle and red cell mass, skeleton, kidney and liver. This knowledge now has definite application mainly in replacement therapy to remedy obvious failures of the natural endocrines, or to inhibit the unwanted growth of tumors derived from some of these tissues. With farm animals, the use of sex hormones for fattening or improving food yield is a well-established euphenic practice. One also hears that masculinizing hormones have been used to promote muscular prowess in women competing in athletics—a rather pointed illustration of the extrapolation of restorative medicine, which has raised perplexing questions of criteria for, and means to enforce, social controls. Is there much logic in prohibiting the use of a hormone to help achieve the same ends that we encourage by physical exercise? It is, of course, the possibility of insidious and irreversible side effects that elicits the deepest concerns, though specific evidence for such side-effects may bear no relationship to the social revulsion against the drugs.

We know the least about the regulation of the most important organ, the brain. The extent to which its growth is regulated in part by external hormones is beginning to become a popular research area.[12] We have long known that the thyroid hormone is indispensible for maturation.

Zamenhof[13] has demonstrated that the pituitary growth hormone can influence the size and cell number of the brain of the newborn rat when administered to the pregnant mother. This effect may, however, be an indirect one, mediated through dietary behavior, since prenatal insufficiency of amino acids limits brain size. A hormone has already been described that regulates the growth of nerve cells of the sympathetic ganglia. Since antibodies to this hormone will inactivate the sympathetic nervous system of the intact animal, the hormone is important in the normal functioning of these neurones.

One can visualize that similar hormones operate on the central nervous system, and even that some forms of mental retardation may be attributed to auto-antibody formation. The elucidation of such a hormone may be the

Table II. *Methods of eugenics, existing and prospective.*

I. *Genetic hygiene*—controlling the environment to minimize germinal exposure to mutagenic chemicals, radiation, and virus infections.

Effects of temperature are theoretically suspect but have not been satisfactorily assessed.

II. *Selective mating*

1. By phenotype of parents (assisted by biochemical and cytological assay)
   (a) negative—distracting, discouraging or sterilizing the "unfit".
   (b) positive—
      i. encouraging select pairs.
      ii. with artificial insemination, donor ("rational germinal choice").
      iii. with oval or ovarian transplant.*
      iv. both, or fertilization in vitro, followed by implantation.*
      v. extracorporeal gestation (est tube baby)—see also euphenics.**
      (i–v are not very different in their *genetic* consequences).
2. By genotype of parents—as above, with deeper analysis of parental constitution. Except for specific aberrations very little can be said at present about genetics of *desirable* traits.
3. By relationship of parents.
   (a) inbreeding. The main impact is to expose recessive, usually deleterious genes; increase phenotypic variability of F_1; decrease the genotypic variability of later generations.
   (b) outbreeding—antithesis of (*a*). Most cultures strongly encourage outbreeding.
4. By age of parents—to forfend accumulation of deleterious mutations and chromosome anomalies which increase with parental age.
5. By phenotype or genotype of the zygote or of fetus (antenatal diagnosis and voluntary abortion). Earlier selections would avoid the trauma of aborting an established fetus.
6. By genotype of the gametes, e. g. separation of X from Y, or normal from defect-bearing sperm.**
7. With sperm of other species (compare 1. (*b*)iv). Nothing is known of the consequences among primate species. All contemporary races of man appear to be freely interfertile.*

III. *Innovations in zygote biology*

Vegetative (asexual) propagation. Cloning.

1. Parthenogenesis—development of an unfertilized egg. (This might be genetically identical to the mother, or might be a product of meiosis, which would be an intense form of inbreeding.)*
2. Regeneration—development of whole individual from somatic tissues (as in some plants and lower animals like earthworms).**
3. Differentiation of gametes from somatic tissues previously subject to extensive genetic manipulation.**
4. Somatic reduction in gamete-forming cells in culture (somatic inbreeding)—would allow predictable outcome of further matings from a given parent which is not now assured.**
5. Nuclear transplantation—renucleation of a fertilized, enucleated egg. Genetically equivalent to cloning from the source of the nucleus.*
6. Embryo—splitting to produce twins or multiplets, not to be confused with multiple ovulation (occasionally induced by fertility-promoting drugs.) About 1/3 of spon-

taneous twins are monozygotic, i.e. arise from the splitting of one embryo.* Note also the opposite phenomenon.

