SOME ASPECTS OF SPACE ECOLOGY AND PHYSIOLOGY

By

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Man's yearning to explore the distant stars and planets is probably as old as human thought. Soaring birds and twinkling stars in the sky beckoned him to leave his terrestrial confines in both waking fancy and in dreams. The idea of Space can be found in Hindu Vedas, in Sanskrit Bhagavata, in early Persian and Egyptian literature, in Inca and Mayan writings, as well as in Greek mythology. However, the means of propulsion suggested to fly through the space, such as harnessing birds, and attaching artificial wings to the arms, could not attract any serious scientific consideration.

The flights in balloons started in 1783, and made an odyssey during the next hundred years. By 1871, more than 3,500 balloon flights had been made with only 15 recorded deaths. However, only few flights were undertaken for scientific purposes. James Glaisher, Chief Meteorologist of the Greenwich observatory in England, and Paul Bert, the founder of the science of high altitude physiology, made very important contributions in this field and much of what they described were their personal observations which they made as participants during the balloon flights. In these balloon flights it was clearly demonstrated that decreased oxygen tension at high altitudes had insidious but lethal effects. Low temperature was also very trying. This led to the use of closed gondolas in which provision was made for oxygen supply and proper clothing to keep warm.

To circumvent the limitations of balloon flights, *i.e.*, limitations of heights reached and non-control of horizontal movements, the next step to make further progress in space exploration led to the introduction of aeroplanes, which used fuel to supply the power for the speed of the manoeuvred flights. Provision of oxygen supply and the pressurization of the vehicle helped in reaching beyond the heights already reached. The combining of jet principles with those of the rocketry, brought in the era of space travel in spaceships and satellites. Landing on moon has already been successfully achieved.

Ecology of Space

The aerosphere constitutes a mixture of gases with a certain concentration of moisture and shows the highest correlation with changes in altitude. The atmosphere of earth is part of this aerosphere, which extends for several miles in height around the earth and possibly reaches the corona of the sun. The most important gas constituents having biological significance are O_2, CO_2 and Nitrogen. The other gaseous elements have very low concentrations and

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do not play any role in biological processes. It is the partial pressures of O_2 and CO_2, rather than their concentrations that are of physiological importance. The partial pressures are closely related to barometric pressure and hence to the altitude. Certain critical altitudes have practical significance so far as the O_2 needs of an individual are concerned. Above 10,000 ft. most persons require the addition of O_2 to the air they breathe. At 35,000 ft. 100% O_2 must be breathed. At about 50,000 ft., little oxygen reaches the alveoli of the lungs even while breathing 100% O_2, since at this altitude the total barometric pressure of 87 mm. Hg. equals the sum of the partial pressures of H_2O, which is 47 mm. Hg., and CO_2, which is 40 mm. Hg. At an altitude in excess of 63,000 ft. the body liquids boil, since the pressure at this altitude, which is 47 mm. Hg., is equal to the vapour pressure of these liquids at body temperature.

Physiological Hazards of Aerosphere

Hypoxia and Dysbarism are the two main hazards of aerosphere beyond a safe altitude, the former because of the low oxygen tension, and the latter because of reduction of atmospheric pressure.

Hypoxia has its effects on the respiratory centre and carotid reflexes, which lead to changes in several body functions. In a more advanced state it affects the brain metabolism. Dysbarism is produced when gas bubbles form in blood and body tissues due to the effects of comparatively sudden lowering of atmosphere pressure. This may lead to symptoms of local pressure, or to vascular obstruction producing varied clinical symptamatology.

Temperature Ranges of the Atmosphere

Vertically the atmosphere is divided on the basis of temperature variation into troposphere, stratosphere, mesosphere and thermosphere. At the equator the troposphere extends up to about 18 km. but at the poles it goes up to only 8-9 km. Within the troposphere temperature decreases with the altitude, until at the tropopause a temperature of about —60°C is reached. The temperature remains at this level in the stratosphere but in the mesosphere, which is the region between 20 and 80 km., it first rises to a value of about 0°C and then drops again to about —65°C to —100°C at 60-80 km.

The thermosphere begins at an altitude above 80 km. and here the temperature rises sharply, until at an altitude of 200 km. it is about 900°C. Recent rocket and satellite data indicate that at about 300 km. temperature is nearly constant at about 1,000°C.

Radiations in Atmosphere

Radiant energy content of the atmosphere is of two types, *i.e.*, non-ionizing radiation and ionizing radiation.

Non-ionizing radiation is constituted by solar radiation, cosmic radiation, and terrestrial radiation. Solar and cosmic radiation fall into optical area. Cosmic radiation contributes an infinitesimally small part as compared to solar radiation.

