LIVING BONES, STRONG BONES

Educator Section

Introduction

Explorers need strong bones so they can face the physical challenges placed on their bodies while in space. The longer astronauts are in the environment of space, the more weak their bones become due to a lack of loading forces (gravity pulling on your body). Bones below the waist are most affected by reduced gravity environments, and the bones located in these areas are more likely to suffer bone loss during spaceflight. It is important for astronauts to train before, during, and after their flight in space to maintain strong bones all their lives. A diet including calcium and Vitamin D also helps astronauts maintain strong bones.

Lesson Objectives

- Students will observe bones, comparing bone size relative to the living being in which the bones are found.
- Students will design a bone model, then compare and contrast the weight bearing capacity of their bone model, making inferences about bone structure, weight bearing bones, and the effects of different environments on those bones.

Problem

How can I make a bone model that is strong and will hold weight?

Learning Objectives

The students will:

- investigate two parts of bone.
- design a bone model that will hold weight.

Materials

Per class:

- meter stick
- balance scale
- gram weights

Engineering Design

Grade Level: 3-5

Connections to Curriculum: Science, Technology, Mathematics, Health and Physical Education

Science Processing Skills: predicting, observing, comparing, gathering, recording data (American Association for the Advancement of Science)

Teacher Prep Time: 30 minutes

Lesson Duration: two 45-minute sessions

Prerequisite: knowledge of the scientific method, science lab safety rules, the new Food Guide Pyramid, and basic physical activity

National Education Standards: Science, Technology, Engineering, Mathematics, Health, and Physical Education

National Wellness Initiative: This activity meets the needs of the federally mandated Local Wellness Initiative, and may help meet the needs of your Local Wellness Plan.

Materials Required:

meter stick
balance scale
stackable gram weights
snack size zipper-seal bags
cooked, clean, dry chicken bones
centimeter rulers
index cards
clear cellophane tape
cardboard squares
textbooks or reams of paper
aquarium gravel
eye protection
red pens
hand lenses

Per group:

- two snack size zipper-seal bags
- one cooked, clean, dry chicken thigh or leg bone
- centimeter ruler
- five index cards (7.6 x 12.7 cm or 3 x 5 in)
- clear cellophane tape
- cardboard square (approx. 24 x 24 cm or 9.4 x 9.4 in)
- textbooks or reams of paper
- enough aquarium gravel to fill a snack size zipper-seal bag to 1/3 full

Per student:

- Living Bones, Strong Bones Student Section
- safety glasses or goggles
- red pen
- hand lens

Safety

Remind students of the importance of classroom and lab safety. Students should wear eye protection during this activity. Students should not remove the chicken bones from the zipper-seal bags.

Pre-lesson Preparation (To be done the day before the activity.)

- To prepare cooked, clean, dry chicken bones:
    - Gather chicken leg or thigh bones, enough for one per group.
    - Place in a large pot and cover with water.
    - Stew chicken bones for 40 – 50 minutes to ensure that they are completely done.
    - Remove the chicken bones from the pot and let cool at least 30 minutes.
    - Remove excess meat and cartilage by scrubbing the chicken bones thoroughly.
    - Use a disinfectant cleaner to sanitize the chicken bones. Rinse with water.
    - Let the chicken bones air-dry overnight.
    - The chicken bones should be clean and dry for use in this investigation.
- Crack each chicken bone slightly so that the inside of the bone may be viewed.
- Place the cooked, clean, dry chicken bones individually into the snack size zipper-seal bags.
- Place aquarium gravel inside a separate snack size zipper-seal bag until it is 1/3 full and pliable. If needed, adjust the amount of aquarium gravel in the zipper-seal bags to fit snug inside an index card cylinder using the following instructions.
    - Using an index card, grasp the shortest side of the index card and roll into a cylinder, fastening with tape. Place the zipper-seal bag with aquarium gravel into the cylinder, removing or adding aquarium gravel as needed.
- Divide class into groups of 3 – 4 students.
- Place group materials in an easily accessible area.
- Stack the textbooks from lightest to heaviest. The heaviest textbook will be used first.
- Place the balance scale in a central location for use during whole group instruction.