7. Embryo fusion (chimerism) so that one individual comprises 2 or more genotypes. This grades into tissue transplantation at later stages. It should allow different genotypes a new latitude for mutual complementation, e.g. mens sana in corpore sano. Somewhat less than 1/1 000 live births are spontaneous chimeras, but some of these arise by other mechanisms.*

IV. *Adjuncts from somatic cell biology*

For eugenic applications these would be coupled with procedures like III 5. For euphenic effects, altered cells can be grafted back to a host or some manipulations done directly on his tissues.

1. Algeny—directed alterations of genes
   (a) Controversial claims of effects of DNA uptake in mammalian cells following a long tradition of genetic work with DNA in bacteria.
   (b) Incorporation of viruses.
      i. Experimental tumor viruses.*
      ii. Use of specially modified viruses
         1) Vaccination to induce immunity to viruses.
         2) Virogenic therapy to replace missing genes.**
         3) Virogenic enhancement for superior performance—if we but knew the biochemistry thereof.**
   (c) Specifically induced mutations. No plausible approaches are now apparent.**
2. Random mutation and specific selection of cells with altered properties—has full precedent in strain selection in microbes. Many uncertainties relating to possible cancer potential of such implants.*
3. Cell fusion to form somatic hybrids. These cells may then lose various chromosomes to give many new forms. Extends scope of 2. Can be readily applied to fuse cells from "distant" species, e.g., fish and human.*
4. Development of symbiotic strains of lower species, with habitats that grade from the external world (e.g. crops) to internal to intracellular. Parasitic worms in man have evolved in this direction with the help of adaptations to thwart immunological rejection. In principle they might be domesticated. So also might algae be trained to an intracellular habitat in man where they might photosynthesize essential nutrients, if not bulk calories, as they already do in primitive animals.**

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* Known from animal experiments, but not observation on man.
** Speculative possibilities under laboratory investigation in animals.

next major turning point in the progress of human mental capacity. We might find, for example, that it bridges the main gap between man and the other apes. It may also pose dilemmas on the social regulation of its use, analogous to those concerning the use of masculinizing hormones. If the "norm" for cerebral capacity were suddenly open to a substantial jump, what place would be left for vestigial imbeciles like ourselves? Or will we therefore take every means to be sure this never happens?

It is not clear whether or how purified repressor proteins could be introduced into target cells from outside, but when this step is also achieved, we will have the tools for the most comprehensive regulation of gene func-

tions. This would be tantamount to instructing undifferentiated cells to cooperate, say, to reform a liver or heart to replace a failing organ, or to produce totally new kinds of tissues and organs.

Needless to say, we spend enormous effort at "manipulating" the development of the child's brain through mental exercise, i.e., education, though the principles of action in wide use are too numerous for them all to be well-founded.

The concept of hormonal regulation has also been expanded by studies on gene action in bacteria, which have culminated in the isolation so far of two specific "repressor" proteins, a prelude, without doubt, to many more. The repressor interferes with the initial transcription of a specific segment of DNA, in the formation of the RNA messenger, thereby regulating the function of that gene. The role of repressors in mammalian systems is a subject of hot controversy, and there is indeed good evidence that regulation can (also?) occur at the level of the differential translation of existing RNA messengers.

To summarize, it is enough to predict that the obstetrics-pediatrics (the hyphenation, i.e., the gulf between the specialties, hints at part of the problem) of the new future will include respectful attention to hormones and other growth regulators, as it now does in principle to nutrition and vaccinations.

Vaccination and virogenic therapy. Since 1798, vaccination has exemplified the use of viro-genic information in medicine, though its practitioners to this day are often oblivious to it. Jenner found that inoculation with cowpox (vaccinia) caused a mild disease immunity which also protected against the dangerous smallpox.

Many aspects of vaccination are still scientifically obscure; but we can now describe the process in terms of molecular genetics. The DNA of the cowpox virus is purposely introduced into certain cells which adopt the genetic information contained therein. These cells thereupon produce new gene products, encoded by the viral DNA, which stimulate other body cells to produce antibodies against them. The cross-immunity is then a byproduct of the virogenic alteration of some cells of the host.

Live viruses are now widely used for vaccination against many other diseases, including polio, measles, and in special cases or in the near future, rubella, mumps, rabies, and so on.

