



NSBRI TAP Classroom Activity

Title: THE EFFECT OF LONG DURATION SPACE FLIGHT ON BONE

Grade Level: 5-8 and 9-12

Content Area: Space/Life Science

National Science Content Standards:

Standard A. Science as Inquiry (Grades 5-8 & 9-12)

- Abilities necessary to do scientific inquiry
- Standard C. Life Science
- Structure and functions in living systems (Grades 5-8)
- The cell (Grades 9-12)
- Standard F. Science in Social and Personal Perspectives (Grades 5-8 & 9-12)
- Personal health

Behavioral Objectives:

- The student will use scientific inquiry methods during field and laboratory investigations to collect data and make valid conclusions.
- The student will examine the relationship between structure and function in living systems.
- The student will organize, analyze, make inferences, and predict trends from direct and indirect evidence and communicate valid conclusions.

Lesson Objective:

- In this lesson the student will examine a diagram of a cross-section of rat femur that has been exposed to earth gravity and one that has been exposed to simulated microgravity (chronic unloading with tail suspension which causes hind limb unloading). The student will use this diagram to determine differences in surface area and determine if the loss of surface area is similar to what is seen in space.

Time:

- Two 45 minute class periods; One 90 minute block period

Materials:

- 1) Drawings representing rat femur bone before and after tail suspension, which causes hind limb unloading (provided in the lesson)
- 2) Centimeter-square graph paper or transparencies with graph markings per individual
- 3) Pencil/Crayons or Colored pencils/Transparency markers
- 4) Calculator

This lesson was developed by participants and staff of the Teacher Academy Project at Texas A&M University with support from the National Space Biomedical Research Institute through NASA NCC 9-58.

Procedure:

- 1) Place graph paper over rat femur (before and after unloading) drawings so that they are visible through the paper.
- 2) Color and count the number of squares where there is black **cancellus bone**. The white area represents marrow and blood vessels.
Note: include squares that are at least 25% covered.
- 3) Determine the total surface area in cm^2 (surface area = number of colored squares) of cancellus bone in each drawing.

Ans:

Loaded Diagram will show approximately 64 cm^2 of bone coverage.

Unloaded Diagram will show approximately 36 cm^2 of bone coverage.

- 4) Determine the total bone loss of the unloaded bone.

Ans:

Loaded surface area - Unloaded surface area = Bone loss of the unloaded bone
 $64 \text{ cm}^2 - 36 \text{ cm}^2 = 28 \text{ cm}^2$

- 5) Calculate the percentage of bone the rat lost.

Ans:

Bone loss of the unloaded bone/Loaded bone x 100 = % loss
 $28 \text{ cm}^2 / 64 \text{ cm}^2 = .4375 \times 100 = 43.75\% \text{ loss}$

- 6) What was the rate (% of bone/day) of bone loss for a 28 day period?

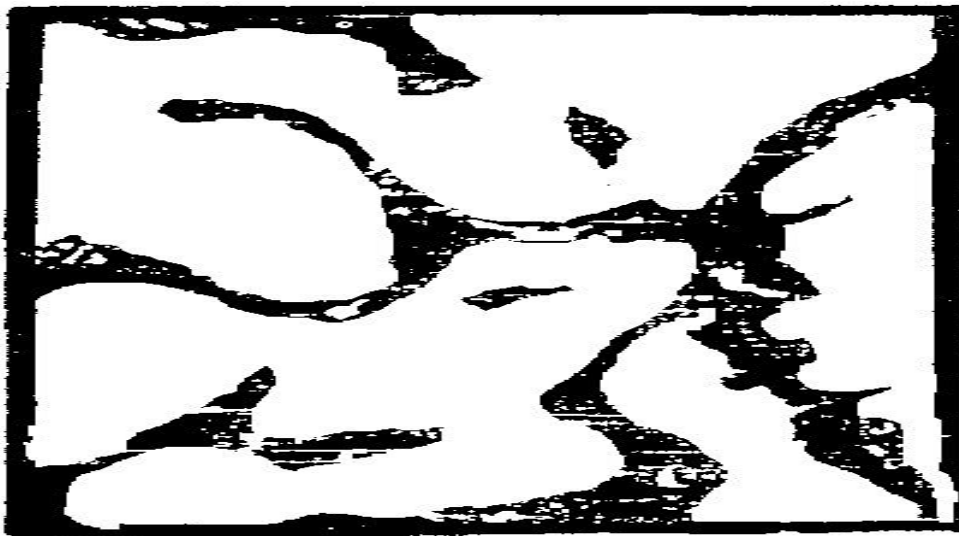
Ans:

