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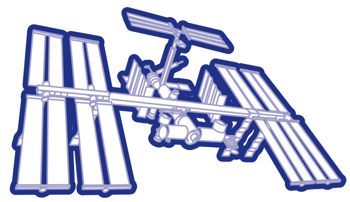
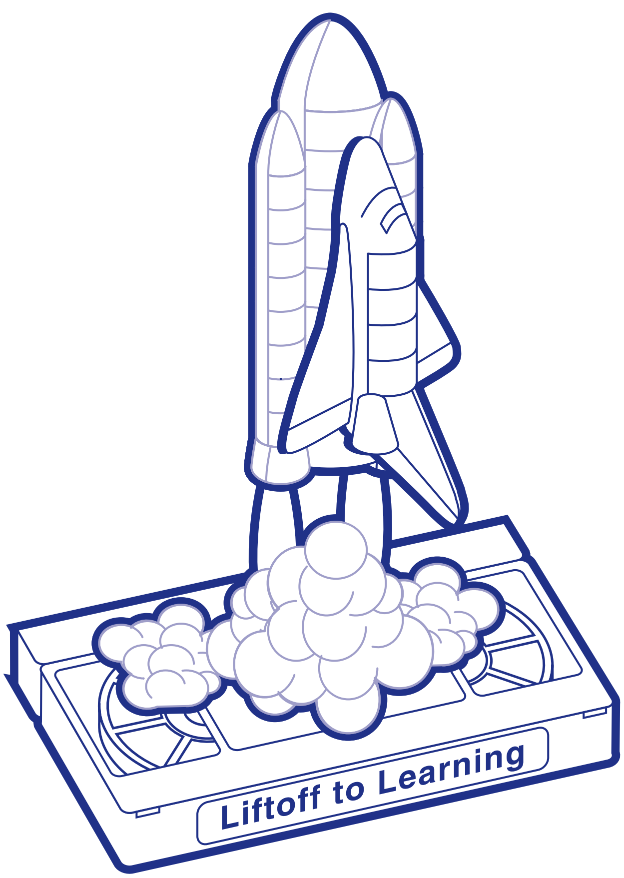
Liftoff to Learning



All Systems Go!

A Videotape for Life Science and Physical Science



Video Resource Guide

EV-1997-07-001-HQ

Video Synopsis

Title: All Systems Go!

Length: 33:34

Subjects: The effects of microgravity on humans.

Description:
This program discusses the reasons and demonstrates some of the physiologic changes that occur in the human body while in the microgravity environment. This video may be shown in its entirety or in segments.

Science Standards:
Science as Inquiry
Life Science
- Organisms and environments
- Regulation and behavior
- The cell
Physical Science
- Position and motion of objects
Unifying Concepts and Processes
-Change, constancy, and measurement

Science Process Skills:
Observing
Communicating
Measuring
Collecting Data
Inferring
Predicting
Hypothesizing
Interpreting Data
Investigating

Mathematics Standards
Communication
Statistics
Measurement

Background

The STS-40 Spacelab Life Sciences-1 (SLS-1) mission conducted extensive research on six human body systems to better understand how humans will be able to live and work for extended periods of time in space.

The experiments on the SLS-1 mission were aimed at trying to answer many important questions about the functioning of the human body in microgravity and its readaptation upon return to the normal gravity environment on Earth. How does spaceflight influence the heart and circulatory system, metabolic processes, muscles and bones, and the cells? Will the human body maintain its physical and chemical equilibrium during long space missions? If certain body adaptations to microgravity are undesirable, how can those adaptations be prevented or controlled? When an astronaut returns to Earth, how does the body readjust to gravity?

Spacelab is an international resource for scientific investigations in space. Built by the European Space Agency for NASA, Spacelab is mounted in the Space Shuttle's payload bay. For SLS-1, the Spacelab long module configuration (seven meters long by five meters wide) was used for the mission. It is a pressurized cylindrical module that is connected to the airlock in the orbiter's middeck by a tunnel. The inside of Spacelab's interior was arranged with two long racks of scientific apparatus and support equipment that stretched along the walls on either side. Larger pieces of equipment, such as a bicycle ergometer and a device that measures body mass, were placed in the center aisle.

The scientific investigations conducted on SLS-1 explored some of the limits, adaptations, and capabilities of the following human body systems in microgravity: cardiovascular, cardiopulmonary, neurovestibular, musculoskeletal, renal-endrocrine, and blood and immune.

