

THE SCIENCE OF

MUSCLES



AND BONES

Arm Model

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>.

BCM[®]
Baylor
College of
Medicine

© Copyright 2012 Baylor College of Medicine
All rights reserved.
Printed in the United States of America

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

BioEdSM

Teacher Resources from the Center for Educational Outreach at Baylor College of Medicine.
The mark "BioEd" is a service mark of Baylor College of Medicine.

The information contained in this publication is intended solely to provide broad consumer understanding and knowledge of health care topics. This information is for educational purposes only and should in no way be taken to be the provision or practice of medical, nursing or professional health care advice or services. The information should not be considered complete and should not be used in place of a visit, call or consultation with a physician or other health care provider, or the advice thereof. The information obtained from this publication is not exhaustive and does not cover all diseases, ailments, physical conditions or their treatments. Call or see a physician or other health care provider promptly for any health care-related questions.

The activities described in this book are intended for school-age children under direct supervision of adults. The authors, Baylor College of Medicine (BCM) and the National Space Biomedical Research Institute (NSBRI) cannot be responsible for any accidents or injuries that may result from conduct of the activities, from not specifically following directions, or from ignoring cautions contained in the text. The opinions, findings and conclusions expressed in this publication are solely those of the authors and do not necessarily reflect the views of BCM, NSBRI or the National Aeronautics and Space Administration (NASA).

Cover Images: Photo of astronaut courtesy of NASA. Photos of girl, boy, group of children, and clothespins © Getty Images. X-ray image © 123RF Stock Photos. Anatomical illustrations © Williams & Wilkins. All Rights Reserved.

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.

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.

No part of this book may be reproduced by any mechanical, photographic or electronic process, or in the form of an audio recording; nor may it be stored in a retrieval system, transmitted, or otherwise copied for public or private use without prior written permission of the publisher. Black-line masters reproduced for classroom use are excepted.

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

BCM
Baylor
College of
Medicine



SOURCE URLS

BAYLOR COLLEGE OF MEDICINE BIOED ONLINE / K8 SCIENCE

www.bioedonline.org / www.k8science.org

CENTER FOR EDUCATIONAL OUTREACH

www.bcm.edu/edoutreach

HARVARD SCHOOL OF PUBLIC HEALTH THE NUTRITION SOURCE

www.thenutritionsource.org

HENDERSON STATE UNIVERSITY ARKANSAS NATURE TRIVIA

<http://www.hsu.edu>

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION (NASA)

NASA CONNECT™

<http://connect.larc.nasa.gov/episodes.html>

NASA IMAGES

www.nasaimages.org

NATIONAL INSTITUTES OF HEALTH

www.nih.gov

NATIONAL SPACE BIOMEDICAL RESEARCH INSTITUTE

www.nsbri.org

U.S. DEPARTMENT OF AGRICULTURE

www.nal.usda.gov/fnic/foodcomp

U.S. FOOD AND DRUG ADMINISTRATION

www.fda.gov

WELLCOME IMAGES, INC.

<http://images.wellcome.ac.uk>

TEAMING WITH BENEFITS

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

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



Dr. Jeffrey P. Sutton

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

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

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

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

help guide the Institute in achieving its goals and objectives.

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

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

NSBRI RESEARCH AREAS

CARDIOVASCULAR PROBLEMS

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

HUMAN FACTORS AND PERFORMANCE

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

MUSCLE AND BONE LOSS

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

NEUROBEHAVIORAL AND STRESS FACTORS

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

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

RADIATION EFFECTS AND CANCER

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

SENSORIMOTOR AND BALANCE ISSUES

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

SMART MEDICAL SYSTEMS AND TECHNOLOGY

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

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

OVERVIEW

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



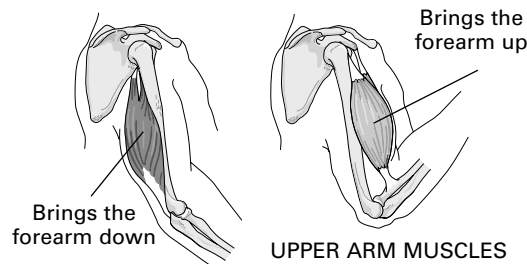
ACTIVITY

ARM MODEL

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 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 setup; 60 minutes to conduct activity

MATERIALS

Each group will need:

- 50-cm length of string
- 2 rulers with holes in the center (to make arm model)
- Clear tape
- Large brad
- Metal paper clip
- Pair of scissors
- Ruler (for measuring)
- Copies of the student sheets

SCIENCE, HEALTH & MATH SKILLS

GRADES 5–8

- Predicting
- Observing
- Drawing conclusions
- Modeling
- Inferring

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.

NASA CONNECT™



The NASA Connect online broadcast, “Better Health from Space to Earth,” is based on *The Science of Muscles and Bones*.

The program features NASA scientists using measurement and estimation skills to 1) help characterize health, environmental, and other operational human biomedical risks associated with living in space, and 2) to identify strategies, tools, or technologies to prevent or reduce those risks.

To view this episode, visit <http://connect.larc.nasa.gov/episodes.html>.

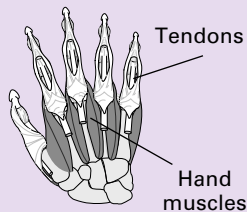


Safety Issues

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.

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.)



