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ABSTRACT

The purpose of this guide is to provide the teacher of secondary school life science classes with resource materials for activities to familiarize students with recent discoveries in bioastronautics. Each section introduces a life science concept and a related aerospace concept, gives background information, suggested activities, and an annotated list of resource materials. Topics covered are: Closed Ecological Systems, Atmosphere of Spacecraft, Water Supply, Nutrition, Radiation, Temperature, Waste Management, Personal Hygiene, Eye, Ear, Weightlessness, Sleep, Medical Research, and Extraterrestrial Life. General lists of resource books, films, and other media are included, together with addresses of distributors and publishers. This work was prepared under an ESEA Title III contract. [Not available in hard copy due to marginal legibility of original copy.] (EB)

AEROSPACE-RELATED LIFE SCIENCE CONCEPTS

FOR USE IN

LIFE SCIENCE CLASSES

Grades 7-12

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Lincoln Aerospace Curriculum Development Project
Lincoln Public Schools
Lincoln, Nebraska

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The material in this book was developed as part of the Lincoln Aerospace Curriculum Development Project, funded under Title III of the Elementary-Secondary Education Act of 1965.

The units were produced during the summer of 1968 by teachers in the secondary schools, in an eight-week workshop-seminar conducted by the Lincoln Public Schools in cooperation with the University of Nebraska. Professor Frank E. Sorenson, Chairman of the Department of Educational Services and Professor of Secondary Education, University of Nebraska, was the general chairman of the institute. He was assisted by Dr. Jean McGrew, Miss Evelyn Sedivy, Mr. Larry Barnes, and Mr. Jerry Beckmann.

Cooperating with the Lincoln Public Schools in this project designed to help bring the curriculum up-to-date are:

The Catholic Diocese Schools, Lincoln, Nebraska

Grand Island Public Schools, Grand Island, Nebraska

Hastings Public Schools, Hastings, Nebraska

Kearney Public Schools, Kearney, Nebraska

Millard Public Schools, Millard, Nebraska

Westside Community Schools, Omaha, Nebraska

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During the summer of 1967, under the leadership of Dr. Milton Horowitz, Queens College, New York, a group of junior high school teachers began work on aerospace-oriented teaching materials for use in science classes. In the summer of 1968, in an eight-week workshop coordinated by Dr. Jean McGrew, University of Nebraska, teachers from junior high schools and senior high schools continued this endeavor.

It is hoped that these aerospace-related concepts will enrich the life science programs at the secondary level, and will increase the students' awareness of advances which are being made in air and space technology.

The following teachers contributed to this book of aerospace-related concepts in life science:

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INTRODUCTION

The science of bioastronautics, the study of the effects of space and space travel upon living organisms, has developed rapidly during the years since 1957 when the first earth satellite was launched. Much has been learned about the effects of space flight upon various systems of the human body and upon the normal processes of growth and development; much is left to be learned.

The purpose of this guide is to provide the teacher of life science classes, at the secondary school level, with resource materials and suggestions for activities which may be used to familiarize the student with recent discoveries in bioastronautics. The guide is organized into subdivisions in which life science concepts are related to aerospace concepts, background information is provided for the teacher's assistance, resource materials (books, films, etc.) are listed, and student activities are suggested.

TABLE OF CONTENTS

CLOSED ECOLOGICAL SYSTEMS

CLOSED ECOLOGICAL SYSTEMS

Life Science Concept

A community is made up of a group of organisms which interact with each other and their environment, through a number of different processes, eventually arriving at a balance of processes which stabilizes and sustains the community.

Related Aerospace Concept

Man's survival on prolonged space flights is dependent upon his becoming a part of a closed ecological system which will sustain his life.

Background Information

Space limitations necessitate the use of some kind of closed regenerative system on prolonged space flights. Various methods to remove carbon dioxide from the atmosphere and to provide sufficient amounts of oxygen have been considered. In one method oxygen is reclaimed by converting carbon dioxide into methane and water and then reducing the water to its components, hydrogen and oxygen. In another method carbon dioxide is absorbed from the air and then decomposed by photolysis, using ultraviolet light energy. Imitation of the closed system of Earth's biosphere by using green plants to regenerate oxygen may be feasible. Alga is usually suggested as the type of plant for this kind of system. Advantages of alga are : (1) it has a high photosynthetic rate, (2) it may possibly be used as food, and (3) it makes possible the conversion of some of the human waste materials. However, algae require very accurately controlled conditions and a supply of special nutrients for them to be able to produce over a long period of time. In addition, algae are not especially palatable when used directly as food.

Atmospheric pressure within the space vehicle and diffusion of gas molecules into the vacuum of space must be controlled. Experiments have shown that a helium-oxygen atmosphere of about five p.s.i. is practicable.

Contaminants in a closed system can become a problem; therefore, there must be a system for cleaning, deodorizing and removing toxic materials. Activated carbon has proved the most successful so far, but a great deal yet needs to be done in the development of systems for decontamination of the space capsule atmosphere.

Cabin temperature may be affected by (1) the type of material used in the skin of the spacecraft, (2) the shape of the craft, (3) the kind of finish used on the surface, and (4) the spacecraft's position in flight relative to the sun.

Food and water requirements are related to the amount of physical exercise by the astronaut and the temperature of the cabin. Greater amounts of food and water will be required if the astronaut is physically active, or if the temperature of the cabin is much below 60°F. At present, two possibilities for meeting food requirements are being evaluated: one is a diet which uses the freeze-dried foods which are packaged for short flights into space; the other is a diet based upon a food cycle which begins with alga grown during the flight.

Water is a more critical need than food. The manufacture of water as a by-product of the operation of fuel cells, the process which is used on short flights, is not feasible for longer flights. Some water will be recovered from the atmosphere in the cabin through condensation, but potable water will have to be recovered, in part, from the liquid waste. Vacuum distillation and the use of activated carbon to absorb odors may prove to a practical way to provide water for astronauts on long flights.

Activities

1. Demonstrate the importance of a balanced environment.

Materials needed:

3 small jars of the same size
2 aquarium snails
Aquarium plants; e.g., Elodea
3 stoppers to fit jars
Water (boiled and cooled to room temperature)

Fill each jar about 2/3 full of water. In the first jar place a snail; in the second, an aquarium plant; in the third, both a snail and an aquarium plant. Seal all three jars tightly. Place in sunlight. Observe to discover which environment maintains life for the longest period of time.

2. Demonstrate that photosynthesis produces oxygen.

Materials needed:

Large glass funnel
Large glass jar
Test tube
Growing water plants

Place a funnel over some growing water plants. Cover the opening of the funnel with an inverted test tube full of water. Place in a well-lighted area. After a few days the test tube will contain a gas which can be tested with a glowing splint to demonstrate that it is oxygen.

3. Construct a microterella and study the problems of a semi-closed ecological system. (See NASA, Space Resources for Teachers - Biology, pp. 40-46 for a detailed description of a microterella.)

Resource Materials

Books

Faget, Max, Manned Space Flight. pp. 98-116. Means of sustaining life and maintaining comfort in a spacecraft.

Gallant, Roy A., Man's Reach Into Space. pp. 128-135. Problems of maintaining a life support system in space.

Glasstone, Samuel, Sourcebook on the Space Sciences. pp. 881-888. Life support in space: Cabin atmosphere, pressure suits, environmental control systems.

Henry, James P., Biomedical Aspects of Space Flight. pp. 92-104. Atmosphere and temperature in spacecraft; food and water requirements; process of regeneration.

Hobbs, Marvin, Fundamentals of Rockets, Missiles and Spacecraft. p. 190. Diagrams of three life support systems.

Kavaler, Lucy, The Wonders of Algae. Possibilities of utilizing algae for food on Earth and on space voyages.

Konecci, Eugene B., "Space Ecological Systems," Bioastronautics. Karl Schaefer, editor. pp. 274-304. An analysis of the factors to be considered in developing a closed ecological system; sample systems discussed.

National Aeronautics and Space Administration, "Lithium Hydroxide Removal of CO_2 in Spacecraft," Educational Brief 3002. Amount of CO_2 produced; method of routing it through LiOH; chemical reactions.

__________, "Living in Space," NASA Facts. Vol. III, No. 5. Life support systems; personal hygiene; food; exercise; thermal and atmospheric control.

__________, Space Resources for Teachers-Biology. pp. 35-49. Gas exchange and waste management; microterella.

Trinklein, Frederick E. and Charles M. Huffer, Modern Space Science. pp. 477-483. Life processes in a space ship.

Welch, B. E., "Ecological Systems," Physiology of Man in Space. J. H. U. Brown, editor. pp. 309-333. Atmospheric requirements of man in space; waste removal; solutions to man's atmospheric requirements; biological regenerative systems; simulators.

Films

Algae and Its Uses (c or b/w, 16 min.)
Algae and their use in closed ecological systems.

Balance of Life and the Space Age. (c or b/w, 14 min.)
Compares balance of life in a pond to balanced system needed in a space capsule.

Crew Systems Division (c, 24 min.)
Environmental control; radiation protection; life support and physiological instrumentation.

Living in Space Series -- A Case for Regeneration (c, 12 min.)
Man's need for oxygen, water and food in space. A regenerative life support system to provide for man's needs.

Living in Space Series -- Regenerative Processes (c, 20 min.)
Atmosphere control; water recovery; food provision; waste disposal; personal hygiene.

Living in Space Series -- A Technology for Spacecraft Design (c, 12 min.)
Technological development for a regenerative life support system in manned missions.

You Must Take It With You (c, 14 min.)
Need for environmental control systems in space.

Transparency

Space Age Science
545 "Basic Life Support System"

ATMOSPHERE OF SPACECRAFT

RESPIRATION

Life Science Concept

Respiration, the process by which an organism exchanges gases with its environment, is a process common to all living things. Animal respiration involves the absorption of oxygen and the release of carbon dioxide.

Related Aerospace Concept

During a space flight, a continous supply of oxygen must be available and the percentage of carbon dioxide and other contaminants in the atmosphere must be kept below a harmful level.

Background Information

Various methods for providing sufficient supplies of oxygen while, at the same time, keeping the level of carbon dioxide and other contaminants at an adequately low level, have been suggested and tested. For short flights, a supply of oxygen can be carried along and some device for filtering out the carbon dioxide can be provided. For long space flights, however, it is highly desirable that the carbon dioxide be converted, by some means, to replenish the supply of oxygen.

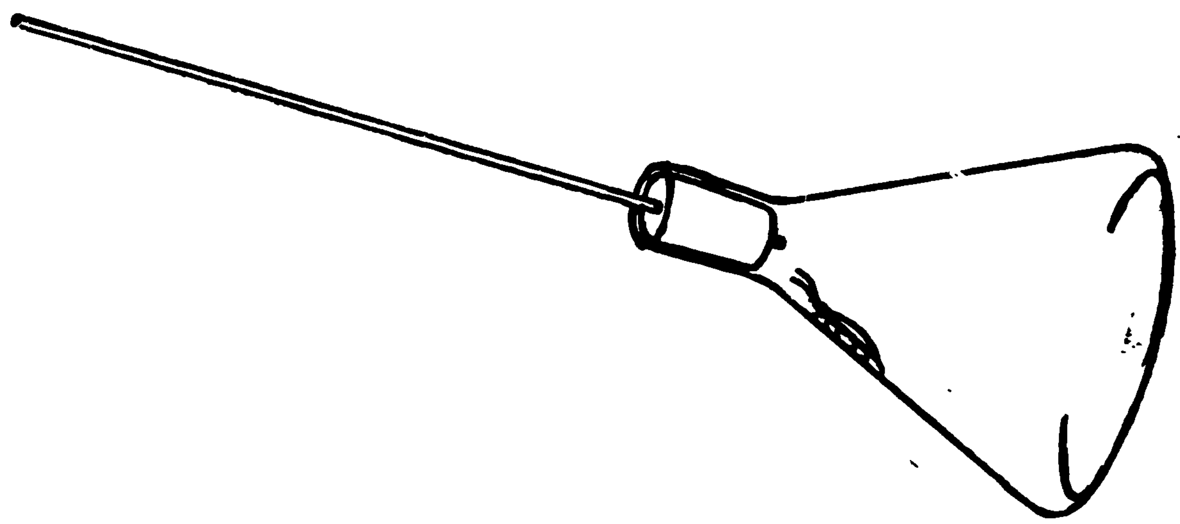
Non-regenerative systems for production of oxygen and the removal of carbon dioxide include the use of the following: (1) potassium superoxide, (2) calcium superoxide, or (3) lithium peroxide. Potassium superoxide has been used for similar purposes in fire fighting and mountain climbing and is commercially available. The other two chemical systems need further research before they are developed to a point of high feasibility.

