MISSION X

TRAIN LIKE AN ASTRONAUT

LIVING BONES, STRONG BONES

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Team Leader Guide

MISSION OVERVIEW

Students will identify ways to keep bones healthy and observe the effects of reduced gravity on bone models.

FAST FACTS

Subject: Physics and biology
Age: 8-14
Prep: 20 mins
Lesson Time: 1 hour lesson
Cost: 0-10 euros
Location: Lab recommended

LEARNING OBJECTIVES

- Understand the physical properties of bones and their role in supporting the body.
- Analyse how environmental factors, like a reduced gravity environment, can affect bone health.
- Apply knowledge of bone structure to design and test models.
- Evaluate and improve models based on observations and testing.

Skills: observation, design, hypothesising, deducing inferences, collaboration and communication.

RELATION TO OTHER MISSION X MISSIONS

This scientific resource complements the physical resource 'Jump for the Moon'.

SUMMARY OF ACTIVITIES

Summary of activities					
	Title	Description	Outcome	Requirements	Time
1	Observe a human bone model	Making observations about the properties of bones	• Examine the physical proprieties of a human bone mode. • Identify key features of bone structure. • Explore the structure of bone marrow. • Take notes on observations for later use.	None	**Preparation**: 5 minutes
2	Construct a bone model	Creating a hypothesis about bones and constructing a bone model using index cards and gravel	• Understanding how models represent reality. • Creating hypotheses. • Construct a model to represent bones. • Understand how to maintain healthy bone.	Completion of activity 1	**Preparation**: 15 minutes **Lesson time**: 45 minutes

INTRODUCTION

Astronauts must keep their bones strong while in space to ensure they stay healthy and return home in good condition.

Gravity pulling on your body, also known as 'loading', is essential for bone health. On the International Space Station (ISS), astronauts live in weightlessness, which means that they do not feel the weight of their own body, and this can cause them to lose up to 1% of their bone mass every month. Therefore, they need daily resistive exercise and a balanced diet to keep their bones strong and healthy.

Weightlessness on the ISS is caused by being in orbit, meaning that the astronauts and the space station are in a continuous freefall around the Earth. Therefore, astronauts do not feel their weight. The ISS is still in the Earth's gravitational field, but astronauts do not feel the force of gravity because they are falling towards the Earth at the same rate as the ISS, which is moving fast enough to stay in orbit, so weightlessness persists. Imagine being on a roller coaster: in the descent stage you feel your arms and body have no weight, and this is a similar sensation to what the astronauts feel. Jump in the air: as you fall, you will feel this weightless sensation for a split second. Due to the astronauts not experiencing the weight of their bodies, their muscles and bones lose strength and mass; therefore, they must exercise rigorously, with specialised devices, to prevent their bodies from atrophying.

Even on Earth, eating a proper diet, rich in calcium and vitamin D, and being physically active, will help to keep bones strong.

This activity focuses on studying human bones and creating a model of a bone using paper and gravel.

ACTIVITY 1: OBSERVATIONS

Preparation

Divide the group of students into groups and display the bone on a digital screen (see Appendix) or print one model of a bone per group. Alternatively, you can use a physical bone model if you have one in your classroom. If you would prefer to use real bones, read the appendix on page 11.

Before starting this activity, you may show a video of ESA astronaut Andreas Mogensen exercising on the ISS.

Note: The duration of the video is 04:34 and the video is available in English.

Procedure

Divide the group of students into groups and display the bone on a digital screen (see Appendix) or print one model of a bone per group, or use the real bone as prepared in the Appendix.

1. Start the activity by showing a model of a human bone, both internally and externally. Older students may benefit from an explanation of stem cells in bone marrow forming blood cells.

2. Divide students into groups and have them make observations about the size, shape, and texture of a bone (or use the online model of a bone). They should carefully examine the properties of the bone, including its internal structure and outer surface, and make predictions about what makes a bone so strong yet lightweight, what makes a bone rigid, and any other properties that you or they can think of.