% Loss / 28 days = % bone loss per day
 $43.75\% / 28 = 1.56\% \text{ bone loss per day}$

Loaded Diagram



Unloaded Diagram (28 days)



Extension:

- Have students take the “Effect of Microgravity on Bone” worksheet and determine the amount of bone loss between the ground based rat femur (Before Unloading) and the 28 day microgravity rat femur (After Unloading). The students will use the same steps that were used to determine density in the previous procedure.
- Have the students make a life size skeleton drawing of themselves on brown craft paper. On one side of the body create an “earth side” and the other a “space side”. The “space side” should show a loss of bone density, greater body height due to vertebra separation and the “puffy face/bird leg” syndrome due to fluid shift.
- Use chicken bones soaked in vinegar to dissolve calcium and determine differences in bone mass. Be sure to weigh the bones before and after soaking in vinegar.

Resources:

Human Physiology in Space (pp.241-284) by R. J. White & B. F. Lujan, NASA Life and Biomedical Sciences and Applications Division, 1994. Available online at:

<http://www.nsbri.org/HumanPhysSpace/>

Lesson reviewed for scientific validity by Dr. Michael Delp, Professor/NSBRI Researcher, Department of Health & Kinesiology, Texas A&M University

Background Information:

*Note: Use the background information before the activity to explain the process of bone decalcification. It may be used as a hand out.

Astronauts experience bone loss in space because they do not have to use their lower body for support and movement. Normal bone development in humans consists of the growth of both calcium and phosphate (great **compressional strength**) plus collagen fibers (great **tensile strength**). The thickness and strength of bone is maintained by old bone being replaced by new bone at an equal rate so that the total mass of bone remains constant. **Osteoblasts** are bone cells that help form new bone while **osteoclasts** are cells that eat away old bone. This process continues until about age 40 when osteoblast activity decreases and bones become more brittle (osteoporosis). Bone deposition is proportional to the compressional load that the bone must carry or the stress applied to the bone. For example, bones on athletes are heavier than non-athletes and the bone in the racket arm of tennis players is denser than bone in their non-racket arm. Also, a leg in a cast loses up to 30% of calcium in a few weeks while a healthy leg bone remains thick and calcified.