Early SLS-1 Results

Although the data analysis from the SLS-1 mission is continuing, researchers have pieced together some of the changes that take place in living organisms and living cells during exposure to microgravity. Human, plant, and animal cells exposed to the microgravity of space for only a few days show changes in function and structure. The data suggest that alterations in cell metabolism, immune cell function, cell division, and cell attachment have occurred in space. Scientists have reported that after nine days in space, human immune cells failed to differentiate into mature effector cells. The results of investigations into how the stress of spaceflight can alter normal metabolic activities and important aspects of immune cell function may indicate the body's inability to produce mature and fully differentiated cells in space. This may lead to health problems on long-term spaceflights, including impaired healing abilities and increased risk of infection.

Studies on rat bone cells revealed a significant number of floating, dead bone-forming cells. Bone cells die if they are unsuccessful in attaching themselves to something. This finding could be significant since many biological processes, both in single cells and in multicelled organisms, depend on cell attachment and the recognition processes. The finding suggests that gravity clues may be required to show the cells where to attach themselves. Furthermore, studies of rat bone cells also revealed that healthy cells showed no signs of producing minerals. It may be that bone cells do not need to produce minerals to support themselves in a microgravity environment.

Similar studies of mouse bone cells developed in space and of those developed on the ground revealed similar changes in attachment properties in microgravity. Microscopic examination of the surfaces of flight cells revealed that they were smoother than cells used in the ground-based control experiment. This finding indicated that matrix production or secretion is altered in microgravity. Matrix forms the basic structure of bone.

Plant cell studies also revealed unusual responses to microgravity. Data collected indicated that cells in the roots of plants subjected to spaceflight undergo major changes in their cell division profile, even after as few as four days in space. One plant studied, *Haplopappus gracilis*, has only four chromosomes. Overall root production in this plant was significantly faster under spaceflight conditions than in ground control studies. Furthermore, changes in chromosomes were found in up to one-third of the cells that flew in space.

Scientists have reported dramatic changes associated with space travel in some of the human body systems, with a resiliency in others—all of which may affect long stays in space and medical research on Earth. These results point to the need for a long-term laboratory in space to complement Earth-based laboratory research. Key findings from the SLS-1 mission for three of the major body systems studied (cardiovascular, musculoskeletal, and neurovestibular) revealed important changes that take place in the human body in microgravity.

<u>Cardiovascular</u>

Space travel presents a drastic change in working conditions to the heart and lungs. Often, astronauts who have just returned from space have difficulty maintaining normal blood pressure and blood flow when standing. One SLS-1 experiment used a catheter inserted preflight into an arm vein of an astronaut and later moved nearer to the heart. This catheter had a sensor attached which measured the blood pressure closest to the heart. The experiment showed that the astronaut experienced a much more rapid fall in central venous blood pressure than was predicted.

In another area of cardiovascular research, it was found that exposure to space impairs an astronaut's pressure-regulating reflexes, called baroreflexes. A closely-fitting neck collar (similar to a whip-lash collar) was used on astronauts during the SLS-1 mission to test and record two blood pressure sensing areas located in the neck.

By the eighth day of flight, astronauts had significantly faster resting heart rates, less maximum change of heart rate per unit of neck pressure change, and a smaller range of heart rate responses. The changes that developed were large, statistically significant, and occurred in all astronauts studied. These results validated findings obtained on Earth by studying subjects after prolonged bed rest. This validation can lead to important studies in clinical medicine and provide insights into medical problems here on Earth.

Nervous System

The results of another SLS-1 experiment show clear evidence that the number of structures (synapses) used to communicate between the cells of the inner ear's gravity detecting organ and the central nervous system increases during spaceflight, but the size of these structures does not increase. Therefore, these systems should be able to adapt to the differing gravitational environments of space, the Moon, and Mars. Further research in this area should also shed light on the broader topics of memory and learning in neural tissue and on clinical diseases of the inner ear.

Muscles

During spaceflight, there is a significant and dramatic reduction in the size of all muscles needed for standing and moving. Furthermore, it seems that there is a reduced capacity of muscles to burn fat for energy production. Studies have also verified that muscles that support the body when we walk on Earth change their nature in space because they are not needed. Taken together, these findings suggest that properties of the skeletal muscle system, the largest organ system of the body, are greatly altered during spaceflight.

Additional Findings

As researchers continue to analyze the data collected through the experiments of the Spacelab Life Sciences-1 mission, reports of the findings will be made public through professional journals. Refer to the reference list for sources of additional information.