Regenerative systems suggested are of two types: (1) non-biological recycling; for example, electrolysis of water combined with the reduction of carbon dioxide and (2) biological recycling. Biological recycling would involve plant material, either algae or some higher green plant such as duckweed, or hydrogen-oxidizing bacteria.

Activities

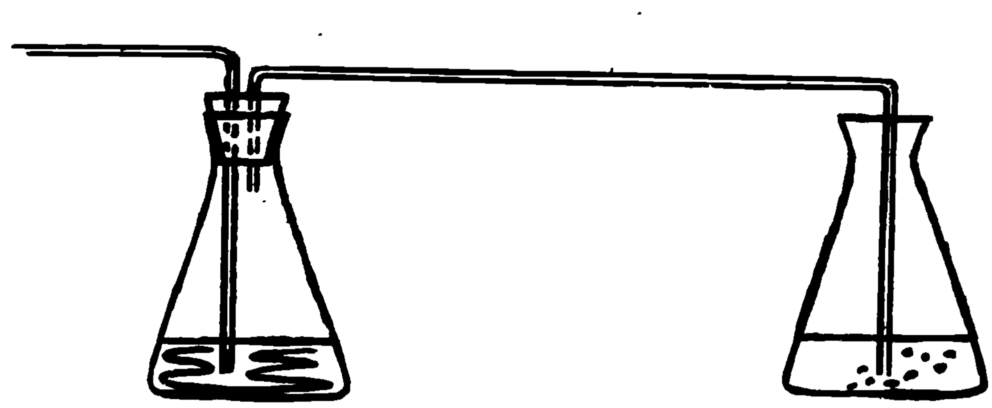
1. Demonstrate the consumption of oxygen in a closed environment.
   - Materials needed:
     - Pipe cleaners
     - Limewater (calcium hydroxide)
     - Pint glass container
     - One-hole rubber stopper to fit glass container
     - Capillary glass tube
     - Petroleum jelly
     - A grasshopper or other insect
     - Ink

Place the insect in the glass container. Dip two pipe cleaners in the limewater solution and hold them in place with the stopper which has been fitted with the glass tube. (See illustration) Touch the top of the glass tube with a drop of ink. As the calcium hydroxide absorbs the carbon dioxide and the insect uses the oxygen, the ink will move down the tube.



2. Demonstrate the removal of carbon dioxide from the air.
   Materials needed:
   - 2 or more flasks
   - 1 or more two-hole stoppers to fit flasks
   - Glass tubing
   - Limewater

Arrange the flasks in a series with glass tubing connecting them as shown in the illustration. Pour limewater in each flask. Blow into the first tube with sufficient pressure to force air into the other flask or flasks. Observe that there is less carbon dioxide to react with the limewater in the successive flasks.



3. Demonstrate the generation of oxygen.
   Materials needed:
   - Hydrogen peroxide
   - Manganese dioxide (black powder from an old flashlight dry cell)
   - Splinter or straw

Place about an inch of hydrogen peroxide in a glass container. Add manganese dioxide and cover. Notice the bubbles of oxygen gas escaping from the mixture. Light a splinter or straw, blow out the flame, insert glowing splinter into the gas and observe how oxygen affects the rate of combustion.

HUMIDITY

Life Science Concept

The amount of humidity in the atmosphere affects the comfort of man.

Related Aerospace Concept

The humidity of the spacecraft must be controlled in order for the astronaut to be comfortable enough to perform the tasks assigned.

Background Information

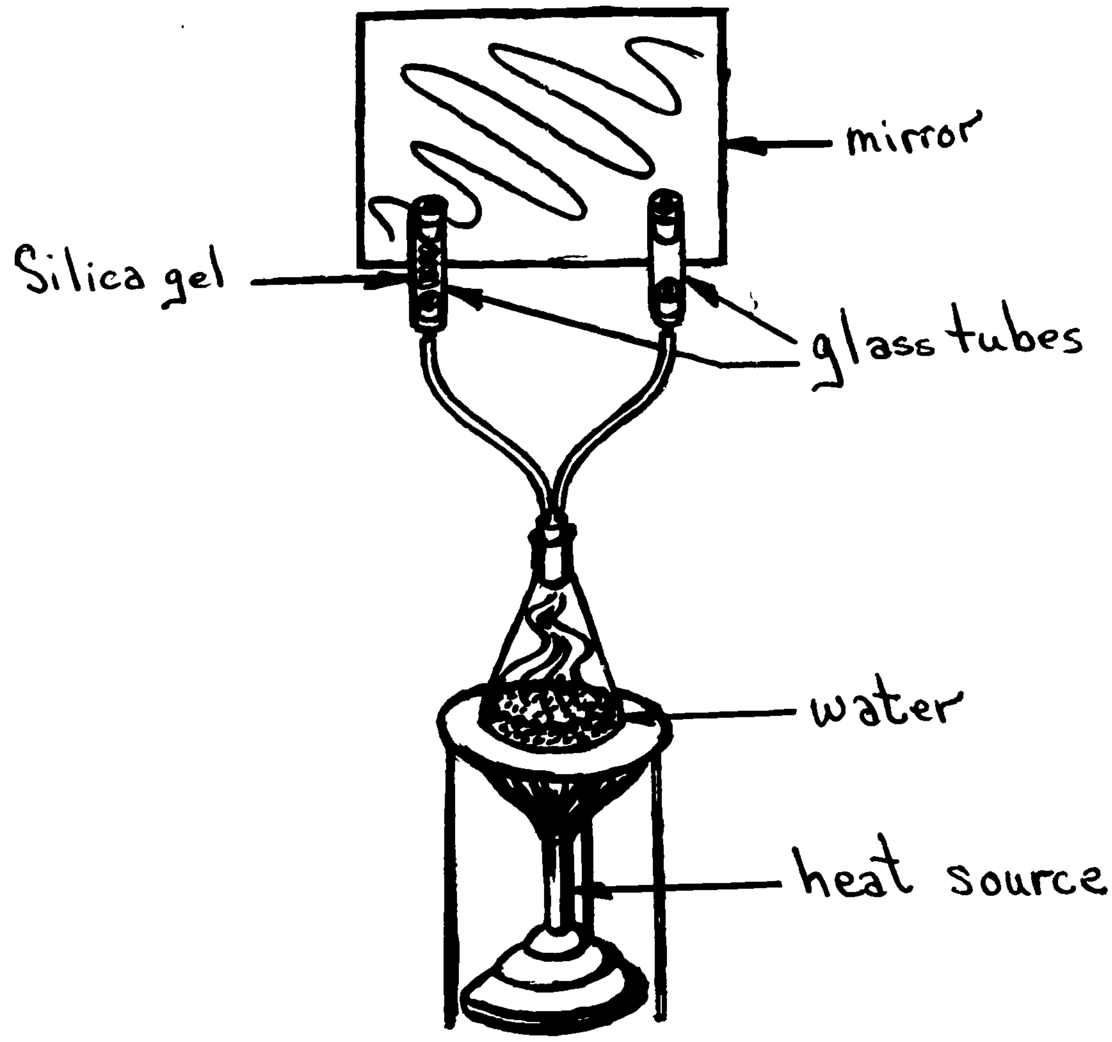
Proper humidity control is more critical when man is wearing restraining flight clothing and is working in a restricted area, than under normal conditions. Under ordinary conditions, a relative humidity of 40 to 60 per cent seems to be comfortable. However, experiments have shown that at higher temperatures these levels of relative humidity may be intolerable. In terms of absolute humidity, Air Force specifications set 10 mm Hg as a comfort level for water vapor pressure.

Cooling the spacecraft's atmosphere to the point of condensation of moisture is the method usually suggested for removing excess water vapor from the cabin atmosphere.

Activities

1. Demonstrate the removal of water vapor from air.
   Materials needed:
   - 2 glass tubes, 1 inch diameter
   - Silica gel or calcium chloride
   - Mirror
   - Flask
   - Water
   - Heat source
   - Tripod holder for flask
   - Rubber or plastic tubing
   - 4 one-hole stoppers to fit glass tubes
   - 1 2-hole stopper to fit flask

Assemble materials as illustrated. Heat the water in the flask. Observe the difference in the amount of moisture escaping from the two tubes.



2. Compare the reactions of laboratory animals or insects under different levels of relative humidity.

3. Keep a record of your "good" days and "bad" days for a month. See if there seems to be a correlation between your mood and the relative humidity.

PRESSURE

Life Science Concept

Internal respiration depends upon adequate atmospheric pressure.

Related Aerospace Concept

The well-being of the astronaut in the space vehicle is dependent upon the use of a suitable mixture of gases under sufficient pressure to support respiration.

Background Information

A pressure gradient is essential to the transfer of oxygen to living cells. Normal oxygen pressure in the lung alveoli is about 100 mm Hg. For a man acclimated to high-altitude breathing, this pressure level can be safely reduced to 22 mm Hg, though someone not acclimated can seldom survive under pressures of less than 30 mm Hg.

Various mixtures of gases have been proposed for the artificial atmosphere of the spacecraft. A pure oxygen atmosphere under slightly increased pressure is one possibility. A pressure of 5 pounds per square inch was chosen for the Mercury, Gemini and Apollo spacecrafts. (Normal partial pressure of oxygen is approximately 3.1 pounds per square inch.) A 100% oxygen atmosphere has the great disadvantage of being a potential fire hazard except under weightless conditions. The death of three astronauts practicing for the first scheduled manned Apollo flight is tragic proof of this great hazard. The effect of prolonged exposure to an atmosphere with no nitrogen has not been adequately assessed, therefore, it must be considered a possible disadvantage.

A second possible atmospheric mixture would be a combination of oxygen and nitrogen. Equal parts of nitrogen and oxygen at a pressure of 7 pounds per square inch have been considered as an alternative to a pure oxygen atmosphere for the Apollo spacecraft. This mixture has fewer possibilities of adverse biological effects, however there is a possibility of the occurence of bends caused by bubbles of nitrogen dissolved in the blood. This mixture would be heavier than a pure oxygen atmosphere, thus adding to the weight of the payload. A nitrogen-oxygen combination is believed to be the mixture used in Russian spacecraft.

A combination of oxygen and helium is a third possibility. This mixture has been used for underwater diving; however, the potential effects of prolonged exposure to this combination of gases is not known.

Activities

1. Compare the reactions of insects placed in environments which differ only in the amount of atmospheric pressure.

2. Keep a record of your "good" days and "bad" days for a month. Compare this record with the average daily barometric pressure to see if there seems to be a relationship between your mood and the amount of barometric pressure.

HYPOXIA - HYPEROXIA

Life Science Concept

Oxygen is vital to the metabolism of the human body. Hypoxia, the lack of sufficient oxygen, or hyperoxia, excess oxygen, result in numerous deleterious physiological reactions.

