

THE SCIENCE OF

MUSCLES

AND BONES

Gravity and Buoyancy



by

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RESOURCES

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Printed in the United States of America

ISBN-13: 978-1-888997-82-8

BioEdSM

Teacher Resources from the Center for Educational Outreach at Baylor College of Medicine.
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ACKNOWLEDGMENTS

The authors gratefully acknowledge the support of Bobby R. Alford, M.D., Laurence R. Young, Sc.D., Ronald J. White, Ph.D., and William A. Thomson, Ph.D., as well as the contributions of the following reviewers: Cassius B. Bordelon, Jr., Ph.D., Greg Byrne, Ph.D., Paula Cutler, Maitihili Daphtary, Ph.D., Michael Grusak, Ph.D., Kathy Major, Grant Schaffner, Ph.D., and Carola Wright, Ph.D. Preparation of this guide would not have been possible without the invaluable assistance of the following field test teachers: Cheryl Anderson, Dorothy Arceneaux, Cathy Bucchino, Veronica Curry, Sharon Fontaine, Lollie Garay, Delores Hall, Marilyn Manning, Demetria Rutherford and Kim Walker.

This work was supported by National Space Biomedical Research Institute through NASA NCC 9-58.

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TEAMING WITH BENEFITS

by Jeffrey P. Sutton, M.D., Ph.D., Director, National Space Biomedical Research Institute (NSBRI)

Space is a challenging environment for the human body. With long-duration missions, the physical and psychological stresses and risks to astronauts are significant. Finding answers to these health concerns is at the heart of the National Space Biomedical Research Institute's program. In turn, the Institute's research is helping to enhance medical care on Earth.



Dr. Jeffrey P. Sutton

The NSBRI, a unique partnership between NASA and the academic and industrial communities, is advancing biomedical research with the goal of ensuring a safe and productive long-term human presence in space. By developing new approaches and countermeasures to prevent, minimize and reverse critical risks to health, the Institute plays an essential, enabling role for NASA. The NSBRI bridges the research, technological and clinical expertise of the biomedical community with the scientific, engineering and operational expertise of NASA.

With nearly 60 science, technology and education projects, the NSBRI engages investigators at leading institutions across the nation to conduct goal-directed, peer-reviewed research in a team approach. Key working relationships have been established with end users, including astronauts and flight surgeons at Johnson Space Center, NASA scientists and engineers, other federal agencies, industry and international partners. The value of these

collaborations and revolutionary research advances that result from them is enormous and unprecedented, with substantial benefits for both the space program and the American people.

Through our strategic plan, the NSBRI takes a leadership role in countermeasure development and space life sciences education. The results-oriented research and development program is integrated and implemented using focused teams, with scientific and management directives that are innovative and dynamic. An active Board of Directors, External Advisory Council, Board of Scientific Counselors, User Panel, Industry Forum and academic Consortium

help guide the Institute in achieving its goals and objectives.

It will become necessary to perform more investigations in the unique environment of space. The vision of using extended exposure to microgravity as a laboratory for discovery and exploration builds upon the legacy of NASA and our quest to push the frontier of human understanding about nature and ourselves.

The NSBRI is maturing in an era of unparalleled scientific and technological advancement and opportunity. We are excited by the challenges confronting us, and by our collective ability to enhance human health and well-being in space, and on Earth. ◆

NSBRI RESEARCH AREAS

CARDIOVASCULAR PROBLEMS

The amount of blood in the body is reduced when astronauts are in microgravity. The heart grows smaller and weaker, which makes astronauts feel dizzy and weak when they return to Earth. Heart failure and diabetes, experienced by many people on Earth, lead to similar problems.

HUMAN FACTORS AND PERFORMANCE

Many factors can impact an astronaut's ability to work well in space or on the lunar surface. NSBRI is studying ways to improve daily living and keep crewmembers healthy, productive and safe during exploration missions. Efforts focus on reducing performance errors, improving nutrition, examining ways to improve sleep and scheduling of work shifts, and studying how specific types of lighting in the craft and habitat can improve alertness and performance.

MUSCLE AND BONE LOSS

When muscles and bones do not have to work against gravity, they weaken and begin to waste away. Special exercises and other strategies to help astronauts' bones and muscles stay strong in space also may help older and bedridden people, who experience similar problems on Earth, as well as people whose work requires intense physical exertion, like firefighters and construction workers.

