The Knee Knows: Resiliency of Cartilage and Osteoarthritis

Subject Area(s) **Measurement; Science and Technology**

Associated Lesson **Biomedical Engineering and the Human Body**

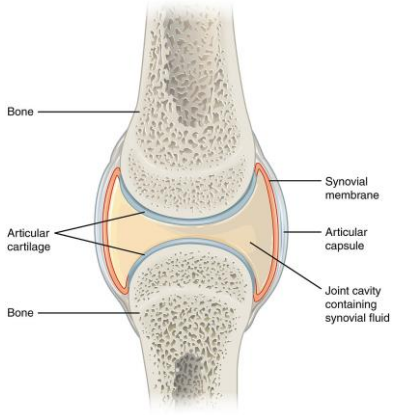
https://www.teachengineering.org/curricularunits/view/cub_biomed_curricularunit

Activity Title **The Knee Knows: Resiliency of Cartilage and Osteoarthritis**

Header

Image 1

Image file:



ADA Description: Diagram of knee joint showing bone, articular cartilage, joint cavity with synovial fluid and synovial membrane

Source/Rights: © Illustration from Anatomy & Physiology, Connexions Web site. http://cnx.org/content/col11496/1.6/, Jun 19, 2013.

Caption: Knee Joint

Activity Dependency

Time Required 220 minutes

Group Size 3-4

Expendable Cost per Group US $5

Summary

Students learn about testing methods of biomedical engineers and gain experience in research as they study osteoarthritis of the knee joint. They conduct stress/strain tests on simulated bones and brainstorm devices they can develop to alleviate stress on the knee joint. Students work in centers to discover the effects of osteoarthritis, how stress/strain are measured and graphed, material durability, and to observe patterns of different kinds of stress/strain.

Engineering Connection

Biomedical engineers design testing devices that can collect data on certain conditions within the body in order to design and develop tools to help people live more comfortable lives. They also develop medical devices that are compatible with the body.

Engineering Category =

Choose the category that best describes this activity's amount/depth of engineering content:

1. Engineering analysis or partial design

Keywords

Biomedical engineering, osteoarthritis, load sensor, stress gauge, design process testing, shear stress, stress/strain curve

Educational Standards (List 2-4)

Common Core State Standards Connections:

ELA/Literacy

RST.6-8.1	Cite specific textual evidence to support analysis of science and technical texts. (MS-ETS1-1),*(MS-ETS1-2),(MS-ETS1-3)*
RST.6-8.7	Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table). *(MS-ETS1-3)*
RST.6-8.9	Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic. (MS-ETS1-2),(MS-ETS1-3)

Next Generation Science Standards MS-ETS1-3 Engineering Design

Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.

Next Generation Science Standards MS-ETS1-1 Engineering Design

Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

Pre-Requisite Knowledge

Biomedical Engineering and the Human Body Lesson

Learning Objectives

After this activity, students should be able to:

- understand that biomedical engineers sometimes fabricate their own testing devices
- conduct stress/strain testing on different materials
- analyze patterns on digital images of stress/strain on different materials
- graph compression stress/strain curve

Materials List

Each group needs:

- Access to spreadsheet software
- Paper
- Ruler

Materials for Centers

1. Reading material (for centers while groups are testing) https://www.britannica.com/science/arthritis
2. Worksheet for stress/strain (for centers while groups are testing)
3. Shear stress device (teacher created)
4. Testing device diagram
5. Bag of different materials and prediction worksheet

To share with the entire class:

- Load sensor tester
- Fake knee with plastic material as cartilage, fake knee with foam material as cartilage (for demonstration only, not for testing)

Introduction / Motivation

Osteoarthritis is a leading cause of pain and a lower quality of life for our aging population. According to Epidemiology of Osteoarthritis, it is the most common joint disorder in the United states and symptoms of the knee occur in 10% of men and 13% of women aged 60 and older.

Betty, a 60 year old mural artist, is suffering from knee pain and her doctor suspects osteoarthritis. Once symptoms of pain start, it is often too late for treatment without the major surgery of joint replacement. Betty often works on ladders and in various positions that place stress on her knees as she creates large murals across the world. She worries that her knee pain will prevent her from continuing to work in a career she loves.

You are a biomedical engineer tasked with testing stress and strain on knee joints in order to observe patterns of displacement of cartilage, a firm whitish and flexible connective tissue found in articulating surfaces of the joints (Dictionary.com).

Changes in patterns of tissue of the cartilage is less able to resist wear on the joints so more strain will be observed.

