

THE SCIENCE OF

# MUSCLES

## AND BONES



### Good Stress for Your Body

*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**<sup>®</sup>  
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

# BioEd<sup>SM</sup>

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, Maitihili Daphtary, Ph.D., Michael Grusak, Ph.D., Kathy Major, Grant Schaffner, Ph.D., and Carola Wright, Ph.D. Preparation of this guide would not have been possible without the invaluable assistance of the following field test teachers: Cheryl Anderson, Dorothy Arceneaux, Cathy Bucchino, Veronica Curry, Sharon Fontaine, Lollie Garay, Delores Hall, Marilyn Manning, Demetria Rutherford and Kim Walker.

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

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](http://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](http://www.bcm.edu/edoutreach)

**BCM**  
Baylor  
College of  
Medicine



## SOURCE URLS

### BAYLOR COLLEGE OF MEDICINE BIOED ONLINE / K8 SCIENCE

[www.bioedonline.org](http://www.bioedonline.org) / [www.k8science.org](http://www.k8science.org)

### CENTER FOR EDUCATIONAL OUTREACH

[www.bcm.edu/edoutreach](http://www.bcm.edu/edoutreach)

### HARVARD SCHOOL OF PUBLIC HEALTH THE NUTRITION SOURCE

[www.thenutritionsource.org](http://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](http://www.nasaimages.org)

#### NATIONAL INSTITUTES OF HEALTH

[www.nih.gov](http://www.nih.gov)

#### NATIONAL SPACE BIOMEDICAL RESEARCH INSTITUTE

[www.nsbri.org](http://www.nsbri.org)

#### U.S. DEPARTMENT OF AGRICULTURE

[www.nal.usda.gov/fnic/foodcomp](http://www.nal.usda.gov/fnic/foodcomp)

#### U.S. FOOD AND DRUG ADMINISTRATION

[www.fda.gov](http://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



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](http://www.nsbri.org).

# OVERVIEW

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



ACTIVITY

## GOOD STRESS FOR YOUR BODY

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 the activity, "What Are Bones Made Of?"). 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.

### Needing Stress

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.

### Do Bones Age?

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.

#### SCIENCE, HEALTH & MATH SKILLS GRADES 5–8

- Observing
- Gathering data
- Drawing conclusions

#### CONCEPTS

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



## 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.

## Exercise and Aging

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).

## 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.”



## MATERIALS

### Teacher:

- Overhead projector and screen
- Timers or clock with second hand

### Each group will need:

- 2 transparent plastic knives

### Each student will need:

- Spring-hinge clothespin
- Copy of the student sheet

## SETUP & MANAGEMENT

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

For Part 1, divide students into groups of 2–4 and give each group two plastic knives.

For Part 2, give every student one clothes pin and a copy of the student sheet.

## 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, *Is 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

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 tiny, invisible stress patterns in bones. 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 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 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. Have students 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?*

## EXTENSION

- 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. ◆

## Exercising and Sore Muscles

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.

## Teacher Resources



Downloadable activities in PDF format, annotated slide sets for classroom use, and other resources are available free at [www.bioedonline.org](http://www.bioedonline.org) or [www.k8science.org](http://www.k8science.org).

# ACTIVITY

## STRESS THIS!

You will need a clothespin and a timer, watch or clock with a second hand.

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