NEUROBEHAVIORAL AND STRESS FACTORS

To ensure astronaut readiness for spaceflight, preflight prevention programs are being developed to avoid as many risks as possible to individual and

group behavioral health during flight and post flight. People on Earth can benefit from relevant assessment tests, monitoring and intervention.

RADIATION EFFECTS AND CANCER

Exploration missions will expose astronauts to greater levels and more varied types of radiation. Radiation exposure can lead to many health problems, including acute effects such as nausea, vomiting, fatigue, skin injury and changes to white blood cell counts and the immune system. Longer-term effects include damage to the eyes, gastrointestinal system, lungs and central nervous system, and increased cancer risk. Learning how to keep astronauts safe from radiation may improve cancer treatments for people on Earth.

SENSORIMOTOR AND BALANCE ISSUES

During their first days in space, astronauts can become dizzy and nauseous. Eventually they adjust, but once they return to Earth, they have a hard time walking and standing upright. Finding ways to counteract these effects could benefit millions of Americans with balance disorders.

SMART MEDICAL SYSTEMS AND TECHNOLOGY

Since astronauts on long-duration missions will not be able to return quickly to Earth, new methods of remote medical diagnosis and treatment are necessary. These systems must be small, low-power, noninvasive and versatile. Portable medical care systems that monitor, diagnose and treat major illness and trauma during flight will have immediate benefits to medical care on Earth.

For current, in-depth information on NSBRI's cutting-edge research and innovative technologies, visit www.nsbri.org.

OVERVIEW

Students learn why organisms have support structures. They compare and contrast the behavior of a water-filled plastic bag, both outside and inside of a container of water, to begin to understand the differences between environments with gravity and environments with reduced gravity.



ACTIVITY

GRAVITY AND BUOYANCY

All organisms on our planet are adapted to living with gravity, the force that pulls objects toward the center of the Earth. Gravity keeps objects from floating into space and it is the reason why “what goes up must come down.” It is not exclusive to the Earth. Amazingly, all objects in the universe attract each other. The force of the attraction depends on the distance between the two objects and their masses. Gravitational forces are normally too tiny to notice, unless one of the objects has a lot of mass (such as a planet or moon).

Many students have difficulty with the concepts of mass and weight. All objects in the universe have mass, which can be understood as a measurement of how difficult it is to set an object in motion or to stop it once it is moving. The mass of an object, measured in kilograms, is constant no matter where the object is.

Weight, on the other hand, varies with the amount of gravity and can be measured in units called “newtons”

(named after the famous physicist). On Earth, something with a mass of 1 kg weighs about 10 newtons. On the Moon, where gravity is less, the same object still has a mass of 1 kg but weighs less than two newtons. It is important to note, however, that in everyday language people are much more likely to say that “something weighs two kilograms.” For ease of understanding, in this guide we use the words “weigh” and “weight” in their everyday sense instead of their strictest scientific interpretation.

Understanding the difference between mass and weight is important if you go into space. Deep in space, something can be virtually weightless because it is too far away from other objects to be affected by their gravity. An object in orbit around Earth (or other celestial body) also is weightless, but for a different reason. Though this object is close to the Earth, it circles the planet at a velocity that overcomes the downward pull of Earth’s gravity. In other words, orbiting bodies fall freely toward the Earth, but because they have so much forward speed, their trajectories follow the curvature of the Earth’s surface.

This activity allows students to observe and compare the pull of gravity on water contained within a plastic bag when the bag is standing alone and when it is submerged in water, at which time, the force of gravity is counteracted by buoyancy.

Safety Issues

Please follow all school district and school laboratory safety procedures. It always is a good idea to have students wash hands before and after any lab activity.

Buoyancy

Something that floats is said to be buoyant (“buoy” = float).

An object will float on top of a liquid if it is less dense than the liquid. An object close to the same density as the liquid will float under the surface. An object will sink if it is more dense (weighs more) than the liquid it displaces.

A boat will float even though its walls are very heavy, because the total volume of the boat is made up mostly of air. The combined density of the sides of the boat and the air inside is less than the density of the water that has been moved aside.

SCIENCE, HEALTH & MATH SKILLS

GRADES 5–8

- Predicting
- Observing
- Comparing
- Inferring

CONCEPTS

- Gravity holds us to the Earth’s surface.
- The force of gravity can be counteracted by other forces.