Vocabulary / Definitions

Word	Definition
stress	The ratio of applied force F to a cross section area, defined as force per unit area (Engineeringtoolbox.com)
compressive stress	stress that tends to compress or shorten the material (Engineeringtoolbox.com)

shearing stress	stress that tends to shear the material (Engineeringtoolbox.com)
strain	deformation caused by stress (Engineeringtoolbox.com)
normal strain	elongation or contraction of a line segment (Engineeringtoolbox.com)
shear strain	change in angle between two line segments (Engineeringtoolbox.com)
biomedical engineer	Biomedical engineers combine engineering principles with medical sciences to design and create equipment, devices, computer systems, and software used in healthcare (Bureau of Labor Statistics)
load cell	a type of force gauge. It consists of a transducer that is used to create an electrical signal whose magnitude is directly proportional to the force being measured. The various load cell types include hydraulic, pneumatic, and strain gauge (Wikipedia)
human articular cartilage	**Articular cartilage** is the smooth, white tissue that covers the ends of bones where they come together to form joints. Healthy **cartilage** in our joints makes it easier to move. It allows the bones to glide over each other with very little friction. **Articular cartilage** can be damaged by injury or normal wear and tear (American Academy of Orthopedic Surgeons)
stress strain curve	Graph of the measure of elasticity of material (ScienceABC)
rehabilitation engineering	The use of engineering science and principles to develop technological solutions and devices to assist individuals with disabilities, and aid the recovery of physical and cognitive functions lost because of disease or injury (Department of Health and Human Services)
biomedical imaging	The science and the branch of medicine concerned with the development and use of imaging devices and techniques to obtain internal anatomic images and to provide biochemical and physiological analysis of tissues and organs (Department of Health and Human Services)
Young's Modulus	In solid mechanics, **Young's modulus** (also known as the **modulus** of elasticity or elastic **modulus**) is a measure of the stiffness of a given material. It is defined as the limit for small strains of the rate of change of stress with strain (Academic Kids Encyclopedia)

Procedure

Background

Fact: Cartilage under large strain compression (up to 30%) softens with the onset of OA (Pearce et al)

Watch and discuss: PPT Osteoarthritis and Biomedical Engineering

Before the Activity

- Set up centers for groups of students to complete different activities while each group has their turn testing different materials
    - Center 1: **Materials Observation and Prediction Center Worksheet**
        - Instructions: Observe the materials in the bag and make predictions on the worksheet. Which materials would work better to protect the bone in the simulated knee? (Read article about cartilage and complete matching activity)
    - Center 2: Reading center https://www.britannica.com/science/arthritis
        - Instructions: Read the article about arthritis and answer the questions on **Reading Center – Arthritis Sheet**

- Center 3: Breaking the Mold Activity (Optional – Advanced)
  - https://www.teachengineering.org/activities/view/cub_brid_lesson04_activity1
- Center 4: Load Cells https://learn.sparkfun.com/tutorials/getting-started-with-load-cells/all
  - Instructions: Read the information about load cells. Review the diagram of the testing device. On a blank piece of paper, create a diagram of the testing device and label the load cell.
- Center 5: Shear stress center (YouTube video, worksheet and shear stress patterned device)
  - Instructions: Review the following two videos.

  https://www.youtube.com/watch?v=ZhjqC64g4Rc
  https://www.youtube.com/watch?v=Xdo5VXoHlrI
  - Use the shear strain device to observe patterns of stress. **Shear Stress Center Activity**
  - Do you think some of the materials will work better than the foam in a shear stress test?
- Center 6: Testing Center for Compression Strain on different materials
  - Bring your bag of materials to the testing center
  - Test each material and record your results for stress and amount of displacement for different amounts of force
  - Create a graph on spreadsheet software to show results

    Testing Center for Compression Strain on Different Materials
    Optional Advanced - https://www.youtube.com/watch?v=Q6iIM_Qvj0U

With the Students

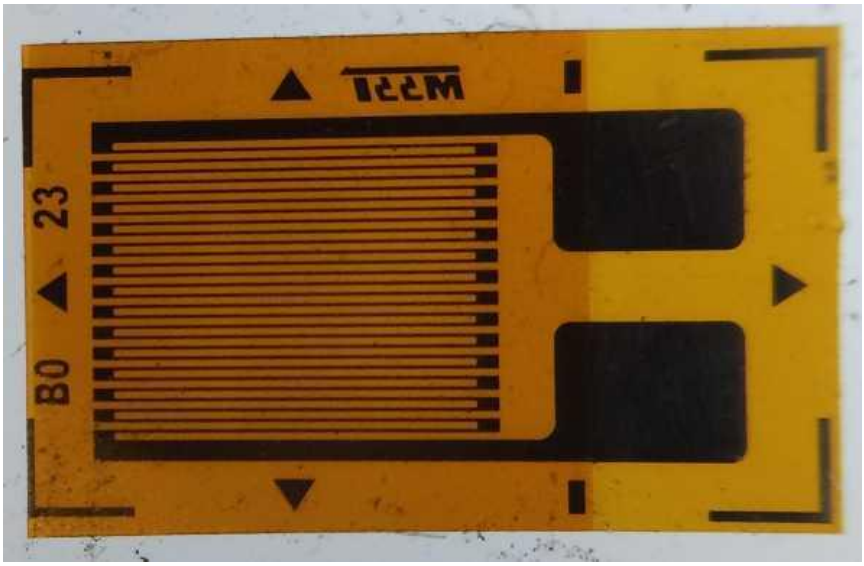
- Demonstrate two knees, one with "bad" foam cartilage and one with "good" plastic cartilage.
- Ask students how bones might be affected depending on cartilage.
- Explain that biomedical engineers sometimes create their own testing devices and explain the testing device up close. Complete one test and show students how to record results.
- Explain each station (also have directions at each station).
- Students work in groups of 3-4 to complete each activity.

