NSBRI TAP Classroom Activity

Title: **BAG OF BONES**

Grade Level: 5-8 and 9-12

Content Area: Life and Space Science

National Science Content Standards:
Standard A. Science as Inquiry (Grades 5-8 & 9-12)
- Abilities necessary to do scientific inquiry
- Understanding about scientific inquiry

Standard C. Life Science
- Structure and function in living systems (Grades 5-8)
- The cell (Grades 9-12)

Standard F. Science in Personal and Social Perspectives
- Personal health (Grades 5-8 & 9-12)

Behavioral Objectives:
- The student will use scientific inquiry methods during laboratory investigations and collect data by observing and measuring
- The student will explore the relationship between structure and function in living systems.

Lesson Objective:
- In this lesson the student will explore and investigate how decreased bone density is related to increased risk of bone fracture. The students will also discuss the subject of bone loss in space and how research in this area can benefit individuals here on earth.

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

Materials:
1. Honey Combs™ or generic Honey Buzzers™ cereal (approx. 4.5 oz. per group)
2. Snack size zip locking plastic bags (6 5/8 X 3 1/4 inches), 5 per group.
   (Note: Make sure to use the small, snack-sized bags; the large ones hold too much cereal to count in a reasonable amount of time.)
3. Heavy books – one per group
4. Calculators
5. Meter stick
6. Broom and dustpan (for clean-up)

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:

Pre-activity Preparation

Before performing this lab you will need to find a book with enough mass to break most of the cereal pieces in the NBDx.6 bag, but only a few in the NBDx1.0 bag.

Activity

1. Using a permanent marker, label sandwich bags as in column 1 of the data table: 100% NBD, 90% NBD, 80% NBD, 70% NBD, and 60% NBD.

2. The 100% normal bone density (NBD) bag will represent a healthy bone on Earth. To build this "bone", fill the bag with cereal pieces, being careful to use *only* whole, unbroken pieces. Try adding 10 at a time, so you can keep track of how many cereal pieces are in the bag. Fill the bag, as full as possible, with very little air, but not so full that you cannot securely close it. Record the exact number of cereal pieces on the data table below under column titled number of pieces intact.

3. To represent a bone that has lost mass as a result of space flight or aging, you now need to fill each bag with less cereal, or mass, than is in Bag 1. To calculate the amount of "bone" you need for bag 2, for example, multiply NBD x 0.9, the original bone density. Record the number of bone (cereal pieces) in each bag on the table in the column Density (# of pieces intact).

4. Place bag 1 on a hard surface. Drop a large weight (book) from a fixed height (e.g. 1 meter) onto the bag trying to let it fall in a horizontal position.

5. Count the number of unaffected (whole) cereal pieces left in the bag, and record this on your worksheet.

6. Repeat steps 4 and 5 for the other bags.

7. Combine data into a class set. Have each group write their data on the board. Plot data points on a scatter plot.

8. Compare results across groups. Did there appear to be a relationship in bone density versus number of pieces broken? Does bone density have an effect on ease of bone breaking?

9. Discuss sources of error they might encounter in this activity.

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Data Table

Before experiment **After experiment**

Bag Label	Bone loss represented	NBD (Normal Bone Density)	Density # of pieces intact	# of pieces unaffected after experiment
100% NBD	0%	NBD x 1.0		
90% NBD	10%	NBD x 0.9		
80% NBD	20%	NBD x 0.8		
70% NBD	30%	NBD x 0.7		
60% NBD	40%	NBD x 0.6		

Extensions:

- Research bone density and relate to activity findings.
- Compare to bone density loss when humans wear a cast to heal broken arms/legs to bone loss in space (disuse osteoporosis).
- Invite a guest speaker, orthopedic surgeon, or a nutritionist to explain the importance of bone integrity or nutrition as a factor in bone growth.
- Produce bar graphs of data (graph the density vs. number of pieces unaffected) to look for linear relationships.

Resources:

http://virtualastronaut.jsc.nasa.gov/
This website is a virtual tour and lab experience dealing with the International Space Station

http://depts.washington.edu/bonebio/ASBMRed/ASBMRed.html
Extensive bone curriculum website- great graphics

http://www.osteo.org
National Institutes of Heatlth website dedicated to osteoporosis and bone diseases

http://www.cdc.gov/powerfulbones/index2.html
Great website that deals with the subject of promoting healthy habits for girls as it relates to bone growth.

http://www.osteofound.org
Website dedicated to bone issues on an international scale.

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http://www.nof.org
Osteoporosis awareness site sponsored by the National Osteoporosis Foundation.

Background Information:

*Note: This information should be given to the students prior to performing the activity.

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, changes in behavior, and body-wide alterations initiated by a changing nervous system are some of the most apparent and potentially detrimental effects of microgravity. Changes to bone are particularly important because they increase the chances that a bone will fracture if the astronaut falls doing work or exercise upon return to Earth's gravity, or during a stay on the surface of Mars.

Bone is a living **tissue**. It is dynamic, responsive to disease and injury, and self-repairing. Bone has both an **organic matrix component** and an **inorganic component**. The organic component is composed mainly of **collagen**, long chains of protein that intertwine in flexible, elastic fibers. **Hydroxyapatite**, the inorganic component, is a calcium-rich mineral that stiffens and strengthens the collagen. Together, the interwoven organic and inorganic components of bone create a sturdy yet flexible skeletal structure.

