

THE SCIENCE OF

MUSCLES

AND BONES

Skeletal Structures



by

Kimberly Chang, Ph.D.

Nancy P. Moreno, Ph.D.

Barbara Z. Tharp, M.S.

RESOURCES

For online presentations of each activity and downloadable slide sets for classroom use, visit <http://www.bioedonline.org> or <http://www.k8science.org>.

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Authors: Kimberly Chang, Ph.D., Nancy P. Moreno, Ph.D., and Barbara Z. Tharp, M.S.
Senior Editor: James P. Denk, M.A.
Creative Director: Martha S. Young, B.F.A.

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NATIONAL SPACE BIOMEDICAL RESEARCH INSTITUTE

1 Baylor Plaza, NA-425, Houston, Texas 77030-3498
www.nsbri.org

CENTER FOR EDUCATIONAL OUTREACH

Baylor College of Medicine, 1 Baylor Plaza, BCM411, Houston, Texas 77030
713-798-8200 / 800-798-8244 / www.bcm.edu/edoutreach

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TEAMING WITH BENEFITS

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

Space is a challenging environment for the human body. With long-duration missions, the physical and psychological stresses and risks to astronauts



Dr. Jeffrey P. Sutton

are significant. Finding answers to these health concerns is at the heart of the National Space Biomedical Research Institute's program. In turn, the Institute's research is helping to enhance medical care on Earth.

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

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

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

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

help guide the Institute in achieving its goals and objectives.

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

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

NSBRI RESEARCH AREAS

CARDIOVASCULAR PROBLEMS

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

HUMAN FACTORS AND PERFORMANCE

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

MUSCLE AND BONE LOSS

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

NEUROBEHAVIORAL AND STRESS FACTORS

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

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

RADIATION EFFECTS AND CANCER

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

SENSORIMOTOR AND BALANCE ISSUES

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

SMART MEDICAL SYSTEMS AND TECHNOLOGY

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

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

OVERVIEW

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



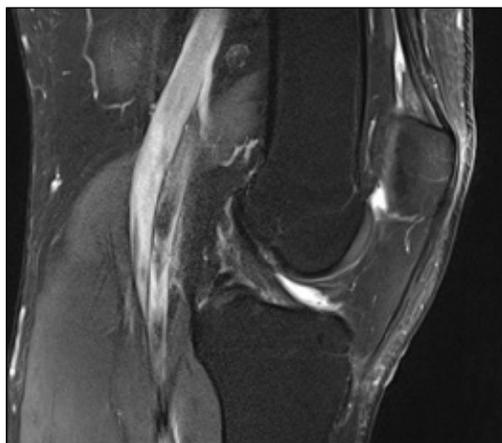
ACTIVITY

SKELETAL STRUCTURES

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.



MRI of a human knee (side view) in a 44 year old male. The bones, darkest gray, are clearly defined.

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 setup; 45 minutes for activity

MATERIALS

- 15 paper clips
- 10 straws

Safety Issues

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

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.

Water Support

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.

SCIENCE, HEALTH & MATH SKILLS

GRADES 5–8

- Observing
- Comparing
- Modeling

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.



- 2 sheets of card stock
- Clay
- Clear tape
- Pair of scissors
- Resealable plastic bag or plastic wrap (for skin or outer covering)
- Ruler
- Copy of the student sheet

SETUP & MANAGEMENT

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

PROCEDURE

1. Ask students to remember what happened to the plastic bag filled with water that they examined in the activity, “Gravity and Buoyancy.” 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 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.
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, card stock 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 (see sidebar, right): “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. ◆

Endoskeletons: Inside the Body

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.

Exoskeletons: Outside the Body

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

SKELETAL SUPPORT

To create an imaginary animal, follow the steps below.

1. Decide on the appearance 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 provided. 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 or plastic-wrap 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?