    - Paperclips may be substituted for gram weights. If alternative weights are used, pre-weigh them for accuracy.
- Prepare the Data Chart for the Observation Section and display in a central location for use during whole group instruction.
- Display the Living Bones, Strong Bones Glossary in a central location for use during whole group instruction. (Appendix B)
- Display the Bone Comparison Diagram in a central location for use during whole group instruction. (Appendix C)

Lesson Development

To prepare for this activity, the following educator background information is recommended:

- Read about the skeletal system and spaceflight in the National Space Biomedical Institutes' textbook, "Human Physiology in Space", found at http://www.nsbri.org/HumanPhysSpace/focus6/index.html.
- Read about bone remodeling or bone turnover here http://teachhealthk-12.uthscsa.edu/curriculum/bones/pa12pdf/1203D-cycle.pdf.
- Exercise countermeasures to spaceflight can be found at http://hacd.jsc.nasa.gov/projects/ecp.cfm
- Watch animations about the bone remodeling process that show how bone is degraded and rebuilt at http://courses.washington.edu/bonephys/physremod.html.
- Read the following text taken from the Observation Section of the Living Bones, Strong Bones Student Section.

  Observation

  Astronauts need to be able to walk long distances to explore the moon or Mars surface, especially if their rover breaks down. This long distance is called a 10 km walk-back (6.2 miles). Astronauts need to be in top condition to keep their bones strong and healthy, which is essential for performing tasks in space such as the walk-back.

  Bone is a living organ in your body. Bone is broken down and built back up by special cells in the bones. It takes 10 years for your entire skeleton to be replaced with new bone!

  There are two ways to keep your bones healthy – proper diet and resistive exercise. One without the other is not as effective as using both together.

  First, a proper diet will ensure that bones stay healthy. You require calcium and vitamin D to build healthy bones. Where do calcium and vitamin D come from? Calcium is found in dairy products such as milk, cheese, and yogurt, and in leafy green vegetables. Vitamin D is called the "sunshine vitamin" because regular exposure to sunlight gives your body the vitamin D it needs. Vitamin D is added to foods such as milk and orange juice. Astronauts need proper amounts of calcium and vitamin D to keep their bones strong and healthy.

  Second, gravity pulling on your body, or "loading" is essential to bone health. A type of exercise that "loads" your bones is called resistive exercise. When you do push ups, jump rope, or push against a surface, you are doing a resistive exercise, and that helps you build strong bones! Astronauts need resistive exercise to keep their bones strong and healthy.

  Eating a proper diet rich in calcium and vitamin D and being physically active will keep your bones strong. If you go outside to play hopscotch on a sunny day, you are taking in vitamin D from the sun, and getting resistive exercise – two parts of having proper bone health. Doing these things will keep your bones strong, the same way the astronauts keep their bones healthy. Who knows? One day, if you keep your body well-conditioned you could become one of our next space explorers to travel to the moon, Mars, and beyond!

- If needed, additional research can be done on the following topics:
    - calcium
    - vitamin D
    - space travel and bone loss
    - bone remodeling or bone turnover
    - resistive exercise
    - Advanced Resistive Exercise Device (ARED)
    - spaceflight countermeasures for bone loss
- Physical activities that will use energy and allow your students to *train like an astronaut* can be found in the NASA Fit Explorer Challenge at http://www.nasa.gov/fitexplorer or on the STS 118 educator website at http://www.nasa.gov/audience/foreducators/STS-118_index.html.

Instructional Procedure

Throughout this lesson, emphasize the steps involved in the scientific method. These steps are identified in ***bold italic*** print throughout the Instructional Procedure Section.

1. Review the Scientific Investigation Rubric with your class. This performance rubric is located in the Living Bones, Strong Bones Student Section. A sample of performance-based grading is located at the end of this Educator Section.
2. Remind students about how to build and keep strong bones by using the force that holds us on Earth – gravity.
3. Introduce the lesson objective and learning objectives to the students. Review the definition of a model with your class.
4. Review the ***problem*** with the students, “How can I make a bone model that is strong and will hold weight?”
5. Review the Living Bones, Strong Bones Glossary with your class. (Appendix B)
6. Have the students read the Observation Section in their Living Bones, Strong Bones Student Section and discuss what they read with their group. Use your own technique to check for comprehension of the Observation Section.
7. As a class, discuss what bones look like, making ***observations*** about bones using the following strategies. Refer to the Bone Comparison Diagram (Appendix C) during instructional delivery. *Questions and facts for students are in italics.*
    1) Display the meter stick.
    2) Have the students predict how tall a chicken might be.
    3) Record predictions on the Data Chart.
    4) Show the students how tall a chicken might be (Approx. 0.5 meter or 1.64 feet).
    5) Record this measurement on the Data Chart for all students to view.

       This is a good time to apply the skill of conversions from metric to customary units.

Data Chart

Property	**Chicken**		**Chicken Bone**
Length	Predicted	Actual	
Weight			

6) Have students put on eye protection.

7) Distribute to each group, one zipper-seal bag containing a cooked, clean, dry, cracked chicken bone.

8) Give each child a hand lens.

9) Have the students make observations, using hand lenses, about the size and shape of the bone without taking the bone out of the zipper-seal bag. Have students discuss these observations in their group and be ready to share the observations.

