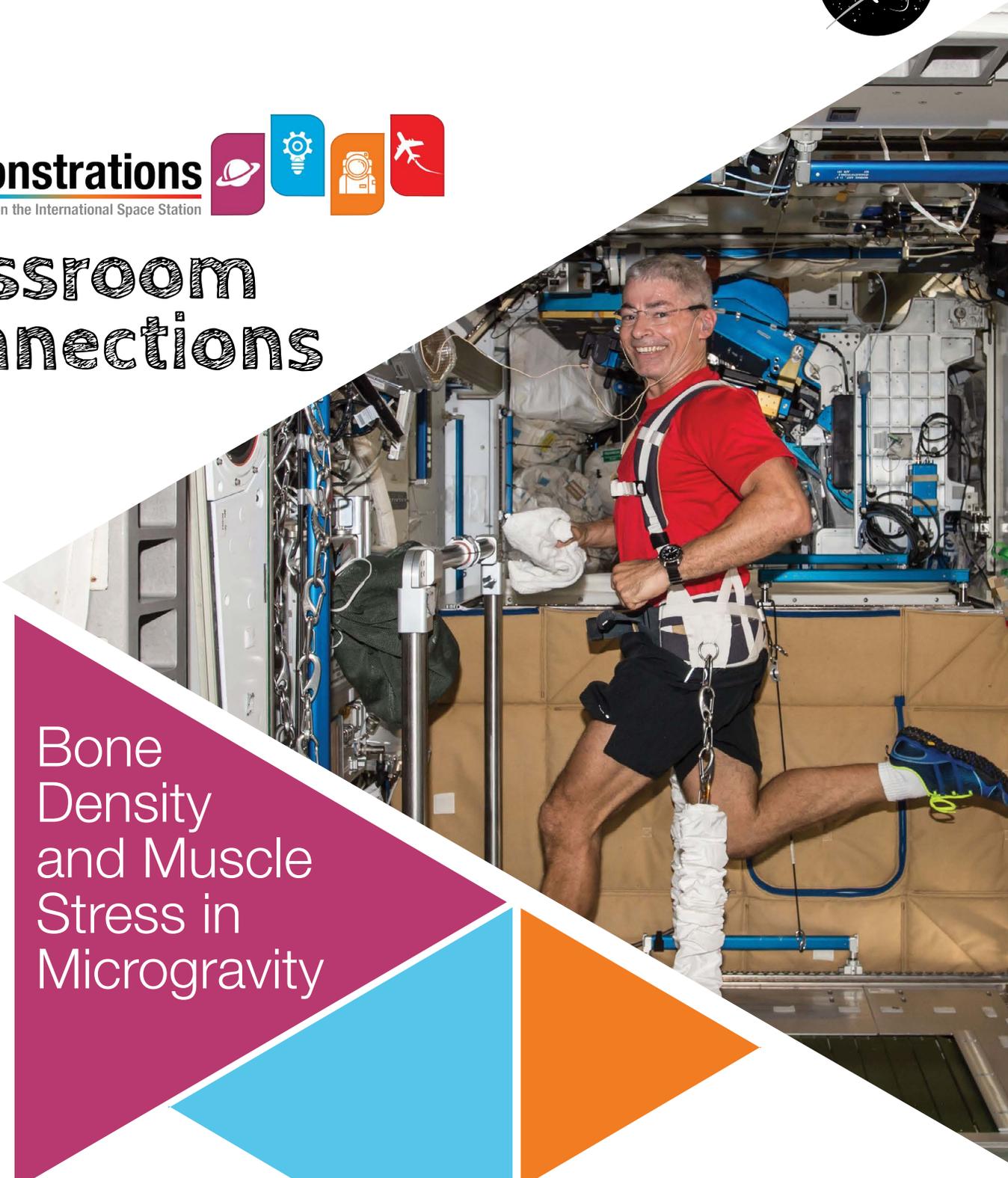




Classroom Connections

Bone
Density
and Muscle
Stress in
Microgravity



For more STEMonstrations and Classroom Connections, visit www.nasa.gov/stemonstation.

