In Focus

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Health in space—and on Earth

Because astronauts confront unprecedented hazards, manned space exploration has to proceed gradually and cautiously, each new step being taken with the benefit of what has been learned during earlier stages about bodily requirements. As well as helping to protect the lives of astronauts, however, space medicine is proving to have valuable applications in global health care.

Since Yuri Gagarin orbited Earth in the spacecraft “Vostock” in 1961 there have been some 140 manned space flights, involving more than 250 astronauts. The duration of the journeys gradually increased, as did the volume of medical, biological and other research. Flights lasting up to a year have become possible as a result of the large quantity of biomedical information collected, most notably on the effects of weightlessness on the human organism. Each new step can be taken with increased confidence thanks to the accumulating body of research.

Weightlessness

Research performed during space flights has revealed characteristic symptoms caused by weightlessness. Its first effect is to produce illusions about the position or movement of the body in space. This happens because the senses do not function properly. People may feel as if they are falling or nose-diving, and dizziness, weakness, nausea and other kinds of discomfort may occur. These symptoms develop in approximately 50% of astronauts; their duration and degree vary from person to person, but as a rule they diminish or disappear within the first two or three days of flight. Some astronauts find that such symptoms develop during the first few days after returning to Earth.

Certain delayed reactions are primarily attributable to the lack of hydrostatic blood pressure during weightlessness, the mass of circulating blood being redistributed from the lower to the upper part of the body. During long space flights there are reductions in the stroke and cavity volumes of the left ventricle at rest. However, the pumping and contractile functions of the myocardium do not differ significantly from those exhibited in the pre-flight period. In

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addition to the haemodynamic changes and a reduction in muscular weight during long flights, the heart’s vascular system does not work at the normal rate; consequently, tolerance of physical and orthostatic loads during and after flight may be reduced.

A later set of reactions to protracted weightlessness is caused by the lack of weight on the musculo-skeletal system. The underloading of muscles leads to partial muscular atrophy. This is reflected by changes in protein and electrolyte metabolism and in the organism’s general energy level. The coordination of movement is markedly affected and all motor activity acquires new characteristics. The decline in body weight which occurs is largely attributable to loss of muscular mass, mainly from the back and lower limbs. Osteoporosis occurs because of a loss of salts of calcium and phosphorus. During flight the calcium and phosphorus content of the blood increases, as does their urinary excretion and that of hydroxyproline and nitrogen.

Changes in the condition of bony tissue under conditions of weightlessness may be linked to a reduced load on the skeleton, modification of the force field, changes in haemodynamics and changes in the rate of metabolic processes in the bones. In computer tomograph tests it was found that an astronaut, after a 150-day flight, had an 11% reduction in mineral saturation in the lumbar vertebrae; another astronaut, after a 237-day flight, had a 7% reduction in mineral density of the leg bones. Changes observed after flights of a year were no more pronounced. Even during the longest flights, calcium loss and consequent changes in the strength of the skeleton did not pose any danger. However, since these effects cannot yet be counteracted they may prevent flight periods from being increased.

Changes in salt and water metabolism and its regulation during flight seem to reflect the organism’s adaptation to the redistribution of fluids towards the skull. Reflexes trigger the hormones that regulate salt and water balance, and this leads to a partial loss of fluids and some electrolytes from the organism, as well as to a potassium and calcium imbalance. As a result there are decreases in body mass, the volume of the lower limbs, and the volume of blood plasma and intercellular fluid. The ability of the muscular system to transfer potassium declines during long flights as a result of its relative inactivity and loss of mass, and this may play a specific role in the changes in salt and water balance, and particularly in the development of a potassium deficit.

Especially during long flights, specific changes occur in metabolic processes involving fats, proteins, carbohydrates and vitamins. On the whole these changes are functional but it is essential to consider them when preparing food rations and devising prophylactic measures for astronauts.

Tests conducted during and after long space flights suggest that the blood system can adapt to conditions during such flights and resume normal functioning subsequently. After long flights the decreases observed in erythrocyte mass, blood plasma volume, haemoglobin and erythropoietin are comparable to those occurring after shorter flights. In the post-flight period a very rapid build-up of blood plasma leads to an even greater reduction in erythrocytes and haemoglobin per unit of blood volume.

Prophylactic measures are particularly important during long space flights.
Within one and a half to two months after this the erythrocyte level gradually increases to the norm. Changes in the structure and metabolism of erythrocytes do not become more pronounced with increased flight duration.

The neuropsychological condition of astronauts during long flights changes in highly individual ways that vary in degree and occur at different periods.

