

THE SCIENCE OF

# MUSCLES

## AND BONES



### Muscle Fibers

*by*

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### 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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Printed in the United States of America

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

# BioEd<sup>SM</sup>

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

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

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

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# TEAMING WITH BENEFITS

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

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



Dr. Jeffrey P. Sutton

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

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

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

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

help guide the Institute in achieving its goals and objectives.

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

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

## NSBRI RESEARCH AREAS

### CARDIOVASCULAR PROBLEMS

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

### HUMAN FACTORS AND PERFORMANCE

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

### MUSCLE AND BONE LOSS

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

### NEUROBEHAVIORAL AND STRESS FACTORS

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

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

### RADIATION EFFECTS AND CANCER

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

### SENSORIMOTOR AND BALANCE ISSUES

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

### SMART MEDICAL SYSTEMS AND TECHNOLOGY

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

For current, in-depth information on NSBRI's cutting-edge research and innovative technologies, visit [www.nsbri.org](http://www.nsbri.org).

# OVERVIEW

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

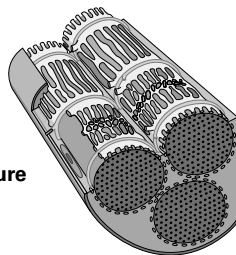


ACTIVITY

# MUSCLE FIBERS

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

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



Muscle Structure

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. Within these large bundles are numerous muscle cells (also called fibers).

## SCIENCE, HEALTH & MATH SKILLS

GRADES 5–8

- Observing
- Modeling
- Inferring

## CONCEPTS

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

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 setup; 45 minutes to conduct the activity

## MATERIALS

### Teacher:

- Approximately 1/2 pound of stringy or fibrous cut of beef, such as brisket, flank steak or stew meat (see Setup)

### Each group will need:

- 12-in. section of yarn
- 4 pairs of disposal safety gloves
- 4 toothpicks
- 1-in. cube of prepared stringy beef
- Plastic knife
- Plate or tray to work on
- Disposable plastic gloves
- Copies of the student page

## SETUP & 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

## 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.

## Facts About Human Muscles

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.



## Muscle Fibers

Muscle cells contain protein filaments, or fibers, that slide past one another, producing a contraction that changes both the length and shape of the cell.

## Animal Muscles

Animals with exoskeletons 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.

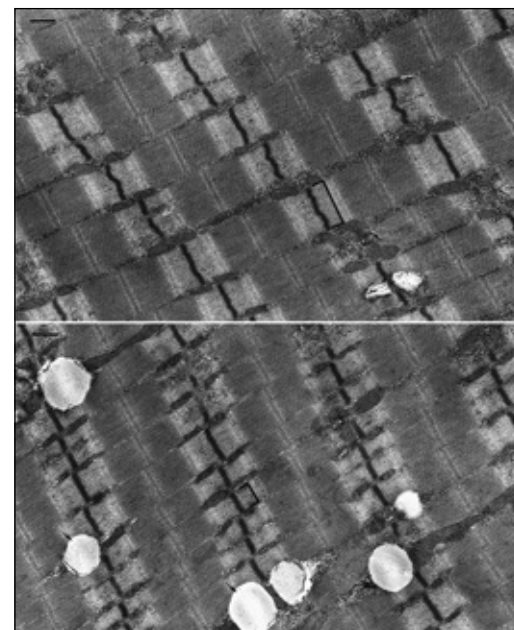
## Extension

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.

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 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 student 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.
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*



Muscle fiber taken from an astronaut before spaceflight. Astronauts in orbit and patients on Earth fighting muscle-wasting diseases need countermeasures to prevent muscle loss, indicated here with white lipid droplets (bottom) in the sample taken from the same astronaut after spaceflight.

*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. ◆

# ACTIVITY

## THE POWER OF FIBERS

You will need a piece of yarn, one piece of cooked beef, a plastic knife, and a 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.

**Table 1: Yarn Investigation**

	Appearance	Result of Snap Test
<b>Yarn</b>		
<b>Strand</b>		
<b>Fiber</b>		

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?
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.

**Table 2: Meat Investigation**

Top View	Side View

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 the meat and yarn samples 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?

## MUSCLE RESEARCH

NSBRI Web site: [www.nsbri.org](http://www.nsbri.org)

Scientists and researchers work constantly to find ways to improve people's health. Scientists associated with the National Space Biomedical Research Institute (NSBRI) are conducting studies to help astronauts stay healthy in space. Findings of these studies can benefit people on Earth.

One such study was conducted by NSBRI scientist, Dr. Robert Wolfe, at The University of Texas Medical Branch at Galveston. Dr. Wolfe and his team looked for ways to counteract some of the changes that occur in the bodies of astronauts after they have been in space for a while.

In space, astronauts' muscles don't have to work as hard as they do on Earth, because there is almost no gravity. Also, astronauts are confined in a small space, so it is difficult for them to get enough exercise. After a while, their bodies adjust to the space environment and astronauts begin to lose muscle, especially in their legs. Though astronauts exercise at least twice a day while in space, muscle loss is still a problem. Dr. Wolfe and his team examined whether nutritional supplements can help prevent some of the muscle loss (or atrophy).

Doctors and researchers know that people here on Earth experience similar muscle loss when they are confined to bed for long periods of time due to illness or other circumstances. Dr. Wolfe enlisted the help of healthy people (subjects) to stay in bed for 28 days. The subjects could get up only briefly to use a bedside commode. They ate and bathed from their beds, and their daily physical activities were limited to watching television, reading books or using a computer—all done while in lying or sitting in bed.

During the study, some of these subjects received nutritional supplements of amino acids (the raw materials of protein, which makes up muscle) three times a day. Other subjects in the study received a similar drink, but without any supplements. None of the subjects knew if they were receiving the drink with the amino acid supplements.

Each subject's muscles were measured before and after the bed-rest study. Halfway through the study, researchers also measured the muscles and function of all subjects by testing their strength and body composition.

The researchers also looked at the role of stress in muscle loss. Under stress, the body breaks down proteins (muscles are made of protein). Conditions in space elevate the body's level of the stress hormone, cortisol, which increases the rate at which proteins—and therefore muscles—break down.



Through an NSBRI bed-rest study, an amino acid and carbohydrate supplement was studied to determine its value as a nutritional countermeasure to muscle loss.

To study this process further, Dr. Wolfe's team gave stress hormones to some of the subjects in order to mimic the cortisol concentrations found in astronauts' bodies during space flight. The scientists hoped to learn whether the amino acid supplement was effective under conditions experienced by astronauts during space missions.

Results from this NSBRI study suggest that nutritional supplements may lessen muscle loss brought on by space travel, prolonged bed confinement or immobility.

Muscle loss is common in many populations on Earth, as well as in astronauts working in space. The elderly, children with burns, patients in intensive care, some physically challenged individuals, and people who have had major operations often suffer from muscle loss. Though the study was begun to keep astronauts healthy while they work in space, the results also may benefit many people here on Earth. ◆

The NSBRI, funded by NASA, is a consortium of institutions studying the health risks related to long-duration spaceflight. The Institute's science, technology and education projects take place at more than 60 institutions across the U.S.

*Everyone has unique nutritional and health care needs. The information provided here is not intended as a replacement for professional medical advice. Before beginning any supplement, diet or exercise program, discuss it with your doctor or health care provider.*