10) Ask the students to brainstorm as many properties of the bone as they can with their group.

11) Ask open-ended questions about the chicken bone to the groups, taking all comments from the students. As students answer the questions, record all results in a central location in the classroom.

- *What is the shape of the bone? The bone is cylindrical.*
- *What other shapes do you see in the bone?*
- *What is the color of the bone?*
- *How does the bone feel?*
- *How large is the bone compared to your hand?*

12) Have the students measure the bone with their group, using the centimeter ruler.

13) Record the length of each group's bone on the Data Chart displayed in the classroom.

14) Have students analyze the data collected about the chicken bone by asking open-ended questions to the groups.

- *What is the bone's size (recorded earlier) compared to the size of the chicken? The bone is much smaller than the chicken.*

15) Have the students make observations, using hand lenses, about the outside of the bone without taking the bone out of the zipper-seal bag. Have students discuss these

observations in their group and be ready to share their observations. Record these properties in a central location in the classroom.

16) Ask the students to brainstorm as many properties of the outside layer of the bone as they can with their group.

17) Ask open-ended questions about the outside layer of the bone to the groups, taking all comments from the students. As students answer the questions, record all results in a central location in the classroom.

    - *Why is this layer so thick? To perform the duties of walking, running, jumping, and landing while supporting the weight of the chicken against the pull of gravity.*

18) Have the students make observations, using hand lenses, about the inside of the bone without taking the bone out of the zipper-seal bag. Have students discuss these observations in their group and be ready to share their observations. Record these properties in a central location in the classroom.

19) Ask the students to brainstorm as many properties of the inside of the bone as they can with their group.

20) Ask open-ended questions about the inside of the bone to the groups, taking all comments from the students. As students answer the questions, record all results in a central location in the classroom.

    - *What is inside the bone?*
    - *What does it look like? This part of the bone, found inside the hard outer covering, has spaces between the framework that provide the bone more surface from which calcium can be extracted. The interlocking material gives the bone strength.*
    - *What does this bone remind you of?*
    - *What role does the inside bone have on how strong the bone is? It is lightweight and has cross-bridge structures which help to maintain strength without being heavy.*
    - *What is the function of bones inside the chicken? To give the chicken its shape and to hold the chicken's body up against the force of gravity.*

21) Display the weight of a chicken on the Data Chart for all students to view. (Approx. 2.6 kg or 5.7 lbs)

22) Model for the students how to weigh the chicken bone on the balance scale using gram weights.

23) Have students weigh their group's chicken bone using the balance scale and gram weights.

24) Record the weight of each group's bone on the Data Chart displayed in the classroom.

25) Ask students to compare the weight of the chicken bone to the weight of the chicken. Let the students draw conclusions on how the bone holds the weight of the chicken, using data collected.

    The bone can support the weight of the chicken because it is strong. Each bone has an outside layer and an inside layer making it strong.

    - *How does the chicken compare to a human? Both have bones. Humans are much larger than chickens.*
    - *Are human legs like chicken legs? Yes, they both have bones that hold up the body against the force of gravity.*

- *What is the difference between human bones and chicken bones? Chicken bones are smaller and more lightweight.*
- *Have the students compare the chicken and the chicken bone to a human and a human bone using the relative size and weight of each.*
- *What would happen to bones if we took the force of gravity away from the body? Lack of gravity makes bones become weak.*

8. Collect materials used by the groups during the Observation Section according to your materials rules. Replace all materials appropriately.

SUGGESTED PLACE TO STOP ACTIVITY AND CONTINUE DURING ANOTHER CLASS PERIOD.

9. Have the students discuss and make ***observations*** about bones by completing the first two columns in the KWL (KNOW/WANT TO KNOW/LEARNED) chart in the Living Bones, Strong Bones Student Section with their group. Use the KWL chart to help students organize prior knowledge, identify interests, and make real world connections. As students suggest information for the KNOW column, ask them to share how they have come to know this information.
10. Display one index card for all students to see.
11. Explore what an index card is by using the following questions.
    - *What is an index card? What is it used for? What else can an index card be used for? Where have you seen one before?*
12. Ask the students if they have predictions relating to this activity, and the problem question. Help them refine their predictions into a ***hypothesis*** or educated guess to answer their problem question. In their student section, they should restate the problem question as a statement based upon their observations, materials, and predictions. As they formulate a hypothesis, have students include verbs from the objectives. Encourage the students to share their hypothesis with their group.
13. Students will ***test*** their hypotheses following this procedure.

    (These steps were taken from the Living Bones, Strong Bones Student Section. Educator specific comments are in *italics*. Diagrams are included for modeling by the educator.)