During the first seven to nine days of flight the phases of sleep undergo a series of changes. There is an increase in the proportion of the fourth phase of deep sleep and a fall in that of the phase of rapid eye movement. According to astronauts’ self-appraisals, changes in the phase structure do not cause inferior sleep, nor is efficiency reduced.

The main aim of research in gravitational biology has been to study weightlessness as an ecological factor and to understand its influence on the ways in which life is organized. Such research has thrown new light on the evolutionary role of Earth’s gravity.

Experiments conducted at the cell, organism and population levels indicate that many forms of life can exist under conditions of weightlessness. Weightlessness does not cause mutations; nor, as a rule, does it impair cell division. Whether weightlessness has a direct effect at the cellular level, however, remains an open question: some physiological reactions at zero gravity may be a consequence of changes in cell behaviour. Work is needed on the cell as a mechanical structure in the gravitational field, and on the extent to which the effects of weightlessness depend on the type of cellular differentiation and the amount of functional load. It is desirable to study the role of genetic make-up in the way the organism adapts to long periods of weightlessness. On the whole we can assume that zero gravity does not prevent organisms from going through their life-cycles. Tests on some types of insect show that weightlessness may stimulate or depress the separate stages of autogenesis, and speed up or slow down embryonic development and aging. It remains to be clarified how and to what degree these effects are species-related.

Resistance to pathogenic microorganisms

Not all the changes occurring in the body during space flights can be attributed to weightlessness. For example, changes in the relationship between the body and microorganisms reflect food intake, changes in the general reactivity of the body, and changes in associated microorganisms. Astronauts experience changes in a number of immunity indicators: after long flights
there are reductions in the quantity and reacticity of T-lymphocytes, the functional activity of helper cells and natural killer cells, and the synthetic activity of the principal lymphokines. In addition there are increases in microbial distribution on the skin and mucous membrane, and some microorganisms show increased resistance to antibiotics and signs of pathogenicity. Consequently, measures have to be taken during long flights to prevent bacterial, viral autoimmune and allergic disease.

Participation of medical researchers

The participation of physicians in space exploration allows detailed medical tests and experiments to be carried out. Manned space flight demands continuous modernization of medical safety systems. Among the factors that have to be considered are the choice and preparation of the astronauts, the optimization of the living environment, medical surveillance, the provision of medical assistance, the organization of work and rest schedules, the implementation of prophylactic measures, and rehabilitation on return to Earth.

In orbiting space stations there is equipment for monitoring vital bodily functions in conditions of weightlessness. Medical specialists are thus enabled to evaluate the health of crews, draw up prognoses, make corrections to work and rest schedules, make recommendations on diet and the use of prophylactics, and give psychological support.

Prophylaxis

Prophylactic measures are particularly important during long space flights. In exercise programmes, special attention is given to muscular strength and coordination. Astronauts run approximately five kilometres daily on a treadmill and cycle about ten kilometres daily on an exercise bicycle. Additional exercise is taken using expanders and other devices. Except when sleeping, astronauts wear special suits with rubber rods sewn into the material so that pressure is exerted on the muscles when movement takes place. In order to prevent haemodynamic disorders the astronaut uses a suit with wide rubber trousers, inside of which a negative pressure is achieved by means of a vacuum pump. As a result the blood moves to the lower half of the body, creating hydrostatic blood pressure at the normal level. Prophylaxis also includes the use of various biologically active substances, salt water supplements, electrostimulation of muscle groups, an optimal diet, and a rational rest schedule. These measures maintain health and efficiency during long flights and allow quick rehabilitation afterwards. Nevertheless, much remains to be learned about the individual physiological reactions of astronauts to conditions in space and about the delayed effects of space travel.

Interplanetary hazards

Cosmic rays present a potential hazard for space travellers. High-energy particles produce specific damage in cell nuclei, and in order to proceed forwards, let us say, manned expeditions to Mars, it would be necessary to look much more closely at the medical and biological safety of astronauts.
A flight to Mars would be beyond the protection against radiation afforded by Earth’s geomagnetic field. During flights in orbits near Earth there is a reduction in the dose of cosmic and solar radiation. As long as spacecraft fly below Earth’s radiation belt, no very serious problems arise, the dose received by astronauts on long flights being 15–30 millirad a day; the total effective radiation dose on the longest flights, lasting a year, has been about 13 rem (or 0.13 Sv). On interplanetary flights, however, cosmic radiation becomes significant; it consists of atomic nuclei travelling at speeds approaching that of light.

Interplanetary travel would also require conditions adequate for man’s long-term biological needs. Life-support systems would have to be replaced by a living environment resembling Earth’s biosphere.

Astronauts would have to be prepared psychologically for autonomous flight, which would inevitably involve a degree of risk.