Related Aerospace Concept

Hypoxia or its converse, hyperoxia, is a threat to the aviator or astronaut who frequently works under conditions where the supply of oxygen is regulated.

Background Information

Man reaction to the lack of sufficient oxygen depends upon two factors: (1) the rate with which the supply of oxygen is decreased and (2) individual tolerance levels. A gradual decrease in the supply of oxygen can result in the following symptoms: increased breathing rate, lightheaded or dizzy sensations, tingling or warm sensations, sweating, loss of vision or reduced vision, sleepiness, psychologic impairment, inability to perform simple tasks, and eventually a loss of consciousness. A sudden withdrawal of oxygen causes a rapid loss of consciousness, spasms and convulsions.

The length of time it takes for an individual to feel the effects of hypoxia to the point of ineffective operation also depends upon several factors: (1) atmospheric pressure, (2) rate of change to low atmospheric pressure or limited supplies of oxygen, (3) amount of physical activity, and (4) day-to-day physical fitness of the individual. The length of time varies from 30 minutes or more at 15,000 feet elevation to 30 to 60 seconds at 35,000 feet elevation.

The altitude limits of the average person, while breathing air, are between 18,000 and 25,000 feet; while breathing oxygen, the limits are between 44,000 and 48,000 feet unless pressure is increased.

A person, unconscious because of the effects of hypoxia, will usually recover completely and rapidly if oxygen is administered within three to five minutes after loss of consciousness. However, on occasion, the reaction to hypoxia is a state of shock, which should be treated as a shock reaction to any other stress should be treated.

An oversupply of oxygen can also have deleterious effects. As with an insufficient supply of oxygen, the kinds of reactions depend upon the speed with which man is subjected to the oversupply and the length of time he is exposed. Long exposure to pure oxygen at one atmosphere of pressure can produce the following symptoms: inflammation of the lungs, respiratory difficulties such as coughing and gasping, irregularities of heart action, numbness of the extremities, and nausea. Exposure to higher pressures of oxygen causes nervousness, irritation of the eyes, tunnel vision, nausea, loss of consciousness, and convulsions.

Activities

1. Place insects in four jars of the same size and shape. Fill one with oxygen, the second with carbon dioxide, the third with a mixture which is half oxygen and half carbon dioxide, leave the fourth full of room air. Seal the jars. Observe the differences in the actions of the insects in each jar.

2. Place animals in containers which can be sealed airtight, and observe the changes in behavior as the supply of oxygen is used up.

CONTAMINANTS

Life Science Concept

Atmospheric contaminants, e. g., smoke, poisonous compounds, etc., can injure health.

Related Aerospace Concept

Systems must be developed to remove contaminants from the atmosphere of the spacecraft.

Background Information

Sources of contamination of the atmosphere of the spacecraft are numerous: the crew members, various life support subsystems, and materials utilized in the manufacture of the equipment within the spacecraft. For example, carbon monoxide is formed in the body through the breakdown of hemoglobin. With the maximum allowable concentration of carbon monoxide in confined quarters, such as a space vehicle, estimated to be only 50 ppm and an estimated rate of formation of carbon monoxide of 10 cc per day per man, it is essential that a means of removing this contaminant be devised.

Danger in these trace contaminants lies not only in their toxicity for the astronaut, but also in their possible explosive potential, especially when mixed with a pure oxygen atmosphere. Among the many trace contaminants which may be produced are: methane, carbon monoxide, hydrogen sulfide, ammonia, methyl alcohol and hydrogen. A catalytic burner has been used in the Apollo to oxidize the trace contaminants which were then absorbed. Activated charcoal and lithium hydroxide were used to remove odors and carbon dioxide.

Activity

Cover the intake side of an electric fan with a cheesecloth to trap dust particles from the air. Observe the amount of dust collected over a period of time. Repeat the observations in several locations.

Resource Materials

Books

Balke, Bruno, "Human Tolerances," Physiology of Man in Space, Brown, J.H.U., editor. pp. 153-162. High altitude tolerance.

Caidin, Martin and Grace Caidin, Aviation and Space Medicine. pp. 58-100. Need for oxygen and methods for providing it.

Faget, Max, Manned Space Flight. pp. 98-105. Spacecraft atmospheric requirements, oxygen supply, CO_2 and H_2O removal, oxygen regeneration, atmosphere contaminants.

Federal Aviation Agency, Physiological Training. pp. 5-10. Respiration, hypoxia, hyperventilation.

Gallant, Roy A., Man's Reach into Space. pp. 23-33. Man's need for oxygen; effects of insufficient oxygen.

Henry, James P., Biomedical Aspects of Space Flight. pp. 27-49. Effects of reduced atmospheric pressure and insufficient oxygen.

National Aeronautics and Space Administration, "Gemini Spacesuits," Educational Brief 10004. Life support system of spacesuit, including oxygen supply.

________, "Lithium Hydroxide Removal of CO_2 in Spacecraft," Educational Brief 3002. Amount of CO_2 produced, method of routing it through LiOH, chemical reactions.

________, Space Resources for Teachers-Biology. pp. 50-55, 92-101. Oxygen consumption; toxicity.

Schaefer, Karl E., "Gaseous Requirements in Manned Space Flight," Bioastronautics. Karl Schaefer, editor. pp. 76-104. Technical discussion of atmospheric systems for spacecraft.

Select Committee on Astronautics and Space Exploration, Astronautics and its Applications. pp. 108-113. Composition and pressure of the atmosphere.

Stambler, Irwin, Breath of Life: the Story of Our Atmosphere. pp. 25-44. Methods of providing adequate atmospheric composition for flight. (Easy reading)

Webb, Paul, "Thermal Balance, Heat Tolerance, and Protection," Bioastronautics. Karl E. Schaefer, editor. pp. 71-116. Humidity control in a sealed cabin.

Wunder, Charles C., Life into Space: An Introduction to Space Biology. pp. 15-119, 234-256. Types of artificial atmospheres for spacecraft; systems for supply, removal, or recycling of respiratory gases, gaseous environment of spacecraft.

Films

The Gas of Life (c, 30 min.)
The importance of oxygen to life and the need for regeneration of oxygen from carbon dioxide in a closed ecological system.

Living in Space Series -- A Case for Regeneration (c, 12 min.)
Man's need for oxygen, water, and food in space.

Living in Space Series -- Regenerative Processes (c, 20 min.)
Atmosphere control; water recovery; food provision; waste disposal, personal hygiene

Living in Space Series -- A Technology for Spacecraft Design (c,12 min.)
Regenerative life support systems, including air and humidity control systems.

The Unseen Border (c, 30 min.)
Effects of air pressure on man.

WATER SUPPLY

WATER SUPPLY

Life Science Concept

Humans need a supply of water free from contamination by pathogenic (disease-causing) bacteria, chemicals and metabolic wastes.

Related Aerospace Concept

Systems which supply potable water for space travellers must be devised.

Background Information

Under ordinary conditions the human body loses from 2 to 3 quarts of water daily. Nearly half of this is lost through the kidneys as urine; very little is lost in the feces. The balance is lost through the lungs during respiration and through the skin as perspiration. Water is replaced primarily by drinking water and by consuming foods which contain water, but some is obtained from foods as a product of combustion. The amount of water needed is dependent upon the surrounding temperature. At 70° F the average man consumes about 5 pounds of water daily; at 90° F, this amount increases to 12 pounds; at 100° F, 20 pounds. Man's water output is greater than his intake; therefore, the quality, not quantity, of water is the problem.

Water for man's use on prolonged space flights could come from several sources. Water lost through the lungs and skin can be collected from the spacecraft's atmosphere by condensation and passed through activated carbon to purify it for reuse. Watermay be a by-product of one of the spacecraft's subsystems. The fuel cells which have been used on Gemini and Apollo flights to produce electrical energy also produce potable water. Methods of purification of liquid wastes to obtain water include the following: (1) freeze-drying (lyophilization) followed by treatment with activated carbon and (2) various types of distillation processes followed by treatment with activated carbon or a heated catalyst. Sterilization of the recovered water is desirable and may be done with heat, ultraviolet light or chemicals.

Activities

1. Fill a sterilized gallon jar with tap water and seal it. Let it stand for several weeks. Observe its appearance and compare its taste to the taste of fresh tap water. Discuss the problems associated with the storage of water for extended periods of time.

2. Compare samples of (1) distilled water, (2) community drinking water, (3) aquarium or pool water, (4) boiled water from each of the first three sources, and (5) sea water in the following ways:

a. Compare solid residue left after an equal quantity of each has been boiled away.

b. Compare the taste of distilled water, community drinking water and boiled water.

c. Compare the odor of each sample with the others.

d. Examine each sample under high power magnification. Record contaminants observed.

e. Compare the reactions of goldfish, of approximately the same size, to being placed in the different samples of water. Use jars of the same size and shape and be sure to use the same amount of water for each goldfish. Use exactly the same method for taking care of each goldfish.

f. In petri dishes, prepare cultures of bacteria from each of the water samples.

3. Use water contaminated with various chemicals to water plants which are similar in size and are growing under the same environmental conditions. Compare their growth to the growth of comparable plants watered with tap water and distilled water.

4. Demonstrate how activated charcoal can be used to filter materials from water. Place activated charcoal in a glass tube. Pour a solution of water which has been contaminated with household detergent (about 0.1 gr to a liter of water) over the charcoal allowing it to drip through into a container. Test water for purity.

Resource Materials

Books

Faget, Max, Manned Space Flight. pp. 105-107, 131. Water requirements; fuel-cell production of water.

Gallant, Roy A., Man's Reach into Space. pp. 132. Uses of water in the body.

Henry, James P., Biomedical Aspects of Space Flight. pp. 98-101. Water requirements and water recovery.

Konecci, Eugene B., "Space Ecological Systems," Bioastronautics, Karl Schaefer, editor. pp. 300-302. Recycling of waste water.

National Aeronautics and Space Administration, "Living in Space," NASA Facts. Vol. III, No. 5. pp. 7-8. Production of potable water.

Trinklein, Frederick E. and Charles M. Huffer, Modern Space Science. pp. 478-479. Water requirements related to ambient temperature.

Welch, B. E., "Ecological Systems," Physiology of Man in Space. J. H. U. Brown, editor. pp. 320-322. Water requirements; water recovery.

Wunder, Charles C., _Life into Space: An Introduction to Space Biology_. pp. 108, 235, 119. Water intake and output; water recycling.

Films

Living in Space Series -- Regenerative Processes (c, 20 min.) The technology of a closed ecological system including water recovery.

NUTRITION

NUTRITION

Life Science Concept

An adequate supply of proper nutrients is necessary to the health of any plant or animal.

Related Aerospace Concept

An adequate supply of food, containing all necessary nutrients, must be available to space travellers.

Background Information

Basic metabolic requirement for the maintenance of life is approximately 1800 kcal of energy per day per man. Because of the activity involved in performing tasks in space and exercising sufficiently to maintain muscle tone, the required caloric intake for an astronaut is estimated to be from 2900 to 3600 kcal per man per day. The energy requirements of an individual are influenced by his basic metabolic rate (BMR), his physical work load, the amount of psychological stress he is under, and the temperature of his immediate surroundings. Of these factors, the BMR which accounts for about 50% of the caloric requirement can be estimated with greatest accuracy.

Food requirements for flights of short duration -- a few hours to a few days-- are of much less concern than food requirements for longer flights. It is relatively unimportant that the diet of a few days be exactly balanced in terms of nutrients and vitamins. Excursions of several days to a few months require much more careful planning to meet the nutritional needs of the space traveller. Although man can survive and can function or an unappealing diet of concentrated foods, his morale deteriorates. For space flights of more than a few days duration, it is important to develop appetizing, appealing meals that will not have too great a weight penalty. The use of dehydrated foods, at present, seems the most feasible solution.