Have students write down their observations in their table or notebook (in the student section), discuss these observations in their group and encourage them to share their observations. Here are some examples of questions you could ask the students:

a. What is the overall shape of the bone? The bone is cylindrical.
b. What could be the reason why the compact tissue layer of bone is so thick? The compact tissue layer makes the bone strong enough to perform the duties of walking, running, jumping, and landing while supporting the weight of the person against the pull of gravity. The compact tissue is also called cortical. Its job is to protect body parts underneath the bone and hold up muscles around it.
c. What is inside the bone? Inside the bone there is cancellous tissue and bone marrow. More information: Some blood cells are produced from bone marrow. At the ends of long bones, we find, in the bone marrow, a spongy structure formed by smaller bones called trabecular bone.
d. What does the inside of the bone look like? The inside of the bone looks spongy. More information: This part of the bone – found inside the hard, compact tissue layer – has spaces between the framework that provide the bone more surface from which calcium can be extracted. The interlocking material gives the bone strength.
e. What kinds of materials are comparable to bone? Compare bones to wood, rubber, plastic.
f. What role does the inside bone have on how strong the bone is? It is lightweight and has cross-bridge structures, which help to distribute forces without being heavy.
g. What is the function of bones inside a body of a human or other organisms? The bones give the body its shape, hold the body up against the force of gravity and provide protection for some essential organs, such as the heart and lungs.

These two questions will be useful to discuss with your students if you are using real bones:
h. Is the bone marrow the same colour as the bone itself?
i. What texture does the outer bone have?

ACTIVITY 2: CONSTRUCT A BONE MODEL

Preparation

The following tools should be available to everyone:

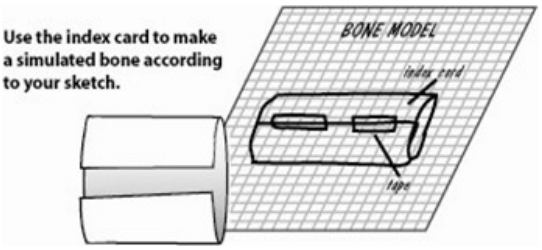
- Weighing scale

Prepare the material for each group of students. Each set should contain:

- Five index cards (7.6 × 12.7 cm or 3 × 5 in)
- Paper
- Tape
- Cardboard square (approx. 24 x 24 cm or 9.4 x 9.4 in)
- Textbooks or reams of paper
- Snack-sized zip-locked bag 1/3 full of gravel

HOW TO PREPARE THE GRAVEL BAGS

To prepare the bag full of gravel, create a cylinder by rolling an index card and fastening it with tape. The bag should be filled such that it fits inside the cylinder. Use Figure 1 as a reference. This is also how the model should be completed by the students.



Procedure

1. Divide the group of students into smaller groups of 3 – 4 students and have them discuss how they could construct a model of a bone using the materials they have. This discussion should result in the design of a bone model drawn on paper.

2. Let each group create their own model based on their design. Encourage them to make predictions about how many books (and their mass) this model should be able to hold. Each group should stack books on the model. The goal of this part of the activity is to test whether the model is strong enough to hold weight.

3. Let the students try different solutions to create stronger models. We suggest at least three different approaches: one model made with a single index card to represent brittle bones; one model made with two index cards to thicken the outer part of the bone; and one model made with gravel inside the index card (representing the inner part of the bone). This final model represents strong, healthy bones resulting from eating a healthy diet and regular resistive exercise.

At the end of the hands-on activity, you can go back to the bone model or real bones that you used for the first activity to associate each part of the experiment they had with the real characteristics of a human bone.

STUDENT WORKSHEET

LIVING BONES, STRONG BONES

Student Worksheet

MISSION OVERVIEW

You will identify ways to keep bones healthy and observe the effects of reduced gravity on bone models.

INTRODUCTION

You might have heard that astronauts need to exercise often and with special training equipment when they are on the International Space Station (ISS), but do you know why? Astronauts are weightless on the ISS!

Credits: ESA/NASA

Weightlessness causes bones and muscles to become weaker, as astronauts do not feel their weight when they are on the ISS. Astronauts need to exercise, using specially designed equipment, for around two hours every single day to keep their bones and muscles strong.

Bone is living tissue in the body, which can be broken down and rebuilt by specialised cells. It takes 10 years for your entire skeleton to be replaced with new bone!

Did you know?

Astronauts lose up to 1% of their bone mass each month in space.
This is a big problem if they stay in space for a long time: imagine what kind of issues they could face if they lived on the ISS for a year at a time, or when the first explorers live on Mars!

Credits: ESA/NASA

Scientists help to keep the astronauts' bones and muscles strong by adding calcium and vitamin D supplements to their diets and preparing special exercise devices and training plans for the astronauts to follow. These exercises provide resistance to keep their bones strong, even in weightlessness.

