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Rockets, Men and Medicine

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Abstract
Space Medicine has at last become an accepted entity in the vast field of medical research after many years of ridicule and scorn. The recent successes of the U .S.S.R. and U .S.A. in launching earth and sun satellites would seem adequate to justify the existence of space medicine. It seems Man's avowed intention to conquer the third dimension, the vertical, which leads to space and as such it is the duty of the medical scientist to make this journey as safe as possible for the would-be space traveller.

Space is not a well defined region since it has no accurate topographical boundaries and in the context of this article the best way of defining space is to think in terms of levels of space equivalency, i.e. levels at which various protective functions of the Earth's atmosphere are lost so creating a space-like state for a certain phenomenon at a particular altitude. From the viewpoint of respiratory physiology space begins at a height of 52,500 feet since the effects of explosive decompression assume a constant value at and over this level. In similar terms the atmosphere acts as a filter against cosmic factors and this function of itself provides a variety of space equivalencies ranging from sea level in the case of infra-red rays, to 10-20 miles for cosmic primaries and as high as 75 miles for visible light. Space, therefore, is a concept which of necessity is a variable and its effects may be just as varied.

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ROCKETS, MEN AND MEDICINE

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By A. L. CROMBIE

"I was thinking this globe enough until there sprung out so
noiseless around me myriads of other globes."
—WALT WHITMAN: *Night on the Prairie.*

Space Medicine has at last become an accepted entity in the vast field of medical research after many years of ridicule and scorn. The recent successes of the U.S.S.R. and U.S.A. in launching earth and sun satellites would seem adequate to justify the existence of space medicine. It seems Man's avowed intention to conquer the third dimension, the vertical, which leads to space and as such it is the duty of the medical scientist to make this journey as safe as possible for the would-be space traveller.

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Man has chosen the rocket to be his vehicle for reaching other parts of the Universe because the rocket if adequately fueled is independent of its environment, unlike conventional aircraft. But the rocket is a short duration, high performance engine and this entails large initial accelerations to reach an "escape" velocity of approximately 7 miles a second. There is a limit to the final speed of a single stage rocket due mainly to practical engineering problems and the "step" or multi-stage rocket has become the standard type. Theoretically any desired terminal velocity may be reached because of the efficient transfer of kinetic energy from one "stage" to the next.

Space travel is not only concerned with problems of rocket engineering. Human engineering will play an important part in the design of a spaceman's environment and of the instruments he will use. The aim and purpose of human engineering is to improve operator efficiency and safety by minimising the stresses induced by the machines which the engineer designs for him. This becomes increasingly important in space travel for even with carefully selected and highly trained personnel the amount of instrumentation needed will be colossal and control finding and decision making will be done as much by mechanical brains as by human ones. Probably the best way to deal with some of the problems of space flight is to deal with them as they would arise in an actual rocket flight and accordingly acceleration will be the first.

An escape velocity can be achieved by varying the acceleration and the duration over which it is applied; thus 7 miles a second could be achieved at an acceleration of 3 "G" for 9½ minutes, or 6 "G" for 3 minutes 48 seconds, or 10 "G" for 2 minutes 6 seconds, this last acceleration hardly being necessary as a more gradual take-off involving orbiting is contemplated. The human frame can stand acceleration best when it is applied in the chest-to-back direction, which is of course the prone position in vertical acceleration, 9 "G" being tolerated for 3 minutes before blackout occurs. Any reduction in the head-heart distance will increase tolerance to acceleration, and the "G" suit is merely a device to prevent pooling of blood in the legs and abdomen while the subject is being accelerated in the upright position. Cardio-vascular compensation occurs after 15 seconds of acceleration, the systolic and diastolic rising with the heart rate; but at prolonged high "G" various cardiac airythemias occur, probably due to coronary insufficiency though this has never proved fatal. Impairment of peripheral vision due to retinal ischaenia occurs when acceleration is applied. The auditory system functions for some time after vision has been lost. A counter-balanced oblatospheroid may be the answer to acceleration problems if it is mounted on gimbals so that vertical and angular accelerations will act as one vector cutting a line joining the vestibuli at right angles, which is the optimum position in which an acceleration should act. The launching of a rocket will have to be automatic since cognitive processes decrease in efficiency with increasing acceleration. Whether this mental impairment is central or due to peripheral sensory impairment is not known; what is known is that kinesthetic reflexes have a higher theshold stimulation value under acceleration. Much work remains to be done in the investigation of the relationship between acceleration patterns and subsequent behaviour.