Space exploration has increased our knowledge of man’s spatial orientation, vestibular apparatus, biomechanics, metabolism, and cardiovascular and central nervous systems.

And solutions would have to be found to physiological problems caused by long periods of weightlessness.

Gains for global health care

Space research has already produced far-reaching advances in health care for the world’s population. Thus satellite communications are being used to link hospitals and physicians who are located in remote regions with leading medical centres so that essential information can be obtained on diagnosis and other matters. A satellite link-up providing medical assistance to the Armenian earthquake victims demonstrated the value of distance diagnosis. This project was organized by the United States National Aeronautics and Space Administration and various Soviet organizations. The Yerevan Republican Diagnosis Centre was linked up to four medical centres in the USA. Sound, video and telefax communication systems were used to provide consultations. Teleconferences affected the diagnosis and treatment of at least 2000 earthquake victims. The satellite link was a highly effective tool in the provision of medical assistance to the affected people.

Space technology could conceivably be used in global surveillance of atmospheric pollution, drought, surface water and other environmental factors, and in studies on processes in the biosphere which could have consequences for health.

Methodologies and equipment designed for use in space are increasingly being used on Earth. The compact, functionally simple and
highly reliable apparatus seen more and more in hospitals and clinics often has its origins in space research. Portable equipment developed for monitoring the cardiovascular system in astronauts has been used successfully in first-aid vehicles. A device used in space medicine for the electrostimulation of muscles is being applied in traumatology to strengthen the muscular system, correct posture, treat flat feet and muscular atrophy, and prevent postoperative blood clotting. A multipurpose system developed for protracted artificial pulmonary ventilation, lung reflation and the administration of aerosol drugs or anaesthetics is being used in resuscitation units and could be widely employed in ambulances. An electrochemical analyser of water quality is being used for the sanitary and epidemiological monitoring of drinking-water and natural and waste waters. The apparatus identifies trace amounts of heavy metals and organic substances in liquids.

A wide array of medical apparatus made for research on orbiting space stations is being used in mobile automated laboratories for mass medical population tests and the evaluation of ecological conditions. The methodology used in space for tests on the cardiovascular system now serves on Earth for the diagnosis and prophylaxis of cardiovascular disease. Astronauts do not undergo such significant changes in blood circulation as sick people, and so it was necessary to devise new methods and apparatus for analysing large quantities of information, with a view to diagnosing and controlling the very first signs of relatively small functional alterations. This has opened the way for the prognosis of unfavourable changes and allows prophylactic measures to be taken at the right time.

The space method for evaluating the functional condition of the human ear is being applied in clinical otolaryngology and otoneurology and in the examination of sportspeople and pilots.

The space methodology for the psychological selection and preparation of people for work in extreme conditions and for the formation of psychologically compatible groups is being used increasingly on Earth.

Prophylactic methods and training devised to combat the unpleasant effects of long periods of weightlessness are being applied in sports medicine for rehabilitating the injured.

In conditions of weightlessness or, more precisely, of microgravity, some physicochemical processes take courses differing from those normally followed. This is particularly true of electromigration, as used in separating substances with similar properties. In this connection, biotechnology experiments conducted in space have suggested possibilities for making some medical preparations and medicines in greater quantities and with greater purity than can be achieved on Earth.

Studies on humans in space have broadened our understanding of healthy individuals. Thus space exploration has increased our
knowledge of man’s spatial orientation, vestibular apparatus, biomechanics, metabolism, and cardiovascular and central nervous systems.

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A great deal of attention is now being paid to the scope for introducing the achievements of space medicine into health practice. One of the most important recommendations of the Second United Nations Conference on the Exploration and Peaceful Uses of Outer Space (in Vienna, August 1982) was that all countries should be able to benefit from the advances that have been made. On the whole there has been good international cooperation in space biology and medicine.

The world community should concentrate on the most important areas of space research and its application, always striving to avoid duplication of effort and wastage of resources. Experience has shown that if various countries collaborate in space research there is a growth of interest and activity in the field, to the direct economic advantage of the participants.

The process of uniting world efforts to use space for peaceful purposes is undoubtedly gathering momentum. It is to be hoped that everything done will benefit humanity both in space and on Earth.

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**Pollution and development**

Pollution that results from lack of awareness, sheer disregard of environmental values, or the lack of basic hygienic measures is unjustified and intolerable. However, sometimes, the question of pollution involves choices among competing goods, between environmental and health values on the one hand, and cheap production, increased output, and greater convenience, on the other. Such choices are central in development decisions, whether taken by individuals, enterprises, or governments. These decisions involve trade-offs between perceived benefits and costs, and they are highly influenced by social values and by what is feasible. Health concerns are not always taken into account in the decision process.