Lesson Closure

Was the testing device effective? Why or why not?
Based on your test results, which materials show the most promise in supporting the pseudo-osteoarthritic knee?
How can test results and the testing device be used to develop an assistive device to take stress off the knee joint?
What do the stress/strain graphs show?
What do you notice about the pattern of shear stress on the Styrofoam piece?

Image Insert Image 2

Image 2

Image file: 

ADA Description: Unmounted resistive foil strain gauge

Source/Rights: © "Strain Gauge." *Wikipedia*, Wikimedia Commons, 26 June 2019, upload.wikimedia.org/wikipedia/commons/0/0a/Unmounted_strain_gauge.jpg.

Caption: Figure 2: Unmounted resistive foil strain gauge

Investigating Questions

How does the testing device work?
Which materials are most resilient?
If biomedical engineers developed a new kind of cartilage to replace bad cartilage in the knee, what would they need to know?
What do the results of the test show?
What is the stress/strain curve and what does it demonstrate?

Assessment

Pre-Activity Assessment
Discussion Questions
Do you know anyone who has knee pain?
What is osteoarthritis and how can it affect a person's quality of life?

What is cartilage? What is its job?
Do you know anyone who wears a device to help their body in some way?
What types of engineers do you think design such devices?

Activity Embedded Assessment

What is the most effective way to utilize the testing machine?
What are your test results showing?
Center work completion

Post-Activity Assessment
Quiz: Testing Device diagram completion, stress/strain curve questions

Activity Extensions

Review the Design Process
Start brainstorming assistive devices that can be developed to alleviate stress

2017 Tissue Chips in Space Project
https://ncats.nih.gov/tissuechip/projects/space2017

Freestudy Mechanical Principles Stress Strain
http://www.freestudy.co.uk/mech%20prin%20h2/stress.pdf

Activity Scaling

- For lower grades, assist with graphs, provide more explanation
- For higher grades, discuss Young's Modulus

Additional Multimedia Support

none

References

"Biomedical Engineers : Occupational Outlook Handbook:" *U.S. Bureau of Labor Statistics*, U.S. Bureau of Labor Statistics, 2019, www.bls.gov/ooh/architecture-and-engineering/biomedical-engineers.htm.

"Cartilage." *Dictionary.com*, Dictionary.com, 2019, www.dictionary.com/browse/cartilage.

"Glossary of Terms." *National Institute of Biomedical Imaging and Bioengineering*, U.S. Department of Health and Human Services, 2019, www.nibib.nih.gov/science-education/glossary.

"Articular Cartilage Restoration - OrthoInfo - AAOS." *OrthoInfo*, 2019, orthoinfo.aaos.org/en/treatment/articular-cartilage-restoration/.

Peshin, Akash. "Stress Strain Curve: What Exactly Is The Stress-Strain Curve?" *Science ABC*, Science ABC, 15 Apr. 2019, www.scienceabc.com/innovation/what-is-the-stress-strain-curve.html.

Shen, Francis H., et al. “Arthritis.” *Encyclopædia Britannica*, Encyclopædia Britannica, Inc., 3 July 2019, www.britannica.com/science/arthritis.

“Stress, Strain and Young's Modulus.” *Engineering ToolBox*, 2019, www.engineeringtoolbox.com/stress-strain-d_950.html.

“Young's Modulus.” *Academic Kids Encylcopedia*, Academic Kids, 21 June 2005, www.academickids.com/encyclopedia/index.php/Young%27s_modulus.

Other

none

Redirect URL

none

Contributors

Sheila Gambino

Supporting Program

UConn Joule Fellowship

Acknowledgements

Special thanks to Dr. David Pierce, Phoebe Szarek, and Stephany Santos

Classroom Testing Information

Name: _____
Date: _____

Materials Observation and Prediction Center

Material	Observations	Rate on scale of 1-4 (4 being most resilient)	How could this material be reinforced?

READING CENTER: THE KNEE KNOWS

Name: _____
Date: _____

Read the following article about arthritis https://www.britannica.com/science/arthritis

Answer the following questions:

1. What is arthritis?

2. How many adults are expected to have arthritis by 2030?

3. What is the difference between osteoarthritis and rheumatoid arthritis?

4. What are the main causes of arthritis?

5. How is arthritis diagnosed?

Write three questions you have about the article:

1.

2.

3.

Name: _____
Date: _____

Shear Stress Center Activity

Force (mass in gm. X 9.8m/s) (use Newton force spring meter)	Measured displacement (cm)	Observations
N		
N		
N		
N		
N		
N		

Create a graph of your results.

Name: _____
Date: _____

Compressive Stress Center Activity

Force (mass in gm. X 9.8m/s)	Measured displacement (mm)	Observations
N		
N		
N		
N		
N		
N		

Create a graph of your results.