Cyborgs and Space

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Altering man's bodily functions to meet the requirements of extraterrestrial environments would be more logical than providing an earthly environment for him in space . . . Artifact-organism systems which would extend man's unconscious, self-regulatory controls are one possibility.

Space travel challenges mankind not only technologically but also spiritually, in that it invites man to take an active part in his own biological evolution. Scientific advances of the future may thus be utilized to permit man's existence in environments which differ radically from those provided by nature as we know it.

The task of adapting man's body to any environment he may choose will be made easier by increased knowledge of homeostatic functioning, the cybernetic aspects of which are just beginning to be understood and investigated. In the past evolution brought about the altering of bodily functions to suit different environments. Starting as of now, it will be possible to achieve this to some degree *without alteration of heredity* by suitable biochemical, physiological, and electronic modifications of man's existing modus vivendi. Homeostatic mechanisms found in organisms are designed to provide stable operation in the particular environment of the organism. Examples of three successful alternate solutions provided by biological mechanisms to the body-environment problem with regard to operating temperature are man, hibernating animals, and poikilothermic fish (organisms with blood that take on the temperature of the environment).

Various biological solutions have also been developed for another problem-respiration. Mammals, fish, insects, and plants each have a different solution with inherent limitations but eminently suitable *for their field of operation*. Should an organism desire to live outside this field, an apparently "insurmountable" problem exists.

However, is the problem really insurmountable? If a fish wished to live on land, it could not readily do so. If, however, a particularly intelligent and resourceful fish could be found, who had studied a good deal of biochemistry and physiology, was a master engineer and cyberneticist, and had excellent lab facilities available to him, this fish could conceivably have the ability to design an instrument which would allow him to live on land and breathe air quite readily.

In the same manner, it is becoming apparent that we will in the not too distant future have sufficient knowledge to design instrumental control systems which will make

it possible for our bodies to do things which are no less difficult. The environment with which man is now concerned is that of space. Biologically, what are the changes necessary to allow man to live adequately in the space environment? Artificial atmospheres encapsulated in some sort of enclosure constitute only temporizing, and dangerous temporizing at that, since we place ourselves in the same position as a fish taking a small quantity of water along with him to live on land. The bubble all too easily bursts.

The biological problems which exist in space travel are many and varied. Long-term space voyages, involving flights not of days, months or years, but possibly of several thousand years, will eventually be hard realities, and resultant physiological and psychological conditions must be considered.

These are reviewed below. In some cases, we have proposed solutions which probably could be devised with presently available knowledge and techniques. Other solutions are projections into the future which by their very nature must resemble science fiction. To illustrate, there may be much more efficient ways of carrying out the functions of the respiratory system than by breathing, which becomes cumbersome in space. One proposed solution for the not too distant future is relatively simple: Don't breathe!

If man attempts partial adaptation to space conditions, instead of insisting on carrying his whole environment along with him, a number of new possibilities appear. One is then led to think about the incorporation of integral exogenous devices to bring about the biological changes which might be necessary in man's homeostatic mechanisms to allow him to live in space *qua natura*. The autonomic nervous system and endocrine glands cooperate in man to maintain the multiple balances required for his existence. They do this without conscious control, although they are amenable to such influence. Necessary readjustments of these automatic responses under extraterrestrial conditions require the aid of control theory, as well as extensive physiological knowledge.

Cyborg - Frees Man to Explore

What are some of the devices necessary for creating self-regulating man-machine systems? This self-regulation must function without the benefit of consciousness in order to cooperate with the body's own autonomous homeostatic controls. For the exogenously extended organizational complex functioning as an integrated homeostatic system unconsciously, we propose the term "Cyborg." The Cyborg deliberately incorporates exogenous components extending the self-regulatory control function of the organism in order to adapt it to new environments.

If man in space, in addition to flying his vehicle, must continually be checking on things and making adjustments merely in order to keep himself alive, he becomes a slave to the machine. The purpose of the Cyborg, as well as his own homeostatic systems, is to provide an organizational system in which such robot-like problems

are taken care of automatically and unconsciously, leaving man free to explore, to create, to think, and to feel.

One device helpful to consideration of the construction of Cyborgs, which is already available, is the ingenious osmotic pressure pump capsule developed by S. Rose for continuous slow injections of biochemically active substances at a biological rate. The capsule is incorporated into the organism and allows administration of a selected drug at a particular organ and at a continuous variable rate, without any attention on the part of the organism. Capsules are already available which will deliver as little as 0.01 ml/day for 200 days, and there is no reason why this time could not be extended considerably. The apparatus has already been used on rabbits and rats, and for continuous heparin injection in man. No untoward general effect on health was noted when the injector was buried in animals. As long as five years ago, an injector 7 cm long and 1.4 cm in diameter, weighing 15 gm, was successfully buried under the skin of rats weighing 150-250 gin. The photo on page 27 shows a rat weighing 220 gm with an injector *in situ*.

