HStrughold/msn/28119 -Prefinal

Results of Biomedical Explorations of Space to Date*

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The topic of this paper "Results of Biomedical Explorations of Space to Date" selected by the Chairman of this Symposium is a very timely one because it was just about 10 years ago that medical science had begun to study the human factors encountered in space flight. It was a virgin field--at the time--although some of the results of previous aeromedical research could have been regarded as basic ones for or applicable to space medicine or bioastronautics. But today--after a decade of extensive theoretical and experimental research specifically carried out in the interest of man's conquest of space--numerous data are available which indicate an enormous progress on the medical (front) side of the vertical frontier.

The discussion in the first part of this paper will be confined to the artificial environment that must be created for a man venturing into the vacuum of space and to the motion dynamics characteristic of a vehicle moving in an environment of emptiness such as that of space.

I would like to begin with the statement that empty space is the rule in the universe, and that concentrations of matter in the form of celestial bodies--including their atmospheres--are the exceptions, and that life is possible only in an environment that is dense enough to supply sufficient bioelements for metabolic processes. This, however, is not the case in space--with its gaseous particle density of not more than 10 particles essentially hydrogen in 1 cm^3. The bioelement par excellance is oxygen. In this respect, for the ever demanding pxygen creature--man--the equivalence of space is (outspoken) reached as soon as oxygen supply from the surrounding atmosphere drops to zero. This, for physiological reasons, is the case at about 87 mm Hg air pressure, or about 15 km altitude. Not less dangerous, but more conspicuous, is the vacuum effect upon man in the form of "Ebullism" --erroneously called "boiling of body fluids." This phenomenon is the result of decreased air pressure which occurs at 47 mm Hg and below, and this pressure level can be considered the physiological barometric border between atmosphere and space. In this regard the physiological vacuum quality of space reaches down to 20 km in the Earth's atmosphere, down to 3-1/2 km on Mars, and on the Moon and on practically all the other planets space directly touches the surface. Venus shall be eliminated here because, according to recent astrophysical theories, the road to Venus goes through (traverses ?) solar coronal plasma and the temperature on the planet itself reaches biocidal levels due to a greenhouse effect within its carbon dioxide atmosphere. The trend in astronautics, therefore, will probably be away from the Sun towards Mars and, of course, to the Moon. For here and everywhere, except on the surface of Mars, the astronaut faces the vacuum environment where the air pressure is 85 millibars or 65 mm Hg, which corresponds to 15 km in our atmosphere. Such is the environmental barometric picture of space and of the prospective target celestial bodies.

~~oxygen thirsty~~ (Preferred above expression)

Closed Ecological System

A supply of all the physiological necessities for life, therefore, must be provided for the astronaut from terrestrial sources and in the manner to which he is accustomed or can adapt himself. For this purpose, an environment of emptiness required in a sealed compartment, needs no explanation. But the task of keeping a man alive and alert, in such an isolated synthetic little earth "terrella" as the space cabin can be characterized, is tremendous---especially when we consider the time factor involved in extended space operations such as a flight to Mars. These developmental possibilities have brought the concept of a closed ecological system into the focus of medical thinking and experimentation, a subject matter new in the history of Medicine. Such a system includes gaseous components such as oxygen and carbon dioxide, liquids and semi-liquids such as food and waste products. This complex of physiological factors must be controlled in terms of human comfort and health and economic logistics; the two stages of control must be differentiated by:

I. Control by replacement and storing,

II. Control by recycling.

Stage I is <u>the</u> method for short time space operations and is based on physical and chemical methods. It includes oxygen supply from tanks, elimination of carbon dioxide and water vapor by chemical absorbents (silicon hydroxide) and storing of liquid and semi-liquid waste products.

Stage II will be required in space flight of long duration and includes recycling of oxygen, carbon and nitrogen in the same manner as we observe it in free nature in the process of photosynthesis. Photosynthesis is the reverse process of respiration and is therefore the logical method to counteract the change of the environment caused by respiration.

All of these methods have been under extensive studies in the laboratory, and some of them in actual space-equivalent and space test flights.

In the following, some of the important points on the state of the art in this field are briefly enumerated:

1. Concerning the first stage of regeneration--by replacing and storing--a flight was made by David G. Simons in 1957 in a sealed gondola lasting 32 hours, with altitude peaks of 30 km in the MANHIGH project. Similar flights--of a little shorter duration--were made by Barr and Ross in the STRATOLAB project.

