SPACE BIOLOGY*

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Prof. Sipra Guha was an Indian Botanist with specialisation in plant tissue culture, plant molecular biology, biotechnology. She is known for her break-through discovery of the technique of producing haploid plants through anther culture. Dr. Guha also collaborated with M.S. Swaminathan for the Green Revolution. She served as a Professor and Dean in the school of Life Sciences, Jawaharlal Nehru University.

The paper explores the critical role that a Biologist plays in making possible the space mission. It sheds light upon the nature of space and addresses the unique challenges posed by the space environment, such as altered gravitational forces, weightlessness, pressure, extremes of temperature as well as radiation hazards on a space traveller. Additionally, it elaborates upon the criteria required for space travel in the 60s and the scope for space travel in the future.

Keywords: Space, Gravity, Atmosphere, Pressure, Acceleration, Radiation

The twentieth century has been designated by some as the "space age". Man's age-old desire to go to the outer world was realised when on 12 April 1961, the Russians launched the space ship, Vostok I piloted by Major Yuri Gagarin (Fig. 1). Following him a number of Russian and American cosmonauts including a woman have orbited around the Earth in space. This marvellous achievement is the result of teamwork and cooperation between large groups of Scientists including Biologists. While the role of an engineer or a physicist is perhaps very obvious to you, you might well wonder as to what is the contribution of the biologist in man's adventure into space. Living on Earth, we hardly realise how much we are conditioned by the physical forces (like gravitation, atmospheric pressure, temperature, etc.) operating on us. Out in the space the conditions are so different that even the most ordinary activities like drinking water from a tumbler become impossible to perform (Fig. 2). The tremendous speed at which a rocket is shot would cause horrifying sensations and a paralysis of the mental activities of any one who boards this rocket. The science of space biology and space medicine arose from the need to study and seek solutions to the problems of mans survival in this environment.

Fig. 1. Major Yuri Gagarin, the first Cosmonaut (Coutesy: Soviet Information Service)

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Space exploration has also given an opportunity to biologists, who unlike physicists or chemists are normally concerned with the phenomena on earth, to find out whether life exists outside the Earth. Should any be discovered, the biologists' first wish would be to gain an understanding of the chemical basis of this life. Does it, like life on Earth, use the protein-nucleic acid system? If not, what chemical systems are used for heredity, storage and catalysis? Along with the search for life there is also the need for a clearer understanding of the chemical evolution which led to the origin of life on Earth. Before going further with the biology of space travel, however, let us first learn something about what constitutes space.

Fig. 2. This is how Valentina Tereshkova, the first space woman takes her food in space (Courtesy: Tass)

The Nature of Space

About and above us, surrounding the Earth, is the atmosphere (Fig. 3). Scientists believe that it extends outward for about 960 kilometres or more. The lowest region extending to about 11 kilometres, is the troposphere. Only the first four miles are inhabited by living organisms. Several gases, water vapour and dust are rather tightly packed in this region. It is the weight of the molecules of all these substances that produces a pressure of approximately 10,333 kilograms per square metre on our bodies at sea level. As we go up, the pressure falls 25 millimetres for every 274 metres and the pressure on our bodies also decreases accordingly. The temperature of the lower part surrounding us varies between 10°C to 40°C. In the upper part of the troposphere, however, it may be as low as –20°C.

