# Muscles and Bones

## Activities Guide for Teachers

FROM OUTERSPACE TO INNERSPACE

*National Space Biomedical Research Institute*

NATIONAL SPACE BIOMEDICAL RESEARCH INSTITUTE
NSBRI

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## Activities Guide for Teachers


*National Space Biomedical Research Institute*
Houston, Texas

The National Space Biomedical Research Institute (NSBRI) is combining the basic research capabilities of some of the nation's leading biomedical research centers with operational and applied research conducted by the National Aeronautics and Space Administration (NASA) to understand and achieve safe and effective long-term human exploration and development of space. The NSBRI's discoveries and research products will help to counter the effects of weightlessness and space radiation and will contribute to the health and well-being of all mankind.

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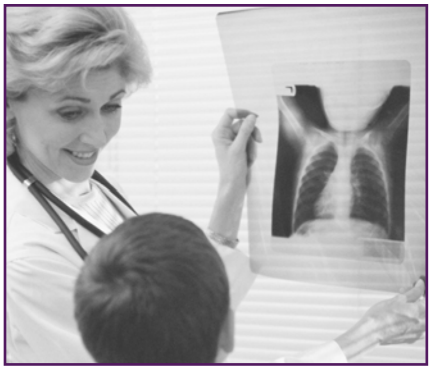
# What Can We Learn in Space

There are many reasons to study life sciences in microgravity, from obvious ones, such as ensuring astronaut health to less obvious ones, such as improving health care on Earth. The human body is



designed to operate in Earth's gravity field. When humans are removed from this environment, as when they travel in space, many complex changes take place: their bones become weaker, fluids shift toward the upper body, body rhythms are disrupted and motion sickness may occur. Life science research allows us to begin planning for long-term stays in space. It also provides important new medical information to improve the health care of people here on Earth, such as the ways we care for persons undergoing prolonged bedrest or those with osteoporosis.

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

**BONES.** Astronauts' bones become weak and porous because they are not working against the Earth's gravity. For different reasons, many people on Earth, particularly older women, also develop weak bones that fracture easily with little or no trauma. This condition is known as osteoporosis (porous bone).

**CANCER/RADIATION.** Outside the Earth's protective atmosphere, astronauts are exposed to many kinds of damaging radiation that can lead to cell damage and increase astronauts' chances of developing tumors. Learning how to keep astronauts safe from space radiation may improve cancer treatments for people on Earth.

# About Our Bodies Here on Earth?

**HEART & CIRCULATION.** Without gravity, the amount of blood in the body is reduced. 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.

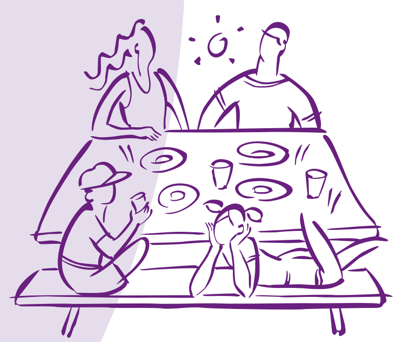
**IMMUNE SYSTEM.** Living and working in space may make it easier for astronauts to become sick or develop diseases. Learning how the body's disease defense systems change in space will help us to understand many illnesses, and their effects on the human immune system, here on Earth.

**MUSCLES.** When muscles do not have to work against gravity, they weaken and begin to waste away. Special exercises and other strategies to help astronauts' muscles stay strong in space also may help older and bedridden people, who experience similar problems on Earth.

**NUTRITION & FITNESS.** Research that uncovers ways to reduce space-related health problems through diet, exercise or rehabilitation will contribute to the development of prevention and treatment programs for osteoporosis and other bone disorders, muscle wasting diseases and many other illnesses.

**SLEEP & TEAM WORK.** It is hard for astronauts in space to get enough sleep because they lose the day/night cycle of Earth and there are many distractions. Strategies to help astronauts perform without errors and deal with stress also will benefit people who work at night or have irregular schedules.

**TECHNOLOGY.** Special systems and equipment, new remote medical diagnostic tools and intelligent computer software that support life science research—as well as the health of astronauts in space—will improve diagnosis and care for patients on Earth.



# 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 an organized setting for 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 provide support for reluctant learners, model community settings where cooperation is necessary, and 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. When a class is "doing" science, each student must have a specific role, or chaos may result.

The Teaming Up! model* provides an efficient system for cooperative learning. Four "jobs" are delineated: Principal Investigator, Materials Manager, Reporter and Maintenance Director. Each job entails specific responsibilities. Students wear job badges that describe their duties. Tasks are rotated within each group for different activities so that each student has an opportunity to experience all roles. Teachers even may want to make class charts to coordinate job assignments within groups. 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. All students are aware of their responsibilities and are able to contribute to successful group efforts.

| Principal Investigator | Maintenance Director | Reporter | Materials Manager |
|---|---|---|---|
| • Reads the directions | • Follows the safety rules | • Writes down observations and results | • Picks up the materials |
| • Asks the questions | • Directs the clean up | • Explains the results | • Uses the equipment |
| • Checks the work | • Asks others to help | • Tells the teacher when the group is finished | • Returns the materials |

* Jones, R.M. 1990. Teaming Up! LaPorte, Texas: ITGROUP.

# Extension Activities

There are many opportunities for exciting extension activities focusing on space travel and its effects on the human body. The NASA and NSBRI internet sites provide a wealth of educational resources that may be useful in developing such activities. For more information, go to <www.nasa.gov> and <www.nsbri.org>.

## CONCEPTS

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

## OVERVIEW

Students will 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.

## SCIENCE, HEALTH & MATH SKILLS

- Predicting
- Observing
- Comparing
- Inferring

# 1. Weighty Questions

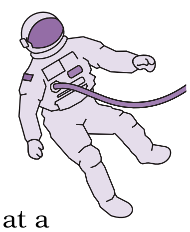
## Background

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.

## Time

15 minutes for set-up; 45 minutes to conduct activity

## Materials

Each group will need:

- water
- snack-size plastic zip-top bag

**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 space is so weak that it is called 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.**

- food coloring
- clear container with straight sides that holds at least 1 liter of water, or a glass aquarium in a central location
- paper towels
- copy of "The Shape of Things" sheet

## Set-up and Management

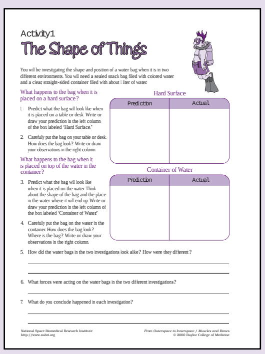
Students will observe a water-filled bag. Depending on time and your students' ages, you may want to fill the bags for students. Fill each bag with as much water as it will hold and add a drop of food coloring. Zip the top tightly closed, while removing as much air as possible. Place the bags and other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



Activity1

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 box 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.

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 box 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. How did the water bags in the two investigations look alike? How were they different?
6. What forces were acting on the water bags in the two different investigations?
7. What do you conclude happened in each investigation?

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4. Have each group predict what will happen to the shape of the bag when it is placed on a hard, flat surface. Let 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?*

5. 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.

6. 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.

7. 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.

8. Conclude by leading students in a discussion of what the water in the

### Floaties!

**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.**

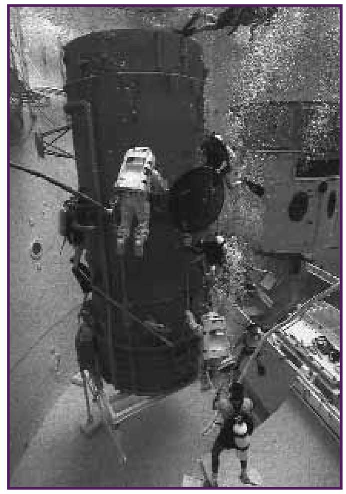
**Something that floats is said to be buoyant ("buoy" = float).**

To practice for space walks, astronauts work under water in a giant swimming pool at the Neutral Buoyancy Lab at NASA. 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.

For work 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 outside the shuttle or space station.



*(Photos courtesy of NASA)*

**Human physiology changes as a person goes from the Earth to outer space. As we move away from the surface of the Earth, the gravitational pull of the Earth decreases. The human body is designed to operate in the gravitational field of the Earth. When the body no longer experiences the Earth's gravitational force, complex changes begin to occur as the body adapts to microgravity conditions.**

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 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.

Photos. *Left:* Astronaut Catherine G. Coleman is assisted with suiting up for a training exercise in the deep pool of Johnson Space Center's Neutral Buoyancy Laboratory. The training suit that Coleman is wearing is weighted and otherwise accommodated to afford neutral buoyancy in the deep pool. *Right:* Underwater training is conducted in Marshall's Neutral Buoyancy Simulator in preparation for on-orbit Hubble Space Telescope operations.

## Activity 1

# 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?

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**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 box labeled "Container of Water."
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**Container of Water**

| Prediction | Actual |
|---|---|
| | |

5. How did the water bags in the two investigations look alike? How were they different?

______________________________________________

______________________________________________

6. What forces were acting on the water bags in the two different investigations?

______________________________________________

7. What do you conclude happened in each investigation?

______________________________________________

______________________________________________

## CONCEPTS

- Land animals and plants need support systems in order to stand and move against forces such as Earth's gravity.
- Skeletal systems, which can be inside or outside the body, provide support for animals.

## OVERVIEW

Students will design and build an exoskeleton or an endoskeleton for an animal of their own invention.

## SCIENCE, HEALTH & MATH SKILLS

- Observing
- Comparing
- Modeling

# 2. Supporting Structures

## Background

Living things support and move their bodies against the pull of Earth's gravity in many different ways. Tree trunks, lobster shells, floating lily pads and snake backbones all represent different solutions to this problem.

An animal's support structure depends upon the size and shape of its body and also the environment in which it must live. Support structures can be inside (internal) or outside (external) of the body. External supports (exoskeletons) usually consist of hard plates or tubes that cover most or all of the body. Insects, spiders, clams and crabs all have exoskeletons. Exoskeletons protect internal organs, prevent water loss from the body surface and provide a protective shield from enemies/predators. However, since they encase the body, some kinds of exoskeletons must be shed and remade as an animal grows. Endoskeletons are located inside the body. Humans, mice, frogs, snakes, birds and fish all have endoskeletons. An endoskeleton grows along with the body but provides incomplete protection. Endoskeletons are living tissues that can have several functions. Some of these include storage of red bone marrow where red blood cells are made, storage of fat and minerals, and regulation of calcium distribution between bone and other tissue.

Most skeletons have one or more rigid sections connected at joints to allow movement. In endoskeletons, bones are connected across joints by tough fibrous ligaments. Muscles, which usually are attached to bones by tendons, make movement possible and also help support the body.

## Time

15 minutes for set-up; one or two sessions of 45 minutes for activity

## Materials

Each group will need:

- sealable plastic bag or plastic wrap for skin or outer covering
- 10 straws
- clay
- scissors
- 15 paper clips
- two sheets of cardstock
- tape
- ruler
- copy of "From the Outside In" student sheet

## Set-up and Management

Place the plastic wrap, straws, clay, paper clips, tape, rulers, cardstock and scissors in a central location.

### Human Bone Facts!

**Human bones are about half water and half solid material.**

**The smallest bones in your body are in your ear. They are the malleus (or hammer), incus (or anvil), and stapes (or stirrup).**

**Half of your bones are in your hands and feet.**

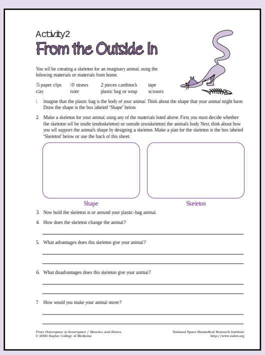
**Humans and giraffes each have seven neck bones.**

**Some plants and animals (like water lilies and jellyfish) are adapted to float in water and survive without a rigid support system. Earthworms use water pressure instead of a hardened skeleton to provide support and strength to their bodies.**

## Procedure

1. Ask students to remember what happened to the plastic bag filled with water that they examined in Activity One. Ask, *Did the bag have the same shape in water as on the table?* Students should be able to report that the bag was much flatter on the table. Follow by asking, *Why don't you and I flatten out on the floor, the way the bags did on the table?* Use students' answers to guide them into a discussion of support structures for living things, particularly animals. You might ask questions such as, *Do all animals have some kind of support for their bodies? When present, what do we call these supports?* (skeletons). *Are all skeletons the same? How are skeletons different?* (some are internal and some are external; some consist of many parts, others do not; some grow with the organism, others must be shed and replaced).

2. After students have had opportunities to think about the variety of support structures for animal bodies, challenge them to invent an animal using the "From the Outside In" sheet as a guide. Depending on your students, you may want them to investigate different types of animal bodies using the World Wide Web or the library before they proceed further.


Activity2

From the Outside In

You will be creating a skeleton for an imaginary animal, using the following materials or materials from home.