Freeze-dried foods from which almost all the water content has been removed are light in weight, easily stored, simply prepared, and offer a varied diet of delicious foods. A day's ration of freeze-dried food weighs about 19 ounces and requires about 4 pounds of water to reconstitute it.

Flights lasting for months, or even years, seem to necessitate the development of some kind of closed ecological system which will provide a total regenerative system. Theoretically, a recycling process involving biological regeneration which utilizes a photosynthetic exchange seems most feasible. Numerous experiments have been conducted using Chlorella algae cultures as the agent for photosynthesis. While, theoretically this seems to be good solution, there are numerous problems yet to be solved. Some of these are: (1) the equipment necessary to "farm" Chlorella successfully is heavy, (2) Chlorella, as well as man, produces a certain amount of carbon monoxide which will have to be removed from the cabin atmosphere, (3) Chlorella cultures vary greatly in their nutritional composition, (4) Chlorella's transformation of cellulose, protein, and fat must be assisted by the action of other microorganisms which are sensitive to the light which will be needed to produce crops of the algae. In addition to these problems, the lack of palatability of algae as the total diet for man has to be solved.

Other proposals to meet the nutritional needs for long space flights include suggestions for changing the astronaut's metabolic requirements. A reduction in the amount of thyroid secretion through utilization of drugs, surgical removal of the thyroid, or irradiation of the gland to cause its degeneration, has been suggested. Direct reduction of the metabolic requirements of the body cells through sedation, hibernation, hypnosis, or drugs yet to be devised, is another theoretical solution. Another proposal is to retrain the astronaut's metabolic processes prior to flight to reduce his nutritional requirements.

Activities

1. Grow beans in vermiculite or sphagnum moss. Use various nutrient solutions, such as distilled water, deficient nutrient solutions, and complete nutrient solutions. Compare the growth characteristics under each environment.

2. Obtain some freeze-dried fruit from one of the commercially prepared cereals. Weigh the fruit before and after rehydration. Measure the quantity of water absorbed by the fruit during rehydration.

3. Plan a balanced diet for one day; figure the total caloric intake; and determine the vitamin and mineral content of the diet.

4. Simulate space foods by chopping foods in a blender and sealing them in plastic bags. Clip a small opening in one corner of the plastic bag and squeeze food into the mouth to eat.

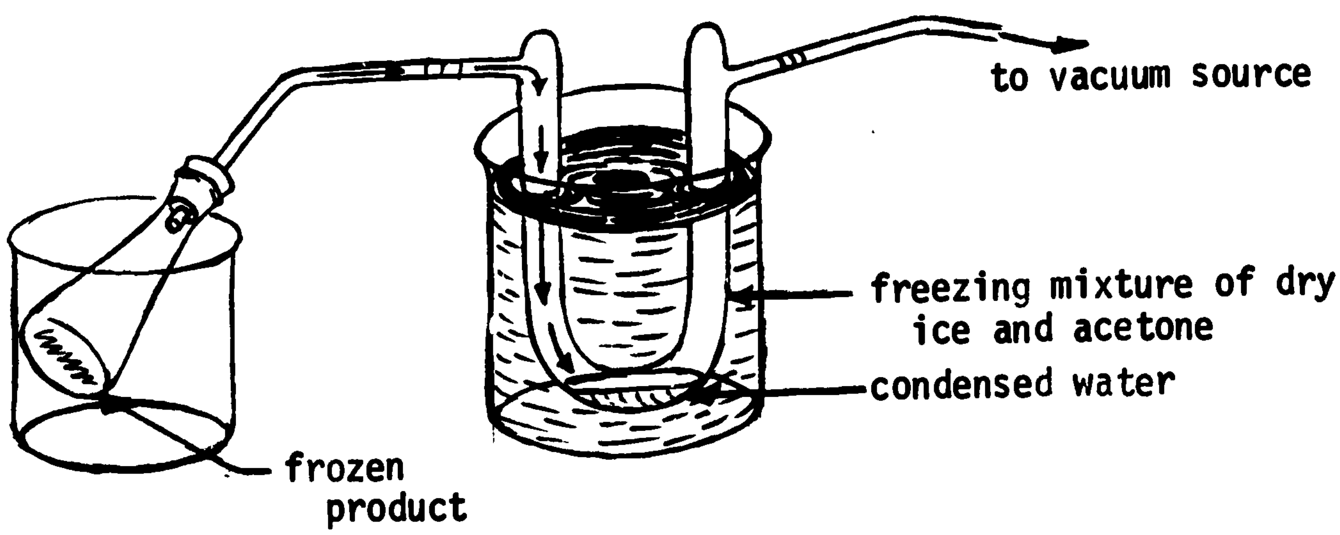
5. Demonstrate freeze-drying of food.

   Materials needed:

   - Pyrex bottle or 150 ml flask
   - 2 metal containers, approximately 4" deep
   - Vacuum source
   - 1/2 to 1 pint of acetone
   - Plastic tubing, thick-walled (long enough to reach vacuum source)
   - one-hole stopper
   - U-shaped drying tube
   - 1/2 pint liquid nitrogen
   - 1/2 pound dry ice
   - Glass, copper, or rigid plastic tubing (2-3 ft.)

Assemble Pyrex bottle, stopper. glass tubing, drying tube, and plastic tubing as illustrated. Submerge the U-shaped portion of the drying tube in the container of dry ice and acetone.

Quick-freeze a thin layer of material by dipping it into the liquid nitrogen and place the material in the Pyrex bottle. Submerging the Pyrex bottle in a water bath to maintain its temperature below 70^{o} will aid in the drying process. Evacuate the bottle and continue to maintain a vacuum until all evidence of moisture disappears. The time required depends on the strength of the vacuum source, the thickness of the frozen material and the original moisture content. (See National Aeronautics and Space Administration, "Space Food Preparation: Freeze-Dehydration Process," Educational Brief, 1007.)

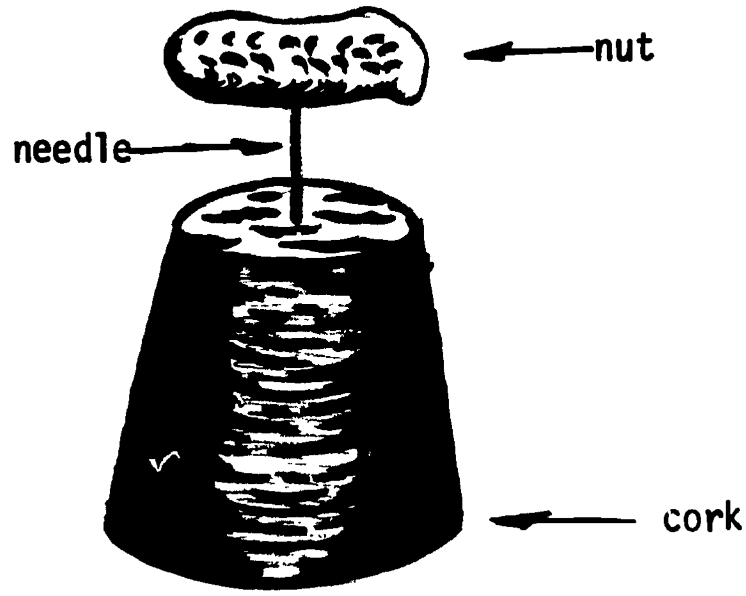


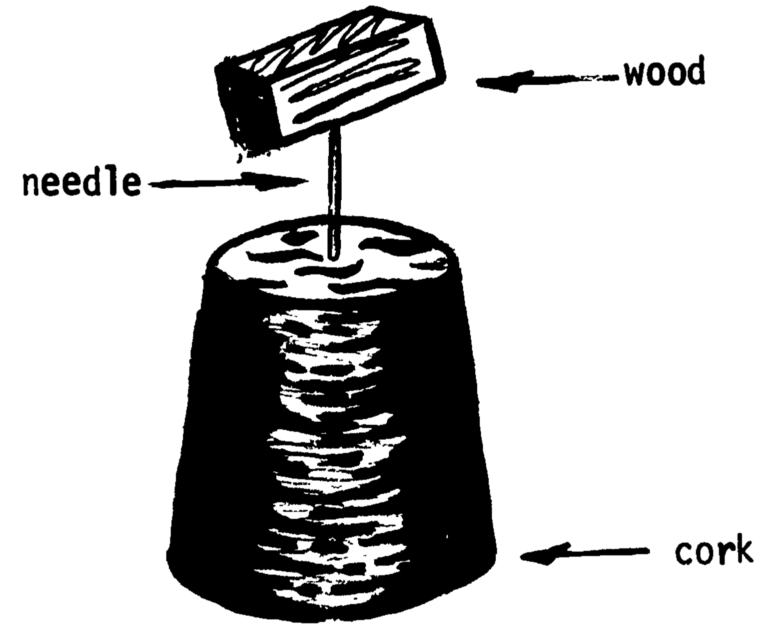
6. Demonstrate differences in the amount of heat energy liberated by different materials.

Materials needed:

- 2 large corks
- 2 large needles
- 1 large shelled nut; e.g., butternut, pecan, Brazil nut
- 1 piece of soft wood about the size of the nut used
- 2 small beakers
- 2 tripod stands for beakers
- 2 thermometers
- Water

Mount the butternut and piece of wood as shown in the illustration and place under the beakers of water. Burn both the butternut and the wood. Record the length of burning time and the highest temperature to which the water is heated.





7. Demonstrate that milk contains fat, protein, and carbohydrates.
   Materials needed:
   - Raw milk (not homogenized)
   - White vinegar
   - Paper toweling
   - Double boiler
   - Cloth for a filter

Allow milk to stand in the refrigerator until the cream rises to the top. Pour the cream off and allow it to stand several days at room temperature. Butter can then be obtained by shaking the cream vigorously. The butter is the fat content of the milk.

Heat the skimmed milk until lukewarm and add a few drops of vinegar, a drop at a time. Filter the milk through a cloth. The curds are a protein called casein.

Boil the remaining liquid, the whey, for a few minutes. Filter through paper toweling to obtain milk albumin, which is another kind of protein. Evaporate the remaining liquid in a double boiler until only the milk sugars, minerals, and water soluble vitamins remain.

8. Grow cultures of algae, such as Chlorella or Scenedesmus (See NASA, Space Resources for Teachers - Biology, pp. 23-25, for suggestions on growing algae cultures.)

Resou ce Materials

Books

Adams, Carsbie C., "Nutritional Aspects of Space Flight," Medical and Biological Problems of Space Flight. Geoffrey H. Bourne, editor. pp. 237-244. Food requirements and types of foods suggested for different length space flights.

Faget, Max, Manned Space Flight. pp. 105-107. Types of food needed by astronauts.

Kavaler, Lucy, The Wonders of Algae. Algae and its potential as food for man.

Lubitz, Joseph A., "Growth and Toxicity Studies on Rats Fed Chlorella 71105," Medical and Biological Problems of Space Flight. Geoffrey H. Bourne, editor pp. 245-260.

Mayo, Alfred M. and James Parker Nolan, Jr., "Bioengineering and Bioinstrumentation," Bioastronautics. Karl E. Schaefer, editor. pp. 250-251, 300-302. Food regeneration, closed ecological systems.

National Aeronautics and Space Administration, "Food for Space Flight," NASA Facts NF 41/12-67. Foods for the Mercury, Gemini, and Apollo programs.

________, "Living in Space," NASA Facts. Vol.III, No. 5, pp. 8-10. Sample menus.

________,"Space Food General Collation," Educational Brief 1002, 1003, 1006.2, 1007.0, 1007.2, 1008. Nutrition in space; foods for use in space; space food specifications; space food preparation.

________, Space Resources for Teachers-Biology. pp. 10-34. Food and water requirements; food preparation; food replenishment.