Terms

Adrenal Glands - Glands located just above the kidneys.

Baroreflexes - Blood pressure regulating reflexes.

Cardiopulmonary System - A system that interrelates the functions of the heart and lungs.

Cardiovascular System - The heart and a network of thousands of kilometers of blood vessels, capillaries, and arteries.

Catheter - A hollow tube inserted into a vein or artery.

Central Venous Pressure - The fluid pressure in the veins near the heart. It is directly related to the volume of blood the heart pumps.

Gas Exchange - The exchange of carbon dioxide and oxygen within the lungs.

Homeostasis - Stable environment within the body.

Hormone - A chemical, created in one organ of the body, that has a specific effect on another part of the body.

Hypothalamus - Part of the brain that secretes hormones that control many body functions such as temperature.

Lymphocytes - White blood cells.

Microgravity - An environment, produced by free-fall, that alters the local effects of gravity and makes objects seem weightless.

Musculoskeletal System - Bones and muscles.

Neurovestibular System - System combining the inner ear and nervous systems.

Orthostatic Hypotension - Abnormally low blood pressure.

Osmosis - The diffusion of fluids through a semipermeable membrane.

Osteoblasts - Bone cells that build new bone matter.

Osteoclasts - Bone cells that eliminate old bone matter.

Otoliths - Small crystals within the inner ear that aid in the detection of motion.

Pancreas - Gland that secretes digestive juices and produces insulin.

Pituitary Gland - Small gland that secretes hormones regulating body growth, metabolism, and the actions of other glands.

Renal-endrocrine System - System including the kidney and various glands such as the pituitary, hypothalamus, and thyroid glands.

Space Anemia - A shortage of red blood cells that is experienced by astronauts upon their return to Earth.

Space Motion Sickness - Similar to sea sickness.

Spacelab - A self-contained cylindrical science laboratory carried in the payload bay of the Space Shuttle.

Synapse - The point of contact between neurons in the nervous system across which impulses are transmitted.

Thyroid Gland - Gland that secretes thyroxin to control metabolism and body growth.

Classroom Activities

The following hands-on activities can be used to demonstrate some of the concepts presented in this videotape.

Spine Lengthening

Materials
Tape measure
Pencil or masking tape tab (to mark height against a wall)

Procedure
Demonstrate one of the changes that takes place in the human body in microgravity by having students measure their height immediately after rising in the morning and just before going to bed at night. People are measurably taller in the morning than they are in the evening. During bed rest, the disks that separate the vertebrae in the spinal column expand slightly. This increases the total body height by a centimeter or more. By evening, the disks have been compacted, producing a shorter body height. During exposure to microgravity, the spine expands and doesn't contract until return to Earth.

Upper Body Fluid Shift

Materials
Tape measure
Washable (non-toxic) marker pen
Table (long)
Wood blocks (cut from 2x4s)

Procedure
Measure the circumference of the mid-calf of several volunteer students while they are standing. Carefully mark the placement of the tape measure with the marker pen. Record the measurement. Lay each student down on the table in turn and elevate one end of the table by placing the legs on the wood blocks. The student should be in a head-down position. Ask the student to describe the sensations felt, especially in the head and upper body. After five minutes of "bed rest," measure the circumference of the calf again in the exact place as before. Record the measurement. Is there a difference in the two measurements? What might cause these differences?

Note: While standing on Earth, gravity tries to pull blood and other body fluids to the feet. Without the pumping action of the legs during movement, humans standing still for long periods tend to black out. In Earth orbit, the local effects of gravity are counteracted, but the pumping actions of the legs continue. This leads to an upper body fluid shift that creates a puffy look in the face and neck and a thinning of the calf ("chicken legs"). Bed rest can simulate this effect.

Cardiac Output and Exercise

Materials
Stopwatch or watch with a second hand
Hand weights
Table (long)
Wood blocks (made from 2x4s)

Procedure
Measure the pulse rate (in beats per minute) of a volunteer student standing at rest. Record the rate. Give the volunteer the hand weights and have the student exercise vigorously with them for two to four minutes. Again, measure and record the heart rate. When the heart rate has returned to the rate at rest, place the student on the table. Elevate the end of the table under the student's feet. After five minutes of "bed rest" with the feet elevated, measure the volunteer's heart

rate. Again, give the student the hand weights and have the student exercise vigorously for two to four minutes while still lying down. Measure and record the heart rate after exercise. Calculate the cardiac output for each measure. The cardiac output in milliliters per minute equals the stroke volume (ml/beat) times the heart rate (beats per minute).