The combination of an osmotic pressure pump capsule with sensing and controlling mechanisms can form a continuous control loop which will act as an adjunct to the body's own autonomous controls. In this manner, these controls can be changed to the desired performance characteristics under various environmental conditions. If these characteristics were determined, such a system would be possible today with the selection of appropriate drugs.

For example, systolic blood pressure may be sensed, compared to a reference value based on the space conditions encountered, and regulated by letting the difference between sensed and reference pressures control administration of an adrenergic or vasodilator drug. Of course, any such system presupposes that we would be cognizant of what optimum blood pressure would be under various space conditions.

While it is quite difficult to set up per limits to "natural,, human physiological and psychological performance, we can take as minimal the capabilities demonstrated under control conditions such as yoga or hypnosis. The imagination is stretched by the muscular control of which even the undergraduate at a Yoga College is capable, and hypnosis per se may prove to have a definite place in space travel, although there is much to be learned about the phenomena of disassociation, generalization of instructions, and abdication of executive control.

We are now working on a new preparation which may greatly enhance hypnotizability, so that pharmacological and hypnotic approaches may be symbiotically combined.

Psycho-Physiological Problems

Let us now turn our attention to some of the special physiological and psychological problems involved in space travel, and see how Cyborg dynamics may help achieve better understanding and utilization of man's natural abilities.

Wakefulness. For flights of relatively short or moderate durations few weeks or even a few months-it would appear desirable to keep the astronaut continuously awake and fully alert. The extension of normal functioning through the use of that group of drugs known as psychic energizers, with adjunctive medication, for this purpose is a present-day reality. In flights lasting a month or two, no more than a few hours a day of sleep would be required in the normal environment if such drugs were employed. Tests indicate efficiency tends to increase, rather than decrease, under such a regime, and extended usage appears entirely feasible.

Radiation Effects. One subsystem of the Cyborg would involve a sensor to detect radiation levels and an adaptation of the Rose osmotic pump which would automatically inject protective pharmaceuticals in appropriate doses. Experiments at the AF School of Aviation Medicine already indicate an increase in radiation resistance resulting from combined administration of aminoethylisothioronium and cysteine to monkeys.

Metabolic Problems and Hypothermic Controls. In the case of prolonged space flight, the estimated consumption of 10 lb a day for human fuel -- 2 lb of oxygen, 4 lb of fluid, and 4 lb of food -- poses a major problem. During a flight of a year Or longer, assuming that the vehicle was operating satisfactorily, there would be little or no reason for the astronaut to be awake for long periods unless some emergency arose. Hypothermia (reduction of body temperature) would appear to be a desirable state in such long voyages in order to reduce metabolism, and thus human "fuel" consumption. The use of external cooling, reduction of the temperature of the blood in an arterio-venous shunt, and hibernation (through pituitary control), alone or in combination with pharmaceuticals, all seem to offer possibilities in attempting to obtain and maintain such a state. Control of the temperature by influencing the heat-regulating center would be more desirable than changing the reference level.

Oxygenization and Carbon Dioxide Removal. Breathing in space is a problem because the apace environment will not provide the necessary oxygen, and respiration eliminates needed carbon dioxide and involves heat and water losses. An inverse fuel cell, capable of reducing C02 to its components with removal of the carbon and recirculation of the oxygen, would eliminate the necessity for lung breathing. Such a system, operating either on solar or nuclear energy, would replace the lung, making breathing, as we know it, unnecessary. Conventional breathing would still be possible, should the environment permit it, discontinuing the fuel-cell operation.

Fluid Intake and Output. Fluid balance in the astronaut could be largely maintained via a shunt from the ureters to the venous circulation after removal or conversion of noxious substances. Sterilization of the gastrointestinal tract, plus intravenous or

direct intragastric feeding, could reduce fecal elimination to a minimum, and even this might be reutilized.

Enzyme Systems. Under conditions of lowered body temperature, certain enzyme systems would tend to remain more active than others. The extent to which pharmaceutical or chemical agents could influence this enzyme activity has not been systematically investigated, but beyond question they will play an important role. Since metabolism is subject to enzyme control, several intriguing possibilities exist. For example, it may be possible through in vitro radiation to convert certain organisms from aerobic to anaerobic states and, by studying changes in the enzyme systems, to adapt them for eventual human use. In the same manner, selected atmospheres of other types could be investigated.

Vestibular Function. Disorientation or discomfort resulting from disturbed vestibular function due to weightlessness might be handled through the use of drugs, by temporarily draining off the endolymphatic fluid or, alternately, filling the cavities completely, and other techniques involving chemical control. Hypnosis may also be useful for controlling vestibular function.