15 paper clips, 10 straws, 2 pieces cardstock, tape, clay, ruler, plastic bag or wrap, scissors

1. Imagine that the plastic bag is the body of your animal. Think about the shape that your animal might have. Draw the shape in the box labeled "Shape" below.
2. Make a skeleton for your animal, using any of the materials listed above. First, you must decide whether the skeleton will be inside (endoskeleton) or outside (exoskeleton) the animal's body. Next, think about how you will support the animal's shape by designing a skeleton. Make a plan for the skeleton in the box labeled "Skeleton" below or use the back of this sheet.

Shape | Skeleton

3. Now build the skeleton in or around your plastic-bag animal.
4. How does the skeleton change the animal?
5. What advantages does this skeleton give your animal?
6. What disadvantages does this skeleton give your animal?
7. How would you make your animal move?

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3. Each group of students will need to decide where its animal lives and how it looks (especially body shape). Once groups have discussed their ideas, they should decide which type of skeleton (external or internal) would serve their animals best. Finally, each group should draw a design or plan for its animal. Encourage students to be creative. Show students the supplies (see materials list) that will be available for creating their animals OR ask students to make a list of materials to bring from home to build their animals.

4. Once the groups' plans are completed, have the Materials Managers collect straws, plastic bag/plastic wrap, tape, scissors, clay, paper clips, cardstock and rulers for their groups from a central area in the classroom.

5. Have each group create its imaginary animal. Designate a time frame for this work.

6. Ask groups to display their animals and to describe how they designed their skeletons.

7. Draw a chart on the board with "Similarities" at the top of one column and "Differences" at the top of a second column. Ask the students to think about and discuss the similarities and differences of the various internal and external skeletons created by the groups.

8. Extend the discussion by drawing two more charts on the board: "Internal Skeleton—Advantages and Disadvantages," and "External Skeleton—Advantages and Disadvantages." Work with one chart at a time and ask students to respond.

9. Conclude by asking students to share their ideas about how their animals might move. Ask, *What allows us to move? What would we need to add to our animals so that they could move?* Help students understand that, in most cases, muscles and joints are necessary, in addition to endo- or exoskeletons, to achieve movement of a body.

### Internal Skeletons

**Advantages**

- **Grow with organism.**
- **Can be stronger and thicker than external plates or tubes.**
- **Store or manufacture other materials inside bones.**
- **Can support a large-sized body.**
- **Store minerals, like calcium.**

**Disadvantages**

- **Provide only limited protection of internal organs.**
- **Do not prevent water loss from body.**

### External Skeletons

**Advantages**

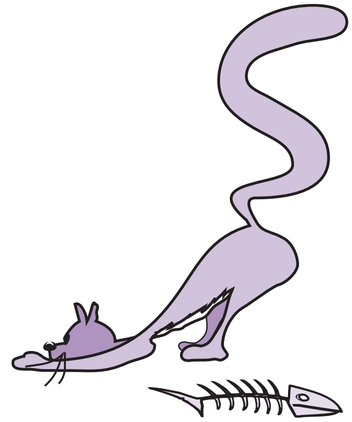
- **Serve as protection for soft body (except during molting).**
- **Prevent water loss from body.**

**Disadvantages**

- **Can make an animal temporarily vulnerable if old skeleton must be shed to accommodate growth.**
- **Limit animal size because the skeleton has to be very strong and heavy to support a large body. (The largest animals with exoskeletons, such as lobsters, are found where water helps support their weight.)**

## Activity 2

# From the Outside In



You will be creating a skeleton for an imaginary animal, using the following materials or materials from home.

| | | | |
|---|---|---|---|
| 15 paper clips | 10 straws | 2 pieces cardstock | tape |
| clay | ruler | plastic bag or wrap | scissors |

1. Imagine that the plastic bag is the body of your animal. Think about the shape that your animal might have. Draw the shape in the box labeled “Shape” below.
2. Make a skeleton for your animal, using any of the materials listed above. First, you must decide whether the skeleton will be inside (endoskeleton) or outside (exoskeleton) the animal’s body. Next, think about how you will support the animal’s shape by designing a skeleton. Make a plan for the skeleton in the box labeled “Skeleton” below or use the back of this sheet.

Shape | Skeleton

3. Now build the skeleton in or around your plastic-bag animal.
4. How does the skeleton change the animal?

________________________________________

5. What advantages does this skeleton give your animal?

________________________________________

________________________________________

6. What disadvantages does this skeleton give your animal?

________________________________________

________________________________________

7. How would you make your animal move?

________________________________________

________________________________________

## CONCEPTS
- Endoskeletons are made of connected bones inside a body.
- Bones provide support for the body.

## OVERVIEW
Students will learn about endoskeletons by observing, comparing and contrasting different kinds of chicken bones, and by relating their chicken bone observations to human bones.

## SCIENCE, HEALTH & MATH SKILLS
- Observing
- Comparing and contrasting
- Inferring


# 3. Inner Strength

## Background
Internal skeletons, or endoskeletons, must be strong enough to support a body against the pull of gravity. They also must be light and flexible enough to allow easy movement. Endoskeletons meet all these requirements by connecting bones of different shapes and sizes (flat, irregular, long, short) that provide support, allow freedom of movement, and protect many of the body's most vital internal organs.

With only a few exceptions, like the tailbone in humans, each bone fulfills a particular need. The skull protects the brain and sense organs (eyes, nose, mouth and ears). A flexible spine encloses and protects the spinal cord—the main highway for messages from the brain to the rest of the body. The rib cage surrounds the lungs, heart and other internal organs. Four limbs (arms and legs in humans) are joined to the spine via broad flat bones (shoulder blades and hip bones). Arms, legs and wings contain some of the longest and strongest bones in vertebrates. More than half of the 206 bones in the adult human body can be found in the limbs.

Vertebrate skeletons are comprised primarily of cartilage and bone. Cartilage is firm, but flexible. The skeletons of most embryos are made of cartilage, which gradually is replaced by a harder material—bone. Bone is living tissue that changes in response to exercise and use.

## Time
20 minutes, one day ahead of time, for set-up; 45–60 minutes to conduct activity

## Materials
Each group will need:
- at least one chicken bone that has been cooked and cleaned (see Set-up)
- magnifiers
- blank paper or science journals to make drawings and record observations
- copies of "Chicken Bones" and "Head-To-Toes" student sheets

## Set-up and Management
Before class, cook enough chicken pieces to provide one or more different bones (any sizes or shapes) to each group of students. You also may have students bring leftover cooked chicken bones from home. Remove all meat from the bones (additional boiling may be necessary) and soak the bones in a 1:10 bleach/water solution for five minutes. Allow the bones to dry before using them in class. After the activity, save any long leg or wing bones to use again during Activity 4. Have students work in groups of 2–4.

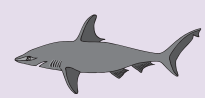
## Procedure
1. Remind students of the skeletons they constructed in Activity Two. Ask, *What kind of skeleton do vertebrate animals* (animals with backbones) *have?* (endoskeleton). *What are some examples of vertebrates?* (fish, birds, reptiles, amphibians, mammals).

2. Distribute cleaned chicken bones.

### Bone To Stone
**Most plant and animal remains rot away over time. Hard parts, such as bones and shells, sometimes become buried in sand and mud. Over millions of years, the shells and bones become transformed into stone. We call them fossils.**

---

**Some animals, like sharks, maintain a skeleton made of**



**cartilage throughout their entire lives. Some parts of our bodies also are made of cartilage that never becomes bone. Some examples include the outer ear, the ends of the ribs and the nose. Why might it be important for these structures to stay flexible?**

3. Direct the groups to observe the bones carefully with and without their magnifiers. Ask questions to promote careful observations, such as, *What color are the bones? Are the bones as hard as rock? Does the surface texture vary along the length of the bone?* (Students may be able to observe that the ends of some bones are porous, while other parts are smooth.) *Can you see softer parts* (cartilage) *attached to any of the bones?* (Ribs, for example, will have flexible cartilage tips.)

4. Have each student make a detailed drawing or written description of a single bone. Challenge students to think about where the bones they observed would be found in a chicken's body. Discuss their observations.

5. Make a class list of the similarities among the different bones observed. Follow by making a list of the differences.

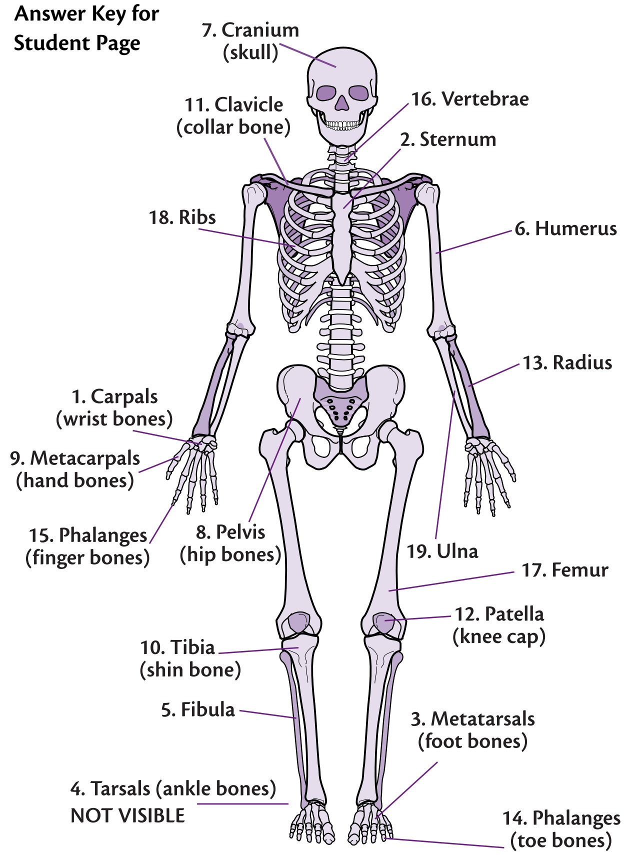
6. Give each student a copy of the "Chicken Bones" page and have students identify the bones they observed. Ask, *Were you able to predict the location of the bones you observed? What helped you decide where the bones would be found?*

7. Next, ask students to think about the human skeleton. Ask, *Do you think human skeletons are very different from chicken skeletons? Why or why not?* Make an overhead transparency or give each student a copy of the "Head-to-Toes" page. Have students compare the drawing of the human skeleton to the drawing of the chicken skeleton and identify similarities and differences.

8. Using context clues from the poem, help students fill in the appropriate names for the major bones of the body. You may want to have students read the poem aloud or write additional verses.

9. Discuss the human skeleton with students. Have them notice that bones are precisely arranged with bilateral symmetry. Point out that we have pairs of bones. Ask, *Why is this structure a good design for us to maintain balance? Did anyone build an unsymmetrical skeleton* (Activity 2)? Help students understand that the symmetrical skeleton provides balance and potential for mobility.

**SKELETAL SYSTEM—**
**Answer Key for Student Page**

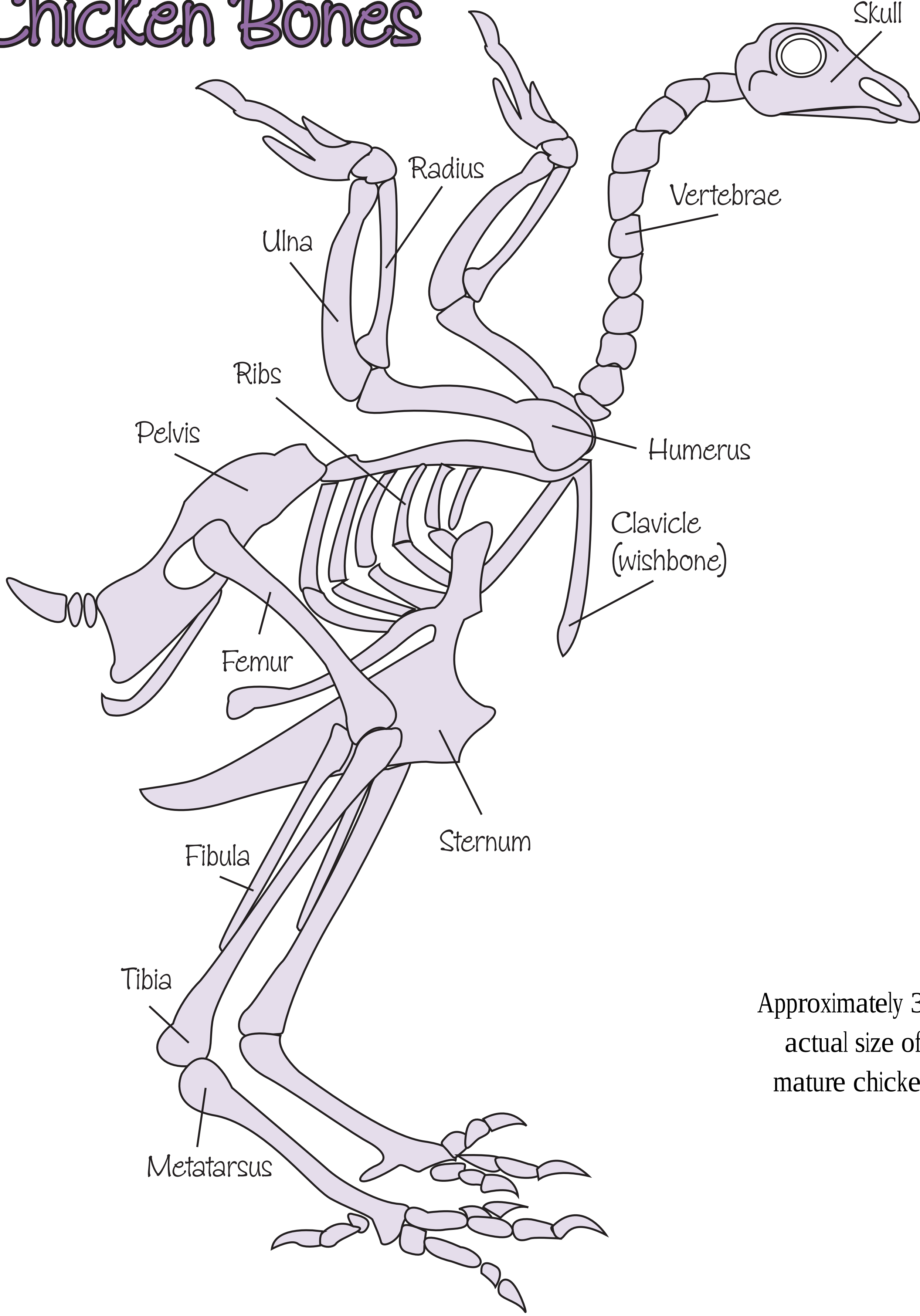



**Bones come in many varieties, so they are grouped according to shape: long (arm and leg bones); short (wrist and ankle bones); flat (ribs and bones of the skull); and irregular (vertebrae). The skeletons of many different animals look very similar and contain close to the same number of bones.**