    Students should be in groups when testing their hypotheses. Follow your normal group materials distribution process, but refrain from passing out or letting the students see the zipper-seal bags filled with aquarium gravel until called for in the test procedure. Do not distribute index cards until prompted. The students should use their red pens for predictions only.

    1) Study the index card.
        - Discuss the shape, size, and thickness of bones.
        - Decide how you would like to design your group bone model from the index card.
            - Design a bone model making sure your bone model is:
                - made much like the chicken bone, and
                - sturdy enough to hold weight.
    2) Complete your individual bone model design drawing on your own piece of graph paper.

        This is not a picture of a bone, but a model of a bone made from the index card. Be prepared for students to make different types of models. Demonstrate to students how to design the bone model by using a rolled index card, making it into a cylinder, and fastening with tape. The bone model should be rolled grasping the shortest side of the index card to *start the rolling process. Make sure the students understand that this represents the outer part of the bone, leaving the inside hollow. Each group should have one design. All students should have the same drawing.*

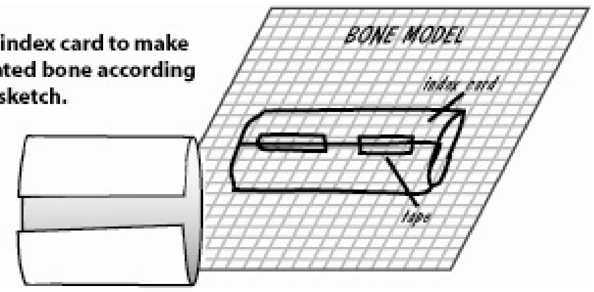
3) Label the materials in your design on your graph paper.
4) Group members should agree on a title for your bone model design, and include it on your graph paper.

   Pass out one index card to each group, reserving the rest of the cards for use later.

5) Use the index card to build a bone model according to your sketches, using the tape for fastening.

   Observe each group making their bone model, making sure each group builds according to their design. Prompt students to refer back to their design for comparison between their bone sketch and their bone model. Warn the students to use caution when rolling the index card so that it does not crease. You may want to model this rolling of the index card for the class again.

Use the index card to make a simulated bone according to your sketch.

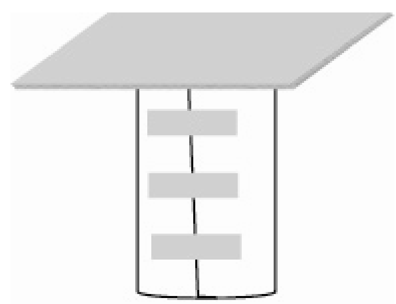


6) Place the bone model on the table in the same way your leg bone is in your body when you are standing up.
7) Record the materials you will use to construct your bone model on your Living Bones, Strong Bones Data Sheet.
8) Place the cardboard square on top of the bone model.
9) Predict how many textbooks you will be able to stack on the bone model.

   The textbooks represent the weight of your body.

   Review how to make predictions with your class.

10) Record your prediction on your Living Bones, Strong Bones Data Sheet using a red pen.
11) Place the textbooks, one at a time, on the cardboard square until you run out of textbooks or your bone model collapses.



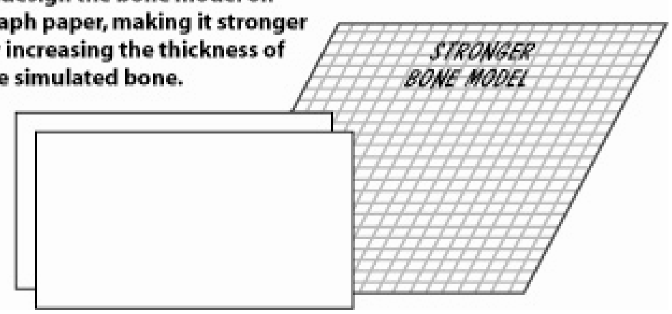
Place the cardboard square on top of the bone model.

   The bone model should collapse easily under the weight of the textbooks. Explain to the students that this bone has not had the proper amount of calcium, vitamin D, and resistive exercise, or has been in a reduced gravity environment. Reserve this bone model for later reference.

12) ***Collect and record data*** by counting the number of books your bone model was able to hold and recording the number on your Living Bones, Strong Bones Data Sheet.

   The bone model you tested represents bones that are weak due to improper amounts of

Redesign the bone model on graph paper, making it stronger by increasing the thickness of the simulated bone.



calcium and vitamin D, a lack of resistive exercise, or the force of gravity no longer pulling on them. Your bones need resistive exercise and a healthy diet including calcium and vitamin D to stay strong.