Ionizing radiation environment in space appears at present to be a major concern for manned space flights. It is difficult to modify, hard to avoid, and cannot even be realistically assessed. Ionizing radiations are chiefly emitted from the corona of sun and to some extent from other cosmic regions. They vary greatly in energy and seem to reach the maximum during solar flares which are very irregular in time. The ionizing radiation is mostly concentrated in the inner and outer Van Allen belts. The inner belt lies from 600 to 3,600 km. from the earth and the outer belt covers a distance of 15,000 to 22,000 km. Exposure to this type of radiation is lethal for the living cell. It damages the nucleus, chromosomes, and genes, and in sublethal effects produces mutations which lead to cancer or other abnormalities of growth. The tissues which suffer the maximum damage are lymphnodes, testes, bone marrow, gastrointestinal tract, skin, connective tissues, and blood vessels, and least of all brain. However, it is surmised that in time human tissues do develop some tolerance.

Biodynamics of Space Flight

Space flight has very potent biological effects, concerning mainly with the effects of acceleration, deceleration and weightlessness.

Similarly, atmospheric re-entry and landing on earth's surface present complex problems. The fate of meteoroid burning to incandescence on entering earth's atmosphere demonstrates the necessity of controlled means of deceleration. Safe re-entry has been achieved by ballistic means or by aerodynamic lift. To minimize heat production, re-entry is effected at an altitude where heat transfer is low. The descent is made safer by the use of parachutes and the size and shape of the vehicle.

The main hazards come from the increase of G force, which can only be tolerated within a definite range. The best experimental technique to simulate acceleration and deceleration is in the human centrifuge and the date collected have been very useful for preventing the hazards of flight operations.

The main effects of 'G' forces in the longitudinal axis is on the blood. During headward acceleration blood is centrifuged into the lower extremities and the blood flow to the heart and brain diminishes. During footward acceleration blood is displaced towards the head and brain. During transverse acceleration there is minimal effect on the blood while abdominal and thoracic compression with some respiratory difficulty is produced. Man's tolerance to accelerations is greatest, if taken in a forward facing position with a slight inclination of the upper body in the direction of the acceleration. It must be remembered that human tolerance to acceleration is influenced not only by duration, magnitude, rate of onset and direction, but also by other environmental factors. Hypoxia significantly decreases the G tolerance of man for positive acceleration. Heat stress also significantly decreases acceleration tolerance. Weightlessness preceding acceleration decreases tolerance. Conversely recovery from the effects of acceleration takes longer during weightlessness than during normal conditions. Anxiety in man is a contributory factor in decreasing G tolerance.

The problems of weightlessness during space flights arise when the vehicle travels unpowered at the stage of coasting flight beyond the earth's atmosphere. Perception of weight depends on three major sensory mechanisms, *i.e.*, mechanoreceptors in the body, specialized receptors in vestibular apparatus, and indirectly vision. The eyes does not sense force or weight as such like the mechanoreceptors or the vestibule. However it perceives the results of such forces in the relationship of objects to each other. Vision remains to be the only sensory function for orientation in space.

Amongst the physiological hazards of weightlessness cardiorespiratory function shows only minimal changes. Neuromuscular co-ordination is affected considerably and a lot of training is required before learning not to overshoot the target during any performance. Psychological reactions to weightlessness are very varied. Majority of the astronauts describe the feeling to be pleasant and are relaxed and comfortable. Very occasionally there may be defects in spatial orientation.

Ecology of Space Cabin

Man's requirements for food, oxygen and water do not vary widely even in the spaceship. Indeed the metabolic requirements in space are the same as anywhere else. All these requirements, however, have to be provided before the start of the flight and the supply has to be just adequate and not liberal because of the limitation of the load to be carried.

The energy requirements of an astronaut doing light work, monitoring and controlling instrument panel, cleaning the cabin, eating, washing and reading is estimated to be about 2,500 Cal/day/man.

For trips of the order of a year or longer, the possibility of photosynthetic gas exchanger has to be considered. The prospects for a complete ecological system in which human wastes are the source for the biosynthesis of food for human consumption are more tenuous for the near future.

Psychological Stress in Space Flight

Psychological Stresses are due to—

(i) Confinement due to limitation of space.

(ii) Cultural and social isolation.

(iii) Space silence and space darkness.

(iv) Strange and unpalatable food, recycled water, unusual sleeping and working hours and weightlessness; and

(v) Any equipment failure, especially failure of communication.

The chief manifestation of these is anxiety which subsequently leads to derangement of clear thinking, coherence, confidence and judgement.

However, due to previous conditioning, astronauts taking long flights have not shown much effects of these stresses as was expected.

Very important observations, however, have been made on actual studies conducted on personnel in Mercury and Gemini flights reported in 1967 and Apollo flights reported in 1970. A brief summary of these observations is now presented.