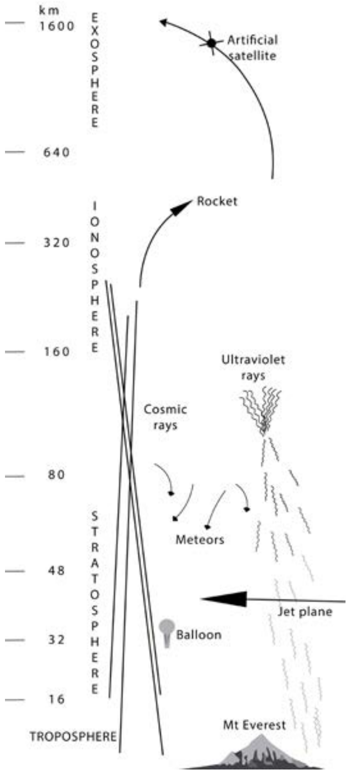

Fig. 3. Different layers of the earth's atmosphere

Above the troposphere, for about 80 kilometres, lies the stratosphere. Here the molecules are few and sparse. At about 40 kilometres above sea level, there is a layer of ozone, very important to us because it filters out most of the ultraviolet radiation from the sun. Though such radiation is beneficial to life, in excess it may be injurious. The temperature in the stratosphere varies from -20°C to +90°C.

Extending outward from the stratosphere to a height of about 960 kilometres from the Earth is the highly electrified ionosphere. This region has a still lower concentration of molecules. Here the temperature is as high as 1000°C. Beyond the ionosphere is the outer space which is practically a vacuum.

The Biology of Space Travel

The conditions prevailing in space, i.e. above an altitude of 960 kilometres are extremely hostile to human life (Fig. 4). Pressure is so low, that the fluids of the body begin to vapourise; and there is no air to breathe. There is also no light because the atmosphere which scatters light rays does not exist. There is only a blazing glare from the sun; all else is dark. Due to a complete lack of any matter, sound waves cannot be transmitted; there is no orientation by gravity; the radiations are hazardous to life and dangerous rocks and meteors hurtle by. Not only these, a long flight through space presents the problem of supplying oxygen, food and water and of getting rid of body wastes. Man's daily needs are about 2,200 grammes of water, 400–500 grammes of food and about 1000 grams of oxygen.

The Effect of Acceleration

In order that a spaceship may leave the gravitational forces of the Earth and orbit around it in the space, it must obtain a speed of 40,000 kilometres per hour. This means that the vehicle must be brought from a stationary position to a speed of 40,000 kilometres per hour in a few seconds. This sudden acceleration (rate of change of speed) exerts an enormous pull on the occupant of the spaceship. You can understand the effect of acceleration by a simple example—when your car starts to move, your body is pressed against the back of your seat. This accelerating force, which has the effect of increasing your weight, is measured in units called *g*. Normally our bodies are being subjected to the force of one *g*. In an ordinary elevator, we may be subjected to forces up to two *g*. A person moving up in a high-speed elevator may, however, be subjected to a pull of five to seven *g*. Under high *g*, blood rushes towards the lower side of the body, and the heart can no longer keep it circulating through the arteries and veins. This results in a failure of the brain and retina of a person who is in a standing position.

In a space flight the first exposure to rapid acceleration is during the boost phase. A second build-up of *g* forces comes during the re-entry of the space craft. One may encounter forces up to 11 g or even more which is well above the tolerance of ordinary men. However, with prior training, such as by whirling in specially designed centrifuges, it is possible to stand a high gravitational pull without any ill effects.

Experiments also indicate that as compared to a standing or sitting posture, the adverse effects of rapid acceleration and deceleration are much less pronounced if a person simply lies down. In fact, in the space capsule the cosmonaut's seat is so fixed that during take off he lies horizontally on his back.