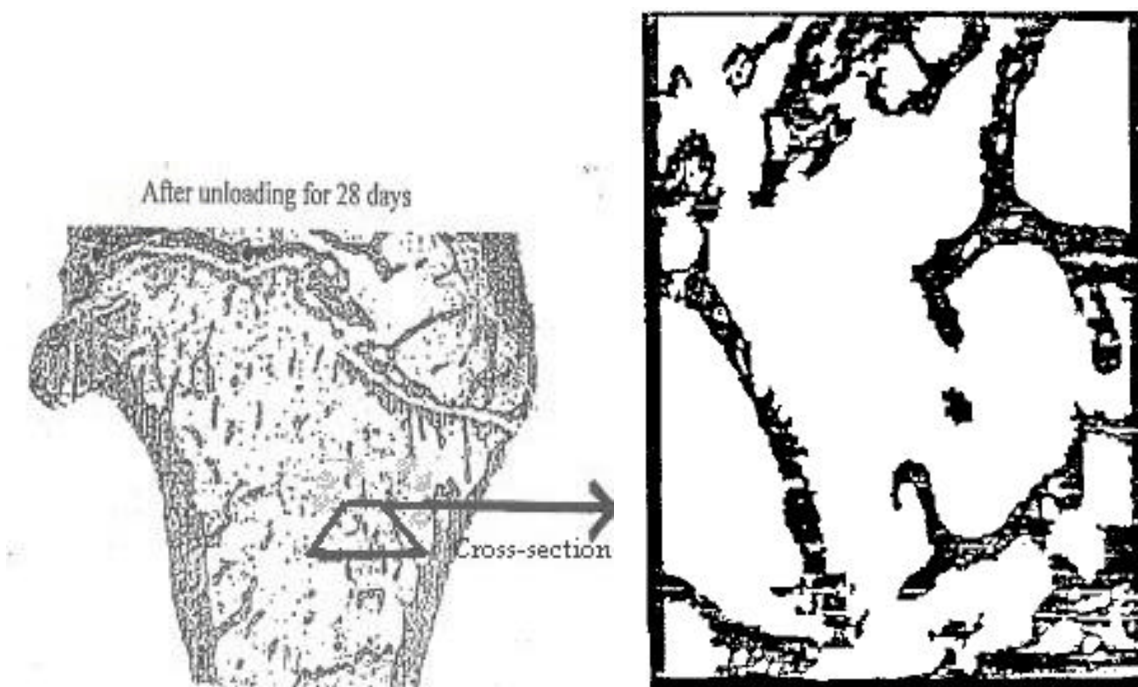
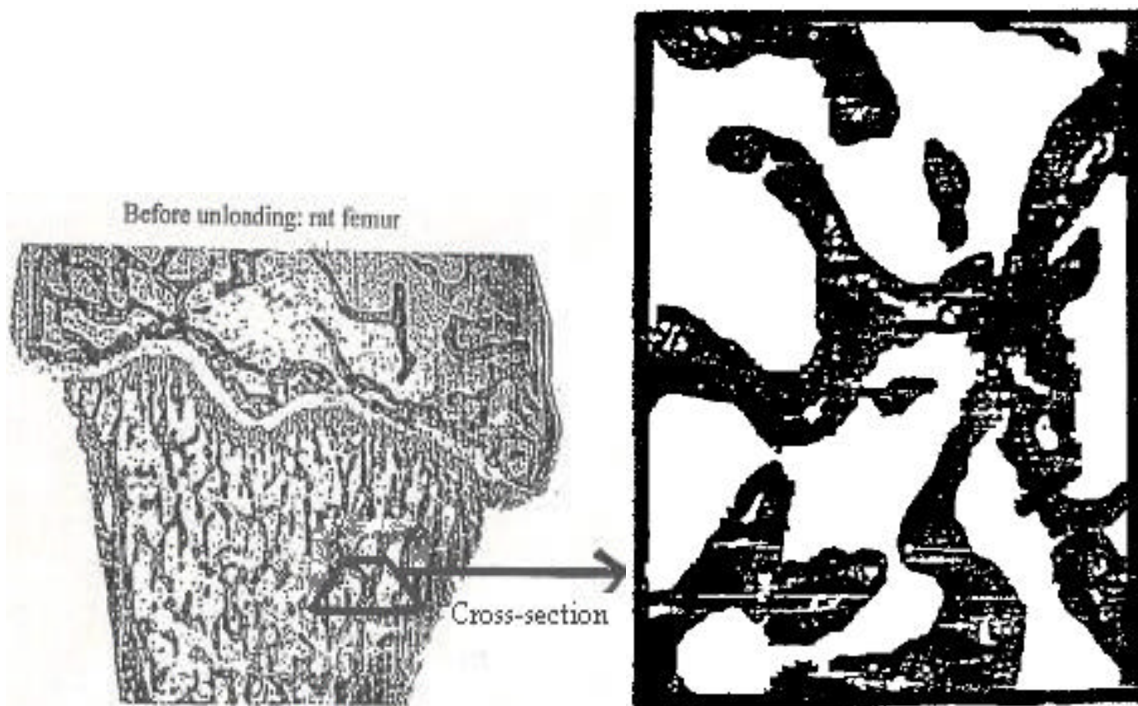
Osteoporosis (which means “porous bone”) is a bone-thinning disease, which strikes one in four American women over 60. Usually, in osteoporosis, the osteoblastic activity in the bone is less than normal, and consequently the rate of bone deposition is reduced. This results in brittle bones in the elderly, and, therefore, their bones are more susceptible to fracture. Older people may also develop a hump in the upper back, often referred to as a dowager’s hump. Some women can lose as much as one-third of their skeletal structure by age 75. This is twice the rate of bone loss in older men, who have about 30% more bone mass to start with. Osteoporosis afflicts more people than any other bone disease.