Report on Mercury and Gemini Flights

Nineteen men had flown 25 manned flights, giving a total weightless experience of nearly 2,000 man-hours and important data has been obtained from them. The astronauts in these flights are exposed to various stresses. Only some of these stresses can be simulated in ground based studies. The physiological indices obtained during these flights consisted of voice reading, two leads of EKG, respiration, body temperature and blood pressure. During extra vehicular activity of space walking, however, only two parameters, *i.e.*, one lead each of EKG and respiration, were monitored through the space suit umblical cord.

There were initially grave doubts whether the maintenance of cabin pressure, adequate composition of cabin atmosphere, cabin and suit temperature, avoidance of micrometeorites, radiation effects, adaptation to the rhythm of light and darkness and effects of weightlessness could be effectively controlled to allow prolonged stay in space.

Mercury and Gemini operations have established that cabin pressure of 5 pounds per square inch and suit pressure of approximately 3-7 psi can be maintained without even a single failure. Cabin atmosphere can be stabilized at 100% O_2 at 5 psi and with denitrogenation two hours before flight there has been no risk of dysbarism. The cabin and suit temperatures have been maintained at a comfortable level of 70°F. No significant micrometeorites or meteorite population have been encountered during these flights. They have also demonstrated that the radiation hazard does not pose any problem. Also, darkening the space craft and keeping to the Cape Kennedy times, effectively solved the difficulties anticipated in providing adequate sleep.

Heart rate during flight remains fairly steady if sleep and waking cycles are maintained. However, it shows an increase during launch and re-entry. The EKG remains normal and the exercise tolerance test shows that even during extravehicular activity this is well tolerated.

Blood showed changes in the WBC counts in the majority and also some changes in the total blood volume, plasma volume and red cell mass. The diminution of red cell mass is attributed to high oxygen content of cabin atmosphere which seems to change the qualities of the red blood cell membrane.

Loss of bone density and body weight also occurred. The diminished density of bone is attributed to lack of exercise and loss of body weight to diminution of fluids in the body. Both these defects were quickly remedied after return to earth. Crew performance, function of special senses and food and water intake did not pose any unsurmountable problem. Similarly, no psychological derangements were observed due to isolation or sensory deprivation.

Special studies were made on extra vehicular activity and it was observed that heart rate was accelerated more than the respiration.

These extensive studies during Mercury and Gemini flights were, therefore, very encouraging and the observations made on these finally led to the accomplishment of Apollo flights.

Report on Appollo Flights

Medical information gained in Mercury and Gemini programmes indicated that extra vehicular activity has a high energy cost and that diminished exercise capacity, loss of red cell mass and disconditioning of cardiovascular system are produced. These facts were very important in respect to the performance of astronauts during lunar activity, which was the main target to be achieved by the Apollo flights. Although the contribution of confinement *per se* to the deteriorative physiological changes observed after flights of long duration in the small Mercury and Gemini space craft cabines could not be determined, it was thought that the freedom of movement and exercising allowed in the Apollo vehicle would maintain the astronaut in optimum physical condition for the duration of Apollo 11 mission.

During Apollo flight the space craft cabin environments of Command Module and Lunar Module were suitably maintained at 60% O_2 and 40% N_2 with crew denetrogenated for 3 hours prior to launch. The cabin-pressure of 5 psi and average temperature of 70°F produced comfortable conditions during the whole operation. Radiation estimates indicated that, even though during these flights Van Allen belts were crossed, these did not result in any physiological hazards. There was no occurrence of solar flares during these flights or during the stay at lunar surface.

Due to their training before the flights, the astronauts were not handicapped by weightlessness in any of their operations.

Thermostabilized meat dishes, with moisture content of 60 to 70% (wet packs), eliminated many difficulties of food intake. Energy intake and body weight showed that although energy intake was normal, the astronauts still showed some loss of weight. This was partly due to water loss. The weight loss easily recovered within a short time after the flight was over.

Work and sleep cycles did not offer any problem after enforcing the regime of letting all the three astonauts go to sleep, according to the schedule to which they were trained before the flight. However, " Command Pilot Syndrome " was a special situation of loss of sleep in the beginning, when he was not fully confident of the safety of the flight during his sleep period.

Medical evaluation in Apollo flights mainly dealt with cardiovascular system especially the orthostatic effects. Cardiovascular function, however, remained steadily normal. The orthostatic effects did not last long after the crew returned to earth.

Blood biochemistry data showed some changes in blood sugar, catecholamines, steroids, serum cholestrol, etc. However, all these changes were reversible and were considered to be mostly due to stress.

Conclusion

All the knowledge gathered so far, by going into the details of biodata as estimated during the actual space operations, inspires hope and optimism on the whole for successful space flights to make inter-stellar travel possible for further exploration. Time does not seem to be far when human beings will be safely travelling between different planets, as they are travelling between the different cotinents of the earth at the present moment.