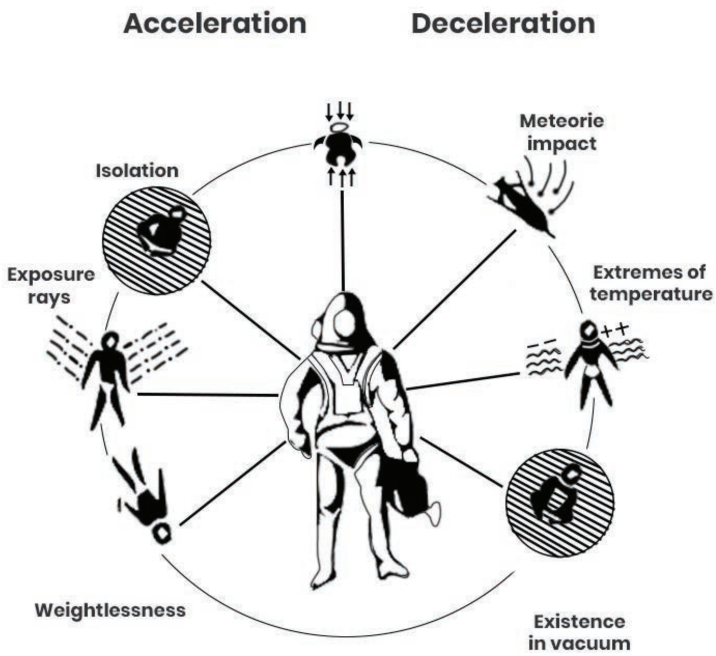

Fig. 4. Conditions Experienced by a Spaceman

The Effect of Weightlessness

The period of the spaceship's rapid acceleration lasts only a few minutes. Once the desired velocity and height have been reached, the power is shut off. At this moment, the g-factor ceases, whereupon the cosmonaut begins to experience the sensation of weightlessness. Because the Earth is so far away, its gravitational pull now exerts practically no effect on his body. If he moves his legs or hands, he hardly feels it. The sense of balance is also lost.

Body Pressure in Space

The reduction in barometric pressure itself can be the cause of a morbid condition. When pressure around the organism is lowered, the Gas in different cavities of the body and in the blood expands damaging the tissues and clogging the vessels. There is also the danger of the boiling of blood. This problem has been successfully solved by developing hermetically sealed cabins in which the desired level of barometric pressure can be maintained. Should a leak develop in a spaceship cabin during flight, the cosmonaut is additionally protected by a specially made space suit. Basically the suit is a tailored rubber bag, a man-shaped balloon, and it is the cosmonaut's final protection against disaster. The pressure-suit is connected to a pump through a pressurestat which can accurately hold a uniform pressure.

Respiration

At 26 kilometres above the Earth, the density of the air is only about 4 per cent of that at sea level. Beyond an altitude of 112 kilometres, there is practically no atmosphere and therefore no oxygen. However, after training, man can exist in an atmosphere of approximately one-half the normal oxygen content on Earth without discomfort and still be reasonably efficient.

Extremes of Temperature

Our atmosphere absorbs much of the heat radiating from the Sun thus affording us a chance to live. However, in space this insulating blanket is absent and therefore there is nothing to ward off the high temperatures produced by Sun radiations. Also, there is no atmosphere in space to conduct the heat away from the spaceship. Thus, a ship in outer space would absorb the high intensity of Sun rays on the side of the ship facing the Sun, whereas the side away from the Sun would be extremely cold. However, the greatest danger is due to heat generated during the re-entry of the ship into the Earth atmosphere. At the great speed of movement of the spaceship, high temperatures would be built up around the ship as soon as it begins to collide with the gas molecules of the atmosphere. The heat generated by this friction has to be reduced in order to prevent the ship and its occupant from burning up. This is done by slowing down the ship in stages as it returns to the Earth atmosphere and also by covering the ship with heat resistant material.

Radiation Hazards in Space

In addition to the visible light and infrared rays, the outer space abounds in ultraviolet and cosmic rays. The ultraviolet rays are derived from the Sun and cause severe burns as well as blinding. The cosmic rays are produced either from the exploding stars or from the Sun itself. They have high energy and great penetrating power and cause genetic mutations. The atmosphere of the Earth filters out the ultraviolet rays to some extent and the cosmic rays almost completely. In space, however, there is no protective atmosphere and thus the cosmonaut has to be protected from their effect.

Experiments indicate that for short periods of flight we need not fear such damage in space. Monkeys have spent as long as 35 hours in balloons at an altitude of 27 kilometres, with no observable genetic change. Balloons have also carried black mice to altitudes of about 30 kilometres and exposed them to cosmic rays. When these mice were returned to the earth, their coats had turned white but no detrimental genetic effects were observed. Moreover, the wall of the cabin affords a good protection against these radiations. However, for journeys to Moon and other planets, which may take several months, cosmic radiation does pose a serious problem.