Vaccination can be regarded as if it were a therapy to replace the functions of hypothetical genes not normally present in the human organism, those that would endogenously stimulate the formation of antibodies. This idea can be extended, in principle, to other gene products, for example en-

zymes that may be missing in certain gene-defect diseases like phenylketonuria and perhaps diabetes. Laboratory models for this kind of virogenic therapy are well established; there is good reason to expect trials for human disease in the near future.[14] Although basic genetic principles underlie this technique, and the genetic apparatus of somatic cells is altered, it is classified as euphenic because the germ cells are left unchanged and there should be no effects in future generations. This is matter of empirical observation, rather than necessary principle in biology, and it is quite conceivable that some inoculated virogenes might also be inherited, as has already been postulated for certain tumor viruses in rodents. This reservation applies with equal force to vaccination against infectious diseases, about which we have little information in proportion to the enormous numbers of children involved.

As applies to euphenics generally, the main limitation to broader applications is not in the detail of the technique. It is in the biochemistry of trait whose modification is in question. When we know enough about the biochemistry of brain development to make sensible statements about which genes might be involved and how, a variety of approaches will be open to reparative or constructive changes in that biochemistry. The poverty of present knowledge is illustrated by our helplessness (late 1969) about diseases like Huntingdon's chorea, despite rather precise knowledge about its mode of inheritance.

The practical application of virogenic therapy might lie in enzyme replacement. For example, a gene for phenylalanine hydroxylase (missing in PKU) might be isolated from human DNA by an extension of techniques successfully applied to bacteria.[15] It would then have to be grafted on to the DNA of some carrier virus already well authenticated for use in a vaccine. After inoculation, some infected cells would be expected to have restored the necessary function. Plainly, many further refinements, especially in the cell-specificity and the regulation of enzyme levels, are also called for—not to mention the most careful tests for the harmlessness of the carrier virus.

The same criteria, may it be repeated, deserve to be applied to contemporary vaccines designed for immunization against virus infection.

Transplantation. The potentials for transplantation as a means of replacing worn-out organs have already been too well advertised to warrant much more comment. There remain serious problems of supply and allocation of vital organs, like hearts, but a socially acceptable market has been organized after some early tribulations. Nevertheless, there will probably never be enough suitable hearts to meet the demand, especially as the procedure

is technically perfected. The heart transplants may, however, serve an important way station in the development of artificial hearts, and for example as an ethically acceptable backstop to their early trials, as well as a source of important physiological information.

The augmentation of the brain has also been accomplished—in fish—by the pooling of primordia from two embryos into a single hatchling. These fish evidently were able to make good use of their enlarged cerebrums, at least from a man's-eye view of their behavior.[16]

We should not, however, confuse any *organ* with *personality,* which is a complex *process* that functions through a variety of tissues, and in a larger sense, even of many extensions of the body in the form of machines (clothing, automobiles, telephones and radio communication, computers, etc.)

The problem of graft-rejection by the immunological defenses of the host remains unsolved at a fundamental level. However, so much important theoretical as well as empirical information is being accumulated that this must also be surmountable. We will then find that the spectacular, life-saving accomplishments of heart-and kidney-transplantation will be much more mundane, but equally important life-enhancing procedures, involving many other tissues. Even cosmetic transplants of skin and hair should not be shrugged off as a humanly important application.

The prime hint to an answer to graft-rejection is the phenomenon of induced tolerance, obtained by exposing the fetus to graft antigens before the stage of immunological reactivity. The antigen-specificity is then treated as part of the "self-identity" of the host, and later grafts of tissues from related sources will be accepted. (The phenomenon also sheds indispensable light on the diseases of "auto-immunity" and some on the prevention of cancerous growths.) If other methods fail, we could envisage the precautionary injection of pooled, purified human tissue antigens as a kind of vaccination during fetal life.

The experiment has, in fact, been done with other intentions—namely the transfusion of a fetus mortally afflicted by RH-disease with fresh blood from another donor. Unfortunately, viable white cells in the donated blood, now protected against rejection by the infant, survived to react instead against him. The result nevertheless verified the theory of induced tolerance as applied to man.[17]

Eugenics. Selective breeding; selective abortion; algeny.

Having domesticated his food crops and animals, and his pets, man has speculated at least as far as his knowledge of heredity permits about influencing his own progeny by the wise choice of genetic "stock". Optimism

may be the most responsive trait, for there is little else to support the tenability of such experiments over any period of time: the recombination of genes that accompanies sexual reproduction is an almost insuperable barrier to eugenic progress by selection alone. The farmyard domesticators have the additional advantage of inbreeding (incestuous matings) to stabilize the genetic characteristics of a given breed. Wisely, even the most enthusiastic eugenicists refrain from this breach of custom—for its short term consequence to human viability would be disastrous. The corn breeder is after all quite willing to sprout and discard millions of seeds in order to select an advantageous genotype—a price no one could negotiate for human improvement.

