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INTRODUCTION TO LIVING IN SPACE

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In the preceding sessions of this conference many of the leaders in the space program have discussed the problems of placing men in space, as well as machines in space. Considerable attention is also being devoted to the practical uses of satellites, and related areas. Dr. Werner M. von Braun gave a very inspiring presentation on the future of space. He emphasized the contributions being made to many aspects of modern life, and he clearly portrayed the nature of things to come and the possible impact of the space program in absorbing the energies of men in the future. One might interpret Dr. von Braun's views to imply that space activities eventually may be substituted for the material and psychological needs which in the past have led to war. Thus, the exploration of space eventually may prove to be "The Moral Equivalent of War," as reminiscent of William James' famous essay on this subject. The objective of our program in this session is to discuss some of the accomplishments and problems relating to *Living In Space.*

First of all, it is important to note that the National Aeronautics and Space Act of 1958 requires that ". . . the aeronautical and space activities of the United States shall be conducted so as to contribute materially . . . to peaceful and scientific purposes. . . ." In other words, those responsible for the space effort must also be concerned with the social, economic, and scientific ramifications of the national space program for our society. In this conference on the peaceful uses of outer space, we are sharing in these objectives. Accordingly, it is appropriate to examine some of the implications of the national space program for medicine and related biological sciences.

It may be too early to appraise accurately the impact of the space effort on medicine. It is possible, however, to examine the role of medicine in areas relating to living in space. The basic objective is to develop principles relating to the avoidance of disease and the prevention of injury. The real goal, however, is not simply *marginal* survival. An attempt must be made to predict and maintain *optimum* human performance.

In order to achieve these objectives relating to human performance in space, it is necessary to consider the interaction between the engineering and medical sciences, or, as commonly expressed, the *trade-offs* or compromises required in the design of equipment. Coordinating the efforts of design engineers and biological scientists has resulted in more efficient and safer aircraft to fly within the Earth's atmosphere, and this objective can also be accomplished for vehicles to operate in space.

It should be emphasized that aerospace medicine involves a team approach including the disciplines of psychology, physiology, biology, medicine, and engineering. Often there is a problem of communication and understanding between the physical and biological scientists. In practice, the engineer and physician, finding themselves as joint participants in a project, are forced to find a common mode of expression—obliged to make their ideas and solutions useful to each other. Thus, there develops an integration between medicine and engineering. Understanding has increased with time, and significant contributions have resulted from a joint effort.

The medical sciences of today, as is equally true of the aerospace sciences, would be very limited if the physician's experience did not include knowledge of the manner in which man responds to his *total* environment. Indeed, the sciences of molecular biology and the art of medicine constitutes only a small fraction of the knowledge required for the care of individual patients and the practice of public health. With the increasing control of communicable diseases, the patient is not as great a threat to the community as the community and its byproducts are a threat to the patient. Likewise, in the exploration of space, it is the hostile environment which must be conquered, whether natural or man made.

One professor of medicine, Dr. John Parks of George Washington University, has made the following points about environmental health, in answer to the question, "What is the nature of that threat in an *effluent* society?"

> It is air pollution and its effects on the cardiopulmonary system; it is water pollution and its relationship to hepatitis; it is the effect of urban noise and auto traffic on the nervous system; it is the body-burden of radiation and its widespread effects; it is the chemicals of the work space; it is the great unknown of pesticides. Surely physicians, who for centuries have fought and conquered the great unknowns of disease, will join in the common attack on these environmental problems.

These statements are directly relevant to space medicine with only slight rephrasing.

We ordinarily think of the relationships between aerospace medicine, preventive medicine, and public health as four general areas.

ENVIRONMENTAL INFLUENCE ON HUMAN HEALTH AND PERFORMANCE

The physician working in the field of bioastronautics is vitally concerned with the effects of the environment on human health and performance. In most cases, physical or chemical hazards are involved. His ultimate task is to establish *scales* which relate duration and intensity of exposure to human tolerance and performance. These must be stated in terms which are useful to design engineers. There is direct applicability of most of these design criteria to preventive medicine here on Earth. Thus, there is a direct interrelationship between the environmental health sciences and space medicine. Radiation, heat and cold, toxic chemicals and barometric pressure are but a few of the areas common to both fields. Obviously, means of protection against these hazards in space flight should contribute significantly to the control of hazardous situations in industry.