**Living things often are symmetrical in one or more ways. Many animal bodies are composed of two halves that are mirror images of each other. This is called bilateral (two-sided) symmetry.**

Activity 3

# Chicken Bones

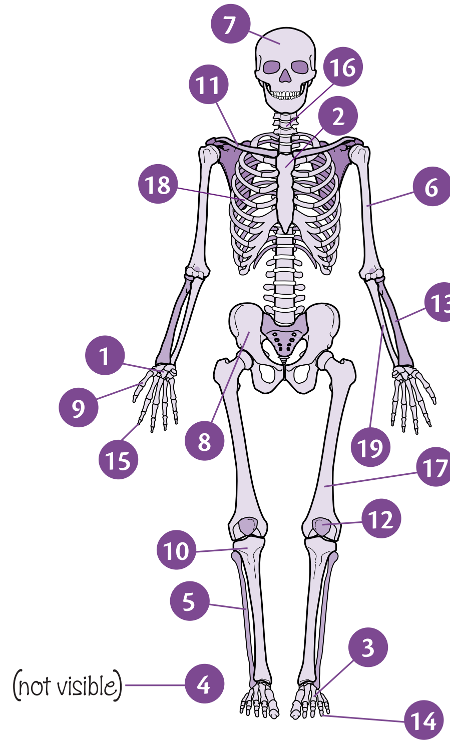



Approximately 3/5
actual size of
mature chicken

# Activity 3

# Head-To-Toes

By Amanda Byers, Barbara Tharp and Paula Cutler




The bones are very important, you know. They hold up your body from your head to your toe.

The **cranium**, the skull, that's the head of the matter—it's connected to **vertebrae** that down your back scatter.

Your chest is made of arches, 12 sets of **ribs** to be exact—from backbone to the **sternum**, 'round the body they do wrap.

The **clavicle** is your coat hanger, with a **humerus** on each side. The bottom end's an elbow—a "funny bone" that tingles when with objects it collides.

Below the elbow, are the **ulna** and the **radius**, too; a pair that span the forearm on either side of you.

Bones at the wrist are the **carpals**—to the **metacarpals** they connect. They're attached to the **phalanges**—the fingers that get flexed.

Your hip bones are your **pelvis**; your **femur** shapes up your thighs. You need your knobby kneecaps—on your **patella**, you can rely.

The **tibia** and the **fibula** are the lower legs' two bones. They are side-by-side together 'cause neither stands alone.

The feet, upon which you can stand with ease, have the **tarsals**, **metatarsals** and more **phalanges**.

Where bones do meet is called a joint, and there are many types. Fixed joints hold your skull bones in place so your brain stays nice and tight!

There are hinge and ball and socket joints that let your bones move 'round. Without shoulders, elbows, knees and ankles, you'd flatten on the ground.

The Skeletal System is the frame that gives your body shape. It holds you altogether, even better than duct tape!

**1.** ______________________

**2.** ______________________

**3.** ______________________

**4.** ______________________

**5.** ______________________

**6.** ______________________

**7.** ______________________

**8.** ______________________

**9.** ______________________

**10.** ______________________

**11.** ______________________

**12.** ______________________

**13.** ______________________

**14.** ______________________

**15.** ______________________

**16.** ______________________

**17.** ______________________

**18.** ______________________

**19.** ______________________

## CONCEPTS

- Long bones are made of hollow tubes, which give strength with minimal weight.

## OVERVIEW

Students will investigate and compare the weight-bearing capacity of solid and hollow cylinders, make inferences about bone structure and observe the interior of cleaned long bones of chickens.

## SCIENCE, HEALTH & MATH SKILLS

- Predicting
- Observing
- Comparing
- Weighing
- Gathering data
- Recording data

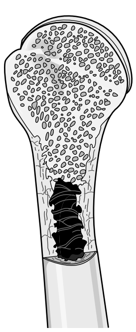
# 4. Round, Light and Hollow

## Background

Bones are living tissues that contain blood vessels and nerve cells within a structure composed of collagen (a flexible fibrous material) and minerals (mainly calcium and phosphate). Without calcium (in the form of calcium salts), bone would be flexible and soft, and without collagen fibers, bone would be brittle. The collagen fibers and calcium salts together make bone almost as strong as steel, but much lighter. Unlike steel, bone can repair itself when broken with the help of bone-forming cells (osteoblasts) and bone digesting cells (osteoclasts). The prefix "osteo" means bone.

To provide support and still be easy to move, bones must be both strong and lightweight. These features are most important for the long bones in arms, legs and wings.

Each human long bone is composed of a shaft (diaphysis) with two flared ends (epiphyses). The diaphysis resembles a hollow cylinder. It is made of hard compact bone that is resistant to bending. The inner cavity of the diaphysis contains yellow marrow that stores fat. The epiphysis is a thin shell of compact bone filled with a lattice or sponge-like structure that is surrounded by red marrow (which makes red blood cells).



## Time

10 minutes for set-up; one or two sessions of 45–60 minutes for activity

## Materials

Teacher will need:
- heavy-weight balance or bathroom scale
- poultry scissors or small saw

Each group will need:
- 2 bathroom-sized paper cups
- 6–10 heavy, stackable items (bricks, cans, reams of paper or books)
- 1/3 cup dried beans
- sheet of corrugated cardboard
- 1 long bone from a chicken leg or thigh that has been cooked and cleaned (see Set-up)
- magnifiers
- copy of "Weighing 'In'" and "Hollow or Solid?" student sheets

## Set-up and Management

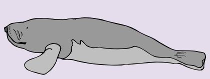
If you wish, you can use the long bones prepared for Activity 3. Otherwise, before class, cook enough chicken legs or thighs to provide one long bone to each group, or have students bring leftover cooked chicken bones from home. Remove all meat from the bones (additional boiling may be necessary) and soak them in a 1:10 bleach/water solution for five minutes. Have students work in groups of 2–4. Place all materials in a central location.

## Procedure

1. Point to your arm or leg and ask students to think about characteristics

**A group of special cells constantly breaks down and rebuilds bones throughout life. This process is important because it allows bone to repair damage and to respond to changes in its environment, including changes in physical activity.**

**Manatees and their relatives live and feed in water. Their rib and**



**leg bones lack marrow cavities, making their skeletons dense and relatively heavy. Water, however, helps support the weight of their bodies.**

that might be important for large arm or leg bones. Stimulate their thinking by asking questions such as, *What type of work does my arm/leg do? Does it matter how much the bones in my arm/leg weigh? Does it matter if my arm/leg bones are very strong?* Based on students' answers, make a list of desirable characteristics of long bones.

2. Tell students they will be conducting an investigation that will provide clues about the structure of long bones in humans and other vertebrates. Specifically, they will be comparing the relative abilities of solid and hollow cylinders to support external weights. Ask, *Is a hollow cylinder or a solid cylinder able to support more weight, relative to its own weight?*

3. Have each group's Materials Manager and a helper collect two paper cups, beans, cardboard and a set of weights from a central location. Using the "Weighing 'In'" sheet as a guide, have students compare the weights that can be supported by a hollow cylinder (empty cup) and a solid cylinder (cup filled with dried beans). Each group should conclude its explorations by calculating the ratio of weight supported to cylinder weight for each kind of cylinder.

4. Initiate a class discussion of students' results by asking, *Which cylinder was heaviest?* (solid), and *Which cylinder held the most weight?* (solid). *Did either cylinder hold more weight than you expected? Which cylinder had a higher ratio of weight supported?* (hollow). *Did you expect this result?*

5. Ask students to think about which type of cylinder (hollow or solid) might make a better bone. Pass out the "Hollow or Solid?" sheets. Have students record their predictions about the structure of long bones (hollow or solid).

6. Have the Materials Managers pick up one or more chicken bones for their groups. Have students observe the outsides of the bones with and without a magnifier, and draw an exterior view of a bone in the space provided on their sheets.

7. Using a small saw, hammer or poultry scissors, cut or break open the bone(s) for each group. Students will observe that the bones have hard walls and a central space filled with a soft substance (marrow). Ask students to compare the structure of the bone to the hollow and solid cylinders. Ask, *Which cylinder does the bone most resemble?* Help students to conclude that the relatively hollow design of real bones allows them to be light, but still strong enough to do their jobs. Relate students' conclusions to the list of valuable characteristics of bones made earlier.

## Extensions

- The thighbone (femur) is the longest bone in the body. Its shaft is round in cross section. The main shinbone (tibia) is the second longest bone in the body. Its shaft is triangular in cross section. Challenge students to investigate the relative strengths of different-shaped columns. Have students use note cards to create columns with different shapes in cross section (round, square, triangular, etc.). Ask them to consider the total amount of material necessary to build each kind of column as they reach their conclusions about relative strength.
- To observe how calcium contributes to the hardness of bones, have students soak cleaned chicken bones in vinegar for about one week. Vinegar, a weak acid, will leach calcium out of the bones, which then will become weaker and softer.

**The mineral calcium gives bones their hardness. People between 11 and 24 years of age need 1,200 milligrams of calcium (three or more servings of calcium-rich foods) each day. Sources of calcium include low-fat dairy products, sardines, green leafy vegetables and nuts.**

### Losing Calcium?

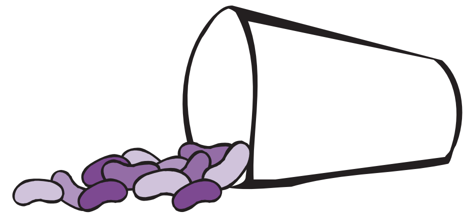
**Chalk is brittle and snaps apart easily. A chicken bone will not snap in half the same way. Although a chicken bone has calcium salts like chalk, the bone also has collagen fibers that make it stronger.**


**When we remove calcium salts from bone, it becomes flexible and cannot maintain its shape to provide support.**

**Babies' bones are very soft and are made of cartilage. Over time, cartilage is broken down and replaced with bone.**

## Activity 4

# Weighing "In"



You will need:

2 paper cups
dried beans
one piece of cardboard
balance
one set of stackable weight units (cans, bricks, etc.)

You will use stackable weight units to investigate the support strength of hollow and solid cylinders.

1. Fill one paper cup to the top with beans. This will be your solid cylinder. The other (empty) cup will be your hollow cylinder.
2. Use a balance to weigh each cylinder and one stackable-weight unit. Record the weights in the table on the right.
3. Predict how many units (bricks, books or cans) each cylinder will support. Record your predictions in the table below.

| | |
|---|---|
| Solid cylinder (with beans) | gm |
| Hollow cylinder | gm |
| One stackable-weight unit | gm |

4. Place your hollow cylinder on the floor and cover it with a piece of cardboard, so that the cardboard is centered over the cylinder. Place the weight units on top of the cardboard, one at a time. Balance the weights carefully so that your experiment does not topple over. See how many units of weight the cylinder will hold before it is crushed. Record this number below.
5. Repeat Step 4 using the solid cylinder instead of the hollow cylinder.
6. Determine the ratio of weight supported by each cylinder. Divide the total number of weight units supported by the cylinder, by the weight of that cylinder. Record your answers below.

| | Hollow cylinder | Solid cylinder |
|---|---|---|
| PREDICTION: Number of units each cylinder will support | | |
| Number of units supported by each cylinder | | |
| Total weight of units each cylinder supported | | |
| Weight of cylinder | | |
| Number of units supported ÷ Weight of cylinder | | |

7. Which cylinder was heavier?

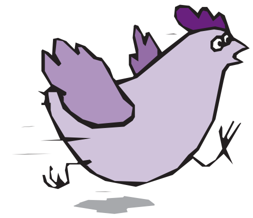
_______________________________________________

8. Which cylinder is able to support more weight, relative to its own weight?

_______________________________________________

## Activity 4

# Hollow or Solid?



1. Based on what you know, do you predict that real bones are solid or hollow?

2. Give a reason for your prediction.

3. Obtain a cooked, cleaned chicken leg bone. Follow the instructions underneath the boxes below.

Observe and draw the outside of the bone.