A specific approach to selective breeding, "germinal choice", has however been strongly advocated by the late Herman J. Muller and by Julian Huxley.[18] Their scheme would provide for the banking of sperm from individual men in cold storage for later voluntary use in artificial insemination. They suggest that a considerable period of time elapse to allow a calm retrospective judgment of which men carried the most useful set of genes. The problems so far of promulgating such a scheme are all social, not technical. So far there is little evidence that "rational germinal choice" has become a household phrase. It is hard to see any fundamental objections to discreet small-scale experiments along these lines: legal recognition of artificial insemination is needed to prevent the hardships that arise from confusion about proper procedures of parental consent and anonymity. We have ample experience with adoption to use as a precedent.

Real problems arise, of course, in the identification of preferred males, even some years posthumously, and the advertisement of the qualities of potential sires probably should be confined to professional journals, package inserts, and a physicians' desk reference.

More recently, a genetic engineering mania, algeny, has been advertised as an aftermath of research on DNA as the chemical embodiment of genetic information. "We have merely to specify the optimum sequence of some 5 billion nucleotides—the DNA information of the fertilized egg—and we can define the ideal man." This fantasy has elicited dark anxieties about "genetic control", in an absurd misunderstanding of the metaphor "specify the sequence". This of course already happens to some degree by the voluntary sexual coupling of two parents. They have thereby decided that a child will be formed, specified as a Mendelian sample of each of their chromosomes.

At the present time, we have no plausible approach to the use of "synthesized" DNA that could begin to match fertilization as a way of "specifying" the DNA of the zygote. And if we did, it could hardly differ from the act

of choosing a particular sperm and an egg from specified parents. Some lay readers have unfortunately misread these fantasies to occasion a worry that "their own genes" might be controlled from without. We should reassure them that this is the least of their legitimate worries, if for no other reason than the redundancy of their DNA in trillions of different cells.

What of the future? The main impact of the fruition of algeny would be to reduce the relevance of the genetic constitution as the seat of destiny. When the genes are so easily changed, this deep knowledge of genetics cannot be developed without the means to divert the action of the genes in specific developmental pathways—i.e., the full realization of euphenics. Finally, algeny will hardly be possible before the materialization of other manipulations of the germ cells, for example the renucleation of egg cells with nuclei taken from somatic cells of an existing individual or in cell culture.

This technique has already been worked out in frogs by Briggs and King; Gurdon and others.[19] Their experiments were intended to determine whether tissue differentiation is invariably associated with a permanent loss of developmental functions in the cell nucleus. Apparently this is not always true, for some nuclei of adult tissue cells are capable of supporting the total development of a new frog from a re-nucleated egg. From a genetic point of view, however, the new frog was vegetatively propagated from the mature tissue since it carries exactly the same set of genetic information.

Groups of individuals derived by vegetative propagation and having identical genetic constitutions are called clones. The propagation of new plants from cuttings is such a familiar experience in horticulture that the term "vegetative propagation" is used generally for the by-passing of sexual reproduction. In lower animals like the earthworms, cloning is a common occurrence with the spontaneous regeneration of "whole animal from cuttings" of the previous individual. (There is no theoretical argument against this kind of regeneration in mammals, but no experimental evidence for it either.) The most immediate implication of cloning is the production genetically homogenous groups of individuals, and particularly of propagating a genotype already tested in one generation for further trial in a second.

We already have a foretaste of the properties of a clone in the behavior of identical twins. Twins are commonly recognized as having an unusual psychological relationship to one another, and in that sense, differing already from non-twin individuals. There has, however, been relatively little critical psychological study of twins, particularly from the point of view of objectively testing their capacity to communicate with one another more efficiently than obtains for randomly chosen individuals. These observa-

tions would be very difficult to control for the usual reason that the hereditary similarity between twins will often be confounded with the empirical fact of their having been reared together and treated nearly as identical individuals during their early development. One can argue on purely theoretical grounds, however, that at least some twins will have a great advantage in mutual communication (and this, of course, also means education) just by virtue of the similarity in their blueprints for their central nervous systems. Since the thread of culture is what binds the human experience, the mere fact of their homogenity may make clones more efficient in intellectual cooperation and educational advance. This hypothesis is independent of the opportunity to select those genotypes for clones which already manifest outstanding capabilities.