There are many other examples of this interchange of knowledge and techniques. Studies of weightlessness on various biological organisms show the effect of gravity on cellular growth and differentiation, and other physiological effects such as decalcification. The use of pressure-suit-type devices may aid in venous return of blood to the heart in certain types of patients. The mechanisms by which microbial spores are transported by air are highly important to both biology and medicine; there are direct implications for reducing the spread of agricultural crop diseases and for protecting persons suffering from allergies. The use of hyperbaric oxygen in certain surgical procedures is proving to be of interest in a variety of clinical conditions.

THE DESCRIPTION AND MEASUREMENT OF "NORMAL HEALTH"

A general principle in industrial medicine is the effective matching of men and jobs. Implicit in this procedure is knowledge of the characteristics of both the man and the job. The selection of astronauts and the design of their training program are based essentially on this procedure. However, criteria for selection were essentially nonexistent at the outset. Because of the need for this data in the selection process, a great deal of information on healthy individuals, with and without the factor of stress, has been developed within studies in aerospace medicine. The immediate usefulness of this type of information to clinical medicine is obvious.

THE ALTERATION OF BASIC BIOLOGICAL MECHANISMS TO INCREASE OR TO PROLONG USEFUL ADAPTATION

The specialist in aerospace medicine is vitally interested in basic physiological mechanisms. His interest is directed not only toward an understanding of these bodily systems, but equally toward prediction of behavior in times of anticipated stresses. Knowledge of the mechanical characteristics of the vestibular apparatus allows the aerospace physician to predict the distortion of visual perception and disorientation which would occur to a tumbling or spinning astronaut. The otolaryngologist uses this same knowledge when he traces through a causative disease process. Closed ecological systems, withdrawing of normal sensory inputs, variations in oxygen pressure, and the prolonged effects of certain gases and toxic agents provide a few illustrations of other areas under current study.

Means of altering the biological organism to increase resistance to disease are of common interest to clinical and aerospace medicine. For example, findings in the field of antiradiation drugs obtained from research in one specialty are useful to the other.

THE REFINEMENT OF INSTRUMENTS FOR OBSERVING, RECORDING, AND ANALYZING DATA

The man-in-space program requires that a large volume of information about the astronaut be remotely collected and transmitted instantaneously to ground-based observers. A large number of tools have been perfected during the past few years to observe, record, and analyze physiological data. These developments are often referred to as an important contribution of bioastronautics to clinical medicine. A wide variety of sensors have been developed, as well as miniaturized telemetry devices and computers. Many of these have found immediate application in surgery, medicine, and anesthesiology. The transmission of physiological data via the communications satellite Relay I between England and a major medical center in the United States in order to make a diagnosis for an individual patient provides a dramatic illustration.

STIMULUS OF SPACE RESEARCH

After this brief summary of the relationships between space and terrestrial medicine, one may ask the question whether these contributions could have arisen without the stimulus and challenge of the space program. Analysis has suggested that while a few developments might have appeared, most would not. A Brookings Institute Report, "Implication of Peaceful Space Activities for Human Affairs," written in 1960, noted that: ". . . major breakthroughs in science and technology have always produced acceleration in the rate of succeeding innovation, but space activities appear to be pushing the pace of innovation to unprecedented levels."

The Mercury program found man not only an effective link in a complex system, but on three of seven missions, an indispensable element in terms of their success. Many have asked, "Why send a man on such a dangerous mission? Wouldn't it be better to use instruments?" One space scientist has recently pointed out that as we approach these more advanced studies we need a skilled interpretation of the broad situation from which alternative courses of action can be weighed objectively. If we were to try to design an instrument to exercise this broad comprehension, it would look surprisingly like a man.

More specifically, a human operator in the spacecraft can: (1) report upon and cope with unexpected events and phenomena; (2) make generalizations from specific observations; (3) profit from experience as the mission progresses by assimilating bits of pertinent information into intelligible form, and reprogram as necessary; (4) improvise and use flexible procedures which contribute to the success of a mission; and, finally, (5) exercise judgment. Because of these abilities it can be seen that a well-trained astronaut is very essential when there is a need for flexibility and when there is an extreme range of alternative conditions.

The experience obtained from the Mercury project has provided a basis for judgment in planning later man-in-space programs. The results demonstrate that man can survive for short intervals in space. The effects of missions of longer duration are unknown. Prominent among these are the effects of weightlessness and the interaction of this variable with other hazards. Man's function and behavior while breathing an artificial atmosphere, altered as to pressure and composition for long periods of time, are as yet unknown.