USING COOPERATIVE GROUPS IN THE CLASSROOM



Cooperative learning is a systematic way for students to work together in groups of two to four. It provides organized group interaction and enables students to share ideas and to learn from one another. Students in such an environment are more likely to take responsibility for their own learning. Cooperative groups enable the teacher to conduct hands-on investigations with fewer materials.

Organization is essential for cooperative learning to occur in a hands-on science classroom. Materials must be managed, investigations conducted, results recorded, and clean-up directed and carried out. Each student must have

a specific role, or chaos may result.

The Teaming Up! model* provides an efficient system for cooperative learning. Four “jobs” entail specific duties. Students wear job badges that describe their duties. Tasks are rotated within each group for different activities so that each student has a chance to experience all roles. For groups with fewer than four students, job assignments can be combined.

Once a cooperative model for learning is established in the classroom, students are able to conduct science activities in an organized and effective manner. The job titles and responsibilities are as follow.

Principal Investigator

- Reads the directions
- Asks questions of the instructor/teacher
- Checks the work

Maintenance Director

- Directs carrying out of safety rules
- Directs the cleanup
- Asks others to help

Reporter

- Records observations and results
- Shares results with group or class
- Tells the teacher when the investigation is complete

Materials Manager

- Picks up the materials
- Directs use of equipment
- Returns the materials

Microgravity

Imagine you are on an elevator that begins to fall freely toward the ground. You and the elevator car would be moving toward the Earth at the same velocity, and you would be able to “float” within the elevator car. You would be weightless compared to the car, which is falling along with you. This is similar to what astronauts experience when they orbit the Earth.

The amount of gravity experienced while in orbit is about one-millionth of the normal gravity we feel at the Earth’s surface. The gravity experienced in orbit is so weak that it is called microgravity.

Physical Changes in Microgravity

Human physiology changes as a person goes from the Earth to space. In orbit or when we move away from the surface of the Earth, the effects of Earth’s gravity decreases. The human body is designed to operate in the gravitational field of the Earth. When the body no longer experiences the pull of Earth’s gravity, complex changes begin to occur as the body adapts to microgravity conditions.

TIME

15 minutes set-up; 45 minutes for activity

MATERIALS

Each group will need:

- Clear container with straight sides that holds at least 1 liter of water (or a glass aquarium in a central location)
- Food coloring
- Paper towels
- Plastic zip-top bag, snack-size
- Water
- Copy of the student sheet

SETUP & MANAGEMENT

Students will observe a water-filled bag. Depending on time and your students’ ages, you may want to fill the bags for students. Fill each bag with as much water as it will hold and add a drop of food coloring. Zip the top tightly closed, while removing as much air as possible. Place the bags and other materials in a central location.

PROCEDURE

1. Begin a class discussion of gravity by asking questions such as, *What keeps us and other objects from floating off the Earth and into space? What happens when you throw a ball into the air? Does it fly into outer space? How could we explore the pull of the Earth on objects near its surface?* Tell students that they will be investigating gravity in action.
2. Have the Materials Manager from each group collect a container of water and a water-filled plastic snack bag, or have students fill the bags following the directions given under Set-up and Management.
3. Tell students that they will be investigating the behavior of the water bag in two different environments: resting on a flat surface and floating in water. They should record their predictions and observations on a copy of the student sheet.
4. Have each group predict what will happen to the shape of the bag when it is placed on a hard, flat surface. Let



Mimicking Space

To practice for space walks, astronauts work under water in a giant swimming pool in NASA's Neutral Buoyancy Lab. The pool, which holds enough water to fill about 60 Olympic-sized pools, is so huge that astronauts can rehearse complicated repair and assembly tasks on life-sized sections of the International Space Station.

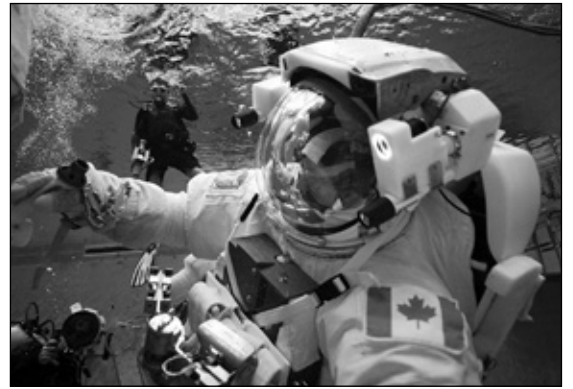
In the pool, astronauts wear special suits that are similar to those worn in space. Once underwater, the suits are weighted to prevent them from sinking or rising in the pool. This condition, which is called "neutral buoyancy," reduces the sensation of gravity and simulates the feeling of working in microgravity.