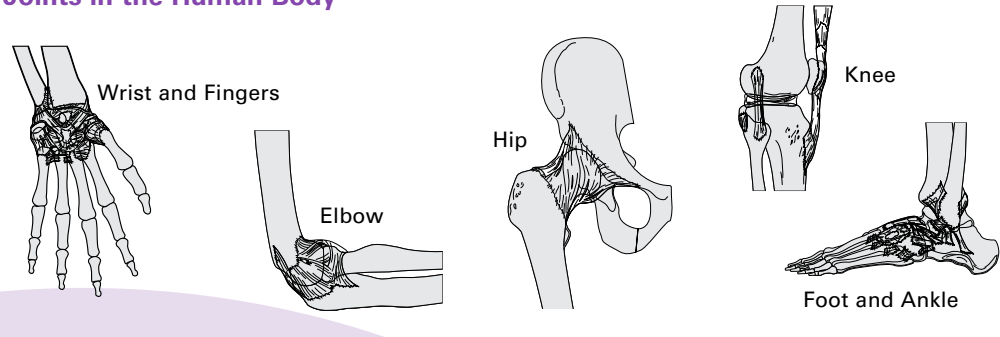
You can see something similar in a chicken foot from the grocery store. The long, white fibers extending from the end are tendons. Pull them and you will see the claws curl.

Locking Joints

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.



Joints in the Human Body



SETUP & MANAGEMENT

Divide students into groups of 2–3. Place 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 “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 “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.

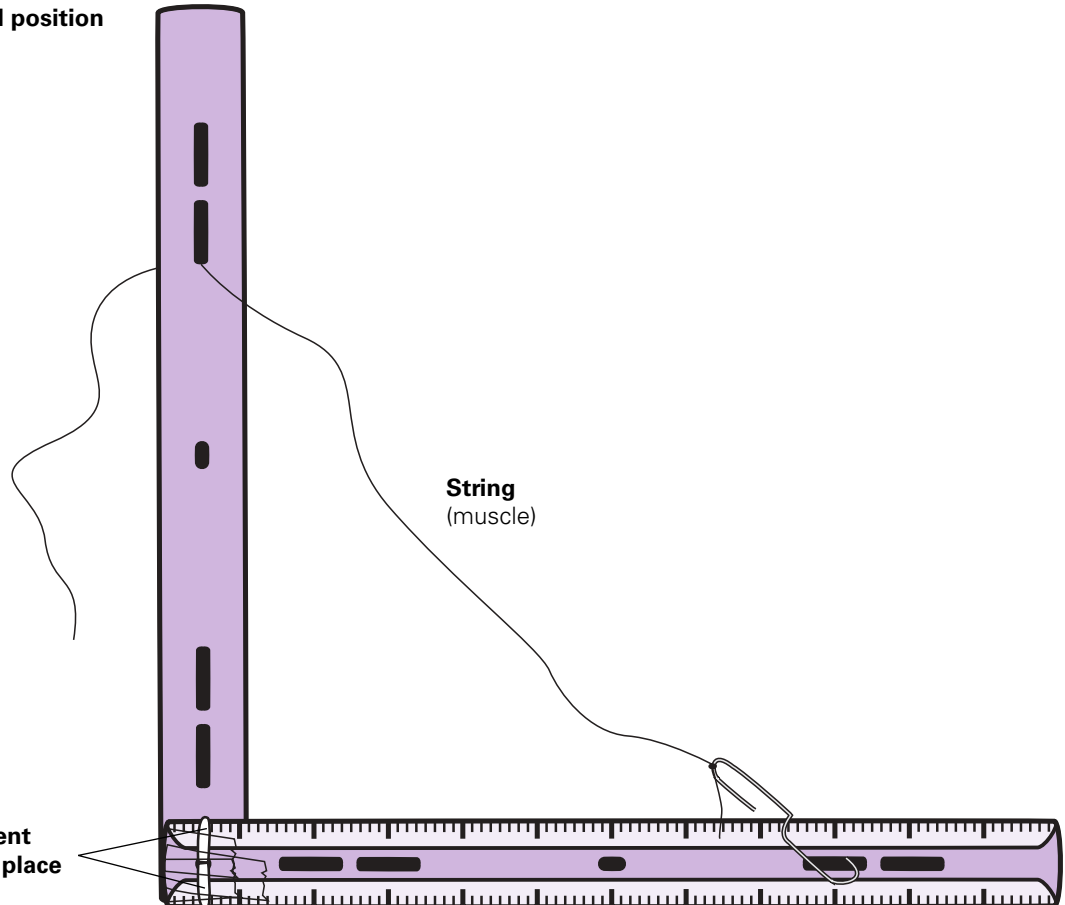
ACTIVITY

ARM MODEL INSTRUCTIONS

To make an arm model, you will need two rulers, 50-cm length of string, a paper clip, a brad and clear tape.

Ruler in vertical position
(upper arm)

**Ends of brad bent
and taped into place**
(joint)



Ruler in horizontal position
(forearm)

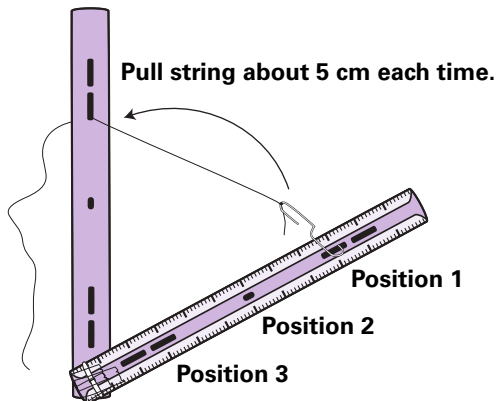
1. Hold the rulers with the smooth sides together. Fasten the rulers together by putting the brad through the end holes of both rulers. Fold the ends of the brad flat against one ruler and tape the ends of the brad in place. Do not overlap the tape onto the second ruler. The rulers will act as an upper 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

MODEL OBSERVATIONS

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

- 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.



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"	

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

- 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!