Select Committee on Astronautics and Space Exploration, Space Handbook: Astronautics and Its Applications. pp. 123-125. Food preservation methods.

Welch, B. E., "Ecological Systems," Physiology of Man in Space. J.H.U. Brown, editor. pp. 319-320. Energy requirements.

Wunder, Charles C., Life into Space: An Introduction to Space Biology. pp. 106-112, 233-237, 256. Energy requirements for metabolism; food requirements.

Films

Food for Space Travelers (b/w, 28 min.)
Problems involved in developing, preparing and eating food for space travel.

Living in Space Series -- A Case for Regeneration (c, 12 min.)
Man's need for oxygen, water and food in space; storage of freeze-dried food in a controlled environment.

Living in Space Series -- Regenerative Processes (c, 20 min.)
An imaginary space flight during which various systems are illustrated; includes systems for providing for food supply.

Menu for Space Flight (c, 6 min.)
Description of foods used during space flight; food packaging.

RADIATION

RADIATION

Life Science Concept

Radiations from the sun are a very important factor in man's earth environment.

Related Aerospace Concept

Man, traveling in space, must have protection from harmful radiations from the sun and from interstellar space.

Background Information

Excessive or prolonged exposure to ionizing radiations can burn the skin, cause eye inflammation, damage reproductive cells, and reduce resistance to infection. Sources of radiation exposure during space travel are: (1) radiations trapped in the Van Allen belts, (2) galactic cosmic rays, and (3) solar cosmic rays. Data collected from space probes and manned space flights indicate that danger from cosmic rays is not as great as was once thought. However, man must be protected from radiation, and it is thought advisable for space flight paths to be planned through regions of less dense radiation and for flights to take place during periods of relatively little solar activity because solar flares greatly intensify the quantity of radiation in space.

The degree of injury due to ionizing radiation depends upon the quantity of radiation absorbed, the kind of radiation, the amount of the body exposed and the organ or area exposed. A large dose of radiation in a small area may produce only local damage, while a similar dose over the whole body may prove fatal. Blood-forming organs, lymphoid tissues, gastro-intestinal tissues, reproductive systems, and eyes are the areas of the body most sensitive to radiation damage. Radiation exposure is measured in rads (a rad= dosage of accumulated ionizing radiation necessary to cause absorption of 100 ergs of energy per gram of irradiated material). In general, a dosage of up to 25 rads will have no observable effects; however, this is very dependent upon the length of time during which that amount of radiation is absorbed.

Astronauts are being observed over the years subsequent to their flights to attempt to detect any harmful effects of radiation upon their reproductive tissues. James Mc Divitt, the American astronaut, has fathered a daughter since his return from orbital flight. The Russian cosmonauts, Adrian Nikolayev (Vostok 3) and Valentina Tereshkova (Vostok 6) were married in November, 1963, and now have a daughter. Russian scientists are observing this child closely to detect any effects upon her of the radiation dosage her parents received. Both children seem to be healthy and normal so far.

Space station orbits can be planned to minimize exposure to radiation. A space station with a maximum apogee distance of 373 miles and a minimum perigee distance of 155 miles would be sufficiently free of the earth's drag to maintain orbital speed and, at the same time, would avoid the higher levels of radiation in the Van Allen belts. For interplanetary travel, speed while passing through the Van Allen belts will probably be sufficient to minimize danger of irradiation, or a polar trajectory can be planned to avoid that part of the magnetosphere where radiation is most intense.

The material used in the hull of the spacecraft can protect the astronaut from much of the radiation he will encounter. A low density material such as aluminum, carbon, or polyethylene, is an effective shield against high energy particles. Lead can be used to cut out X-rays, and protective windows of thick layers of glass may be used. Supplies carried on a space trip may be stored where they can be utilized as an extra thickness of protective material. Possibly a special security area--a radiation storm cellar--will be needed to give extra protection during solar flares.

Other proposals for protecting spacecraft against radiation hazards on prolonged space flights include the development of an internally generated magnetic field which will be capable of deflecting electrically charged particles surrounding the vehicle, or the development of an internally generated electrostatic field which would trap solar protons.

Activities

1. Plant irradiated seed and keep a record of observable mutations.

2. Conduct an experiment in which similar plants are subjected to varying dosages of radiation. Compare their growth patterns.

3. Raise Drosophila (fruit flies) or Tribolium (flour beetles). Expose some to irradiation and compare these to the control group as to mutations, and growth patterns. (See NASA, Space Resources for Teachers-Biology, pp. 85-87 for suggestions on raising Tribolium.)

4. Expose photographic film, protected by different types of materials, to a source of low intensity radiation and then develop the film. Compare the protection offered by the different materials.

5. Compare the capability of different kinds of materials to shield against ultraviolet radiation. Shine an ultraviolet light upon fluorescent minerals in a dark room. Place various kinds of shielding material between the light source and the minerals and observe which materials reduce or eliminate the ultraviolet light rays.

Resource Materials

Books

Bourne, Geoffrey H., "Neuromuscular Aspects of Space Travel," Physiology of Man in Space. J.H.U. Brown, editor. pp. 47-58. Effects of radiation on muscles.

Faget, Max, Manned Space Flight. pp. 12-18. Radiation environment of space.

Gallant, Roy A., Man's Reach into Space. pp. 137-140. Cosmic rays, radiation hazards of space travel.

Glasstone, Samuel, Sourcebook on the Space Sciences. pp. 894-900. Ionizing radiations in space.

Hall, Charles E., "Stress," Physiology of Man in Space. J.H.U. Brown, editor. pp. 132-134. Ionizing radiation; shielding for protection.

Henry, James P., Biomedical Aspects of Space Flight. pp. 105-127. Sources of radiation; Van Allen radiation belts; biological effects of radiation; protection against radiation.

Mayo, Alfred M. and James Parker Nolan, Jr., "Bioengineering and Bioinstrumentation," Bioastronautics, Karl E. Schaefer, editor. pp. 242-244. Protection from radiation.

National Aeronautics and Space Administration, Space Resources for Teachers-Biology pp. 80-91. Physiological aspects of radiation.

Schaefer, Hermann J., "Dosimetry of Radiation Fields in Space," Bioastronautics, Karl E. Schaefer, editor. pp. 129-172. Types of radiations, their intensities, and protection needed against them.

Select Committee on Astronautics and Space Exploration, Space Handbook: Astronautics and its Applications. pp. 119-122. Radiation hazards and need for shielding.

Shepherd, L. R., "Cosmic Radiation and Space-Flight," Space Research and Exploration. D. R. Bates, editor. pp. 84-102. Nature of cosmic radiation in the atmosphere and above the atmosphere.

Slater, A. E., "Medical and Biological Problems," Space Research and Exploration. D. R. Bates, editor. pp. 220-221. Possibility of mutations caused by cosmic radiation.

Trinklein, Frederick E. and Charles M. Huffer, Modern Space Science. pp.484-485. Protection against harmful radiations.

Wunder, Charles C., Life into Space: An Introduction to Space Biology. pp. 184-220. Types of radiation; action upon biological systems; hazards in space.

Films

Crew Systems Division (c, 24 min.)
Environmental control systems, radiation protection and life support.

The NASA Biosatellite Program -- Between the Atom and the Star (c, 28 min.)
Biological experiments in zero gravity; types of experiments planned.

Rx for Space (c, 22 min.)
Problems of space travel, including need for radiation protection.

TEMPERATURE

TEMPERATURE

Life Science Concept

Temperatures between 30° F and 140° F are consistent with the existence of human life.

Related Aerospace Concept

A thermal control system has to be designed to keep the temperature range within a spacecraft or space suit compatible with the comfort of the astronaut.

Background Information

All the energy used in the space vehicle eventually changes to heat energy. Heat may be added to the space vehicle interior as a result of (1) the operation of machinery in the vehicle, (2) the metabolism of the astronauts (Human metabolic heat production is estimated at about 3000 kcal per day, 12,000 BTU per day.), (3) friction between the craft's hull and the gas particles surrounding it (At altitudes 120 miles or more above the earth, heat from friction with the atmosphere is negligible; below 25 miles it is a major source of heating.), (4) solar radiation (At 40 miles or more above the earth's surface. solar radiation becomes a major heat source. The amount of heat fluctuates as the craft orbits in and out of sunlight. The quantity of heat absorbed will depend upon the material from which the spacecraft is constructed and the type of insulation provided. The problem of heating the spacecraft when it is not in sunlight is also involved in keeping the thermal range within tolerable limits.) and (5) cosmic radiation.

Humidity plays an important role in determining the levels of tolerable temperatures. A dry bulb temperature of 70-75° F or a wet bulb temperature of 60-65° F is generally considered to be within the comfort zone. (See the section, "Water Supply" pp. 23-27.)

A spacecraft may be cooled through radiation into the cold of space; however, a stored coolant may be used rather than a radiator. Water is the coolant usually suggested; however, the penalty of weight has to be considered. The need for a coolant may be reduced by varying the absorptivity/emissivity ratio of the surface of the spacecraft through the use of different types of surface finishes, metals, and/or pigments.

Ways of cooling a spacecraft at reentry are: (1) the shape of the craft itself (A blunt nose cone can dissipate over 99 per cent of reentry heat.); (2) ablation cooling in which the nose cone is coated with a material which melts and thereby absorbs some of the heat; (3) pumping liquid between the layers of the spacecraft's skin; (4) forcing liquid through small openings in the skin of the craft to absorb heat; (5) transmission of the heat to large masses of metal used as a heat sink (Beryllium is often used).

Extravehicular activity demands the thermal control of a space suit. This system must be small, light weight and require little power to operate. Pressure suits must be ventilated by introduction of outside air or by recirculation of a closed volume of air. Though a number of different designs have been developed, they are all of two basic types: (1) the design which depends upon evaporative cooling and (2) the design which depends primarily upon convective cooling.

A method of lowering body temperature to decrease metabolic requirements for prolonged flights would seem to be a long range possibility. So far, no such method has been developed. Problems yet to be solved before man can be placed in a condition similar to hibernation are: (1) the capability of lowering body temperature without causing irregular heart action, (2) the capability of maintaining man at low temperatures for long periods, (3) the task of understanding the method of energy turnover in true hibernators, and (4) the development of a method of periodic arousal to rebuild energy levels.

Activities

1. Prepare a chart showing the biothermal range of plants and animals.

2. Design a closed system which will maintain the biothermal range of a rat, mouse, frog, or other small animal.

3. Observe the effect on laboratory animals of temperature changes. Observe changes in activity, food habits, etc. (See NASA, Space Resources for Teachers-Biology, pp. 50-54 for details of a way to study effects of hypothermia on oxygen consumption.)

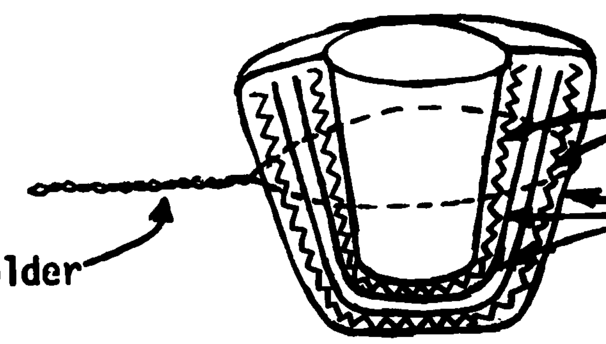
4. Observe the effect on laboratory animals of being placed in similar containers, one painted black, the other white. Measure water and food intake over a period of time and compare.

5. Place a goldfish in a container with just enough water to cover the top fin. Count the number of times per minute the fish's gill cover moves. Change the temperature of the water by adding ice. Count again and compare.