The chief human motivation for taking advantage of clonal reproduction would, undoubtedly, be in the quest for some kind of immortality, which plainly has a deep influence in the direction of human affairs. Quite apart from this, clonal propagation would afford an otherwise unavailable opportunity for certain humanic "experiments", in the same sense that efforts to optimize a child's education are an experiment. It is unlikely that we will otherwise ever be able to know the extent which the performance of acknowledged geniuses or athletic stars are manifestations of unusual genetic endowment.—The technical limitation to cloning by renucleation, is mainly the much smaller size of mammalian eggs by comparison with the frog's egg, but this is almost certainly not an insuperable difficulty. There may be other obstacles based on differences in the biology of the frog egg as compared to that of the human which are unknown to us at present.

What are the real hazards of cloning? The shock of such a large deviation in the fundamental biological system may cloud clear thinking; it is of the same magnitude as the institution of voluntary reproduction, which depends on human knowledge of the relationship of sex to pregnancy. We may not be able to ignore incidental aspects of the technique that may be quite crucial to public acceptance. There are not many arguments *for* bypassing sexual reproduction, but they might include (1) parental narcissism, and instinctive attachment to some form of personal immortality; (2) some social and familial interest in the perpetuation of unique genotypes, for their own sake, and to improve our educational methods; (3) the wish of some couples to have "their own" children when this is frustrated by some forms of sterility or risk of genetic disease that would be unmasked by sexual reproduction, and (4) social need or other dynamic encouragement to produce many similar individuals of a specific genotype, e.g., an elite guard, an SS, or a suicide squad who could be relied upon to end the world in a national interest.

The trap of over-specialization is indeed the main hazard that the evolutionary biologist would warn about. World-enders are all too easy to produce without orthobiotic innovations, but a society might well trap itself into staking its genetic resources to meet more legitimate short-term challenges, and find itself unable to adapt rapidly enough to change. This is a general objection to any scheme for genetic commitment, and to institutional rigidity overall. Cloning has the advantage of retaining the latent variability of heterozygotes, which can be re-expressed in future, sexual generations.

A vegetative progeny suffers from another hazard, the accumulation of new mutations without the constant filtering of natural selection against homozygotes. A commitment to cloning will then require a new level of vigilance about reducing the hazards from mutagenic pollutants of the environment (an important element of any eugenic program).

Biological theory offers no basis for opposing vegetative propagation on a modest scale, as an option to isolated families, so long as the population processes most of its genetic heritage through the sexual mechanism. We have to fear the social hazard that cloning may become *too* attractive,[20] that no parent will again care to face the hazards of bearing a randomized child. However, some of the more serious perils of that gamble can be countered by prenatal diagnosis and abortion (discussed hereinbelow).

Cloning will surely reawaken the zeal of the eugenicists, which is now dampened by the sheer inefficacy of their proposals.[21] It is easy to see how a totalitarian government might wish to add imposed clonal propagation to the repertoire of its techniques for homogenizing its subjects and minimizing dissidents. Legally enforced pregnancy of any kind is an abhorrent violation of human rights.

This is not to exclude the interest of the community in, say, discouraging the birth of a repeated series of defective children who are burdens to themselves as well as the group. However, these incidents are so rare that we ought to exhaust non-compulsive solutions before inviting a massive intrusion of the authority of the state into reproductive decisions.

The deepest and most irrational fears about the abuse of scientific knowledge are fueled by anxieties that some external authority might succeed in dominating our lives through control of the mechanisms of genetic control. Every advance, major or minor, in experimental molecular genetics is followed by editorializing on this theme, rarely spelled out explicitly enough to be answerable.[22] The main thrust is that the state might acquire the means to turn reproduction from a family avocation into an assembly-line for manufacturing loyal citizens, along the lines of The Republic, or Brave New World.

In all candor, this outcome cannot be dismissed but it must be viewed as a political rather than a technological disaster. One should ask more concretely, just which traits is the state likely to impose involuntarily? And how could it enforce unpopular edicts without already having enslaved the population? If there is to be a "correct" skin color or shape of nose, does the totalitarian state—by historical evidence—not already have ample technology to achieve these among its citizenry, at the point of a gun?

These anxieties are in fact promoted, or ought to be, by another movement that holds it necessary to impose legal controls in order to confine population growth. The bureaucracy that administers such controls plainly would have a leverage on the life of the community that would be vulnerable to the most flagrant abuses. (Fortunately, no such involuntary atmospheric contraceptive can now be forecast; we have enough trouble authenticating the safety and wide use of acceptable, voluntary ones. Besides the obvious need for better techniques of contraception, we have the most urgent need for social inventions that can press the needs of the community for population limitations, without destroying personal freedoms.) A well established totalitarian society might, indeed, try to assure its own perpetuation by genetic technology, as further support to its existing apparatus of thought control. The most obvious step would be to encourage the uniformity of outward appearance (which all more primitive cultures have done spontaneously) as a way of bolstering Groupthink or distinguishing Ins from Outs.