A reduced gravity environment promotes loss of bone due to the absence of gravitational pull on bones.

Compare bone models by asking each group to hold up their bone model and state how many textbooks it held. With the class, analyze the shape and size of each bone model and compare how the shape and size affected the weight it held. This analysis will prompt the redesign process of the next bone model.

13) Redesign the bone model on your graph paper, making it stronger by increasing the thickness of the simulated bone. This strengthening of your bone represents increased resistive exercise and a diet rich in calcium and vitamin D. Make sure you label your drawing, including the new materials.

14) Record the materials you will use to construct your new bone model on your Living Bones, Strong Bones Data Sheet.

    Pass out two index cards per group. Simulated bones made from more than one layer of index cards demonstrate increased strength in the outside bone. Model to students how to layer the cards for added strength. Roll the index cards grasping the short ends of the index cards to start the rolling process.

15) Rebuild the bone model using two index cards.

    Observe the students making the new bone model. Refer them back to their drawings for redirection.

16) Predict how many textbooks you will be able to stack on the new bone model.

17) Record your prediction on your Living Bones, Strong Bones Data Sheet using a red pen.

18) Place the textbooks, one at a time, on the cardboard square until you run out of textbooks or your new bone model collapses.

    This improved bone model will hold more weight due to the thickness of the bone. Reserve this bone model for later reference.

19) ***Collect and record data*** by counting the number of books your new bone model was able to hold and recording the number on your Living Bones, Strong Bones Data Sheet.

    The bone model you tested represents bone that is somewhat weak due to less than sufficient amounts of calcium and Vitamin D and resistive exercise. In addition, the force of gravity has been reduced. Your bones need resistive exercise and a healthy diet including calcium and vitamin D to stay strong.

    Compare bone models by asking each group to hold up their new bone model and state how many textbooks it held. With the class, analyze the shape and size of each bone model and compare how the shape and size affected the weight it held. This analysis will prompt the redesign process of the next bone model.

20) Redesign the bone model on your graph paper, making it stronger by placing material inside the bone model. This strengthening of bone is due to proper nutrition, including a diet rich in calcium and vitamin D and resistive exercise. Make sure you label your drawing, including the new materials.

21) Record the materials you will use to construct your new bone model on your Living Bones, Strong Bones Data Sheet.

Pass out two index cards and the zipper-seal bags 1/3 full of aquarium gravel. Explain that the gravel in the bag represents the inside of a bone. Drawings should show aquarium gravel inside the cylinder. This represents strong, healthy bone.

22) Using your new bone model sketch, build a new bone model out of two index cards.

    Observe the students making the new bone model. Refer them back to their design for redirection. Have the students build the bone model just as the previous bone model was built except have them layer the two index cards before grasping the short end of the index cards to begin the rolling process.

23) Place the zipper-seal bag containing aquarium gravel inside the bone model.

24) Predict how many textbooks you will be able to stack on the bone model.

25) Record your prediction on your Living Bones, Strong Bones Data Sheet using a red pen.

26) Place the textbooks, one at a time, on the cardboard square until you run out of textbooks or your bone model collapses.

    This bone model represents a healthy, strong bone. Reserve this bone model for later reference.

27) ***Collect and record data*** by counting the number of books your bone model was able to hold and recording the number on your Living Bones, Strong Bones Data Sheet.

14. After taking all measurements, ***study data*** by answering the questions following the Living Bones, Strong Bones Data Sheet.

    Using this information, ask the students to determine if the data supports or refutes their hypothesis.

Conclusion

- Discuss the answers to the Study Data questions in the Living Bones, Strong Bones Student Section.
- Have the students update the LEARNED column in their KWL chart.
- Have the students restate their hypothesis and explain what happened during testing, including their results.
- Ask students to compare their group data to the class data. What patterns can be found?
- Ask students what they wonder now. Encourage students to design their own experiments.

Assessment

- Assess student knowledge through questioning.
- Assess student understanding by administering the Living Bones, Strong Bones Quiz. (Appendix A)
- Observe and assess student performance throughout the activity using the Scientific Investigation Rubric found in the Living Bones, Strong Bones Student Section.

Activity Alignment to National Education Standards

National Science Education Standards (NSES):
Content Standard A: Science as Inquiry

- Abilities necessary to do scientific inquiry (K-8)
- Understandings about scientific inquiry (K-8)

Content Standard E: Science as Inquiry

- Abilities of technological design (K-8)
- Understanding about science and technology (K-8)

Content Standard F: Science in Personal and Social Perspectives

- Personal health (K-8)
- Characteristics and changes in populations (K-4)
- Changes in environment (K-4)
- Science and technology in local challenges (K-4)
- Science and technology in society (5-8)

National Technology Education Standards (ITEA):
Design:

- Standard 8: Students will develop an understanding of the attributes of design.
- Standard 9: Students will develop an understanding of engineering design.