The body is constantly breaking down old bone, and replacing it with new bone. Cells called **osteoblasts** form bone. These cells lay down new bone organic matrix on the surface of existing bone. **Osteoclasts**, large multinucleate cells, break down old bone, and assist in mobilizing calcium from mineralized bone into the bloodstream. In a healthy individual under the age of 40 on Earth, bone is formed at the same rate at which it is broken down, so there is never an overall loss of bone mass. After the age of 40, the breakdown (resorption) of old bone tends to exceed formation of new bone by a very small amount, resulting in what is termed *age-related bone loss*. Changes in exercise habits or simply in weightbearing activity also impact on this balance between formation and resorption: increased exercise promotes more formation, and less exercise (in the extreme, prolonged bed rest or the weightlessness of spaceflight) promotes more resorption.

On Earth, bones perform four basic functions:

- Mechanical support: The skeleton supports soft tissue and the body's weight. Many bones also act as levers for muscles, enabling movement.

- Storage of essential minerals: Bone stores much of the calcium received from the diet. The calcium is stored in hydroxapatite (the principal bone salt which provides the compressional strength of vertebrate bone). In space, astronauts will experience disuse osteoporosis which occurs from a lack of compressional and muscular forces being applied to the bone. Bone is also a good source of phosphate, hydrogen, potassium, and magnesium. Like calcium, these minerals are used by many systems of the body for a wide range of purposes.

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- Production of blood: In addition to essential minerals, bone is also the storage site of marrow. Marrow is important for the formation and development of red and white blood cells and platelets.

- Protection: The skeleton houses and protects the brain, spinal column, and nerves. Many bones, especially the ribs, also protect the internal organs.

Some of the processes and functions of bones change after the astronaut has lived in microgravity for several days. In space, the amount of weight that bones must support is reduced to almost zero. At the same time, many bones that aid in movement are no longer subjected to the same stresses that they are subjected to on Earth. Over time, calcium normally stored in the bones is broken down and released into the bloodstream. The high amount of calcium found in an astronaut's urine during space flight (much higher than on Earth) reflects the decrease in bone density, or bone mass. This drop in density leads to a condition called **disuse osteoporosis**.

This bone loss begins within the first few days in space. The most severe loss occurs between the second and fifth months in space, although the process continues throughout the entire time spent in mircrogravity. Extended stays on Mars will result in losses of bone mass of as much as 20%. We do not know yet if astronauts, upon return to the normal gravity of Earth, regain bone mass lost while in space. It is possible that some individuals could experience a permanent decrement in bone mineral density.

The exact mechanism that causes the loss of bone mineral in microgravity is unknown. Many scientists believe that microgravity somehow causes bone to break down at a much faster rate than it is built up. Researchers are currently pursuing multiple lines of research, including hormone level, diet, and exercise, in order to determine exactly what causes – and may control or prevent – osteopenia during space flight.

Loss of bone mineral density is a significant clinical problem on Earth. As we grow older, the body begins to absorb bone much faster than it produces new bone. This leads to a lowered bone density, the same effect that microgravity has on astronauts. As a result, bones become more fragile and are more susceptible to fractures, especially in the hip, spine, and wrist. In many cases, people do not know that they have osteoporosis until their bones become so weak that an accidental bump or fall causes a fracture. Just as astronauts eat a careful diet and get plenty of special exercise in space to prevent disuse osteoporosis, steps can be taken to prevent osteoporosis on Earth. Lifestyle changes such as regular weightbearing exercise, a balanced diet rich in calcium and Vitamin D, avoidance of smoking and excess alcohol, all contribute to better bone health. Individuals at higher risk for developing osteoporosis (postmenopausal women, men over 65, anyone on chronic immunosuppressive or glucocorticoid medications) should check with their physicians to see if medications can assist in slowing bone loss.

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Student Assessment (Student Copy)

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Results and Discussion over Activity

1. Name the functions of bones.
2. What is the difference between osteoblasts and osteoclasts?
3. What happened as bone density decreased?
4. What prevented some bone from being affected by the sudden force of the book?
5. What conclusions could one make concerning bone density and the severity of injury to the skeleton?
6. What can be done to prevent osteoporosis?
7. What groups of people would this research benefit?

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Results and Discussion over Activity

1. Name the functions of bones.

   Ans.
   - Mechanical support-for soft tissue and body weight
   - Storage of essential nutrients
   - Production of blood-storage of marrow
   - Protection-brain, spinal column and nerves, vital organs

2. What is the difference between osteoblasts and osteoclasts?

   Ans. Osteoblasts-cells that form bone by depositing new mineral along the surface of the bone. Osteoclasts-large multinucleate cells that break down bone and are partially responsible for releasing calcium into the bloodstream.

3. What happened as bone density decreased?

   Ans. The more brittle, less dense the bones become, the more susceptible to trauma and damage. Survival rate of bones decreased.

4. What prevented some bone from being affected by the sudden force of the book?

   Ans. More mass helped protect from sudden blow, alignment of bone "cells" i.e. cereal pieces, direction of impact. Dissipation of force through increased surface area.

5. What conclusions could one make concerning bone density and the severity of injury to the skeleton?

   Ans. The conclusion one could make is that as density or the amount of bone decreases, the ability to withstand trauma or impact is decreased and the chance of a severe injury increases.

6. What can be done to prevent osteoporosis?

   Ans. Space: Eat a careful diet rich in calcium and vitamin D. Get plenty of weight bearing exercise.

   Earth: A balanced diet rich in calcium, vitamin D, exercise, a lifestyle free of smoking and alcohol, bone density testing and medication.

7. What groups of people would this research benefit?

   Ans. This research can go to benefit women of any age and men over fifty. It has been found that as when people age the depletion of bone occurs at a faster rate than occurrence of new growth.

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