More realistic moral problems arise in the area of the proper social controls over the use of new techniques, even as experiments, by individual family units. Should the community have any concern about isolated trials of cloning, artificial insemination, oval transplantation, or similar techniques, if these are done with an obligation and intention of responsible care for the human individuals born as a consequence? The community does, however, insist that every child be a potential citizen, and therefore invokes such laws as compulsory vaccination and schooling. Its requirement that a child be taught English (in the U.S.) might be regarded as barbarous by any objective onlooker, but we do not usually indict this as an unwarranted intrusion.

It is certain then that the community will properly set bounds on the characteristics of individuals produced by any kind of rational design. If the technical power now existed, it would probably vent its wrath on any person who, for example, intentionally and knowingly produced an idiot. Laws for compulsory sterilization have wisely been held in abeyance mainly out of scientific uncertainties and the difficulties of fair enforcement, not a constitutionally protected privilege to make any kind of monster one

pleases. The same principles will undoubtedly evolve in our adjustment to genetic innovations. In fact, the moral issues that attach to the problems of new genetic technology are fully foreshadowed in our present customs of public health and education.

An interesting variant arises, however, in the speculation that sub-human races might be evolved, like Aldous Huxley's "gammas". This is plainly a vicious parody on the institutions of race prejudice. Szilard has stated the speculation in a possibly more confusing way: what if we were to discover that the dolphins were (or could be altered to be) at least as intelligent as humans? Would we not have to tax them, restrain their movements by requiring visas, conscript them and offer other privileges of human dignity?

It has been answered that the world will continue on its dubious course so long as the scientists and the politicians shuttle the responsibility to one another about these central problems. The definition and nurturing of personal freedom is one of the most difficult and most important that we face. In a non-ideal world, the responsibilities and the temptations of new powers may be more than the system can bear.

The suppression of knowledge appears to me unthinkable, not only on ideological, but on merely logical grounds. How can the ignorant know what they should not know? We can, however, try to play the other game better, to use our scientific skill and artistic intuition to forecast some glimpses of the future, and in particular of the worst paths to be avoided.[23] That prevision may help to plan the compensatory institutions, the public education, or the balancing research to regain the harmony that is the best measure of human progress.[24, 28]

Appendix

Does modern science dehumanize man?

It is easy to find deeply ambivalent feelings about science among intellectuals (even including some scientists), in Congress, among alienated youths and among bewildered citizens. We live in a scientific age whose glories and terrors are both credited to science. At this level, we can hardly deny that our ever-growing scientific mastery over the forces of nature imposes an almost unbearable responsibility on political authority and on a democratic electorate to learn about, think about, plan for, and use these forces for real human benefit.

In this climate, many people have become highly sensitized to more ethereal questions that are raised by the scientific study of man. One such question is the doctrine of mechanism. Dr. D. E. Wooldridge, a well-known

physicist and systems engineer and a successful industrialist—formerly president of TRW (Thompson–Ramo–Wooldridge) Inc.—has written several excellent syntheses of present day thought in biology. His latest work, *Mechanical Man—the Physical Basis of Intelligent Life,* concludes "that a single body of natural laws operating on a single set of material particles completely accounts for the origin and properties of living organisms. Accordingly, man is essentially no more than a complex machine."

A few eccentrics aside, the whole community of contemporary science shares the view that the same laws of nature apply to nonliving and living matter alike. All of us who investigate the chemistry and physics of living organisms pursue our work as if organisms were complex machines, and we find man to exhibit no tissues or functions that would except him from this way of analyzing human nature.

Nevertheless, we are or should be careful to state just what we mean before we assert that "man is a machine," and much more so before using the phrase "merely a machine". The statement that man is "a mere machine", or a mere anything, is a needless irritant to precise communication between scientists and laymen. (We might better proclaim that "man is merely the most complex product of organic evolution on earth, the only organism whose intelligence has evolved to the point that his culture far transcends his biological endowment.")

The "mere machine" phrase is usually a retort to the claim that there are mysteries of human nature that are, in principle, beyound the reach of scientific investigation. Scientists would do better to save their breath quarreling about what they can analyze in principle; in their own work, they are mercilessly pragmatic about confining their conclusions to what they can examine in practice.