National Mathematics Education Standards (NCTM):
Data Analysis and Probability Standard:

- Develop predictions that are based on data.

Measurement Standard:

- Apply appropriate techniques, tools, and formulas to determine measurements.

National Health Education Standards (NHES) Second Edition (2006):
Standard 1: Students will comprehend concepts related to health promotion and disease prevention to enhance health.

As a result of health instruction in grades 3 through 5, students will:

- 1.5.1 Describe the relationship between healthy behaviors and personal health.

Standard 5: Students will demonstrate the ability to use decision making skills to enhance health.

As a result of health instruction in grades 3 through 5, students will:

- 5.5.1 Identify health related situations that might require thoughtful decision.

Standard 7: Students will demonstrate the ability to practice health enhancing behaviors and avoid or reduce health risks.

As a result of health instructions in grades 3 through 5, students will:

- 7.5.1 Identify responsible personal health behaviors.
- 7.5.2 Demonstrate a variety of healthy practices and behaviors to maintain or improve personal health.

Curriculum Explorations

To extend the concepts in this activity, the following explorations can be conducted:

Mathematics Exploration

Ask students to display their data in a graphic organizer of their choice. Ask them to explain why they have chosen to display their data in this format.

Analyze the data, looking for patterns and trends.

National Mathematics Education Standards (NCTM):

Algebra Standard:

- Understand patterns, relations, and functions
    - represent and analyze patterns and functions, using words, tables, and graphs

Data Analysis and Probability Standard:

- Develop and evaluate inferences and predictions that are based on data
    - propose and justify conclusions and predictions that are based on data and design studies to further investigate the conclusions or predictions

Language Arts Exploration
Ask students to explain the experiment. How might students improve this experiment? Where might there have been mistakes made? How might these mistakes have affected their results?

Write a fictional story about the lifestyles and environments of people whose bone health demonstrates the results found in each of the bone models.

National Council of Teachers of English Standards (NCTE):

- Students conduct research on issues and interests by generating ideas and questions, and by posing problems. They gather, evaluate, and synthesize data from a variety of sources (e.g., print and non-print texts, artifacts, people) to communicate their discoveries in ways that suit their purpose and audience.

Fine Arts Exploration
Ask students to display their bone models in a creative way, illustrating what happened in each test. Students could also display the results according to healthy and unhealthy bone, using a progression.

National Visual Arts Standards

- Content Standard 5: Reflecting upon and assessing the characteristics and merits of their work
    a) Understand there are various purposes for creating works of visual art.

Sources and Career Links

Thanks to subject matter experts Dr. Jean Sibonga, Dr. Scott Smith, Dr. Don Hagan, Dorothy Metcalf-Lindenburger, and Sara Zwart for their contributions to this NASA Fit Explorer activity.

Dr. Jean D. Sibonga is a senior scientist and is the Scientific Lead for the Bone Mineral Laboratory (http://hacd.jsc.nasa.gov/labs/index.cfm) at the NASA Johnson Space Center in Houston, TX. You can find out more about Dr. Sibonga here: http://www.dsls.usra.edu/sibonga.html.

Dr. Scott M. Smith is the Scientific Lead for the Nutritional Biochemistry Lab at the NASA Johnson Space Center in Houston, TX. You can find out more about Dr. Smith and his work here: http://hacd.jsc.nasa.gov/labs/nutritional_biochem.cfm.

Dr. R. Donald Hagan is the Exercise Lead for the Human Adaptations and Countermeasures Office at the NASA Johnson Space Center. You can read more about his laboratory here: http://hacd.jsc.nasa.gov/labs/exercise_physiology.cfm.

Dorothy Metcalf-Lindenburger is an Astronaut, Educator Mission Specialist, at NASA Johnson Space Center in Houston, TX. You can read more about Metcalf-Lindenburger at http://www.jsc.nasa.gov/Bios/htmlbios/metcalf-lindenburger-dm.html.

Sara R. Zwart is a Research Scientist at the Nutritional Biochemistry Laboratory at the NASA Johnson Space Center in Houston, TX. You can read more about Ms. Zwart here: http://www.dsls.usra.edu/zwart.html.