6. Demonstrate how layers of materials can be used to insulate the astronauts against the heat of reentry.

Materials needed:
- Paper cup (6 to 8 oz.)
- Paper towels
- Aluminum foil
- Coat hanger wire
- Thermometer
- Masking tape
- Bunsen burner

Crumple a paper towel around the outside of the paper cup. Add two layers of aluminum foil and another loosely crumpled towel. Add a final covering of aluminum foil and tape it securely to the top edge of the cup. Make a holder of the coat hanger wire. Place two ounces of water in the cup. Record the temperature of the water and then place the covered cup in the flame of the burner for one minute. Record the water temperature again. If the cup is properly insulated, the temperature of the water will not rise more than 2^0 Fahrenheit.



7. Keep a record of your "good" days and "bad" days for a month. See if there is a correlation between your moods and the daytime temperature or diurnal range of temperatures.

Resource Materials

Books

Balke, Bruno, "Human Tolerances," Physiology of Man in Space. J. H. U. Brown, editor. pp. 164-165. Tolerance for temperature extremes.

Faget, Max, Manned Space Flight. pp. 15-18. Thermal environment of space.

Gallant, Roy A., Man's Reach into Space. pp. 75-78, 91-100. Man's tolerance to heat; cooling systems.

Hall, Charles E., "Stress," Physiology of Man in Space. J.H.U. Brown, editor. pp. 125-126. Thermal extremes.

Henry, James P., Biomedical Aspects of Space Flight. pp. 8-20, 96-98. Temperature control; requirements for temperature control.

Konecci, Eugene B., "Space Ecological Systems," Bioastronautics. Karl E. Schaefer, editor. pp. 284-294. Thermal systems.

Mayo, Alfred M. and James Parker Nolan, Jr., "Bioengineering and Bioinstrumentation," Bioastronautics, Karl E. Schaefer, editor. pp. 262-263. Sensors for measuring temperature.

National Aeronautics and Space Administration, "Living in Space," NASA Facts. Vol. III, No. 5. pp. 11-12. Thermal control systems in the spacecraft.

______, Space Resources for Teachers-Biology. pp. 50-55, 58-62. Effect of ambient temperature on metabolism; temperature stress.

Oberth, Hermann, Man into Space. pp. 54-56. Space suit temperature regulation.

Select Committee on Astronautics and Space Exploration, Space Handbook: Astronautics and its Application. pp. 116-118. Results of high or low temperature exposure.

Trinklein, Frederick E. and Charles M. Huffer, Modern Space Science. pp. 478-479. Water requirements dependent upon heat.

Webb, Paul, "Thermal Balance, Heat Tolerance, and Protection," Bioastronautics. Karl Schaefer, editor. pp. 111-128. Thermal control inside and outside of spacecraft.

Welch, B. E., "Ecological Systems," Physiology of Man in Space. J. H. U. Brown, editor. pp. 317-318. Temperature and relative humidity.

Films

Living in Space Series -- A Technology for Spacecraft Design (c, 12 min.)
Technology of regenerative life support systems; sequence on thermal control.

Suited for Space (b/w, 28 min.)
History of the development of space suits; life support system proposed for moon wear.

WASTE MANAGEMENT

WASTE MANAGEMENT

Life Science Concept

Elimination of body waste is necessary to proper functioning of the life processes of any animal.

Related Aerospace Concept

Systems for disposal or reuse of body wastes must be designed for spacecraft.

Background Information

Management of human wastes--solid, liquid, and gaseous--is an important part of the planning of any spacecraft ecological system. The method devised must be reliable, sanitary, and psychologically acceptable to the space traveller.

Several different systems have been devised and tested for the recycling of carbon dioxide and other waste gases. See the section, "Spacecraft Atmosphere," pp. 19, for a brief discussion of atmosphere contaminants.

Systems for the recycling of urine and perspiration are discussed briefly in the section, "Water Supply," pp. 23.

Two basic problems are related to the management of solid wastes. First, there is the problem of collection which is complicated by the possibilities of outgassing that might contaminate the spacecraft atmosphere. On shorter flights such as those of the Gemini and Apollo programs, fecal material is collected in a plastic bag, treated with a bacteriacidal pellet and stored until return to Earth. Proposed systems for prolonged flights use forced air as a transport rather than water.

Second, there is the problem of disposal and/or reuse of fecal material. By international agreement, waste materials cannot be disposed of in space. Several possibilities for storage, such as (1) dehydration and storage until return to the earth, (2) dehydration and return to the earth's atmosphere by rocket where waste would be incinerated, (3) incineration on the spacecraft, and (4) freezing and storage on the spacecraft, are being investigated and tested. Reuse possibilities suggested so far are: (1) use as part of the food supply for algae which are being cultured for oxygen production and (2) use as a part of the spacecraft's propellant. Neither of these proposed methods for reuse has been perfected as yet.

Resource Materials

Books

Henry, James P., Biomedical Aspects of Space Flight. pp. 99-102. Waste recovery and regeneration.

National Aeronautics and Space Administration, "Living in Space," NASA Facts. Vol. III, No. 5. pp. 10-11. Waste collection; equipment and facilities.

_____, "Waste Management: Project Gemini," EPS-HISD-MSC #1500 651208.

Trinklein, Frederick E. and Charles M. Huffer, Modern Space Science. pp. 482-483. Recycling of waste materials.

Welch, B. E., "Ecological Systems," Physiology of Man in Space. J. H. U. Brown, editor. Waste management.

Wunder, Charles C., Life Into Space: An Introduction to Space Biology. pp. 108, 235, 237. Quantity of waste produced.

Films

Living in Space Series -- Regenerative Processes (c, 20 min.) Atmosphere control; water recovery; food supplies; waste disposal; personal hygiene.

Rx for Space (c, 22 min.) Problems encountered in space; includes sequence on treatment of waste materials.

PERSONAL HYGIENE

PERSONAL HYGIENE

Life Science Concept

Cleanliness is an important part of the body's defense against disease. In addition, cleanliness makes an important contribution to a feeling of well-being.

Related Aerospace Concept

On prolonged space flights, the astronaut must be provided with methods and devices for use in performing the tasks related to personal hygiene and cleanliness.

Background Information

Zero gravity conditions present a challenge to the inventor of methods and devices for use in personal hygiene. Bathing must be done with water squeezed from a sponge, for free water will form into globules and float about the cabin. For the same reason, toothbrushing must be done with the mouth closed. Shaving can only be done if there is a provision for collecting the whiskers to prevent their floating about into the equipment. A vacuum-like electric razor has been proposed. Nail clippings will have to be collected inside a container, probably a plastic bag. A vacuum-like massager may be used to combat the floating of loosened hair and dandruff when the hair is "combed".

Resource Materials

Books

National Aeronautics and Space Administration, "Living in Space," NASA Facts. Vol. III, No. 5. pp. 10. Personal hygiene on long space flights.

Films

Living in Space Series--Regenerative Processes (c, 20 min.)
An imaginary space flight showing operation of various systems and techniques of personal hygiene during prolonged flights.

EYE

EYE

Life Science Concept

The human eye converts light waves into nerve impulses which, when transmitted to the brain by the optic nerves, are interpreted as vision.

Related Aerospace Concept

Vision is affected by stresses of space flight and by conditions in the space environment.

Background Information

Visual tasks during space flight include: (1) making astronomical observations to collect scientific data; (2) making observations to aid in celestial navigation; (3) observing the horizon for orientation during vehicle maneuvers; (4) observing ground cues during landing; (5) viewing the instruments within the capsule; and (6) using visual cues as a means of orientation within the capsule in order to perform necessary assignments.

Visual problems in space include the following: (1) absence of environmental cues makes space orientation difficult; (2) sharp contrasts in illumination intensity in and out of shadows make it difficult for the eyes to adjust; (3) high illumination levels outside the earth's atmosphere make it necessary to protect the eyes with goggles, filters, or other protective devices; (4) empty-space myopia occurs because the eyes have difficulty adjusting to depth without visual cues for comparison; (5) the lack of normal environmental cues makes it difficult for the astronaut to determine at what depth his eyes are focusing. Therefore, he has difficulty determining how far away an object is. Both size and distance information become unreliable.

The astronaut's visual acuity is affected by the amount and type of acceleration and by vibrations of the spacecraft. Positive acceleration can cause grayout and even blackout. Transverse acceleration can cause some difficulty in moving the eyes and can affect peripheral vision. Deceleration can cause redout which is a result of the displacement of the lower lid over the cornea.

Activities

1. Determine how long it takes for eyes to adjust to darkness by timing individuals place in a dark room and assigned a simple visual task to perform.

2. Read an eye chart in normal room light. Then read the same chart while looking through red or blue cellophane. Compare the visual acuity under each condition.

Resource Materials

Books

Chambers, Randall M. and Robert Fried, "Physchological Aspects of Space Flight," Physiology of Man in Space. J. H. U. Brown, editor. pp. 182-185. Visual tasks in space flight and effect of altitude upon vision.

Federal Aviation Agency, Physiological Training. pp. 17-18. Visual problems under flight stress.

Gallant, Roy A., Man's Reach into Space. pp. 57-58, 65. Effect of g forces on vision.

Henry, James P., Biomedical Aspects of Space Flight. pp. 77-81, 130-131, 159-161. Visual acuity in space; wavelengths to which eye is sensitive; visual requirements for astronauts.

Meehan, J. P., "Acceleration Stress," Bioastronautics. Karl E. Schaefer, editor. pp. 7-12. Effects of acceleration on vision.

National Aeronautics and Space Administration, Space Resources for Teachers-Biology. pp. 114-130. Perceptual problems; spatial disorientation.

EAR

EAR

Life Science Concept

The ear is an organ which interprets sound and controls the equilibrium of the body.

Related Aerospace Concept

The stresses of space flight affect the operation of the ear, especially that part of the ear which controls the equilibrium of the body.

Background Information

Noise tolerance varies from individual to individual, but, in general, a noise level of 130 decibels or above is unpleasant and damage to the tympanic membrane is possible when the level is above 150 decibels. High frequency noises, above 300 cycles per second, can cause greater damage than low frequency noises.

Though there is a possibility that acceleration affects hearing, this has been questioned and has not yet been proven. (Not enough is known about the permanent effect of zero g, high g, or prolonged or extremely rapid fluctuations in g levels on either hearing or spatial orientation.)

Spatial orientation under normal conditions is supplied, in part, by the action of the otoliths in the inner ear. Linear acceleration causes the otolith particles to bend the sensory hair cells which are imbedded in a gelatinous material. Under normal earth gravitational fields, the otoliths will respond to as little as 10 cm/sec^2 linear movement.

Spatial disorientation is of great concern to those planning space stations which produce artificial gravity by rotation of the space station. Illusions of vision and motion arising from the Coriolis effect of rotation are: (1) an oculogavic illusion of apparent movement of visual stimuli in which the visual field seems to tilt; (2) an oculogyral illusion in which there is a sensation of the visual field spinning about the body axis; (3) an autokinetic illusion in which there is a faulty perception of motion of a fixed object, and (4) false sensations of falling, floating, or rolling. A sudden stop, after rapid rotation causes a sensation of rotation in the opposite direction. There is some evidence that disorientation can be reduced by practice.

Activities

1. Compare the performance of students on similar tests given in a high volume noise environment and in a quiet environment.

2. Demonstrate pilot disorientation and illusions caused by motion. To create the illusion of night flight, blindfold the student. Seat him in a simple swivel chair. Start the chair rotating to the right at about 5 degrees per second; increase to about 90 degrees per second, or 15 rpm. Continue spinning the chair at this rate. There is no other movement of the chair. Position someone in a corner of the room to give directions. Ask the blindfolded student to report his sensations as the experiment progresses.