There are, in fact, theoretical limits to scientific analysis that may justify men in repudiating Dr. Wooldridge's assertion that "the concept of the machine-like nature of man is incompatible with a long-cherished belief in human uniqueness". There is nothing "mere" about a machine as complex as a man; the word "machine" is just a manner of speaking about the scientist's faith in a universe ordered by natural law. That faith was expressed most eloquently by the French philosopher the Marquis de Laplace, who averred that, given complete knowledge of the universe at one instant, the scientist could in principle compute all of its future states in infinite detail.

In practice, we must now remind ourselves, the scientist and his computers are machines that occupy space and consume energy. Dr. Rolf Landauer of IBM has pointed out that the process of calculation itself soon reaches fundamental limits. If the whole visible universe were one gigantic

computer, made of components at the theoretical lower limit of size and energy consumption, it would still be insufficient for some problems that are soluble "in principle".

Far short of the complexity represented by a human being, some mere machines called computers nevertheless have already reached the point where their actual behavior is predictable only to a rough approximation, and we must be careful to program internal checks to detect when these highly individualized robots deviate from *their* intended instructions. (*Washington Post,* 28.12.68.)

Notes

[1] Dobzhansky, T. *Mankind Evolving.* New Haven and London: Yale University Press. 1962, page 342; Simpson, G. G. *The Major Features of Evolution.* New York: Columbia University Press. 1953.

[2] Kohlberg, L. "The development of moral character and ideology." in M. Hoffman (Ed.), *Review of Child Psychology.* Russell Sage Foundation. *Vol. 1* 1964.

[3] Haldane, J. B. S. *The Inequality of Man and Other Essays.* London: Chatto and Windus. 1932. Chapter Three, "Science and Ethics".

[4] Huxley, J. UNESCO: *Its Purpose and its Philosophy.* Washington: Public Affairs Press. 1948.

[5] Muller, H. J. "Mankind in Biological Perspective." in The Centennial Review, *Vol. X,* No. 2, Spring 1966, pages 163–213; Thorpe, W. H. *Science, Man and Morals.* Ithaca, N.Y.: Cornell University Press. 1965; Haldane, J. B. S. *The Inequality of Man and Other Essays.* London: Chatto and Windus. 1932. Chapter Three, "Science and Ethics".

[6] Koestler, A. and Smythies, J. R. *Beyond Reductionism.* The Alpbach Symposium 1968. London: Hutchinson of London. 1969. See Appendix to this article for the view of the present author on the mechanistic theory of man.

[7] Lederberg, J. "Experimental genetics and human evolution." in Bulletin of the Atomic Scientists. *Vol. XXII,* No. 8, October 1966.

[8] Dorolle, P. "Old plagues in the jet age." in WHO Chronicle, *Vol. 23,* No. 3, pages 103–111.

[9] Fraser, G. R. and Motulsky, A. G. "Genetic effects of selective abortion for inherited diseases." in *Program and Abstracts.* American Society for Human Genetics. Annual meeting, October 10–13, 1968. Austin, Texas.

[10] Brewer, T. H. *Metabolic Toxemia of Late Pregnancy: A Disease of Malnutrition.* Springfield, Illinois: Charles C. Thomas. 1966.

[11] Olney, J. W. "Brain lesions, obesity and other disturbances in mice treated with monosodium glutamate." in Science, *Vol. 164,* pages 719–721, May 9, 1969.

[12] Hamburgh, M. "The role of thyroid and growth hormones in neurogenesis." in Moscona, A. A. and Monroy, A. *Current Topics in Developmental Biology.* New York: Academic Press. 1968. *Vol. IV,* Chapter Two.

[13] Zamenhof, S., *et al.* "DNA (Cell Number) and protein in neonatal brain: alteration by maternal dietary protein restriction." in Science, *Vol. 160,* pages 322–323, April 19, 1968; Zamenhof, S., *et al.,* "Stimulation of proliferation of cortical neurons by prenatal treatment with growth hormone." in Science, *Vol. 152,* page 1396, 1966.

[14] Rogers, S. "Skills for genetic engineers." in New Scientist. *Vol. 45,* No. 686, pages 194–196, January 29, 1970.