Cardiac Output = Stroke Volume x Heart Rate

Assume that the standing stroke volume is about 75 ml/beat. During bed rest and in microgravity, the stroke volume increases to about 95 ml/beat. Was there a difference in cardiac output before and after exercise while standing? During bed rest? Compare standing cardiac output with bed rest (microgravity) output. Is there a difference? Why or why not?

Note: This activity and the proceeding one can be combined into a single study.

References

NASA On-line Resources for Educators provide current educational information and instructional resource materials to teachers, faculty, and students. A wide range of information is available, including science, mathematics, engineering, and technology education lesson plans, historical information related to the aeronautics and space program, current status reports on NASA projects, news releases, information on NASA educational programs, useful software and graphics files. Educators and students can also use NASA resources as learning tools to explore the Internet, access information about educational grants, interact with other schools, and participate in on-line interactive projects, communicating with NASA scientists, engineers, and other team members to experience the excitement of real NASA projects.

Access these resources through the NASA Education Home Page:
http://education.nasa.gov

Other web sites of interest:

http://www.jsc.nasa.gov
http://www.hq.nasa/gov/office/olmsa

Curriculum Guides:

Lujan, B. & White, R. (1994), Human Physiology In Space, Teacher's Manual, National Institute of Health, The Universities Space Research Association and The University of Texas Southwestern Medical Center, 1994.

Vogt, Gregory L., Wargo, Michael J. Microgravity - Teaching Guide With Activities for Physical Science, EG-103, National Aeronautics and Space Administration, 1995.

STS-40 Crew Biographies

Commander: Bryan D. O’Connor (Col., USMC). Bryan O’Connor, from Twentynine Palms, California, received a bachelor of science degree in engineering from the U.S. Naval Academy and a master of science degree in aeronautical systems from the University of West Florida. He is a Marine Corps test pilot and served as the pilot of the STS-61B mission.

Pilot: Sidney M. Gutierrez (Lt. Col., USAF). Sidney Gutierrez comes from Albuquerque, New Mexico. He earned a bachelor of science degree from the U.S. Air Force Academy. Gutierrez is an Air Force test pilot and a master parachutist. This was his first spaceflight.

Mission Specialist: James P. Bagian (M.D.). James Bagian is from Philadelphia, Pennsylvania, and earned a bachelor of science degree in mechanical engineering from Drexel University and a doctorate in medicine from Thomas Jefferson University. He has worked as a mechanical engineer with the Navy and as a flight surgeon at NASA. Bagian served as a mission specialist on the STS-29 mission.

Mission Specialist: Tamara E. Jernigan (Ph.D.). Tamara Jernigan comes from Santa Fe Springs, California. She earned a bachelor of science degree in physics and a master of science degree in engineering science from Stanford University. She also earned a master of science degree in astronomy from the University of California-Berkeley and a doctorate in space physics and astronomy from Rice University. This was her first spaceflight.

Mission Specialist: Margaret Rhea Seddon (M.D.). Rhea Seddon is from Murfreesboro, Tennessee. She received a bachelor of arts degree in physiology from the University of California-Berkeley and a doctorate in medicine from the University of Tennessee College of Medicine. Seddon served as a mission specialist on the STS-52D flight.

Payload Specialist: F. Andrew (Drew) Gaffney (M.D.). Drew Gaffney comes from Carlsbad, New Mexico, and earned a bachelor of arts degree from the University of California-Berkeley and a doctorate in medicine from the University of New Mexico. He received a fellowship in cardiology at the University of Texas and was the assistant director of echocardiography at Parkland Memorial Hospital, Dallas, Texas. Gaffney is an associate professor of medicine at Southwestern Medical Center in Dallas. This was his first spaceflight.

Payload Specialist: Millie Hughes-Fulford (Ph.D.). Millie Hughes-Fulford is from Mineral Wells, Texas. She earned a bachelor of science degree in chemistry from Tarleton State University and a doctorate in chemistry from Texas Woman’s University. She conducts research at the University of California and the Veterans Administration Medical Center on cholesterol metabolism, cell differentiation, DNA synthesis, and cell growth. This was her first spaceflight.

NASA Liftoff to Learning
All Systems Go!

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Video Resource Guide

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Otherwise, please return the reply card by mail. Thank you.

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   College/University - ______ Undergraduate ______ Graduate

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3. This is a valuable video and video resource guide.

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