Educator and Student Resources

Web resources:

The Healthy Kids website teaches your students good health practices with correct food choices and exercise. http://www.kidshealth.org/parent/nutrition_fit/index.html

The Action for Healthy Kids website can help your school design a wellness plan. Investigate new ways to engage students in physical activity and how to provide nutritious meals during school. http://www.actionforhealthykids.org

The Learn to Be Healthy website offers activities and lesson plans on nutrition and physical activity. http://www.learntobehealthy.org

This Centers for Disease Control and Prevention website highlights bone health for women and girls. http://www.cdc.gov/powerfulbones

This NASA resource from the Nutritional Biochemistry Lab at the NASA Johnson Space Center in Houston, TX provides Space Nutrition Newsletters for kids. http://hacd.jsc.nasa.gov/resources/kid_zone_newsletters.cfm

The National Space Biomedical Research Institute has a variety of space-related educational materials ready for download. http://www.nsbri.org/Education/Elem_Act.html

Books and articles:

The Skeleton Inside You, by Phillip Balestrino, True Kelley (Illustrator),ISBN: 0064450872, ISBN-13: 9780064450874 Publisher: HarperCollins Children's Books Age Range: 5 to 9, **Annotation:** An introduction to the human skeletal system, explaining how the 206 bones of the skeleton join together, how they grow, how they help make blood, what happens when they break, and how they mend.

Bones: Our Skeletal System by Seymour Simon, Grade 3-5, Publisher SCHOLASTIC INC. ©1999, ISBN 0439078083 (EAN 9780439078085). **Annotation:** In his instantly recognizable style, Simon addresses the anatomy and function of bones. Describing bones as being like "the framework of a building," he emphasizes that they are living parts of the body.

Skeleton (Eyewitness Book Series)**.**by Steve Parker, ISBN: 0756607272 Pub. Date: August 2004 Series: Eyewitness Books Series. Age Range: 9 to 12. **Annotation:** Along with the 206 human bones, readers can browse through over sixty pages of animal skeletons. Organized in twenty-five chapters, the text is tiny, packed with information. Large shots entice tracing, drawing, and scrutiny.

This hands-on activity was adapted from activities in *From Outer Space to Inner Space/Muscles and Bones: Activities Guide for Teachers* created by Baylor College of Medicine for the National Space Biomedical Research Institute under NASA Cooperative Agreement NCC 9-58. The activities used with permission of Baylor.

Lesson development by the NASA Johnson Space Center Human Research Program Education and Outreach team.

Living Bones, Strong Bones Quiz

Answer the following questions about the Living Bones, Strong Bones activity.

1. Draw a picture of the inside and the outside of a strong bone. What does it look like? Label the bone.

   Draw a picture of the inside and the outside of an unhealthy bone. What does it look like? Label the bone.

2. List two factors that help make bones strong.

   a.

   b.