[15] Shapiro, J., *et al.* "Isolation of pure *lac* operon DNA." in Nature. *Vol. 224,* pages 768–774. November 22, 1969.
[16] Bresler, D. E. and Bitterman, M. E. "Learning in fish with transplanted brain tissue." in Science. *Vol. 163,* pages 590–592. February 7, 1969.
[17] Naiman, J. L., *et al.* "Possible graft-versus-host reaction after intrauterine transfusion for Rh erythroblastosis fetalis." in The New England Journal of Medicine. *Vol. 281,* No. 13, September 25, 1969, pages 697–701.
[18] Muller, H. J. "Human evolution by voluntary choice of germ plasm," in Science, *Vol. 134:* page 643+, September 8, 1961. Reprinted in Young, Louise B. (Ed.) *Evolution of Man.* New York: Oxford University Press. 1970, page 530.
[19] Harris, M. *Cell Culture and Somatic Variation.* New York: Holt, Rinehart and Winston. 1964.
[20] Brunner, J. *Stand on Zanzibar.* New York: Ballantine Books. 1969 (Fiction).
[21] Haller, M. H. *Eugenics.* New Brunswick, N. J.: Rutgers University Press. 1963; Osborn, F. *The Future of Human Heredity.* New York: Weybright and Talley. 1968; Pickens, D. K. *Eugenics and the Progressives.* Vanderbilt University Press. 1968.
[22] Taylor, G. R. *The Biological Time-Bomb.* New York and Cleveland: The World Publishing Company, 1968; "The gene: iolated—for good or evil?" *The New York Times.* November 30, 1969; "Genetic tampering." *Washington Post.* November 3, 1967; "Genetic warnings." *The Christian Science Monitor.* January 8, 1970; "Voice fears on possible uses; Scientists isolate single gene." *The Palo Alto Times.* November 24, 1969.
[23] Popper K. *The Open Society and Its Enemies.* Princeton, N. J.: Princeton University Press. 1950.
[24] Tiselius, A. "Balance and unbalance in scientific progress." Address to the Athens Meeting 1964. The Royal National Foundation. Elsevier Publ. Comp. 1966.
[25] Lederberg, J. "Humanics and genetic engineering." in 1970 *Yearbook of Science and the Future.* Encyclopaedia Britannica. Metz, C. B. "Gamete surface components and their role in fertilization." in Metz, C. B. and Monroy, A. (Eds.) *Fertilization. Comparative Morphology, Biochemistry and Immunology.* New York: Academic Press. 1967. *Vol. 1*; Harris, H., *et al.* "Suppression of malignancy by cell fusion." in Nature *Vol. 223.* No. 5204. Pages 363–368. July 26, 1969; Gurdon, J. B. "Transplanted nuclei and cell differentiation." in Scientific American. *Vol. 219.* No. 6, pages 24–36. December, 1968.
[26] Eichenwald, H. F. and Fry, P. C. "Nutrition and Learning." in Science. *Vol. 163,* page 645–648. February 14, 1969; Shooter, E. M. "Some aspects of gene expression in the nervous system." in Schmitt, F. O. (Ed.) *The Neurosciences: Second Study Program.* New York: Rockefeller University Press. in press; Scott, J. P. "Critical periods in behavioral development" in Science, *Vol. 138,* No. 3544. Pages 949–958. November 30, 1962; Levine, S. and Mullins, R. F., Jr. "Hormonal influences on brain organization in infant rats." in Science. *Vol. 152.* Pages 1585–1592. June 17, 1966. Denenberg, V. H. and Rosenberg, K. M. "Nongenetic transmission of information." in Nature. *Vol. 216,* pages 549–550. November 11, 1967; Mintz, B. "Gene expression in allophenic mice." in "Symposia of the International Society for Cell Biology". *Symposium on Control Mechanisms in Expression of Cellular Phenotypes.* New York: Academic Press. in press; Altman, J., *et al.* "Behaviorally induced changes in length of cerebrum in rats." in Developmental Biology. *Vol. 1* (No. 2), pages 112–117. March 1968.
[27] A recent report suggests that rats reared on cyclamates suffer from an irrever-

sible induced hyperactivity. (The effect was initially interpreted as an augmentation of "intelligence")—see Stone, D., E. Matalka, and J. Riordan "Hyperactivity in rats bred and reared on relatively low amounts of cyclamates." in Nature. *Vol. 224,* page 1326. 1969.

[28] The general subject of value questions in relation to science is the subject of several comprehensive studies, including the Harvard University Program on Technology and Society, and the Columbia University Institute for the Study of Science in Human Affairs. At Indiana University, the Program in Public Policy for Science and Technology of the Department of Government has published an unusually extensive annotated bibliography, so far in two volumes, 1968–69.