Even on Earth, you can keep your bones healthy by eating lots of calcium and vitamin D. Calcium is found in leafy green vegetables and in dairy products – such as milk, cheese and yoghurt.

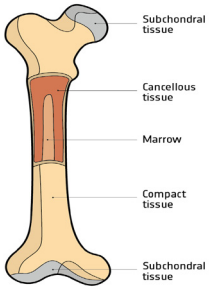
Vitamin D is called the "sunshine vitamin" because your skin produces it when exposed to sunlight. Vitamin D is also found in oily fish, eggs and is added to some cereals. During the winter, it's especially important to focus on vitamin D in your diet since your skin is less exposed to sunlight. Taking a vitamin D supplement throughout the autumn and winter is often recommended.

Resistive exercise – like running, doing push-ups, or skipping rope – also helps to strengthen your bones.

Credits: ESA/NASA

ACTIVITY 1: OBSERVATIONS

Make observations of the bone model and record them in the table below. Carefully examine the properties of the bone, including its internal structure and outer surface, and make predictions about what makes a bone so strong yet lightweight, what makes a bone rigid, and any other properties that you can think of.



Properties	Your prediction	Actual
What makes a bone strong?		
What makes a bone resistant to impacts?		
What makes a bone rigid?		
What can you tell about the external texture?		
What can you tell about the internal texture?		
Other observations		

Credits: ESA–S. Corvaja, 2015

Did you know?

Weakened bones and muscles are why you sometimes see astronauts being carried away from the spacecraft when they land on Earth – the astronauts can be too weak to carry themselves.

ACTIVITY 2: CONSTRUCT A BONE MODEL

HYPOTHESIS

Your hypothesis should be a statement that answers the problem based on your observations, predictions and the materials available.

Question: How can I make a bone model that is strong enough to hold weight?

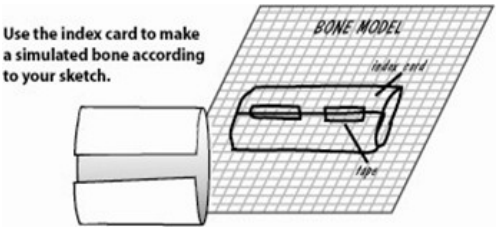
Hypothesis:

_____
_____
_____
_____
_____
_____

TEST PROCEDURE

With your group:

1) Discuss the shape, size, and thickness of bones. How would you design your group's bone model using the index cards?



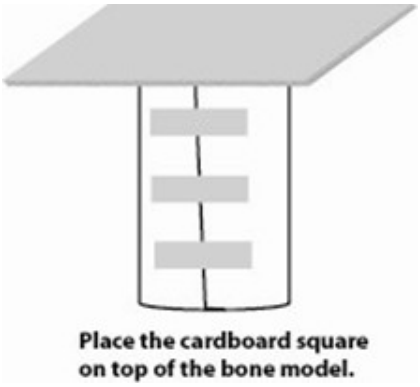
2) Design a bone model, making sure your bone model represents a bone and is sturdy enough to hold weight. Draw the design on a sheet of paper and label the materials in your design.

3) Build the bone model based on your design, using tape to fasten the index card, then place the model on the table in the same way as your leg bone would stand.

4) How many textbooks do you think the model can hold? Predict the number and mass of the textbooks and record your predictions in the table at the bottom of the page.

5) Stack textbooks on the cardboard square, one at a time, until it collapses, or you run out of books.

Weigh the books with your weighing scale and record the data in the table, noting both the number of books and the weight that your model was able to hold.

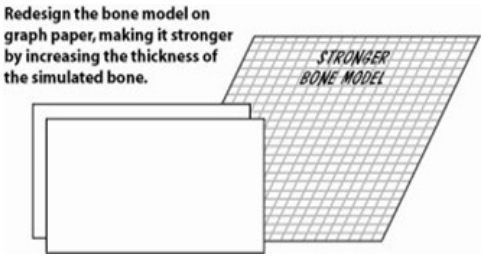


Place the cardboard square on top of the bone model.

The bone model you tested represents weak bones due to a lack of calcium, vitamin D and resistive exercise.

This bone model represents an astronaut's bones if they do not exercise whilst on mission because of the microgravity environment they are living in.

6) Redesign your bone model on paper, making it stronger by using two index cards or by inserting the bag of gravel inside.



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

Repeat steps 1 – 5 to predict the weight this new model can hold and to test it.
You might need to do more than one redesign.