2. In the space cabin simulator of the USAF School of Aviation Medicine, experiments have been carried out over 7 days, by George R. Steinkamp,* and staff, 1957-58. This duration would completely cover a flight to the Moon and return, and could easily be expanded to a duration expressible in the order of weeks.

3. The russian dog Laika was kept alive by physico-chemical regenerative means ~~fxx~~ in actual orbital flight for a number of days.

4. Concerning the second stage of regeneration--by recycling based on photosynthesis--it has been found by Jack Myers, University of Texas, that 5.2 kg of fresh weight of the algae chlorella pyrenoidosa are capable of meeting the metabolic respiratory requirements of one man. Recently in the Department of Space Médicine, Randolph AFB, Texas, another more bacteria-like alga "anaystis nidulous" has been found by ~~Rxx~~ William Kratz, to be more effective; one pound of fresh weight produces 850 liter

of oxygen per day at 39°C and under conditions of light saturation; three mice could easily be kept alive in a small ecological system equipped with such a photosynthetic gas exchanger for more than three weeks. Research in this field goes on in the direction of finding still better strains of green microorganisms and of attaining high rates of light saturation under operational conditions. Photosynthetic recycling, of course, must be extended to metabolic nutritional requirements. The first (pioneer)? pilot studies in this research with another alga Synochraystis , which can utilize urine as a nitrogen source, are under way. It has been discovered by Syrrel S. Wilks, Department of Physiology-Biophysics, SAM, that in the process of photosynthis, carbon monoxide is produced in small amounts which--after some time--accumulates to toxic quantities. Until now this was not known in botany, but already, a solution has been found to counteract this hazard by eliminating this hemoglobin blocking gas by means of oxydizers such as hypolite or potassium peroxide.

An interesting point has recently been brought to my attention by Hans G. Clamann in a metabolic study concerning water supply in a closed ecological system. Dr. Clamann emphasized that in a recycling system it is not necessary to take along all the water needed for a long trip. [The human body gives off about 10 percent more water per day than he takes in. This 10 percent represents the so-called metabolic water produced in cellular oxidation of carbohydrates, the latter of which are consumed in the form of food. Only an initial small amount of water need be taken along at the start because more will be produced physiologically during the trip.]

These are only some of the Steps of progress made in the complexity of the problems involved in a closed ecological system.

Weightlessness

Another medical problem as the result of emptiness in space is weightlessness. Weightlessness in space flight is not a function of the distance from the gravitational center of the earth rather than a dynamic condition. It occurs when no external forces-such as atmospheric friction--interfere with the free ixtxxxxtixx interaction of gravitational and inertial forces of the vehicle. The atmospheric borderline between permanent dynamic weightlessness and weight lies on earth in the region of 200 km, or 120 miles. On Mars this line might b not be very much lower. On the Moon dynamic weightlessness ceases on its surface. Weightlessness in the universe seems to be the rule---weight is the exception. We--in a cosmic sense, with out body structure and function--are, therefore, adapted to an exceptional condition. The question is - can terrestrials xdapt, orxI mixghtxsayx adapt, or I might say readapt, themselves functionally to this cosmic condition?

In more than 4000 parabolic flight maneuvers carried out at the SAM, Randolph AFB, and at Holloman AFB, ---which have lasted only some 40 seconds--it could be shown that performances which require fine coordination of the movements of the limbs, was not affected. This can be explained by the twofold function of our mechanoreceptors involved in the movement of our limbs and body, namely, their extraoceptive and proprioreceptive function Only the first is eliminated during the weightless state. Besides this behavior of the somatic nervous system, the autonomic nervous system which controls respiration, circulation, digestion, etc. has been the object of experimentation in man again in parabolic flight maneuvers and on animals xduringxxsubxorbitalxandxorbitalxflightsx during suborbital and orbital flights.

There is one point I would like to mention: In the astronautical literature orbital flight is occasionally explained with a constant falling around the Earth. And it is also noted that this might be a nightmare for man insofar as he might have the sensation of continuously falling. The subjects in parabolic flight maneuvers do not report this sensation and xxx psychologically explained--as one subject puts it xxxxxxxxxxxxxxxx xxxxx "because he knows he is weightless, he hs not the feeling of falling." There is, however, a physiologic explanation. Take, for instance, the simplest example: in a free fall, the otoliths becoming weightless, move into another position; this may take one second or xxxxxxxx so, and then they attain a new equilibrium. Only during the dislocation of the otoliths should the sensation of falling occur but not necessarily thereafter. Thus, physical falling and the sensation of falling associated with the physiological otolith reaction are different stories; xxxxx this point has been somewhat overlooked.

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