Directions	Usual Reaction
1. Incline head slowly to the right about 1/3 of the distance to the shoulder. (Note: If this maneuver causes a nausea reaction, it is time to quit!)	Smooth rapid turn to right
2. Slowly raise head to upright position.	Vertical dive slowly decreasing and returning to straight and level
3. Slowly push your head forward until your chin is on your chest.	Complete roll to right
4. Slowly bring your head back upright.	Another roll; this time to the left. Inverted position definitely felt--then return to straight and level
5. Silently signal the student turning the chair to allow it to come slowly to a stop.	Turn to left
6. When chair has come to a complete stop ask blindfolded student which way he is turning.	Left bank

3. Demonstrate visual and muscular disorientation that may result from rotation.

Materials needed:

- Swivel chair with arms
- Ball
- Wastepaper basket
- Student volunteer

Have student sit in chair, grasp arms of the chair firmly, and hold head erect and facing forward. Rotate chair with a uniform motion, not necessarily fast, for 30 seconds. Ask student to look straight ahead. Notice eye movements. Ask student to describe visual effects which follow rotation. Repeat rotation and then have student toss ball into the wastebasket placed directly in front of him and about five feet away. (See NASA, Space Resources for Teachers-Biology, pp. 127-129, for further suggestions for demonstration of disorientation.)

Resource Materials

Books

Chambers, Randall M. and Robert Fried, "Psychological Aspects of Space Flight," Physiology of Man in Space. J H. U. Brown, editor. pp. 185-194. Effect of flight upon audition; vestibular and kinesthetic effects; illusions and spatial disorientation.

Federal Aviation Agency, Physiological Training. pp. 19-20, 23-24. Effect of noise; inner ear reactions.

Gallant, Roy A., Man's Reach into Space. pp. 144-148. Effect of weightlessness on otoliths.

Henry, James P., Biomedical Aspects of Space Flight. pp. 71-74, 81-84. Effect of weightlessness on otoliths; vestibular symptoms.

Levine, Raphael B., "A Device for Simulating Weightlessness," Medical and Biological Problems of Space Flight. Geoffrey H. Bourne, editor. pp. 90-93. Effect of space flight upon balance cues.

National Aeronautics and Space Administration, Space Resources for Teachers-Biology, pp. 126-130. Spatial disorientation.

von Gierke, Henning E., "Transient Acceleration, Vibration and Noise Problems in Space Flight," Bioastronautics. Karl E. Schaefer, editor. pp. 59-75. Physiological effects of noise; tolerance to noise; protection from noise.

WEIGHTLESSNESS

WEIGHTLESSNESS

Life Science Concept

The structure and function of the human body are related to the gravitational field of Earth.

Related Aerospace Concept

Weightlessness experienced in space flight may affect the structure and function of parts of the human body.

Background Information

Prior to manned space flight, it had been predicted that weightlessness would result in disorientation, hallucinations, nausea, and other debilitating reactions, either permanent or temporary. However, results obtained as a result of tests made during manned space flight indicate that there are no permanent adverse physiological effects. The highly trained astronaut has little difficulty when weightless and, in fact, usually finds the experience enjoyable.

Following are some of the findings about weightlessness and its affect upon man.

1. Sleep -- There seems to be no difficulty in sleeping -- no hallucinations, nor disturbed dreaming. Sleep patterns seem to follow the biological rhythm of the individual astronaut.
2. Vision -- No affect on sight.
3. Orientation -- At least temporary disorientation may result because of failure of otoliths to respond under weightless conditions. Visual cues aid in orientation.
4. Muscular coordination -- There is no affect on muscle coordination; however, temporary loss of muscle tone may result from prolonged flight unless muscles are properly exercised. On Mercury and Gemini flights, astronauts used isometric exercises.
5. Psychological -- No detection of sensory deprivation or other adverse psychological phenomena.
6. Circulation -- The circulatory system is temporarily affected: kidneys excrete more fluid; blood volume decreases; desire for fluid intake decreases; blood accumulates in the chest; work load on the heart decreases. Pressurized bladders inside the space suit help to adjust somewhat for the difference in gravitational pull. The adverse affect upon the circulatory system is temporary and astronauts readjust quickly when back on Earth.
7. Bones -- Some demineralization, due to lack of gravity stress, is evidenced by increased calcium output in urine; however, this was shown to be negligible during the Mercury and Gemini flights.

8. Perceptual and motor skills -- At the beginning of the weightless state, perceptual and motor skills are somewhat reduced. If visual cues are not present the decrease in motor skill is greater. The effects of weightlessness are quickly compensated for; training can aid in reducing the amount of decrease in motor skill.

For the purpose of training and testing, different methods have been used to attain weightlessness on Earth: (1) the Keplerian trajectory in which an airplane, ascending and descending at a prescribed angle and rate, produces momentary weightlessness at the height of its climb; (2) immersion in water; (3) a zero gravity tower in which freefall provides temporary weightlessness.

It has been proposed that gravity be simulated in a space station by providing some means for rotating the entire ship around its axis. A disadvantage of this is that man moving within the space station will feel the effects of any change in his distance from the center of the station and, due to the Coriolis effect, any change in the direction of his motion. (See the discussion of spatial disorientation in the section, "Ear" pp. 61.)

Activities

1. Place some plants on a spinning turntable and observe their growth pattern over a period of days. For the plants, rye grass or coleus plants are good choices. Vary the distance from the center of the turntable and/or vary the speed with which the table turns and observe the reactions of the plants. (See NASA, Space Resources for Teachers-Biology, pp. 66-69, for further suggestions related to plants and gravity orientation.)

2. Demonstrate how artificial gravity can be developed by rotation around an axis.

Materials needed:
- Phonograph turntable
- Strip of paper slightly longer than the circumference of the turntable
- Scotch tape
- A marble

Using scotch tape, attach the strip of paper around the rim of the turntable. Using the 78 rpm rate start the table turning. Drop the marble close to the center and note that the marble moves out to the rim "down" from the center.

3. Plan a program of exercises based upon isometrics such as the following which are planned to strengthen the arms and chest muscles.

For the arms: Sit or stand erect. Place bent right arm close to body with palm up. Place left hand over right hand. Try to bend right arm upward while resisting with left hand for 6 to 8 seconds. Reverse and repeat with left arm.

For arms and chest: Sit or stand erect. Clasp hands, palms together, close to chest. Press hands together hard and hold for 6 to 8 seconds.

Resource Materials

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Bourne, Geoffrey H., "Neuromuscular Aspects of Space Travel," Physiology of Man in Space. J. H. U. Brown, editor. pp. 16-33. Effects of weightlessness on muscles.

Brown, Edward L., "Human Performance and Behavior During Zero Gravity," Weightlessness--Physical Phenomena and Biological Effects. E. T. Benedikt, editor. pp. 156-170. Motor and mental task performance at zero g.

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Gallant, Roy A., Man's Reach into Space. pp. 141-149. Method used to simulate zero g by climb-and-dive flights.

Gazenko, O. G., and A. A. Gyurdzhian, "Physiological Effects of Gravitational," Life Sciences and Space Research, Volume IV. A. H. Brown and M. Florkin, editors. pp. 1-21. Translation of Russian article about physiological effects of weightlessness and recommendations for training for weightlessness.

Generales, Constantine D. J. Jr., "Weightlessness; Its Physical, Biological, and Medical Aspects," Medical and Biological Problems of Space Flight. Geoffrey H. Bourne, editor. pp. 123-187.

Glasstone, Samuel, Sourcebook on the Space Sciences. pp. 890-894. Description of weightlessness; physiological effects of weightlessness.

Graveline, Duane E., "Maintenance of Cardiovascular Adaptability During Prolonged Weightlessness," Medical and Biological Problems of Space Flight. Geoffrey H. Bourne, editor. pp. 115-122. Multiple tourniquet technique for maintenance of cardiovascular adaptability.

Hall, Charles E., "Stress," Physiology of Man in Space. J. H. U. Brown, editor. pp. 122-125. Stresses developed due to state of weightlessness.

Hauty, George, "Psychophysiological Problems in Space Flight," Bioastronautics. Karl E. Schaefer, editor. pp. 196-198. Immersion in water to simulate weightlessness.

Hawkins, Willard R., "Space Flight Dynamics -- Weightlessness," Physiology of Man in Space. J. H. U. Brown, editor. pp. 287-307. History of studies of weightlessness; methods of studying weightlessness.

Henry, James P., Biomedical Aspects of Space Flight. pp. 70-91. Effects of weightlessness on vision and spatial orientation.

Howard, I. P. and W. B. Templeton, Human Spatial Orientation. pp. 419-444. Methods of producing weightlessness; effects of weightlessness.

Levine, Raphael B., "A Device for Simulating Weightlessness," Medical and Biological Problems of Space Flight. Geoffrey H. Bourne, editor. pp. 85-113. Problems involved in devising a simulator.

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Mayo, Alfred M., and James Parker Nolan, Jr., "Bioengineering and Bioinstrumentation," Bioastronautics. Karl E. Schaefer, editor. pp. 251-253. Artificial gravity in a spacecraft.

Meehan, J. P., "Acceleration Stress," Bioastronautics. Karl E. Schaefer, editor. pp. 22-23. Effect of weightlessness on cardiovascular system, locomotion and motor performance, and sensory and vestibular systems.

National Aeronautics and Space Administration. Space Resources for Teachers-Biology. pp. 63-71. Weightlessness.

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Oberth, Hermann, Man into Space. pp. 62-65. Use of weightless state in biological experimentation.

Slater, A. E., "Medical and Biological Problems," Space Research and Exploration. D. R. Bates, editor. pp. 206-216. Problems experienced during weightlessness.

Trinklein, Frederick E. and Charles M. Huffer, Modern Space Science. pp. 474-477. Individual reactions to weightlessness; problems of weightless living.

Wunder, Charles C., Life into Space; An Introduction to Space Biology. pp. 156-171. Effects of weightlessness; rotation to simulate gravity.

Films

All About Weightlessness (c, 11 min.)
Cartoon representation of problems of weightless living.

G-Forces (c, 26 min.)
Effects of positive, negative, and transverse g-forces upon man.

Living in Space Series -- A Technology for Spacecraft Design (c, 12 min.)
Life support systems for manned missions; includes sequence on zero gravity.

Medical Experiments for Manned Space Flight (c, 29 min.)
Effects of prolonged weightlessness.

The NASA Bio-Satellite Program -- Between the Atom and the Star (c, 28 min.)
Effects of gravity upon animals.

Reduced Gravity Simulator for Study of Man's Self Locomotion (c, 10 min.)
The Langley Lunar Gravity Simulator

Rx for Space (c, 22 min.)
Problems of space travel; reactions under zero gravity.

SLEEP

SLEEP

Life Science Concept

Sleep, necessary for all mammals, seems to follow a diurnal pattern.

Related Aerospace Concept

Space flight may interfere with the diurnal sleep pattern of man.

Background Information

So far, in space flights, there seem to be no deleterious effects due to an inability to sleep. The astronauts seem to have found it relatively easy to sleep, especially when they were allowed to follow the diurnal pattern they followed at home in Houston. There were apparently no hallucinations nor disturbing dreams.

Speculation has been that the work-rest cycle, on prolonged space flights, might be adjusted to a diurnal rhythm other than Earth's 24-hour clock.

Activities

1. Show that body temperature follows a daily rhythm by having students keep graphs of their temperatures taken at regular intervals for several days.

2. Study the emergence rhythms of Drosophila or their sensitivity to brief periods of light. (See NASA, Space Resources for Teachers-Biology, pp. 148-153, for suggestions for other types of experiments related to circadian rhythms, including directions for constructing a "jiggle cage" for measuring the diurnal activity of small animals.)

Resource Materials

Books

Henry, James P., Biomedical Aspects of Space Flight. pp. 75-77, 139-140. Sleep patterns of astronauts; diurnal rhythms.