Grade Level: **4th-8th**Time Required: **60 Minutes**

5 minutes to watch & discuss the video STEMonstration: Exercise; 50 minutes to conduct activity; 5 minutes to wrap up discussion with students and their peers.



Next Generation Science Standards (NGSS):

4-LS1-1. Construct an argument that plants and animals have internal and external structures that function to support survival, growth, behavior, and reproduction.**MS-LS1-1.** Conduct an investigation to provide evidence that living things are made of cells; either one cell or many different numbers and types of cells.**MS-LS1-3.** Use argument supported by evidence for how the body is a system of interacting subsystems composed of groups of cells.**Crosscutting Concepts:** Cause and Effect**Science and Engineering Practices:** Asking questions; Planning and carrying out investigations; Analyzing and interpreting data; Constructing explanations

Background

Life in the microgravity environment of space brings many changes to the human body. The loss of bone and muscle mass, change in cardiac performance, variation in behavior, and body-wide alterations initiated by a changing nervous system are some of the most apparent and potentially detrimental effects of microgravity. Loss of bone mass is particularly noticeable because it affects an astronaut's ability to move and walk upon return to Earth's gravity. Astronauts spend much of their days "floating" and propelling themselves with their arms, which eliminates the need for bones used in standing and walking on Earth.

Astronauts who spend more than a week in space can suffer from bone loss. This drop in density, known as disuse osteoporosis, leaves bones weak and less able to support the body's weight and movement upon return to Earth, putting the astronaut at a higher risk of fracture. Disuse osteoporosis occurs because astronauts do not use their bones in space the same way that they do on Earth.

Exercise is imperative for any astronaut's daily routine. It slows the rate of bone mass loss and keeps the crew healthy and ready for any challenge. In this activity, you will show how an impact affects bones of varying mass, and you will see how important it is to stay active and keep your bones healthy.



Objective

Following this activity, students will be able to:

- Identify the effects of decreased bone mass
- Describe why healthy bones are important in space and on Earth

Today you will test how an impact can affect bones of different densities. You will use a piece of cereal to represent a bone cell. Some bones have more cells which means they have higher density. Disuse or inactivity will lead to a decrease in bone density. You will make 4 bags filled with cereal to represent 4 bones, each with a different amount of bone loss.

Materials Per Group

- 4 plastic snack bags (smaller bags make cereal easier to count)
- Corn puff cereal
- Heavy textbook
- Permanent marker
- Copies of student worksheet (1 per student or 1 per group)

Also, have a broom and dustpan on hand for any potential clean-up!

Procedure

1. Begin with a discussion of osteoporosis. Students may know someone – grandparents, for example – who suffers from osteoporosis. Do they know what osteoporosis is? Do they know what causes it?
2. Show the STEMonstrations: Exercise video available at www.nasa.gov/STEMonstrations. Following the video, talk with students about the effects microgravity can have on bones.
3. Tell students they are going to investigate bone loss and its effects. To do this, they will use baggies filled with varying amounts of cereal to represent different bones of different densities. By removing some of the cereal from bags, students will simulate a bone with lower density.
4. Distribute supplies to the students. It is recommended that students work in groups of four for this activity.
5. Students should follow directions on the worksheet. Note about cereal smashing: some cereal will have existing imperfections (holes, partial pieces, etc.). These pieces should not be used in the bags. Discuss what students should look for when they are counting “affected” pieces of cereal. Pieces that have dust (from other smashed pieces) or only a tiny flake taken off should not be counted as “affected.”
6. After the students complete the activity, have each group share their results with the class and discuss.
7. If some groups’ results did not turn out as expected, discuss possible reasons (miscounting, uneven force, etc.).

NOTE: This activity has been adapted from NASA's Bag of Bones activity. For the original activity, please visit https://www.nasa.gov/pdf/663094main_Bag_of_Bones_Activity.pdf.