3. What happens to astronauts' bones when they leave the Earth?

4. How do astronauts keep bones healthy before flight, during the mission, and when they return to Earth?

Living Bones, Strong Bones Glossary

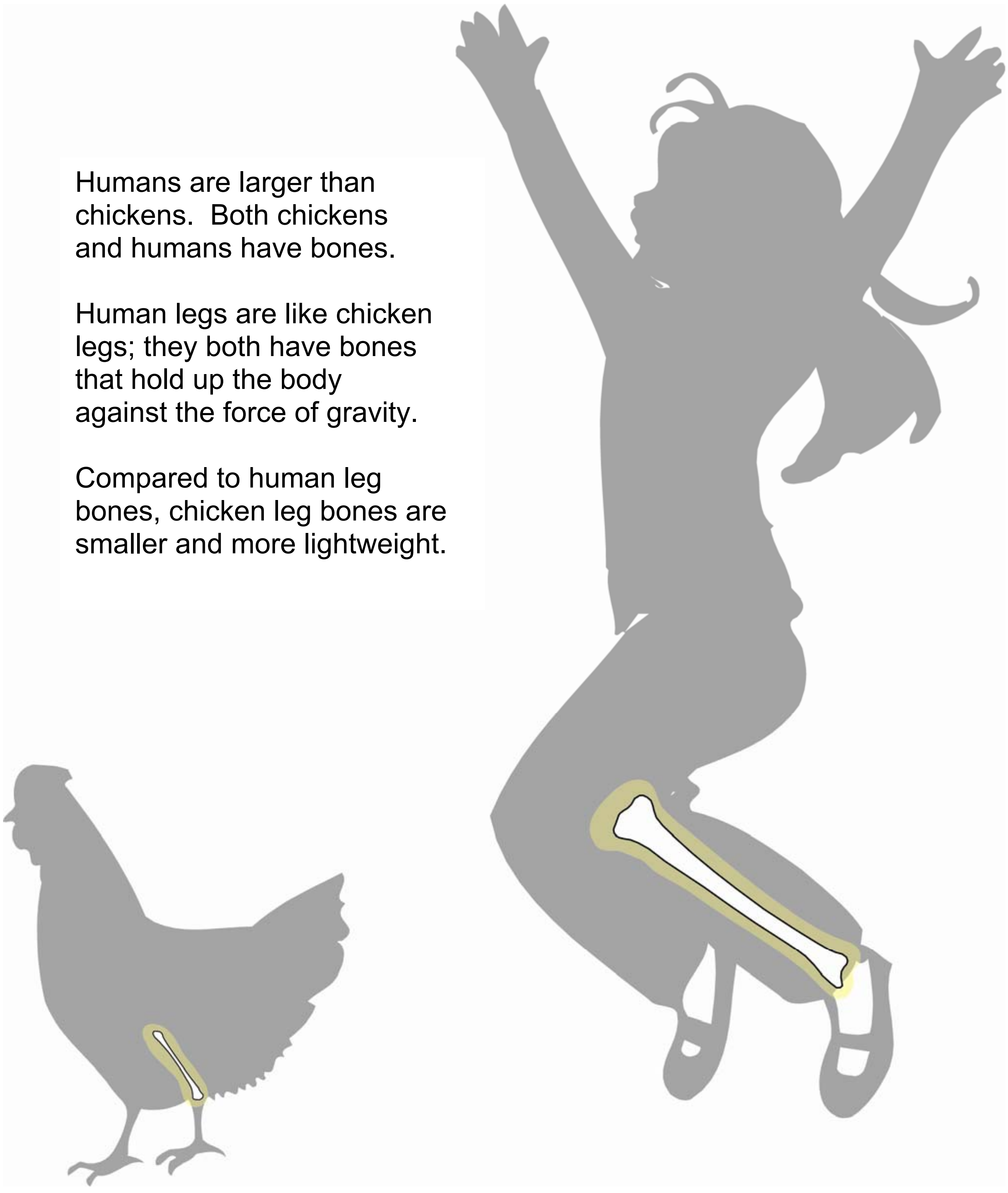
walk-back	The task of walking a distance up to 10 km (6.2 mi) which astronauts must be able to complete in order to return to their base station.
loading	The weighted effect of gravity on your body. Loading can be further increased by adding resistance.
model	A physical representation of an object.
resistive exercise	A type of exercise in which the body's muscles move (or try to move) against a force or weight; usually created using a type of equipment.
bone marrow	The spongy tissue that fills most bone cavities and is the source of red blood cells and many white blood cells.
cortical bone (kôr'tĭ-kəl)	A dense and compact outer layer of bone that forms a shell around bone marrow.
trabecular bone (trə-bĕk'yə-lər)	Smaller bones that form a spongy structure in the bone marrow found inside the cortical bone shell.

Bone Comparison Diagram

Humans are larger than chickens. Both chickens and humans have bones.

Human legs are like chicken legs; they both have bones that hold up the body against the force of gravity.

Compared to human leg bones, chicken leg bones are smaller and more lightweight.



Scientific Investigation Rubric

Experiment: Living Bones, Strong Bones

Performance Indicator	4	3	2	1	0
The student developed a clear and complete hypothesis.	The student developed a clear, complete hypothesis.	The student developed a complete but not fully developed hypothesis.	The student developed a partial hypothesis.	The student made very little attempt at developing a clear and complete hypothesis.	The student made no attempt at developing a clear and complete hypothesis.
The student followed all lab safety rules and directions.	The student followed all of the lab safety rules.	The student followed most of the lab safety rules.	The student followed two or more lab safety rules.	The student followed one lab safety rule.	The student followed no lab safety rules.
The student followed the scientific method.	The student followed all of the steps in the scientific method.	The student followed most of the steps in the scientific method.	The student followed two or more of the steps in the scientific method.	The student followed one of the steps in the scientific method.	The student followed none of the steps in the scientific method.
The student recorded all data on the data sheet and drew a conclusion based on the data.	The student recorded all data and completed the conclusion.	The student recorded most data and had a conclusion nearing completion.	The student showed two or more records of data collection and showed a partial conclusion.	The student showed one record of data collection and did not complete the conclusion.	The student showed no record of data and no evident conclusion.
The student asked engaging questions related to the study.	The student asked four or more engaging questions related to the study.	The student asked three engaging questions related to the study.	The student asked two engaging questions related to the study.	The student asked one engaging question related to the study.	The student asked no engaging questions related to the study.
The student designed a bone model that was strong and held weight.	The student designed a bone model that was strong and held weight.	The student had a complete design that did not hold weight	The student had a partial design that did not hold weight.	The student had a partial design but did not test the model.	The student did not design a bone model.
Point Total					

Grading Scale:

A = 22 - 24 points B = 19 - 21 points C = 16 - 18 points D = 13 - 15 points F = 0 - 12 points