Have your teacher break open the bone. Draw what you see inside the broken end.

4. Are real bones solid or hollow?

5. What might be some advantages of this structure?

## CONCEPTS

- Bones come together at joints.
- The position of a muscle affects the amount of movement it causes a bone to make.
- Muscles work in pairs, in opposition to each other.

## OVERVIEW

Students will construct a model arm and learn how muscles and bones work together to achieve efficient movement.

## SCIENCE, HEALTH & MATH SKILLS

- Predicting
- Observing
- Drawing conclusions
- Modeling
- Inferring

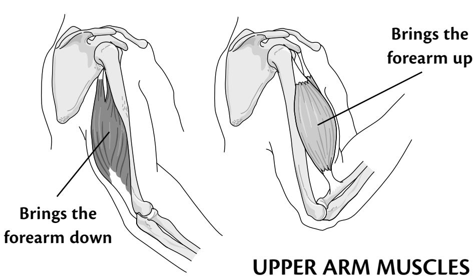

# 5. The Power of Togetherness

## Background

In a skeleton, the places where bones or external plates (as in insects) come together are called joints. Joints allow an animal's body to flex and bend. Most animals, whether they have exoskeletons or endoskeletons, have joints.

In vertebrate skeletons, some bones, such as those in the skull, are connected at joints that do not allow movement. These "immovable" joints are called sutures. Most bones, however, are connected by ligaments at "moveable" joints that permit bone movement. Of course, the moving is done by muscles, which are attached directly or by tendons to the bones.

Muscles move the parts of a joint by contracting (becoming shorter) and




UPPER ARM MUSCLES

pulling two bones closer together. Since each muscle can pull in only one direction (and not push), muscles must work in pairs. One muscle or group of muscles bends part of a joint; a different muscle or group of muscles pulls it back to its original position. Muscle placement is very specific to optimize maneuverability and strength.

Our bodies can be thought of as machines. We lift, push and pull objects, and we work continuously to maintain posture and balance against the force of gravity. Bones, muscles, joints, ligaments and tendons all are necessary to do this work. In fact, there are simple machines within the body's component parts. One example is the arm, which is a lever.

This activity allows students to explore how the arm's bones and muscles work efficiently together. Students will see that muscles are positioned to achieve the most movement or power with the least possible effort.

## Time

10 minutes for set-up; 60 minutes to conduct the activity

## Materials

Each group will need:

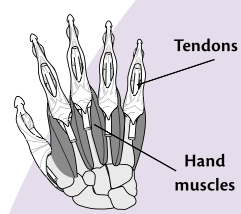
- copy of "Arm Model Instructions" and "Arm Model Observations" sheets
- 3 rulers (with holes in the center)
- metal paper clip
- 50 cm of string
- large brad
- scissors
- clear tape

## Set-up and Management

Divide students into groups of 2–3. Place

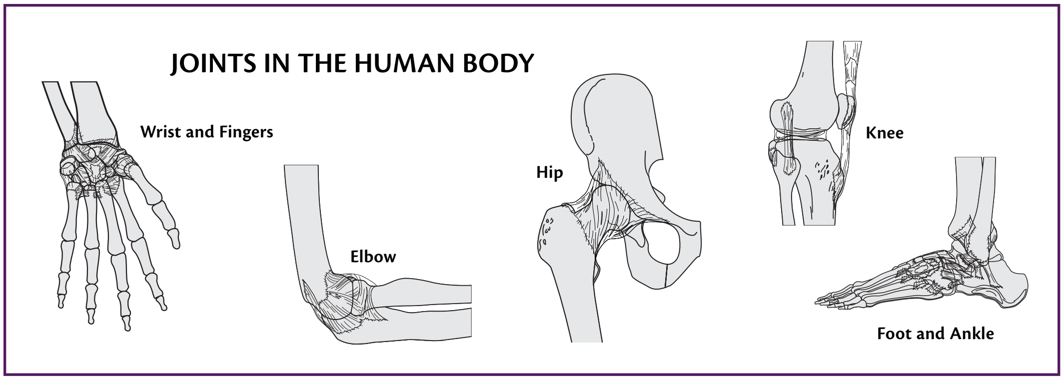
### It's a Snap!

**There are almost no muscles in your fingers. The muscles**




**that move your fingers are in your arms. These muscles have very long tendons that attach to the bones in your fingers. (Other muscles are located in the palm of your hand.)**

**You can see something similar in a chicken foot from the grocery store. The long, white fibers extending from the end are tendons. Pull them and you will see the claws curl.**

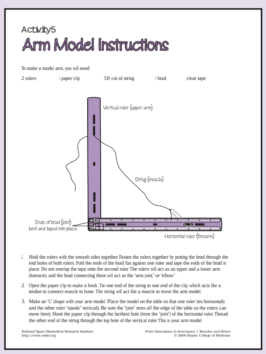



materials in a central location for the Materials Manager from each group to collect.

## Procedure

1. Tell students that they are going to build and explore a model of the arm. Have Materials Managers collect the rulers, string, paper clip, brad and tape for each group.

2. Tell students to follow the steps on the "Arm Model Instructions" sheet to make their model arms.

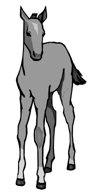



3. When each group has built its model arm, ask, *In what ways does this model represent a human arm?* Discuss the similarities and differences noted by students between their models and their real arms. Point out that actual muscles pull by contracting and becoming shorter.

4. Explain to students that they will investigate muscle attachment sites using their model arms. Have them continue with the instructions on the "Arm Model Observations" sheet.

5. Discuss with students their data and conclusions about muscle attachment sites. Students will discover that moving the string on their arm model will move the bottom ruler different distances, depending on where the string is attached. Students also may notice that when the string was connected closer to the joint, it was harder to pull. Ask students how these concepts might apply to the placement of the biceps muscle in the arm. Explain that each muscle in the body has a precise attachment point. Muscle placement balances the movement of the bone with the effort of the muscle. The points at which muscles attach to bones allow muscles to cause a large movement with a relatively small amount of contraction.

6. Use the "Challenge" at the bottom of the "Arm Model Observations" sheet to help students learn about how muscles work in pairs. After students have completed the "Challenge," discuss the relationships between pairs of muscles. For instance, the biceps muscle bends the arm and the triceps muscle straightens it. Ask, *How do we straighten the arm after bending it?* Have students bend their arms at the elbow and feel their biceps muscles contract. Ask, *Can you straighten your arm by contracting your biceps muscle? Where is the muscle that you contract to straighten your arm?* It is the triceps muscle, located on the back of the upper arm. Have each student bend and straighten his/her arm and feel the triceps muscle contract and relax.



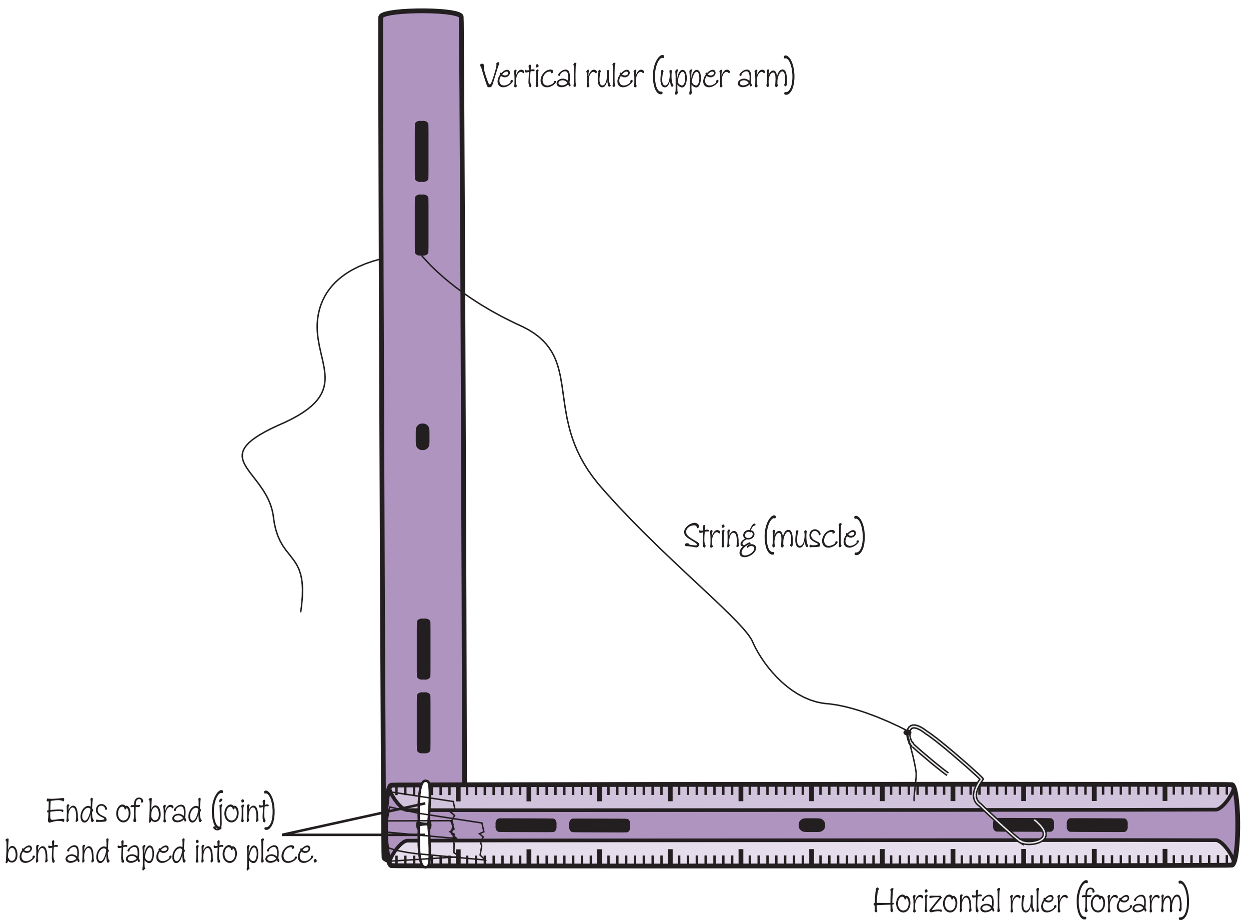
**Horses have a joint in their knees (stifle joint) that allows them to lock their knees in place so they can stand for hours. Animals, like goats and cows, that eat plants have a joint that allows them to move their jaws side-to-side and forward and back, in addition to up and down, for chewing.**

**Activity 5**

# Arm Model Instructions

To make a model arm, you will need:

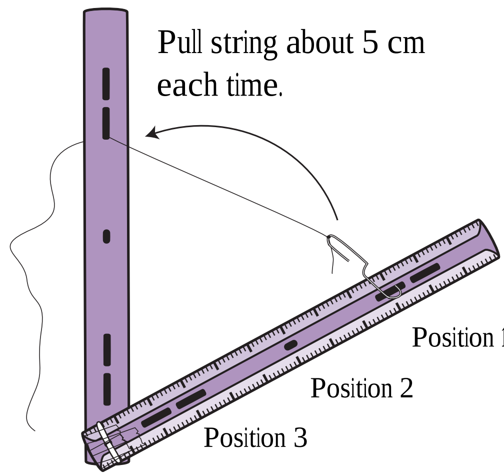
2 rulers 1 paper clip 50 cm of string 1 brad clear tape




1. Hold the rulers with the smooth sides together. Fasten the rulers together by putting the brad through the end holes of both rulers. Fold the ends of the brad flat against one ruler and tape the ends of the brad in place. Do not overlap the tape onto the second ruler. The rulers will act as an upper and a lower arm (forearm), and the brad connecting them will act as the "arm joint," or "elbow."
2. Open the paper clip to make a hook. Tie one end of the string to one end of the clip, which acts like a tendon to connect muscle to bone. The string will act like a muscle to move the arm model.
3. Make an "L" shape with your arm model. Place the model on the table so that one ruler lies horizontally and the other ruler "stands" vertically. Be sure the "joint" rests off the edge of the table so the rulers can move freely. Hook the paper clip through the farthest hole (from the "joint") of the horizontal ruler. Thread the other end of the string through the top hole of the vertical ruler. This is your arm model.

## Activity 5

# Arm Model Observations




You will need:

arm model ruler

You will investigate what happens when you connect the string to different places on your arm model.

1. Place your arm model on a table or desk. Slowly pull about five centimeters of string through the hole in the top ruler (Position 1), while holding the "elbow joint" of the rulers steady. This will raise the tip of the bottom ruler. Measure the distance between the tip of the bottom ruler and the table. Record your measurement on the chart below.