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Bone Density

Student Activity



Get Ready:

- Four snack bags
- Corn puff cereal
- A heavy book (textbook)
- Permanent marker
- Pen or pencil



Think About It:

- Why is it important to have strong, healthy bones?

- What will happen if your bones become weak?



Form Your Hypothesis:

- What will happen to a bone (represented by your cereal bags), if a force is applied?
- How will the results change if the bone density changes?



Procedure

1. Using a permanent marker, label the bags 1-4.
2. Bag 1 will represent healthy bone on Earth. To build this “bone”, you will use pieces of cereal to represent units of bone mass. As you add cereal into the bag, keep count. You will record the number of cereal pieces you put in the bag on the data table on your worksheet. Fill Bag 1 until there is very little room left, but make sure you can still close the bag. Make sure the bag is closed tightly – otherwise you will end up with a big mess!
3. To represent a bone that has lost mass as a result of spaceflight, fill the remaining three bags with less cereal, or bone mass, than Bag 1.

Bag 1: 0% bone loss (normal bone)

Bag 2: 80% of original bone remains; 20% bone loss

Bag 3: 60% of original bone remains; 40% bone loss

Bag 4: 40% of original bone remains; 60% bone loss

To determine the amount of cereal needed in Bag 2, you will need to calculate 80% of normal bone density. To do this, you will multiply the number of pieces of cereal in Bag 1 by .8 to find the total number of pieces you should put in Bag 2.

4. Use the same method to calculate 60% and 40% of the normal bone density, and fill Bag 3 and Bag 4 with these amounts. Be sure to record data on your worksheet.
5. Now it is time to see what happens when a bone is exposed to a sudden force. Place Bag 1 on a hard surface. Place a heavy book on top of the bag and push down with a hard force. Repeat this step with Bags 2-4.
6. What happened to your bones? Count the number of unaffected cereal pieces in each bag. Be sure to record your data on your worksheet.
7. How much bone was unaffected? To calculate this, use the formula below, and record your values on your worksheet.

$$\left[\frac{\text{\# unaffected remaining in the bag}}{\text{original density of the bag}} \right] \times 100$$

8. How much bone was damaged / affected? To calculate this value, subtract the unaffected bone percentage from 100%. Record your data on your worksheet.

Group Members: _____

Normal Bone Density = _____ pieces of cereal in Bag 1
 Density of Bone 2 (80% of Bag 1) = _____ pieces of cereal in Bag 2
 Density of Bone 3 (60% of Bag 1) = _____ pieces of cereal in Bag 3
 Density of Bone 4 (40% of Bag 1) = _____ pieces of cereal in Bag 4

BEFORE THE EXPERIMENT			AFTER THE EXPERIMENT		
Bag	Bone Loss Represented	Density (# of cereal pieces in bag)	# of unaffected pieces	% of bone unaffected	% of bone affected
1	0%				
2	20%				
3	40%				
4	60%				

Analyze results

1. What observations did you make about damage to the cereal pieces as the amount of cereal in the bags decreased?
2. Does your data support your hypothesis? Why or why not?
3. Imagine your bag was a real bone. What would happen if a sudden force was applied?
4. How do you think we can prevent bone loss both on Earth and in space?

Grade Level: **4th-8th**Time Required: **45 Minutes**
+ 2-3 minutes per day for two weeks*5 minutes to watch & discuss the video STEMonstration: Exercise; 35 minutes to conduct activity; 5 minutes to wrap up discussion with students and their peers.*

Next Generation Science Standards (NGSS):

4-LS1-1. Construct an argument that plants and animals have internal and external structures that function to support survival, growth, behavior, and reproduction.**MS-LS1-1.** Conduct an investigation to provide evidence that living things are made of cells; either one cell or many different numbers and types of cells.**MS-LS1-3.** Use argument supported by evidence for how the body is a system of interacting subsystems composed of groups of cells.**Crosscutting Concepts:** Cause and Effect**Science and Engineering Practices:** Asking questions; Planning and carrying out investigations; Analyzing and interpreting data; Constructing explanations