Cardiovascular Control. The application of control-system theory to biology has already yielded sufficiently fruitful results in studies of the multiple homeostatic functions of the cardiovascular system to indicate the possibility of altering the system by the Cyborg technique. Administration of presently available drugs, such as epinephrine, reserpine, digitalis, amphetamine, etc., by means of Rose injectors, offers one possibility of changing the cardiovascular functions so as to fit them for a particular environment. Alteration of the specific homeostatic references within or outside the brain, and electric stimulation, either as a means of regulating heart rate or affecting selected brain centers in order to control cardiovascular functioning, are other possibilities.

Muscular Maintenance. Prolonged steep or limited activity has a deleterious effect on muscle tone. While reduction of body temperature and metabolism may reduce the magnitude of the problem, further investigation of the chemical reasons for atrophy appears necessary to develop adequate pharmaceutical protection to help maintain muscle tone on prolonged space voyages.

Perceptual Problems. Lack of atmosphere will create markedly different conditions of visual perception than those with which we are familiar. Attention should be given to providing a medium which would recreate some of the distortions to which we are accustomed, and to which the astronaut could become acclimated before takeoff. Part of the problem would come from searching for an adequate frame of reference, and in this regard the factors which influence autokinesis (and illusory movement) may have an influence on space perception problems. Investigation of whether pharmaceuticals would influence autokinesis is therefore desirable.

Pressure. Under pressure lower than 60 mm Hg, man's blood begins to boil at his normal body temperature. Therefore, if he is to venture out of his space vehicle without a pressure suit, some means must be found of reducing his normal operating temperature to a point where the vapor pressure of his fluids is no greater than the internal tissue pressures. This is another reason why lowering of body temperature is essential to avoid the use of constricting pressure suits.

Variations in External Temperature. While man will require the protection of a space ship or station at the real extremes of temperature, there are also likely to be intermediate conditions within or close to the limits of human tolerance. By controlling reflection and absorption by means of protective plastic sponge clothing plus chemicals already in existence which produce changes in pigmentation and provide effective protection against actinic rays, it should be possible to maintain desired body temperature. Needed is a light-sensitive, chemically regulated system which would adjust to its own reflectance so as to maintain the temperature desired.

Gravitation. A change in the ratio of gravity and inertia forces to molecular forces will alter mobility patterns, among other things. Body temperature control and other uses of pharmaceuticals could possibly improve functioning under conditions of greater or lesser gravitation than that on earth.

Magnetic Fields. Chemicals and temperature alteration might also act to retard or facilitate the specific effects of magnetic fields in space.

Sensory Invariance and Action Deprivation. Instead of sensory deprivation, it is sensory invariance, or lack of change in sensory stimuli, which may be the astronaut's bugaboo. In most of the sensory deprivation experiments to date, it has been sensory invariance which has produced discomfort and, in extreme circumstances, led to the occurrence of psychotic-like states. Of even greater significance may be action ' invariance, deprivation or limitation, since in many such experiments subjects have mentioned a "desire for action." The structuring of situations so that action has a meaningful sensory feedback should reduce these difficulties. Here again drugs could play a useful role in reducing resultant tensions. Action without demonstration that such behavior is purposeful or sensory stimuli without opportunity for appropriate response are both highly disturbing.

Psychoses. Despite all the care exercised, there remains a strong possibility that somewhere in the course of a long space voyage a psychotic episode might occur, and this is one condition for which no servomechanism can be completely designed at the present time. While an emergency osmotic pump containing one of the high-potency phenothiazines together with reserpine could be a part of the complete space man's kit, the frequent denial by an individual undergoing a psychotic episode that his thought processes, emotions, or behavior are abnormal, might keep him from voluntarily accepting medication. For this reason, if monitoring is adequate, provision should be made for triggering administration of the medication remotely from earth or by a companion if there is a crew on the vehicle.

Limbo. The contingency of possible extreme pain or suffering as a result of unforeseen accidents must also be considered. The astronaut should therefore be able to elect a state of unconsciousness if he feels it to be necessary. Prolonged sleep induced either pharmacologically or electronically seems the best solution.

Other Problems

There obviously exists an equally large number of medical problems amenable to pharmacological influence which have not been discussed here for lack of space. Among these are such conditions as nausea, vertigo, motion sickness, erotic requirements, vibration tolerance, etc.

However, those selected for discussion offer an indication as to what the Cyborg can mean in terms of space travel. Although some of the proposed solutions may appear fanciful, it should be noted that there are references in the Soviet technical literature to research in many of these same areas. Thus we find the Russians proposing prior oxygen saturation as a solution to the problem of respiration during the first few minutes after space vehicle launchings; reporting on alterations of the vestibular function both by drugs and surgery; studying perception and carrying out research on the laws of eye motion in vision; finding that lowering of temperature can aid in solving pressure problems, etc.

Solving the many technological problems involved in manned space flight by adapting man to his environment, rather than vice versa, will not only mark a significant step forward in man's scientific progress, but may well provide a new and larger dimension for man's spirit as well.