2. Move the paper clip to the middle hole (Position 2) of the bottom ruler. Again pull about five centimeters of string through the hole in the top ruler. Measure the distance between the tip of the bottom ruler and the table. Record your measurement on the chart.

3. Move the paper clip to the closest hole (Position 3) of the bottom ruler. Pull about five centimeters of string through the hole in the top ruler. Measure the distance between the tip of the bottom ruler and the table. Record your measurement on the chart.

| Ruler position | Distance ruler is raised from table (cm) |
|---|---|
| Position 1: Farthest hole from "joint" | |
| Position 2: Middle hole | |
| Position 3: Closest hole to "joint" | |

4. Based on your observations, does it make a difference where the ends of a muscle are connected to a bone? Why or why not?

_______________

_______________

_______________

5. Where would you expect the ends of a muscle to be attached if the objective was to achieve the most movement for the least amount of effort?

_______________

_______________

**CHALLENGE:** Figure out a way to connect another string "muscle" to your arm model that would straighten the arm back out. Keep in mind that muscles can only pull, not push!

## CONCEPTS
- Muscles are made of fibers within fibers.
- The structure of muscles makes them strong.

## OVERVIEW
Students will learn about the structure of muscles by comparing yarn and cooked meat.

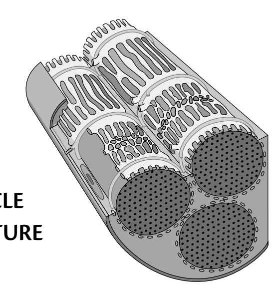
## SCIENCE, HEALTH & MATH SKILLS
- Observing
- Modeling
- Inferring


# 6. Muscle Fibers

## Background
Despite our amazing skeletons, without muscles, we would not be able to stand, balance ourselves or move. Every person has more than 600 muscles thoughout his or her body.

Movement happens when muscles contract and become shorter. As seen in the previous activity, the contraction moves the two places of muscle attachment closer together. These types of contractions take place countless times each day in the body.

Skeletal muscles (the ones responsible for movement of the body) are made of bundles of progressively smaller fibers. The largest fiber bundles can be seen with the unaided eye in a piece of muscle tissue or meat. The "strings" that can be teased (pulled) apart are bundles of fibers.



MUSCLE STRUCTURE

Within these large bundles are numerous muscle cells (also called fibers). Each muscle cell is filled with hundreds of even smaller strands (myofibrils). The myofibrils contain the smallest muscle elements of all—tiny units (sarcomeres) that become shorter by sliding one set of protein molecules over another. Added together, all of the minute contractions shorten the length of the entire muscle.

This activity introduces students to the structure of muscles by having them compare and contrast the structure of yarn to the structure they can observe in a cooked piece of beef stew meat or other coarse meat.

## Time
20 minutes for set-up; 45 minutes to conduct activity

## Materials
Each group will need:
- 12-in. section of yarn
- 4 toothpicks
- plastic knife
- cube of cooked beef (stringy or fibrous cuts such as brisket, flank steak or stew meat work best); approximately 1/2 pound is sufficient for an entire class
- copies of "A Simple Yarn" student page

## Set-up and Management
Cook beef brisket or stew meat in advance for students. Each group should have at least one, 1-inch cube of cooked meat to observe. Place all materials in a central location for students. Have students work in groups of 2–4.

## Procedure
1. Ask students, *Have you ever seen muscle? What does it look like?* If necessary, remind students that "meat" is muscle tissue and that many different kinds of muscle are on display at

### Human Muscle Facts!

**There are 30 different muscles in your face that allow you to do things like smile, frown and raise your eyebrows.**

**Muscle attached to bone (called skeletal muscle) is the most abundant tissue in the bodies of vertebrates (animals with backbones).**

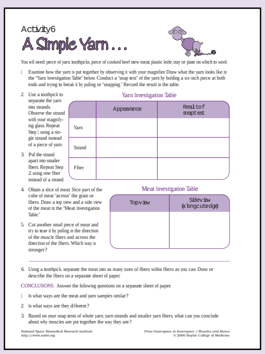
**Training with weights can double or triple a muscle's size. Disuse, such as during space travel, can shrink a muscle by as much as 20% in just two weeks.**

**As people age, their muscle mass shrinks. By age 50, skeletal muscle often is reduced by around 10%. By age 80, almost half of a person's muscle mass can be lost.**

the grocery store. Follow by asking, *Which characteristics of muscle help make it strong?* Tell students that they will be investigating one aspect of this question.

2. Give each group of students a length of yarn, toothpicks and a small cube of cooked beef brisket or stew meat.

3. Have students follow the instructions on the "A Simple Yarn" page to observe the structure of yarn. They should progressively tease apart and test the relative strength of the strands comprising the length of yarn. Have them use a "snap" test, in which they hold the strand between both hands and quickly pull or "snap" it, to estimate the strength of each size of strand.



Activity 6

A Simple Yarn . . .

You will need: piece of yarn, toothpicks, piece of cooked beef stew meat, plastic knife, tray or plate on which to work

1. Examine how the yarn is put together by observing it with your magnifier. Draw what the yarn looks like in the "Yarn Investigation Table" below. Conduct a "snap test" of the yarn by holding a six-inch piece at both ends and trying to break it by pulling or "snapping." Record the result in the table.
2. Use a toothpick to separate the yarn into strands. Observe the strand with your magnifying glass. Repeat Step 1, using a single strand instead of a piece of yarn.
3. Pull the strand apart into smaller fibers. Repeat Step 2, using one fiber instead of a strand.

Yarn Investigation Table

| | Appearance | Result of snap test |
|---|---|---|
| Yarn | | |
| Strand | | |
| Fiber | | |

4. Obtain a slice of meat. Slice part of the cube of meat "across" the grain or fibers. Draw a top view and a side view of the meat in the "Meat Investigation Table."
5. Cut another small piece of meat and try to tear it by pulling in the direction of the muscle fibers and across the direction of the fibers. Which way is stronger?

Meat Investigation Table

| Top view | Side view (along cut edge) |
|---|---|
| | |

6. Using a toothpick, separate the meat into as many sizes of fibers within fibers as you can. Draw or describe the fibers on a separate sheet of paper.

CONCLUSIONS. Answer the following questions on a separate sheet of paper.

1. In what ways are the meat and yarn samples similar?
2. In what ways are they different?
3. Based on your snap tests of whole yarn, yarn strands and smaller yarn fibers, what can you conclude about why muscles are put together the way they are?

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4. After students have made their yarn observations, direct their attention to the cooked piece of meat. Have a student in each group slice the meat across the grain using a plastic knife. Students should observe and draw the meat cross section on their sheets. They will note that the muscle looks stringy. The strings are the large fibers of the muscle. They may see white, rubbery tendons attached to the muscle, or fat, which is a source of energy, along with the fibers.

5. Next, have students tease a section of meat into progressively smaller fibers. Have students observe the fibers using their hand lens and draw the fibers on their student page. Have students explore the strength of the meat by pulling it in two different directions (along the grain and across the grain).

6. Discuss students' observations with the class. Ask, *In what ways were the yarn and muscle sections similar? Did the fiber-within-fiber design of the yarn make it stronger or weaker? Why? What does this imply for the structure of muscles?*

7. Conclude by discussing how muscles contract. Point out that unlike the yarn fibers, which are not very stretchy, muscle fibers can shorten. To demonstrate, have students extend their arms and feel the muscle (biceps) in their upper arms. Ask them to bend their arms at the elbow and notice any changes that occur in their muscles. Help them understand that muscles become short and fat when they contract. Explain that, unlike yarn, muscles are made of a series of fibers packaged inside each other. The largest fibers were the ones the students were able to observe in class. Inside each larger fiber are smaller and smaller fibers. Finally, inside the smallest fibers are tiny filaments that make the whole muscle change shape. The number of filaments determines how big and strong the muscle is.

## Extensions

- Have students compare other meats to the one observed in class. The color of uncooked meat (redder or whiter) depends on the kinds of fibers present. Red or "dark" muscle has more fibers that are specialized for long-term or repetitive activity without fatigue. These muscle fibers release energy from stored fat. White muscle has more fibers specialized for very fast contractions. These fibers, however, provide power for only a short period of time before they become fatigued from lack of oxygen and accumulation of waste products. White muscle uses energy from sugar.

**Animals with endoskeletons also need muscles to**

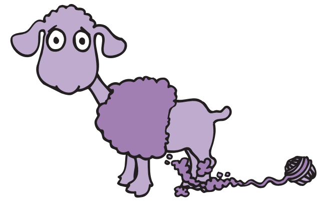
**move wings, legs and jaws. Even clams and oysters have powerful muscles that open and close the two halves of their shells.**

### Safety Note

**You may want students to wear disposable, plastic gloves when they handle meat samples.**

## Activity 6

# A Simple Yarn . . .



You will need: piece of yarn, toothpicks, piece of cooked beef stew meat, plastic knife, tray or plate on which to work

1. Examine how the yarn is put together by observing it with your magnifier. Draw what the yarn looks like in the "Yarn Investigation Table" below. Conduct a "snap test" of the yarn by holding a six-inch piece at both ends and trying to break it by pulling or "snapping." Record the result in the table.
2. Use a toothpick to separate the yarn into strands. Observe the strand with your magnifying glass. Repeat Step 1, using a single strand instead of a piece of yarn.
3. Pull the strand apart into smaller fibers. Repeat Step 2, using one fiber instead of a strand.

### Yarn Investigation Table

| | Appearance | Result of snap test |
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| Yarn | | |
| Strand | | |
| Fiber | | |

4. Obtain a slice of meat. Slice part of the cube of meat "across" the grain or fibers. Draw a top view and a side view of the meat in the "Meat Investigation Table."
5. Cut another small piece of meat and try to tear it by pulling in the direction of the muscle fibers and across the direction of the fibers. Which way is stronger?

### Meat Investigation Table

| Top view | Side view (along cut edge) |
|---|---|
| | |

6. Using a toothpick, separate the meat into as many sizes of fibers within fibers as you can. Draw or describe the fibers on a separate sheet of paper.

CONCLUSIONS. Answer the following questions on a separate sheet of paper.

1. In what ways are the meat and yarn samples similar?
2. In what ways are they different?
3. Based on your snap tests of whole yarn, yarn strands and smaller yarn fibers, what can you conclude about why muscles are put together the way they are?

## CONCEPTS

- Gravity pulls down on all objects on Earth, including the bodies of organisms.
- Muscles work against gravity.
- Center of gravity is the point around which all the weight of an object is equally distributed.

## OVERVIEW

Students will learn about center of gravity and how the body adjusts to the force of gravity to remain balanced.

## SCIENCE, HEALTH & MATH SKILLS

- Predicting
- Observing
- Gathering and recording data
- Drawing conclusions

# 7. Gravity and Muscles

## Background

Gravity places a heavy load on the human body. Only through coordinated muscle movement is the body able to counteract the downward pull of gravity and remain upright. Muscles in the back, legs, ankles and feet are used most. The nervous system tells these muscles which changes to make to help the body maintain posture and balance during movement.

To balance itself, the body makes tiny adjustments to maintain its center of gravity over the feet. The center of gravity is an imaginary point within the body at which there is balance and from where the weight on all sides is equal. Fortunately, the minor muscle adjustments necessary to maintain balance and posture are made automatically.

## Time

10 minutes for set-up; 60 minutes to conduct activity

## Materials

**Part 1**

Each team of 2 students will need:

- copy of "Balancing Act" student sheet
- meter stick
- standard weight items such as heavy coins, washers, etc.
- masking tape

**Part 2**

Each group will need:

- light-weight chair
- copies of "Balancing You!" sheet

## Set-up and Management

Place meter sticks, weights and masking tape in a central location. Have students work in pairs.

## Procedure

**Part 1. Balance, Weight and Stability**

1. Ask students, *Do you usually fall over when you are walking, riding a bicycle or standing on a bus? Why?* Encourage students to think about how the body coordinates balance. Ask, *Do you need muscles to keep your balance? Would your skeletal system alone be able to keep you upright in a moving vehicle?* Explain to students that they will be investigating balance and stability using different amounts of weight and meter sticks (Part One) and that they will be learning how living things use muscles and body position to maintain balance (Part Two).

2. Tell each Materials Manager to collect weights, masking tape and a meter stick for her/his group.

3. Instruct one student in each group to hold the meter stick horizontally by supporting it with one index finger at each end. Have the student move his/her fingers slowly toward each other, keeping the stick balanced until the fingers meet. Explain that the point where the fingers meet is the balance point for the stick. In other words, the balance point is the place

**To keep from toppling over, an object's center of gravity must stay above the area outlined by the object's base. This is why you will fall over if you lean too far forward. Once your center of gravity is beyond the limits of the base defined by your feet, you lose your balance and stability. This is why people will stand with their feet farther apart (and thus widen their "base") to keep their balance in a moving bus or train.**

**NASA scientists find it crucial to have a weightless environment for some of their experiments. They use tall towers, long tubes, rockets and airplanes, as well as spacecraft, to create artificial weightless environments.**

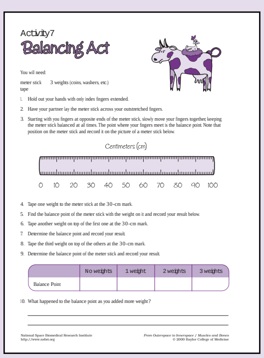
**Astronaut Mary Ellen Weber, STS-101 mission specialist, is shown onboard KC-135 during a brief period of weightlessness afforded by one of the parabola patterns flown repeatedly by the NASA aircraft. Weber is testing a device for stabilizing herself when she operates the robotic arm aboard the Space Shuttle Atlantis.**

*(Photo courtesy of NASA)*

where the weight on each side is equal and the object is balanced. Have the students in each team record the balance point for their meter stick.