Background

The human body, including our muscles and bones, requires physical stress in order to get stronger and grow. Physical stress is a factor that causes bodily tension. You might feel stress in your legs when you ride a bike or lift a heavy object. Astronauts in space require this same type of stress in order to keep their bones and muscles healthy during spaceflight. The pull of gravity on Earth forces us to experience physical stress because we have to work against gravity everytime we move our bodies. Our muscles are always working to counteract the force of gravity and they allow us to stay balanced. Astronauts use resistance exercise machines, such as the Advanced Resistive Exercise Device (ARED), to simulate weight lifting. It helps keep their muscles strong when they are in a microgravity environment. They must exercise two hours per day to maintain their muscle mass that would otherwise be lost during spaceflight.

Just like in space, a lack of stress is bad on our muscles here on Earth, and with regular exercising (AKA putting your muscles through stress), you will eventually get better at performing whatever physical activity you choose to do. This is because your muscles will adapt to the new activity being performed. For example, it might be hard for you to do 25 push-ups right now, but with practice, it should become easier in 1-2 weeks.

Think about how microgravity would affect your own muscles. Since astronauts float from place to place in space, they do not use their muscles as regularly as we do here on Earth. Can you see why exercising in space might be important?

Objective

Following this activity, students will be able to:

- Identify the effects of decreased muscle use
- Understand how muscles adapt
- Describe why healthy muscles and exercise are important in space and on Earth

In this activity, you will use a clothespin to observe how the body reacts to physical stress. You will be the test subject over an extended period of time by using your fingers to open a clothespin. You will try to open the clothespin as many times as possible during a span of 60 seconds. How will you do? How could you become faster and stronger?

Materials

- Clothespins
- Timer / clock
- Student Worksheet



Procedure

1. Show the STEMonstrations: Exercise video available at www.nasa.gov/STEMonstrations. Following the video, talk with students about the effects microgravity can have on muscles.
2. Tell students they are going to investigate how the body reacts to physical stress. They will repeat a simple exercise over two weeks to see how muscles can adapt. For this activity, students should work in pairs.
3. Students should follow directions on the worksheet and record their data.
4. After the students complete the activity, have each pair share their results with the class and discuss.

NOTE: This activity has been adapted from NSBRI's Muscles and Bones activity guide. For the original activity guide, please visit <http://nsbri.org/wp-content/uploads/2015/06/Muscles-and-Bones-Guide.pdf>.



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Muscle Stress

Student Activity



Get Ready:

- Clothespins
- Timer / clock



Think About It:

- Why is it important to have strong, healthy muscles?

- What will happen if your muscles become weak?

- Does microgravity make it easier to lift a heavy object?



Form Your Hypothesis:

- What will happen if you repeat an exercise over and over using the same muscles?



Procedure

1. Predict the number of times you will be able to open a clothespin using your thumb and index finger on your dominant hand during a minute. Record your prediction on the data table.
2. Have your partner time you for one minute. Keep track of how many times you can open and close the clothespin using your thumb and index finger on your dominant hand. Record this result on your data table as Trial 1.
3. Rest for a few minutes and make a prediction about how many times you can open the clothespin for Trial 2. Record your prediction on your data table.
4. Repeat Step 2, and record your results on your data table.
5. Switch places and have your partner open the clothespin while you keep time. Make sure your partner records their predictions and actual results on their data table.
6. Repeat steps 1-5 every day for two weeks for a total of 20 trials. Record your predictions and results on your data table.

Name: _____

TRIAL	PREDICTION	ACTUAL RESULT
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
18		
19		
20		

Analyze results

1. Are your predictions close to your actual results?
2. Did your actual results vary for each trial? Why or why not?
3. How did your results change over time?
4. Does your data support your hypothesis? Why or why not?