Henry, James P., "Effects of Space Flight in Animals and Men," Bioastronautics. Karl E. Schaefer, editor. pp. 317-318. Biological rhythms.

Levine, Raphael B., "A Device for Simulating Weightlessness," Medical and Biological Problems of Space Flight. Geoffrey H. Bourne, editor. pp. 95. Possible readjustment of biological rhythms.

National Aeronautics and Space Administration, Space Resources for Teachers-Biology. pp. 143-157. Circadian rhythms.

Wunder, Charles C., Life into Space: An Introduction to Space Biology. pp. 206. Role of visible light in establishing biological rhythms.

MEDICAL RESEARCH

MEDICAL RESEARCH

Life Science Concept

Through medical research, techniques, methods, and devices for use in alleviating suffering and in prolonging man's life have been developed.

Related Aerospace Concept

Research for space flight has resulted in the development of techniques and devices which are used to preserve man's life during space flight.

Background Information

Some of the medical benefits that have accrued as a result of space research are:

1. Monitoring and analyzing techniques have been greatly changed through the development of multi-patient monitoring systems, cardiac monitoring units, portable automatic blood-pressure recorders, systems for cross-correlating data to analyze brain waves, electromagnetic-flow meters for diagnosis of erratic heart action, a bed that is instrumented to measure body-fluid loss, a microlamp small enough to use for internal diagnosis, oximeters to monitor breathing efficiency, manometers to record blood pressure during surgery, body-powered stimulators such as the heart pacer, computer enhancement of X-ray photographs, infrared sensors which can detect "hot spots" which indicate pathological conditions, and an analyzer of frequency spectra for summarizing electroencephalographs or monitoring anesthesia levels during surgery

2. Laminar-flow, clean-room techniques have been adapted to use in testing antibiotics, in preparation of pharmaceuticals, and in maintenance of antiseptic conditions in surgical operating rooms.

3. For patients with locomotion problems, a six-legged walking vehicle which can be controlled with a chin strap or by hand, a sight switch which makes it possible to control a motorized wheelchair by eye movements alone, or pressure cuffs and special exercising devices for the bedridden have been developed as a spin-off of space research.

4. An adaptation of the space helmet makes an efficient respirometer and an apparatus for measuring basic metabolism rate.

Activities

1. Simulate the way in which sensors respond to the functioning of the body.

Materials needed:
- Manometer
- Rubber or plastic tubing
- 2-inch funnel
- Stand to support manometer
- Water

Half fill the manometer with water. Attach the tubing which has the funnel at the other end. Press the funnel against the carotid artery in the neck or over the heart and observe the water in the manometer as it pulsates with each heartbeat.

Resource Materials

Books

Henry James P., Biomedical Aspects of Space Flight. pp. 65-69. Monitoring man in the spacecraft.

National Aeronautics and Space Administration, Medical Benefits from Space Research. Biomedical applications of space research.

Oberth, Hermann, Man Into Space. pp. 63-65. Medical uses of space flight research.

Films

An Artificial Heart Control System (c, 18 min.)
A control device for artificial hearts developed by the Lewis Research Center and based on their nuclear rocket control.

Biomedical Experiment Chair (c, 12 min.)
A specially designed chair which permits monitoring, without attached sensors, of the person seated in it.

EXTRATERRESTRIAL LIFE

EXTRATERRESTRIAL LIFE

Life Science Concept

Carbon, oxygen, and hydrogen--basic elements in living cells--form proteins, carbohydrates and fats which are essential to living materials on Earth.

Related Aerospace Concept

Life based upon the carbon atom may exist on some other planet in the solar system or somewhere else in space. It is also conceivable that life based on another element, possibly silicon, may exist somewhere in space.

Background Information

Theoretically, life could have evolved chemically under the conditions which were present in the early stages of the evolution of our planet Earth. The temperature, atmospheric conditions, and energy sources needed were all present. The primitive atmosphere probably contained ammonia, methane, water vapor and hydrogen, but no oxygen to cause oxidation. Lightning, ultraviolet light, or volcanic heat could have been the energy source. Simulation of these primitive conditions in the laboratory have resulted in the formation of organic compounds which possibly are the precursors of life as we know it.

Conditions upon a planet depend on its size, which determines the strength of its gravitational field, and its distance from its "sun" or heat source. A planet's atmosphere is composed of the gases which can be retained by the force of the planet's gravity.

The following criteria are suggested as the scientific bases required for the development of intelligent life as we know it on Earth. (1) To provide sufficient time for evolution, a planet with a partially solid, partially water-covered surface and an oxidizing atmosphere, must have existed for a long period of time in the vicinity of a star that is neither too hot nor too cold. (2) The central star must be of the Hertzsprung-Russell main sequency of spectral class F4 or beyond, with a mass between 0.5 and 1.3 times our sun. (3) The planet's orbit must be approximately circular and stable to avoid great differences in temperature and climatic conditions. (4) The planet must be of a size large enough (but not too large) to retain the proper atmospheric constituency (620 miles to 12,400 miles in diameter.).

Life forms can adapt to extremes in several variables. Some form of life, for example, has been shown to grow (1) in temperatures ranging from -18° C to 104° C, (2) in media with acidity ranging from pH zero to pH thirteen, (3) in double distilled water and saturated salt solutions,

(4) under drought conditions, (5) under pressures ranging from 0.1 atmosphere to 1400 atmospheres, (6) under high levels of ionizing radiation, (7) in chemicals such as copper sulfate, citric acid, and phenol, and (8) in atmospheres containing a high percentage of carbon monoxide.

Much speculation has been done about the possibility of living organisms surviving and growing on the planet Mars. Mars' atmosphere has a pressure less than 0.1 of the earth's atmosphere; it contains CO_2, nitrogen, a little argon, and very little water vapor. Oxygen may be present, but only in trace amounts. The polar caps seem to be composed of water; the light areas seem to be iron oxide; and some scientists have interpreted the spectrum of the dark areas as evidence of the presence organic compounds. Attempts have been made to simulate Martian conditions and to study the survival and growth of bacteria or other life forms under these conditions. The relative success of these many experiments make it seem highly likely that some kind of life form can and does exist on the planet Mars.

The detection of extraterrestrial life is both a scientific and an engineering problem. One problem is related to the stage of evolution that may have been reached by the life on an unknown planet. Life might be at any stage from the early chemical evolution, which would require one kind of detection apparatus, to the stage where life has evolved and disappeared leaving only fossil record of its existence, which would require a different method of detection. Evidence of extraterrestrial life might be collected through (1) finding evidence of growth, (2) collecting evidence of metabolic changes, or (3) identifying compounds which are evidence of life here on Earth. Devices being considered by NASA include (1) the Wolf trap and Gulliver which depend upon evidence of growth in a nutrient solution; (2) devices which depend upon gas chromatography to identify organic compounds; (3) an apparatus which uses a mass spectrometer to analyze compounds; (4) an instrument called a "Mars Microscope" which is completely automated microscope to be used to study samples of Martian soil for evidence of organic compounds; and (5) the multivator which is a complex of instruments for making several types of tests.

Many scientists are analyzing meteorites to ascertain whether organisms or organic compounds are present in them. Conclusions are quite controversial because of the many possibilities for contamination of the meteorites as they pass through Earth's atmosphere and land. Other scientists are monitoring communication wavelengths to try to determine if there is evidence of intelligence in space. Life, other than that based on the carbon atom which we find here on Earth, has been postulated. The possibility of a life form based upon the silicon atom has been suggested. Perhaps, ammonia, instead of water, could be the solvent for another life form. Sulphur, rather than oxygen, has been proposed as a possible respiratory chemical. At very high temperatures, fluorine-silicon or fluorocarbon biologies might evolve. At extremely low temperatures, liquid ammonia, liquid methane, or even liquid hydrogen might serve as a solvent for life.

Activities

1. Determine if plant life as we know it could exist under conditions which exist on other planets. Place growing plants in airtight containers which have atmospheres similar to those which occur on other planets. If possible, try to duplicate other environmental conditions such as day length, temperature and atmospheric pressure. Try simple forms of plant life such as algae, lichen, or mosses.

2. Demonstrate the possibility of using ultraviolet light and various chemicals to decontaminate materials.

Materials needed:
- Bean seed
- Cotton
- Several jars
- Iodine
- An antiseptic (Clorox, Lysol, etc.)
- Ultraviolet light source
- Distilled water

Soak beans in cold water overnight or for several hours. Place a few beans in each of the jars and cover them with distilled water. Add iodine to one container, the antiseptics to others. Add nothing to one container to keep it for a control. Expose one container to ultraviolet light. Stopper the bottles with cotton and leave them in a warm place for several days. The unpleasant odor from some of the containers will indicate the presence of microorganisms.

3. Given a handful of soil, prove that it contains life organisms of some type.

4. Given sealed cans of soil, prove, sight unseen, that there is evidence of life. (See NASA, Space Resources for Teachers-Biology, pp. 184-186, for detailed suggestions for methods to use in detecting the existence of life in the sealed cans.)

Resource Materials

Books

Cade, C. Maxwell, Other Worlds than Ours. Evolution of intelligence; life within the solar system; communicating with life in space

Clarke, Arthur C. and the Editors of Life, Man and Space. pp. 169-178. Speculation about possibilities of life in space.

Glasstone, Samuel, Sourcebook on the Space Sciences. pp. 717-725, 904-908. Possibility of life on Mars; intelligent life in the universe

Holmes, David C., The Search for Life on Other Worlds. Communication with life in space; uniqueness of life on Earth.

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Moffat, Samuel and Elie A. Shneour, Life Beyond the Earth. Beginnings of life; search for life in space; attempts to communicate.

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Ordway, Frederick I., III, Life in Other Solar Systems. Life outside the solar system; detecting extrasolar civilizations; speculation about extrasolar beings.

Ovenden, Michael W., Life in the Universe. Environments on other planets; origin of life; adaptability of life forms; life on other planets.

Posin, Dan Q., Life Beyond Our Planet. Possibility of life on other planets and attempts to communicate.

Urey, Harold C., "A Review of Evidence for Biological Material in Meteorites," Life Sciences and Space Research, Volume IV. A. H. Brown and M. Florkin, editors. pp. 35-39. Carbonaceous chondrites examined for material of biological origin.

Vishniac, Wolf, "Techniques of Tele-Analysis," Life Sciences and Space Research, Volume IV. A. H. Brown and M. Florkin, editors. pp. 101-106. Methods of searching for evidence of life on Mars.

Wunder, Charles C., Life into Space; An Introduction to Space Biology. pp. 259-287. Probability of life on other planets.

Young, Richard S., Extraterrestrial Biology. Origin of life and detection of life.

Films

Animal Secrets -- Life on Other Planets. (c, 24 min.)
Possibilities of life beyond our planet.

Biochemical Origin of Terrestrial Life (b/w, 30 min.)
Elements for organic synthesis of life

The Chemistry of Life (c, 18 min.)
Life regeneration and reproduction with macromolecules

Decontamination of Space Vehicles (c, 17 min.)
Need for decontamination of space vehicles and methods for decontamination.

Exobiological Safety (c, 12 min.)
Methods for germ free exploration of space

How Did Life Begin? (c, 20 min.)
Molecular evolution of amino acids which may have been the precursors of life.

Life on Other Planets (c, 29 min.)
Conditions suitable for life.

Life on Other Planets (c, 19 min.)
Interrelationship of nucleic acids, proteins, and amino acids.

Life on Other Worlds (c, 30 min.)
Biological environments on other worlds

A New Look at an Old Planet (c, 26 min.)
Benefits of weather, communications, navigational and earth resources satellites.

The Search for Extra Terrestrial Life (b/w, 28 min.)
Tools being used in search for extraterrestrial life.

RESOURCE MATERIALS

BOOKS

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