4. Next have students tape one weight on the 30-cm mark of the meter stick. Ask students to predict where the new balance point will be and to record their predictions. Have them determine the new balance point of the meter stick as before and record it.

5. Have students add another weight to the one already on the meter stick and repeat the process. They should repeat the experiment one more time with three weights on the meter stick.



Activity7
Balancing Act

You will need:
meter stick 3 weights (coins, washers, etc.)
tape

1. Hold out your hands with only index fingers extended.
2. Have your partner lay the meter stick across your outstretched fingers.
3. Starting with you fingers at opposite ends of the meter stick, slowly move your fingers together, keeping the meter stick balanced at all times. The point where your fingers meet is the balance point. Note that position on the meter stick and record it on the picture of a meter stick below.

Centimeters (cm)
0 10 20 30 40 50 60 70 80 90 100

4. Tape one weight to the meter stick at the 30-cm mark.
5. Find the balance point of the meter stick with the weight on it and record your result below.
6. Tape another weight on top of the first one at the 30-cm mark.
7. Determine the balance point and record your result.
8. Tape the third weight on top of the others at the 30-cm mark.
9. Determine the balance point of the meter stick and record your result.

| | No weights | 1 weight | 2 weights | 3 weights |
|---|---|---|---|---|
| Balance Point | | | | |

10. What happened to the balance point as you added more weight?

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6. Direct students' attention to their data sheets and ask, *What happened to the balance point of the meter stick as more weight was added?* [the balance point moved toward the added weight]. *What would have happened if you had not moved your finger to find a new balance point?* [meter stick would have fallen]. Help students understand that, in order to stay balanced, the weight of each end of the meter stick had to be equal. The only way to achieve this when more weight is added is to move the balance point.

**Part 2. Maintaining Balance**

1. Ask students to think about whether maintaining their own balance is as simple as moving their fingers on the meter stick. Follow by asking them to think about whether their center of gravity ever changes. Ask, *What do you do to keep yourself from falling when you trip over something? How about when you are standing in a moving train or bus?* Tell students that they will be exploring their own centers of gravity in two different ways.

2. First, have students in each group take turns standing up from a seated position in a chair. They should record the results on their data sheets. Ask, *How easy was it to stand up?* (very easy).

3. Follow by having students try again to stand up from a seated position in a chair. This time, however, have them do so without leaning their back and shoulders forward. Have them record their results.

4 Next, instruct one student to stand with feet shoulder-width apart. Have

## Free Fall

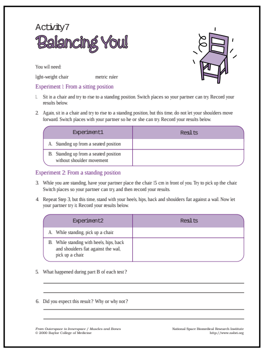
**Objects falling with an acceleration equal to that caused by gravity alone experience "free fall," or weightlessness. The acceleration required to achieve free fall is 9.8 meters per second squared or 1 g at the Earth's surface. Free fall is the lightness that you feel on some amusement park rides. Astronauts orbiting the Earth also experience weightlessness for the same reason.**

**Under these conditions, many movements can be accomplished with minimal effort. However, after long space flights, astronauts may demonstrate changes in their posture upon return to Earth. These changes are believed to be related to adaptation by the body to microgravity conditions.**

the second student place a lightweight chair 15 cm in front of the feet of the first student. Instruct the first student to try to pick up the chair and to record his/her results. Then have the other student in each group try it and record his/her results.

5. Tell students to move to the periphery of the room and take turns repeating the process again, but this time with their heels, hips, back and shoulders against the wall and with feet flat on the floor. Again, have them record their results.

6. Discuss the students' results. Ask them to identify the differences between the two trials of each experiment. Ask, *Why do you think it was not possible to stand up when you didn't move your shoulders? Why was it impossible to pick up the chair when you stood against the wall?* Help students understand that in both cases, their body movement was limited.


Activity 7

Balancing You!

You will need:

light-weight chair  metric ruler

Experiment 1: From a sitting position

1. Sit in a chair and try to rise to a standing position. Switch places so your partner can try. Record your results below.
2. Again, sit in a chair and try to rise to a standing position, but this time, do not let your shoulders move forward. Switch places with your partner so he or she can try. Record your results below.

| Experiment 1 | Results |
|---|---|
| A. Standing up from a seated position | |
| B. Standing up from a seated position without shoulder movement | |

Experiment 2: From a standing position

3. While you are standing, have your partner place the chair 15 cm in front of you. Try to pick up the chair. Switch places so your partner can try, and then record your results.
4. Repeat Step 3, but this time, stand with your heels, hips, back and shoulders flat against a wall. Now let your partner try it. Record your results below.

| Experiment 2 | Results |
|---|---|
| A. While standing, pick up a chair | |
| B. While standing with heels, hips, back and shoulders flat against the wall, pick up a chair | |

5. What happened during part B of each test?

6. Did you expect this result? Why or why not?

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7. Discuss gravity again. Ask, *Does gravity affect people? Do people have a center of gravity?* The meter stick center of gravity changed as students added more weight. Ask, *Have you been able to observe whether a person's center of gravity changes?* Have students think about where their centers of gravity are when they are sitting in chairs and how their centers shift when they begin to stand up. Their weight shifts from their seats to their feet; thus, their centers of gravity must change also. Have students think about where their centers of gravity are when they lift a chair. The chair adds extra weight to the body, so the body must compensate for that weight by moving the center of gravity. The body changes the center of gravity and achieves balance by moving the hips backward. This is why students were not able to pick up the chairs with their backs against a wall. Have students try these two experiments again, and this time have them watch their partners' body movements.

## Extensions

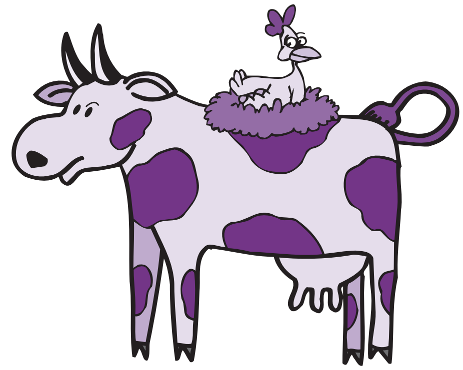
- The body constantly makes adjustments to compensate for the pull of gravity. Some of these adjustments are large, as when we pick up a chair, but many of the adjustments are very subtle. The muscles make minor adjustments constantly to maintain balance and posture. Have students work in pairs and observe the movements made by their partners as they perform certain tasks. The tasks can be: moving from standing on two feet to standing on one foot, walking heel-to-toe, squatting or standing on tip toes.

### Muscle Control!

**The brain and nervous system coordinate muscle movements necessary to maintain balance.**

## Activity 7

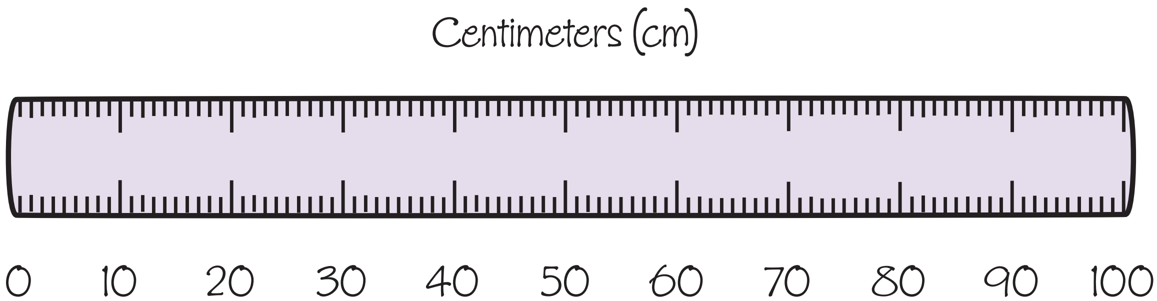
# Balancing Act



You will need:

meter stick   3 weights (coins, washers, etc.)
tape

1. Hold out your hands with only index fingers extended.
2. Have your partner lay the meter stick across your outstretched fingers.
3. Starting with you fingers at opposite ends of the meter stick, slowly move your fingers together, keeping the meter stick balanced at all times. The point where your fingers meet is the balance point. Note that position on the meter stick and record it on the picture of a meter stick below.



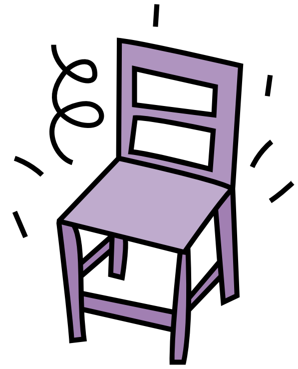

4. Tape one weight to the meter stick at the 30-cm mark.
5. Find the balance point of the meter stick with the weight on it and record your result below.
6. Tape another weight on top of the first one at the 30-cm mark.
7. Determine the balance point and record your result.
8. Tape the third weight on top of the others at the 30-cm mark.
9. Determine the balance point of the meter stick and record your result.

| | **No weights** | **1 weight** | **2 weights** | **3 weights** |
|---|---|---|---|---|
| Balance Point | | | | |

10. What happened to the balance point as you added more weight?

## Activity 7

# Balancing You!



You will need:

light-weight chair metric ruler

### Experiment 1: From a sitting position

1. Sit in a chair and try to rise to a standing position. Switch places so your partner can try. Record your results below.
2. Again, sit in a chair and try to rise to a standing position, but this time, do not let your shoulders move forward. Switch places with your partner so he or she can try. Record your results below.

| Experiment 1 | Results |
|---|---|
| A. Standing up from a seated position | |
| B. Standing up from a seated position without shoulder movement | |

### Experiment 2: From a standing position

3. While you are standing, have your partner place the chair 15 cm in front of you. Try to pick up the chair. Switch places so your partner can try, and then record your results.
4. Repeat Step 3, but this time, stand with your heels, hips, back and shoulders flat against a wall. Now let your partner try it. Record your results below.

| Experiment 2 | Results |
|---|---|
| A. While standing, pick up a chair. | |
| B. While standing with heels, hips, back and shoulders flat against the wall, pick up a chair. | |

5. What happened during part B of each test?

______________________________

______________________________

6. Did you expect this result? Why or why not?

______________________________

______________________________

## CONCEPTS

- Bones and muscles need exercise to be healthy.
- Muscles and bones are constantly changing.
- Stress tells bones and muscles how to change.

## OVERVIEW

Students will learn that muscles and bones need to work to stay strong.

## SCIENCE, HEALTH & MATH SKILLS

- Observing
- Gathering data
- Drawing conclusions

# 8. Good Stress

## Background

Generally, when we think of stress, we think of being over-worked, mentally tired or overwhelmed by our daily lives. While too much stress can be detrimental to the body, too little of some kinds of stress can be harmful. Activities like walking, carrying packages and mopping the floor are physical stresses. Activities like doing crossword puzzles, balancing the checkbook and reading are mental stresses. There also are emotional stresses, like receiving a bad grade on a test or walking into a surprise birthday party. Our bodies, including muscles and bones, require some physical and mental stresses to be healthy and grow.

Physical stress is created when bones and muscles are made to work against a force. It occurs when we pick up something heavy, like a 20-pound bag of cat litter. Gravity pulls down on the bag and we have to work to overcome that force to lift the bag. Swimming also causes stress because muscles and bones have to work against the resistance of the water to move the body. Gravity pulls on our bodies and our muscles and bones constantly work to counteract that force and keep us balanced.

Stress from physical activity is necessary for bone growth and maintenance. The body builds bone based on its needs. The need for any particular bone is dictated by the amount of stress placed on it. During the years a person's bones are growing (birth to about age 25), physical stress on bones causes builder cells to work more, which makes bones grow. Builder cells produce collagen fibers that form the framework of bones. The framework is then filled in with minerals, producing a strong, thick bone (see Activity 4). Even after they stop growing, bones still need physical stress to maintain thickness and strength.

Muscles also rebuild and grow as a result of physical stress. Stress can lead to change in either muscle strength or muscle stamina (the ability to perform an activity for a long time without becoming tired). High-intensity, short-duration exercises (or stresses), like weight lifting, cause muscles to increase in strength. Low-intensity, long-duration activities, such as running and swimming, cause muscles to increase in stamina.

## Time

For Part 1, 10 minutes for set-up; 20 minutes for activity. For Part 2, 50 minutes on Day 1, five minutes every other day for two weeks, and 50 minutes on the final day to conduct activity.