Working under water on Earth, however, does not completely mimic the conditions in outer space. Even though the astronauts float freely, the water offers resistance to their movements. This doesn't happen in space. In addition, even though they feel weightless, gravity is still acting on the astronauts under water. If they work upside down, for example, blood still rushes to their heads.

On average, each astronaut spends eight to ten hours practicing in the giant pool for every hour that he or she will be expected to work in space.

each group set its bag on the table and record the bag's appearance. Groups may choose any orientation for their bags (on the side or with zip top "up" works best). Students will note that the bottom of the bag is flattened. Ask, *Why do you think the bottom of the bag is flat? What would happen to the water if it wasn't in the bag? What would happen to the bag if it wasn't filled with water?*

- Next, have the students predict what might happen when the bag is placed in the water. They should consider where they think the bag will sit in the container (floating on the surface, at the bottom, etc.), and what shape they think the bag might have.
- After they have made their predictions, direct students to place the bags gently in the containers of water. They should orient their bags in the same position that was selected for the observations on the table.
- After each group records its observations, ask, *What happens to the shape of the bag in the water?* Students will observe that the lower surface of the bag is not flattened in the water. Also ask, *Where does the bag rest in the water?* Unless the bags contain large air bubbles, they will float completely or almost completely submerged in an upright or sideways position. Help students understand that the bags float freely under water because buoyancy counteracts the downward pull of gravity. On the table, however, gravity is able to pull the water within the bag toward the Earth's surface without the counteraction of buoyancy.
- Conclude by leading students in a discussion of what the water in the bags might look like in a microgravity environment, such as in space. Help them understand that water bags in space probably would look similar to the



Dr. Dafydd R. (Dave) Williams, STS-118 mission specialist wears a training version of the Extravehicular Mobility Unit spacesuit, participates in an underwater simulation of extravehicular activity in the Neutral Buoyancy Laboratory near Johnson Space Center. Williams rehearsal is intended to help prepare him for work on the exterior of the International Space Station.

bags as they floated under water OR discuss what might happen if they tried to weigh the bags under water, using a small scale. Students should be able to predict that they would be unable to weigh the floating "underwater" bag.

EXTENSIONS

- Challenge students to come up with other examples in which gravity's pull is counteracted. Examples include: flight of birds and insects, hot air balloons, kites and airplanes, jumping into the air (temporarily overcomes gravity), fish swimming upward, etc.
- Have students visit NASA's web site (www.nasa.gov) to investigate how astronauts practice tasks underwater to prepare for future work in space.
- If students have not investigated buoyancy prior to this activity, help them understand concepts related to floating and sinking by using snack bags filled with sand, water, air and any other substances. Students should weigh each bag, including the one with water, and predict which bags will float and which will sink. Any bags that weigh more than the bag of water will sink. Bags that weigh less than the bag of water will float on the surface.

ACTIVITY

THE SHAPE OF THINGS

You will be investigating the shape and position of a water bag when it is in two different environments. You will need a sealed snack bag filled with colored water and a clear, straight-sided container filled with about 1 liter of water.

What happens to the bag when it is placed on a hard surface?

1. Predict what the bag will look like when it is placed on a table or desk. Write or draw your prediction in the left column of the table labeled "Hard Surface."
2. Carefully put the bag on your table or desk. How does the bag look? Write or draw your observations in the right column. What happens to the bag when it is placed on top of the water in the container?

Hard Surface

Prediction	Actual

What happens to the bag when it is placed on top of the water in the container?

3. Predict what the bag will look like when it is placed on the water. Think about the shape of the bag and the place in the water where it will end up. Write or draw your prediction in the left column of the table labeled "Container of Water."
4. Carefully put the bag on the water in the container. How does the bag look? Where is the bag? Write or draw your observations in the right column.

Container of Water

Prediction	Actual

5. Use the back of this sheet or a separate sheet of paper to record your answers to the following questions.
 - a. How did the water bags in the two investigations look alike? How were they different?
 - b. What forces were acting on the water bags in the two different investigations?
 - c. What do you conclude happened in each investigation?