Astronauts experience bone loss while in space because they do not have to stand and support themselves to create loading forces on the bone. This is a problem once they return from long duration space flights. They then have a greater propensity towards osteoporosis, similar to that in older folk. Astronauts are generally older by the time that they fly and this compounds the problem.

Scientists at NSBRI are studying bone loss in astronauts. To do this, they perform experiments on laboratory rats. These rats are suspended from their hind legs so that there is no load on those legs, simulating the similar situation of astronauts in space. Rats are used because their bones are easily accessible and the rat is small and its bones react quickly to environmental changes. Rats are much easier to prepare for space flight in aspects of diet, exercise, housing, and waste processing. Rats would show a greater rate of bone development in the short time of experimentation. Researchers could conduct experiments across generations in a shorter period of time due to the reproductive potential and developmental rate in rats.

*Note: Before beginning the above experiment ask the students which is bone and which is marrow. You may be surprised at the answers. Be sure and explain that the dark areas are bone and the white is soft tissue. These pictures are x-ray micrographs, therefore, only the hard osseous material blocks the x-rays and appears black and the marrow allows the x-rays through to expose the film and looks white.

Worksheet
Effect of Microgravity on Bone



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Student Assessment (Student Copy)

Title: THE EFFECT OF LONG DURATION SPACE FLIGHT ON BONE

1. Why do astronauts experience bone loss while in space?
2. In this experiment we looked at rat femurs. What makes the rat a good model for this type experiment?
3. How are rats used to simulate bone loss in astronauts?
4. Explain the condition of osteoporosis.
5. Explain why there is a difference in bone density before and after unloading.
6. When astronauts are in space for long periods of time they have been found to lose up to 20% of their bone density. Typically, this loss is at a rate of 1-2% a month. Did you see a loss similar to this rate in the experiment you performed? If yes, does this confirm that unloading the hindlimbs of the rodents makes for a good model of bone deposition in microgravity?

Student Assessment**Title: THE EFFECT OF LONG DURATION SPACE FLIGHT ON BONE**

1. Why do astronauts experience bone loss while in space?

Ans.

- Astronauts experience bone loss in space because they do not have to use their lower body for support and movement.
- Astronauts experience bone loss while in space because they do not have to stand and support themselves to create loading forces on the bone.
- There may be other mechanisms controlling this phenomenon, but they are not presently known.

2. In this experiment we looked at rat femurs. What makes the rat a good model for this type experiment?

Ans.

Rats show a greater rate of bone development in a shorter period of time. Researchers could conduct experiments across generations in a shorter period of time due to reproductive potential and developmental rates. Due to the increased metabolism of the rat they also react to environmental changes much more quickly.

3. How are rats used to simulate bone loss in astronauts?

Ans.

Rats are suspended from their hind legs so that there is no load on those legs, simulating the microgravity situation of astronauts in space.

4. Explain the condition of osteoporosis.

Ans.

Osteoporosis is a condition of decreased bone mass and density. This leads to fragile bones, which are at a much higher risk for fractures.

5. Explain why there is a difference in bone density before and after unloading.

Ans.

In the loaded rat femur we see earth normal bone deposition and density. In the unloaded scenario we see disuse osteoporosis occurring. This means that the hindlimbs not being used have caused the osteoclasts to continue breaking down bone; however, the osteoblasts have stopped building new bone. This same situation is seen in space.

6. When astronauts are in space for long periods of time they have been found to lose up to 20% of their bone density. Typically, this loss is at a rate of 1-2% a month. Did you see a loss similar to this rate in the experiment you performed? If yes, does this confirm that unloading the hindlimbs of the rodents makes for a good model of bone deposition in microgravity?

Ans.

You should see a similar rate when looking at the bone loss. This makes the suspended rat a good model for doing this type of experiment.