## Materials

**Part 1**

- overhead projector and screen

Each group will need:

- 2 transparent plastic knives

**Part 2**

- clock with second hand or timer

Each student will need:

- spring-hinge clothespin
- copy of "Stress This!" student sheet

**None of your bones are as old as you are. Each year, about 10% of your bone is eaten away and replaced by special cells.**

---

**Muscle soreness the day after physical activity is the result of a temporary mild inflammation in the muscle. The "burn" felt immediately after vigorous exercise is a result of the accumulation of waste (in the form of lactic acid) in hard-working muscle tissue.**

## Set-up and Management

Place the materials for each session in a central area for Materials Managers to collect for their groups.

**Part 1.** Divide students into groups of 2–4 and give each group two plastic knives. Set up the overhead projector.

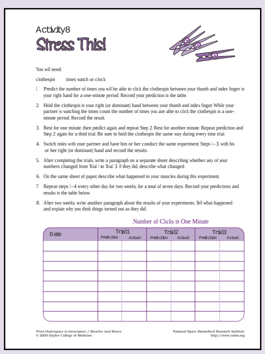
**Part 2.** Give every student one clothes pin and a copy of "Stress This!"

## Procedure

**Part 1. Stress observations**

1. Introduce the topic of stress by asking questions such as, *What is stress? How can stress be a good thing? What are some good stresses?* Explain that there are "good" stresses and "bad" stresses and that the body needs good stresses, like exercise, to be healthy.

2. Tell students that they are going to investigate how physical stress can affect bone—a hard material.




3. Have students compare the two knives to determine if they are the same or different.

4. Instruct students to mark one knife and bend it back and forth several times without breaking it.

5. Again, have the students compare the two knives. Ask them if anything is different between them. Request a volunteer to bring up his/her group's knives and place them on an overhead projector. Have students observe the knives and ask again if there is anything different between them. The students will be able to observe that very thin opaque lines have developed only in the knife that was bent. Often, the lines are observable even without using an overhead projector. However, the projector will make the lines easier to see.

6. Discuss students' observations. Explain that when they bent the knives or plastic strips, they applied physical stress and changed the appearance of the objects. Ask, *If we wanted to break this knife, would it be easier to do so where we bent it before, or at another point? Why do you think it would be easier to break where we've already bent it?* The changes in the knives may look minor, but they are important to the objects' structure. This concept is true for bones, too. Gravity and movement cause invisible stress patterns in bones. These patterns are very small. If we could see them, they would look very unimportant, but they tell the "bone construction crews" where to work to make bone thicker and stronger.

**Part 2. Stress and muscles**

1. Explain to students that they will be exploring the effects of stress on the muscles in their hands.

2. The first trial will test each student's initial muscle strength and stamina. Explain the exercise to students. Ask students to predict how many times they will be able to click a clothespin with their right (or dominant) hand during each of three, one-minute trials, and to record their predictions on their "Stress This!" student sheets. Have each student count the actual number of times he/she can click a clothespin in one minute using his/her right (or dominant) hand, and record his/her results. Have students rest for one minute and then repeat the trials two more times. If students are working in pairs, have one student complete the trial while the other measures the time. Then have students switch roles. After students

**Lack of stress is bad! Stress dictates the amount of bone that is built at a particular site—depending on need.**

**Muscles need stress, too. With regular practice, your body will become better at performing almost anything because your muscles will change in response to the stress caused by the new activity. It may be difficult to run a mile or to do 20 push-ups at first, but if you practice, it may become easier after 1–2 weeks.**

**Exercise has been shown to be effective in improving muscle strength and performance, even in elderly persons. Exercise also helps maintain bone density and may reduce the calcium loss from bones (osteoporosis).**

have completed all trials, ask, *Did you feel your hand muscles burn? Were you more tired after each minute of clicking? Why do you think that happened?*

3. Every other day for the next two weeks, have students repeat the exercise described above. This is the conditioning period. The stress induced by the clothespin on the muscles of the hand will cause the muscles to become stronger and gain stamina. Students should predict and report their results each day.

4. The test of how well the stress conditioning worked comes on the last day of the two-week period. Again, have each student predict how many times he/she will be able to click the clothespin during the timed periods and record his/her prediction. Have each student repeat the clicking-resting experiment again exactly as it is described in Step 2 and record the results.

5. Instruct students to write a paragraph (on a separate sheet of paper) about the results of their experiment. They should explain what happened and why they think things turned out the way they did.

6. Discuss results from the initial and final experiments. Students will discover that they were able to click the clothespin more times (and with less muscle soreness) in the first one-minute period after the conditioning period. This shows that their muscles have grown stronger. Students also will discover that they are able to click more times in the second and third one-minute periods after the conditioning has taken place. This shows that the muscles have increased in stamina. Ask students, *Were you able to click more times in the third trial after two weeks than at the beginning of the experiment? Why do you think that happened? How did your results compare with your predictions?*

## Extensions

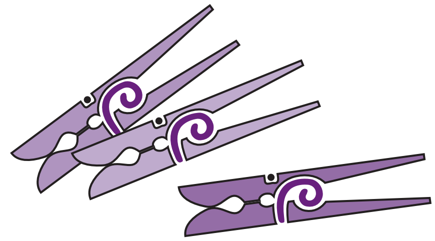
- Have students graph their results to produce a visual representation of changes that occurred in the three bi-daily trials over the course of two weeks. They should create separate graphs for each one-minute period and record how the number of clothespin clicks changed over time. This will help students to understand how their strength and endurance increased.

### Stress Fractures

**Bone construction crew workers, osteoblasts and osteoclasts, repair cracks before they get too large so that bone strength is maintained and fractures are prevented. If an area of bone is repeatedly stressed, the construction crew may not have sufficient time to repair cracks, and fractures (broken bones) may occur. This happens in some athletes who suffer breaks known as "stress fractures."**

## Activity 8

# Stress This!



You will need:

clothespin    timer, watch or clock

1. Predict the number of times you will be able to click the clothespin between your thumb and index finger in your right (or dominant) hand for a one-minute period. Record your prediction in the table.
2. Hold the clothespin in your right (or dominant) hand between your thumb and index finger. While your partner is watching the timer, count the number of times you are able to click the clothespin in a one-minute period. Record the result.
3. Rest for one minute, then predict again and repeat Step 2. Rest for another minute. Repeat prediction and Step 2 again for a third trial. Be sure to hold the clothespin the same way during every time trial.
4. Switch roles with your partner and have him or her conduct the same experiment, Steps 1–3, with his or her right (or dominant) hand and record the results.
5. After completing the trials, write a paragraph on a separate sheet describing whether any of your numbers changed from Trial 1 to Trial 3. If they did, describe what changed.
6. On the same sheet of paper, describe what happened to your muscles during this experiment.
7. Repeat steps 1–4 every other day for two weeks, for a total of seven days. Record your predictions and results in the table below.
8. After two weeks, write another paragraph about the results of your experiments. Tell what happened and explain why you think things turned out as they did.

### Number of Clicks in One Minute

| Date | Trial 1 | | Trial 2 | | Trial 3 | |
|---|---|---|---|---|---|---|
| | Prediction | Actual | Prediction | Actual | Prediction | Actual |
| | | | | | | |
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## CONCEPTS

- Good eating habits help maintain bone and muscle strength.
- Some foods, such as complex carbohydrates, are good energy sources.
- Other foods provide building materials for bones and muscles.

## OVERVIEW

Students will learn about the nutritional needs of healthy bones and muscles, and how to make good food choices, especially in terms of getting enough calcium.

## SCIENCE, HEALTH & MATH SKILLS

- Gathering information
- Comparing
- Charting
- Drawing conclusions
- Inferring


# 9. Building Blocks

## Background

Food provides energy to the body for growth, maintenance and activity. It also supplies building blocks for bones, muscles and other tissues of the body. Making the right food choices can promote and maintain good health throughout life.

Most teenagers do not eat enough foods that promote bone and muscle health. To develop and maintain strong bones, their diets should include plenty of calcium-rich foods, like low-fat dairy foods and green leafy vegetables. Vitamin D, which is made in the skin when it is exposed to mild doses of sunlight, helps the body to absorb calcium. Vitamins A and C also are necessary for proper bone development.

Bone is remodeled throughout life. Old bone is removed and new bone is formed. During childhood and teenage years, new bone is added faster than old bone is removed. As a result, bones become larger and denser. Bone formation occurs faster than bone removal until about age 30. After this age, breakdown of bone begins to occur at a faster rate than bone formation. Bone loss accelerates with age and can be particularly rapid in women in the years around menopause. This can lead to osteoporosis, or "porous bone," a condition in which bones are not rebuilt as quickly as they are broken down. These weakened bones are more likely to fracture. Teenagers can help prevent osteoporosis later in life by including enough calcium in their diets and by exercising.

Protein, found in meats, fish, dairy products and beans, is used by the body to build muscles and the scaffolding within bones. In addition, protein can serve as an energy source for growth and movement. Energy also comes from carbohydrates (breads, pasta, vegetables and sugars), fats and oils.

The "Nutrition Facts" label on packaged foods can be used to make better food choices. This label lists the amounts of nutrients present in grams or as a percentage of the recommended Daily Value. A food product that claims to be a "good source of calcium" must contain at least 100 milligrams (mg) of calcium per serving. This is about one tenth of the total amount of calcium needed by a person each day.

## Time

10 minutes for set-up; 45–60 minutes to conduct the activity

## Materials

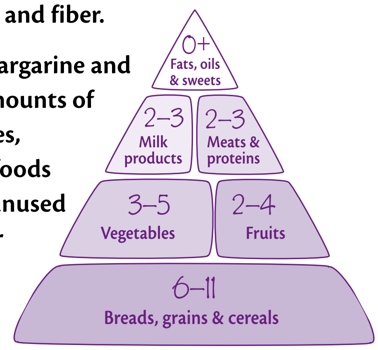
Each student will need:

- copy of "Healthy Choices" and "Foods for Healthy Bones" sheets

**Conditions in space, where bones do not have to work against the force of gravity, cause astronauts to lose bone density and muscle size and strength. While this does not affect their performance in space, it can make them too weak to carry out routine tasks when they return to the full force of gravity on Earth. Countermeasures to help maintain bones and muscles include resistance exercises, such as rowing or using a stationary bicycle, and maintaining a carefully balanced diet.**

### NUTRIENTS: SUBSTANCES IN FOOD NEEDED BY THE BODY

**Carbohydrates**, a major source of energy, are found in fruits, vegetables, grains and flour. Fiber, starches and sugars all are carbohydrates. Most US students tend to eat too many snacks and prepared foods that are high in sugars, instead of choosing vegetables, breads and pasta that contain less sugar and more starches and fiber.




**Fats** are rich sources of energy. Cooking oils, lard, butter, margarine and shortening are almost pure fat. Foods that contain large amounts of fat include some red meats, dairy products, chocolate, cakes, cookies, fried snacks (chips, crackers, etc.) and nuts. Fatty foods should be eaten sparingly because the body will store any unused energy as additional body fat. Fats from plants (like olive or canola oil) or fish generally are healthier than butter, fatty meat, lard or margarine.

**Proteins** are building blocks for the body. Muscles, hair, skin and nails are mostly protein, as is the flexible collagen network within bones. Proteins help carry out essential chemical reactions within every cell. The body can use protein as a source of energy. Meats, fish, poultry, eggs, low-fat dairy products, beans, peas and nuts are good sources of protein.

**Vitamins** are substances needed by the body in small amounts. Vitamin D, for example, helps the intestine absorb calcium into the blood, so it can be delivered to bones. Vitamin C is needed to make collagen, which is used in building bones and connective tissues. Eating a variety of fruits and vegetables every day helps ensure that the body has all of the vitamins it needs.

**Minerals** have a number of roles. Calcium, the most abundant mineral in the body, makes bones hard and is important to muscles and the nervous system. Good sources of calcium are low-fat dairy products, dark green leafy vegetables, tofu, sardines with bones and calcium-fortified juices and cereals. Phosphorous also is important for bone health.

Each group will need:
- several nutrition labels from food packages

## Set-up and Management

Have students bring in nutrition labels from food packages. Put a mixture of labels from different kinds of foods in plastic bags and place them in a central location. Have students work in groups of 3–4.

## Procedure

1. Have each student make a list of everything he or she ate during the past 24 hours (including snacks).

2. Distribute the “Healthy Choices” page. Point out the basic food groups shown on the page and have students identify the food group category in which each item on their lists belongs. Some items may fall into more than one food category. Encourage students to discuss these foods within their groups to decide where they belong. For example, a large portion of lasagna might count as one serving from the bread/pasta group, one serving from the dairy group (cheese) and one serving from the meat group (ground beef or sausage).

3. Have each student make a chart and list all of the food groups in separate columns. Students then should record in the appropriate column what they ate over the past 24 hours and the number of servings eaten for each

### History of Food Labels

**1906 -** Federal government begins regulation of food safety and quality.

**1913 -** Food packages are required to state the quality of their contents.

**1938 -** Every processed, packaged food is required to have a label containing the name and weight of the product and a list of ingredients.