Psychological Effects of Space Travels

We are all used to alternating periods of day and night. Tests indicate that a person cannot tolerate either day or night indefinitely. Spaceships, therefore, will have to be equipped with apparatus capable of producing artificial day and night cycles in order to accommodate this psychological need in long trips. The sensation of weightlessness and the long periods of time spent in cramped quarters are other psychological problems of space travel. However, most of these problems can be solved by an adequate training programme which the spacemen undergo before flight.

Strangely enough, the most difficult problem to overcome has nothing to do with the mechanics of the space-craft. Man's greatest enemy in space may be boredom. According to current estimates a round trip to the nearest planet Mars will require 520 days. Passengers on such trips will have to be provided with some means of activity which will relieve the monotony of uneventful days and nights in a small, closed capusle. Even the success of the trip may depend on this problem. Boredom often leads to carelessness, and there is little or no allowance for mistakes in space voyages.

What Makes a Good Spaceman

On knowing about the exciting experiences of the cosmonauts, you too might be secretly tempted to avail of a chance to travel in the space. You might also be wondering whether you will be able to brave the rigours of the journey.

Anyone who wants to become a space-man should have tremendous physical and moral strength. He must be able to adapt his psychology to the complex conditions of the cosmos. This is achieved by appropriate training. Many tests have to be given to the candidates to determine their physical fitness and psychological stability. One of the initial tests is to place a man in a chamber completely devoid of light and sound and leave him there alone for 48 hours. The purpose of this test is to determine how well he can tolerate such absolute quietness and isolation. Following this are tests to determine how a candidate will react to the severe acceleration to which his body will be subjected during the initial period after a rocket is blast off. This is done by placing the man in a special centrifuge and whirling him round at high speeds. Another test is to place the candidate in a room in which the temperature is raised to 54°C, whereupon he performs specific tests to determine how well he can maintain his reactions at such high temperatures. The candidate is also subjected to ear splitting noises. Also, by means of a series of vacuum pumps, the atmosphere is removed from the room so that he is placed at an 'altitude' anywhere up to 32 kilometres. These are but only a few of the tests that candidates must undergo to determine their fitness and to train them for what they will encounter during long periods of space flight.

The Future

With the achievement of success in space flight, a glorious chapter has been opened in the history of human adventure. Many fundamental problems have been understood and solved, but more complicated problems lie ahead. After the cosmic group flights by the Russians, it has become clear that prolonged manned flights in space are possible. Ahead lie explorations of Moon, Mars, Venus and flights to the furthermost parts of the solar system and beyond it.

Experts maintain that manned flights, with the cosmonauts in a pressurised cabin in which air regeneration is ensured by special chemical substances and the crew's nourishment by supplies taken from the Earth, can last only for 15–20 days.

Interplanetary flights lasting several months or even years, will require different methods of regeneration of the artificial atmosphere and of replenishing food, water and other supplies. In a spaceship this can perhaps be done by creating a midget model of the Earth in it with a closed ecological cycle somewhat like an aquarium. For this reason, manned spaceships will have to carry plants and animals which will help to maintain the necessary chemical composition of the atmosphere. The vegetable kingdom on board the spaceship will also become the main source of organic substances which will serve as food for the cosmonaut and the animals.

The unicellular green alga *Chlorella* is a kind of oxygen factory intensively consuming Carbon dioxide and giving off Oxygen. One litre of *Chlorella* can produce 10 litres of oxygen in 24 hours. *Chlorella* is unpretentious and multiplies very rapidly. So, it would be of great advantage to carry *Chlorella* in spaceships to provide food and for exchange of gases. Of great importance in a closed circulation are microorganisms, through which the excretion of men and animals can be drawn into this process of biological balance and used effectively. Thus, the closed ecological system of stellar ship represents a factory-laboratory where Carbon dioxide and other waste products of metabolism will produce everything necessary for the cosmonaut's vital activity. Most likely within a few years, some of these theoretical possibilities will be translated into realities and a few of you may be reserving your tickets for a holiday journey to the Moon.