The new bone model represents strong bones, which benefit from lots of calcium, vitamin D and resistive exercise. The gravel represents the bone marrow mineralised with calcium and vitamin D.

Bone Model	Materials Used to Construct the Bone Model	Actual How many textbooks will the bone model hold?		Actual Record the number and mass of textbooks the bone model held	
		Number	Mass (g)	Number	Mass (g)
First Bone Model					
Second Bone Model					
Third Bone Model					

Did you know?

The bone models you tested represent different situations of how healthy a bone can be. If the bone breaks under low weight, this might mean that the bones need to become stronger. This can be achieved through increased resistive exercise and supplements of calcium and vitamin D. If the bone is resistant to high weight, this means that the bone is strong.

QUESTIONS

Make observations of the bone model and record them in the table below. Carefully examine the properties of the bone, including its internal structure and outer surface, and make predictions about what makes a bone so strong yet lightweight, what makes a bone rigid, and any other properties that you can think of.

These questions will help you to form a conclusion.

1. Which bone model was the strongest? Explain why.

_____
_____
_____

2. Compare the mass that the different bone models held. What is the difference? How and why did the amount change?

_____
_____
_____

3. Does this data support your hypothesis in the beginning? Why or why not?

_____
_____
_____

4. How do your group results compare to other results?

_____
_____
_____

QUESTIONS

Restate your hypothesis, then explain what happened during testing, including your results.

Question: How can I make a bone model, using the materials provided, that is strong and will hold weight?

Conclusion:

_____
_____
_____

RESOURCES AND LINKS

ESA Resources

In this video, ESA Astronaut Samantha Cristoforetti weightlifts on the ISS and explains why she exercises to maintain healthy bones and muscles: *Weightlifting in weightlessness with ESA Astronaut Samantha Cristoforetti*.

This video highlights some of the training that astronauts undertake on the ISS and during training on Earth: *Highlights from ESA basic astronaut training*.

In this video, ESA Astronaut Andreas Mogensen explains how astronauts on the ISS exercise using three different fitness machines: *Fit for spaceflight | ISS Commander's Log*.

Extra information

The World Health Organisation gives advice on eating a healthy diet: Healthy diet

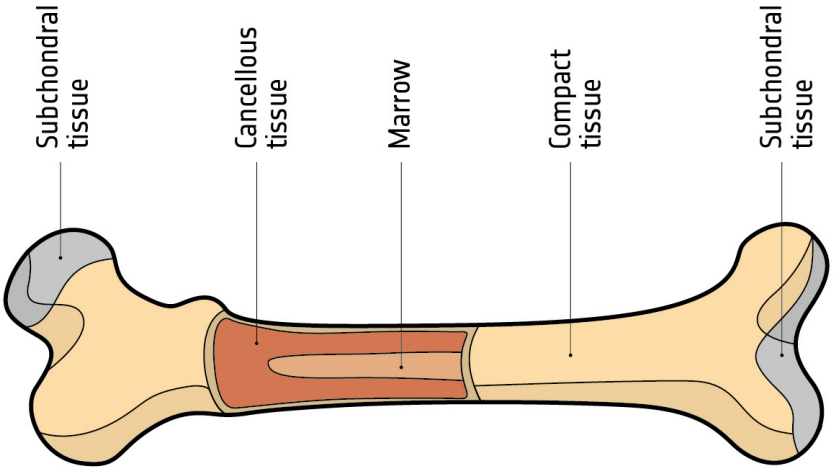
The World Health Organisation gives advice on exercise: Physical activity

Glossary

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	A dense and compact outer layer of bone that forms a shell around bone marrow. Also called compact bone.
Cancellous bone	Smaller bones that form a spongy structure in the bone marrow found inside the cortical bone shell. Also called trabecular bone.

APPENDIX

Bone model



Using a real bone

To prepare cooked, clean, dry chicken bones:

1. Gather chicken leg or thigh bones, enough for one per group.
2. Place in a large pot and cover with water. Stew chicken bones for 40 – 50 minutes to ensure that they are completely done.
3. Remove the chicken bones from the pot and let cool at least 30 minutes.
4. Remove excess meat and cartilage by scrubbing the chicken bones thoroughly.
5. Use a disinfectant cleaner to sanitise the chicken bones. Rinse with water.
6. 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-sized zip-sealed bags.

Acknowledgements

This resource has been adapted in 2025 from NASA's 'Living Bones, Strong Bones' by the ESA Education Office.

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