**1966 -** The Fair Packaging and Labeling Act passes. All products shipped across state lines are required to have accurate labels.

**1973 -** Nutrition labels are required on all foods that have one or more added nutrients and on foods that claim to have a specific nutritional property or dietary use.

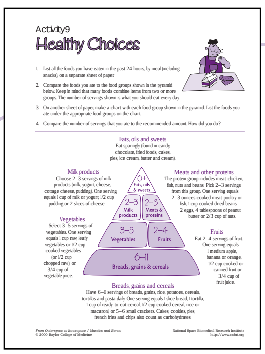
**1984 -** Labels are required to include sodium content.

**1990 -** All food labels are required to list nutritional information, standard serving sizes and uniform health claims.

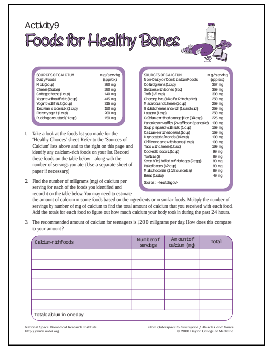
From the Food and Drug Administration <http://vm.cfsan.fda.gov/nlea.html>

item listed. Have students compare their totals to the recommended numbers of servings.

4. Ask, *How many of you had the recommended amounts of fruits, vegetables and dairy products? Did anyone exceed the recommendations for fats and sweets? How about breads and pastas?* Distribute the “Foods for Healthy Bones” page, which focuses on calcium—a nutrient important for strong bones. Have students refer to their “Healthy Choices” sheets and identify any foods that they ate that are sources of calcium. Next, have them calculate the number of milligrams of calcium that they included in their diet over the past 24 hours.


Activity 9
Healthy Choices

5. Ask students, *Is there room for improvement in your eating habits?* Have the Materials Manager from each group collect a bag of nutrition labels from the materials table. Have each group observe their food labels and rank the foods from best to worst in terms of the nutrients needed for bones and muscles (calcium, protein, Vitamins D, C, and A). Then have groups share their lists with the rest of the class.


Activity 9
Foods for Healthy Bones

6. Conclude by asking students to suggest simple changes they could make to improve their diets. Record their ideas. You may want to discuss the word “diet” with students. Even though it is frequently used to describe an eating program to promote weight-loss, “diet” also can mean the usual things that a person eats.

## Extensions

- Have students consult the Internet for additional information on diet and nutrition. The Food and Drug Administration <www.fda.gov>, National Institutes of Health <www.nih.gov>, and the US Department of Agriculture <www.nal.usda.gov/fnic/foodcomp> are good places to start.

**Men as well as women can suffer from osteoporosis—the development of weak, “porous” bone. An inadequate supply of calcium over a lifetime is believed to contribute to the development of osteoporosis. Approximately 6 out of 10 teenage boys and 8 out of 10 teenage girls do not have enough calcium in their diets.**

## Activity 9

# Healthy Choices

1. List all the foods you have eaten in the past 24 hours, by meal (including snacks), on a separate sheet of paper.
2. Compare the foods you ate to the food groups shown in the pyramid below. Keep in mind that many foods combine items from two or more groups. The number of servings shown is what you should eat every day.
3. On another sheet of paper, make a chart with each food group shown in the pyramid. List the foods you ate under the appropriate food groups on the chart.
4. Compare the number of servings that you ate to the recommended amount. How did you do?

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### Fats, oils and sweets

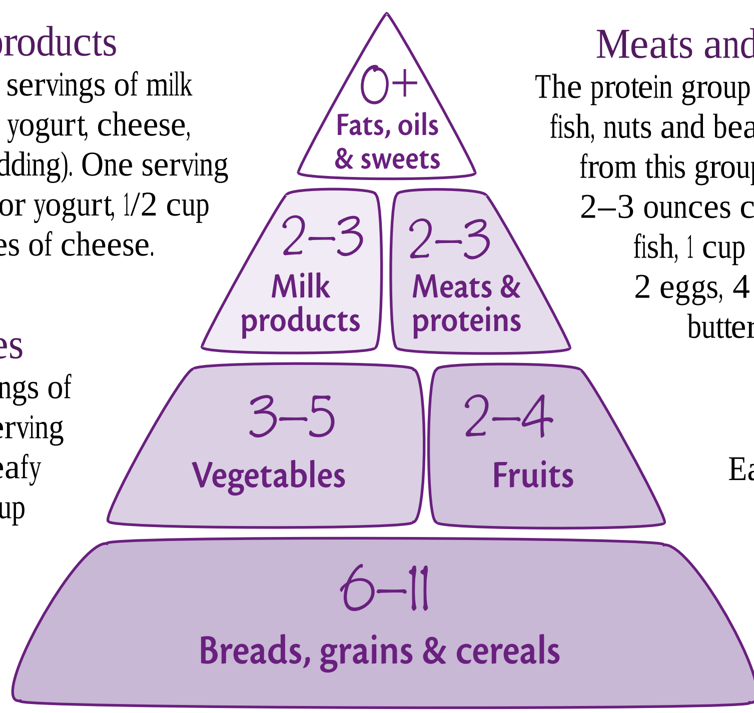
Eat sparingly (found in candy, chocolate, fried foods, cakes, pies, ice cream, butter and cream).

### Milk products

Choose 2–3 servings of milk products (milk, yogurt, cheese, cottage cheese, pudding). One serving equals 1 cup of milk or yogurt, 1/2 cup pudding or 2 slices of cheese.

### Meats and other proteins

The protein group includes meat, chicken, fish, nuts and beans. Pick 2–3 servings from this group. One serving equals 2–3 ounces cooked meat, poultry or fish, 1 cup cooked dried beans, 2 eggs, 4 tablespoons of peanut butter or 2/3 cup of nuts.




### Vegetables

Select 3–5 servings of vegetables. One serving equals 1 cup raw, leafy vegetables or 1/2 cup cooked vegetables (or 1/2 cup chopped raw), or 3/4 cup of vegetable juice.

### Fruits

Eat 2–4 servings of fruit. One serving equals 1 medium apple, banana or orange, 1/2 cup cooked or canned fruit or 3/4 cup of fruit juice.

### Breads, grains and cereals

Have 6–11 servings of breads, grains, rice, potatoes, cereals, tortillas and pasta daily. One serving equals 1 slice bread, 1 tortilla, 1 cup of ready-to-eat cereal, 1/2 cup cooked cereal, rice or macaroni, or 5–6 small crackers. Cakes, cookies, pies, french fries and chips also count as carbohydrates.

## Activity 9

# Foods for Healthy Bones


| SOURCES OF CALCIUM<br>**Dairy Foods** | mg / serving<br>**(approx.)** |
|---|---|
| Milk (1 cup) | 300 mg |
| Cheese (2 slices) | 200 mg |
| Cottage cheese (1 cup) | 140 mg |
| Yogurt without fruit (1 cup) | 415 mg |
| Yogurt with fruit (1 cup) | 315 mg |
| Ice cream or ice milk (1 cup) | 150 mg |
| Frozen yogurt (1 cup) | 200 mg |
| Pudding or custard ( 1 cup) | 150 mg |

1. Take a look at the foods list you made for the "Healthy Choices" sheet. Refer to the "Sources of Calcium" lists above and to the right on this page and identify any calcium-rich foods on your list. Record these foods on the table below—along with the number of servings you ate. (Use a separate sheet of paper if necessary.)

| SOURCES OF CALCIUM<br>**Non-Dairy or Combination Foods** | mg / serving<br>**(approx.)** |
|---|---|
| Collard greens (1 cup) | 357 mg |
| Sardines with bones (3 oz) | 350 mg |
| Tofu (1/2 cup) | 300 mg |
| Cheese pizza (1/4 of a 12 inch pizza) | 250 mg |
| Macaroni and cheese (1 cup) | 250 mg |
| Grilled cheese sandwich (1 sandwich) | 250 mg |
| Lasagna (1 cup) | 250 mg |
| Calcium-enriched orange juice (3/4 cup) | 225 mg |
| Pancakes or waffles (2 waffles or 3 pancakes) | 100 mg |
| Soup prepared with milk (1 cup) | 150 mg |
| Calcium-enriched cereal (1 cup) | 150 mg |
| Dry roasted almonds (1/4 cup) | 100 mg |
| Chili con carne with beans (1 cup) | 100 mg |
| Taco with cheese (1 taco) | 100 mg |
| Cooked broccoli (1 cup) | 90 mg |
| Tortillas (3) | 80 mg |
| Scrambled, boiled or fried eggs (2 eggs) | 80 mg |
| Baked beans (1/2 cup) | 80 mg |
| Milk chocolate (1 1/2 ounce bar) | 80 mg |
| Bread (1 slice) | 40 mg |

Source: <www.fda.gov>

2. Find the number of milligrams (mg) of calcium per serving for each of the foods you identified and record it on the table below. You may need to estimate the amount of calcium in some foods based on the ingredients of similar foods. Multiply the number of servings by number of mg of calcium to find the total amount of calcium that you received with each food. Add the totals for each food to figure out how much calcium your body took in during the past 24 hours.

3. The recommended amount of calcium for teenagers is 1,200 milligrams per day. How does this compare to your amount?

| **Calcium-rich foods** | **Number of servings** | **Amount of** | **Total** |
|---|---|---|---|
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| **Total calcium in one day** | | | |

## CONCEPTS

- Lack of stress causes bones and muscles to become weak.
- Astronauts must counteract the effects of lost stress on bones and muscles.

## OVERVIEW

Students will learn about the changes that occur in bones and muscles while people are in space and then apply their knowledge of muscles and bones to suggest preventative solutions for those changes.

## SCIENCE, HEALTH & MATH SKILLS

- Using resources to gather information
- Applying knowledge
- Drawing conclusions
- Presenting conclusions with supporting information

# 10. Bones and Muscles in Space

## Background

On Earth, muscles and bones are used to working against gravity to maintain posture and balance. In space, where the effects of gravity are almost absent, the muscles and bones of astronauts do not have to work as hard and become weaker. Bone rebuilding falls behind bone dismantling, and bones decrease in diameter and become less dense. The calcium removed from bones is permanently eliminated from the body in urine, leading to a condition similar to osteoporosis on Earth.

Muscles in space also become smaller and weaker through a process called atrophy. In addition, the fibers inside muscles change because most work in space involves short-duration, high intensity tasks.

The adaptation of muscles and bones to microgravity conditions does not have serious consequences in space, where astronauts do not need as much strength to keep their balance and move about. In fact, the bodies of people in space eventually reach equilibrium, called "space normal," with their new environment. This adaptation does, however, cause problems when astronauts return to an environment with the full force of gravity because their muscles and bones have become too weak to function as before.

Similar problems can be observed on Earth among people who are bedridden during a long illness, who have part of their bodies immobilized to allow a fracture to heal or who suffer from osteoporosis. Research to develop measures that will counter changes in muscles and bones in space will benefit these and many other people directly.

## Time

10 minutes for set-up; 30 minutes to conduct activity

## Materials

Each student will need:

- copy of “Muscles & Bones in Space” student sheet

## Set-up and Management

Provide resource materials on space topics.

## Procedure

1. Review the concepts presented in this unit. Discuss how lack of stress affects bones and muscles. Ask the students to think of environments in which stress on the body is reduced. (Some examples are: on the moon, on the space shuttle or space station, or during bed rest.)

2. Hand out the “Muscles & Bones in Space” worksheet and have each student work alone.

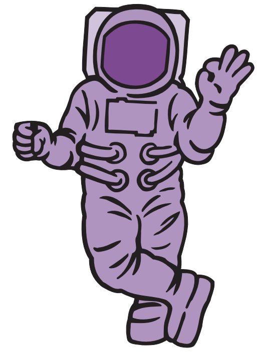
3. Have students share their drawings with the rest of the class.

**Have you or someone you know ever had a broken leg or arm? The limb probably had to be encased in a cast that would keep the broken pieces in place and allow them to mend. The lack of movement causes the muscles and bones inside the cast to become weaker. This usually can be observed once the cast is removed—the diameter of the newly healed arm or leg is noticeably smaller than the arm or leg that wasn’t in a cast. Fortunately, normal use restores bone and muscle size and strength within a few weeks.**

**Something similar happens to the bones and muscles of astronauts who live and work in space.**

## Activity 10

# Muscles & Bones in Space



Maria and Michelle are identical twins who live together and have similar activities. They are special student astronauts with NASA. Both are participating in an experiment on muscles and bones. Tomorrow, Maria will go up in the space shuttle for a 10-day mission. Meanwhile, Michelle will stay on Earth and maintain her normal daily routine. When Maria returns to Earth, scientists will compare the bones and muscles in Maria's and Michelle's right arms. The scientists need your help to know what to expect when the 10-day mission is over.

1. Draw an inside view of Maria's and Michelle's right arms—after the mission—in the spaces below. Label the bones and muscles.

**Maria's Right Arm** **Michelle's Right Arm**

2. Describe how the two arms are different.

3. The scientists do not want the changes seen in Maria's arm to occur in the muscles and bones of astronauts on future missions. They need your help to design a diet and exercise program to prevent these changes. What would you suggest?