The next big problem is that of weightlessness . So far, a true weightless state in which gravity is balanced by inertia has only been obtained in parabolic flying for periods up to 30 seconds, and therefore the physiological effects of long-term weightlessness must be based on known physical principles. Most of the important functions of the body depend on muscular action and not upon weight difference, thus respiration and digestion will not be affected although disposal of excreta may present a problem. Muscular effort will be at a minimum and some disuse atrophy may occur in skeletal muscle and the myocardium. The idea of an orbiting satellite as a cardiac convalescent home is an attractive one.

The central nervous system may also be affected by a zero-gravity state since the otolithic and kinesthetic reflexes which depend on gravity and other accelerations will be rendered non-functional. It is not known if reorientation is possible using the visual and semi-circular canal systems, for there will certainly be a conflict of information received by the cortex from these systems due to the endolymph being "left behind" when the head is turned sharply and a deviation in the path of purposeful movement will result. "Synthetic gravity," i.e. centrifugal force of 1 "G" at the periphery of a spinning, wheel-shaped space ship has been suggested but this may well be worse than weightlessness as very complex patterns would be produced by head movement.

A most important task will be the maintenance of respiratory function including all processes directly or indirectly contributing to oxidative metabolism. Normal atmospheric pressure may be unattainable in a space ship because of engineering limitations and thus low pressures will have to be used. All inert gases will be replaced by oxygen at a pressure of approximately 425 mm. Hg since at this pressure it can be breathed indefinitely without toxic effect. Carbon dioxide and water elimination also constitute a problem although a limited tolerance to a raised partial pressure of carbon dioxide can be acquired at the expense of the acid-base balance. If prolonged, however, it may be fatal. Many elimination methods have been suggested. That involving the alga, chlorella pycsenoidosa seeming the most promising. In ideal growing conditions 2·3 kilos of this could supply one man with his daily requirement of oxygen as well as absorbing all his exhaled carbon dioxide. The one drawback which this plant possesses is that it produces a lot of heat. This could be dissipated by a solar powered refrigeration system in the space cabin, which might also be used to drive a ventilation system since convection and evaporation will be minimal otherwise. The temperature of the outside of the craft could be controlled by a series of folding shutters which would expose black or silvered areas to the radiant heat of space and control the temperature of the silicon monoxide painted hull.

Meteors and meteorite streams are a much exaggerated hazard. It has been calculated that a 3 cubic metre craft would have a 1-2000 chance of being hit by a penetrating meteorite in 24 hours. Whipple has advocated the use of a meteor-bumper one-tenth of the thickness of the hull and placed 1-2 cm. from it, which would decrease the risk of penetration by a factor of 10. If a small penetration occurred there would be ample time for a self-sealing system to function and even if explosive decompression occurred the space traveller would have a 99% chance of survival provided he allowed himself to decompress quickly by keeping his mouth open. Adequate recompression could be effected by a protective suit within 70-90 seconds to offset the anoxia caused by the resurge of oxygen from the blood to the alveoli due to the sudden decrease in the alveolar oxygen pressure. There now remains but one cosmic hazard, that of radiation. The soft X-ray fractions and the ultra-violet fraction of solar radiation are relatively innocuous and adequate shielding would be provided by the hull of the craft. Cosmic rays, on the other hand, are far from innocuous and are a definite hazard though difficult to evaluate. The alpha particles and heavy nuclei only comprise 20% of cosmic radiation on a particle basis, the rest being protons. They do however provide no less than 50% of the radiation as radiation depends directly on the number of nucleons which comprise the particle. From the latest information it seems that there is an intense band of radiation 5-6000 miles thick at a distance of 10,000 miles which gradually fades out at 60,000 miles. But, whereas cosmic radiation at 45,000 feet is nearly all composed of electrons, protons and mesons due to collisions, at 140,000 feet the same amount of radiation is produced by protons and particles and heavy nuclei. This has far-reaching consequences because although radiation is quantitatively the same, it may differ greatly in its biologic effectiveness. It has been worked out that 50 R of X-ray radiation equals 5 R by alpha particles, equals 1 - 5 R by heavy nuclei taking biologic effectiveness as the criterion. This difference in biologic effectiveness can be explained by the larger size of alpha particles and heavy nuclei, and the much greater energy which they carry to cause ionisation and thus cell death. Shielding space personnel with metal would be an engineering impossibility but it may be possible with a hydrogenous fuel such as kerosene.

Many problems and unanswered questions have arisen in this discussion of space travel; the greatest problem, i.e. what will the overall effect be on a human in space, is a mystery. The solution of such problems and difficulties may demand sacrifices, as other scientific projects have done, but at the moment we can only tentatively grasp an idea which, in assuming reality, will become a symbol of our age.