Biomedical Engineering

STEP 1 Ask the students to turn to page 8 of "Dream, Invent, Create" and then read the rhyme aloud to the class. Or ask 3 different students to each read a stanza.

STEP 2 Explain that this page is all about **biomedical engineering,** and read the text around the border, which is also at right.

STEP 3 Introduce the vocabulary from the biomedical pages, by pointing out each image on the illustration. The numbers on the illustration correspond to the vocabulary (next page).

STEP 4 Then, ask the class the thought questions (next page), either verbally or as part of written or illustrated assignment.

STEP 5 Finally, do the activies: Make a Prosthetic for a Classmate, Biomimicry: Natural Designs, and Seeing and Feeling Sound Vibrations

EXTENSION Ask the students to pick any of the vocabulary words and create a poster or short paper, or research a real-life biomedical engineeer.

SO COOL
Biomedical engineers design, build, and test technologies that doctors can use to diagnose and treat patients.

WHAT ELSE?
They design prosthetics so athletes who have lost a limb can still run, jump, and swim.

NEW STUFF
Biomedical engineers are designing surgical tools to make operations quicker and more precise, and working on new types of scanners to see what happens in the brain.

TELL ME MORE
They're building artificial organs like hearts, kidneys, and livers, and growing tissues like skin and bone.

VOCABULARY / CONCEPTS

Point out each image on the illustration and match it with the vocabulary below:

1. Prosthetic leg: For one reason or another, many people require replacement body parts. Those who need artificial legs must have a structurally stable one to replace a critical part of the skeletal system. One specialty of biomedical engineering is designing and creating new and better prostheses (replacement body parts). Biomedical engineers are continually improving the strength, durability, longevity and lifelikeness of prostheses so amputees can lead full lives.

2. Laser knife: A laser is a light beam that can be focused on a very small area. Engineers have created lasers that offer surgeons the ability to operate very precisely on their patients. They can focus on a small area and damage less of the surrounding tissue. Patients who have laser therapy may experience less pain, swelling, and scarring than with traditional surgery.

3. Artificial organ: a man-made device that is implanted into a human to replace a natural organ (like a heart) so the patient may return to a normal life as soon as possible.

4. Camera in a pill: Thanks to biomedical engineers, doctors can now take a really close look at your digestive system: you swallow a tiny camera that's about the size of a large vitamin pill. The capsule contains lights to illuminate your digestive system, a camera to take images, and an antenna that sends those images to a recorder you wear on a belt.

5. Medical scanner: This device creates images of the inside of your body so doctors can figure out if something is wrong, and how to treat you.

ADDITIONAL VOCABULARY FROM LESSONS:

Prosthetics: A specialty of medicine and engineering that designs, constructs, and fits artificial limbs and body parts (prostheses).

Prototype: An original, full-scale, and usually working model of a new product, or new version of an existing product.

Biomimicry: Copying or imitating the special characteristics of naturally existing things (animals, plants, etc.) in human-made designs, products, and systems. From *bios*, meaning life, and *mimesis*, meaning to imitate.

Frequency: The rate of vibrations in different pitches. Low pitch sounds have lower frequencies (and longer wavelengths).

Pitch: The highness or lowness of a sound. Related to the wavelength and frequency of a noise. Short wavelength equates to high frequency and subsequently high pitch.

Sound energy: Audible energy that is released when you talk, play musical instruments, or slam a door.

Sound wave: A longitudinal pressure wave of audible or inaudible sound.

Vibration: When something moves back and forth, it is said to vibrate. Sound is made by vibrations that are usually too fast to see.

Volume: When sound becomes louder or softer. A measurement of amplitude.

Wave: A disturbance that travels through a medium, such as air or water.

THOUGHT QUESTIONS

1. Why might someone need a prosthetic arm or leg? Do you know anyone who uses one?

2. Some doctors are now able to see and treat their patients by examining them through a camera on their phones or computers. What would be the advantages and disadvantages of this type of treatment? (Ability to treat patients in remote locations; diagnosis may not be as accurate as seeing a patient in person.)

3. What kinds of things do animals do better than humans? Is there anything we can learn from them? (Fly; swim)

BIOMEDICAL ENGINEERING ACTIVITY 1

Make a Prosthetic for a Classmate

SUMMARY

Student teams investigate biomedical engineering and the technology of prosthetics. Students create lower-leg prosthetic prototypes using various ordinary materials. Each team demonstrate its device's strength and consider its pros and cons, giving insight into the characteristics and materials biomedical engineers consider in designing artificial limbs.

ENGINEERING CONNECTION

For one reason or another, many people require replacement body parts. Those who need artificial legs must have a structurally stable one to replace a critical part of the skeletal system. One specialty of biomedical engineering is designing and creating new and better prostheses (replacement body parts). Biomedical engineers are continually improving the strength, durability, longevity and lifelikeness so amputees can lead full lives.

LEARNING OBJECTIVES

After this activity, students should be able to:

- Describe the engineering design considerations that go into developing quality prostheses.
- List characteristics and features that are important for a prosthetic leg.
- Analyze a prototype prosthetic leg and make suggestions for design improvements.

MATERIALS LIST

Each group needs:

- yardstick, ruler or tape measure, for measuring
- scissors
- 1 type of prosthetic structural material with which to create a prototype (see suggestions below); note: the number of groups depends on how many different prosthetic resource materials are collected
- Prosthetic Party Worksheet, one per person

For the entire class to share:

- 1 roll duct tape

Provide a variety of prosthesis structural material resources. Suggestions:

- **For leg structure:** toilet plungers (unused), plastic pipes, smooth metal pipes, metal strips, cardboard tube (from wrapping paper roll), wooden "2 x 4," thin metal duct material (to be rolled and taped into a tube shape), all generally 1.5 ft long
- **For comfort:** large sponges, scrap bubble wrap, scrap cardboard, etc.
- **For lifelikeness:** bath towels, pairs of pants, shoes (use students')
- **For body attachment:** string, rope, twine (about 30 ft

INTRODUCTION/MOTIVATION

What is a prosthesis? (Answer: An artificial body part that replaces a missing body part.) Who might need a prosthesis? Many people are in need of various types of prostheses, including injured soldiers, people who live in war zones, and people who have been in accidents. Biomedical engineers design prostheses for these amputees so that they can live as easily as others.

What are some important features required for a good prosthetic leg? The most important characteristics are strength, durability, longevity, shock absorption, lifelikeness and comfort. Biomedical engineers research and design new ways to create prosthetic legs that have all of these characteristics.

Today, we will be biomedical engineers, and design and create our own prosthetic lower legs! Then we will test our prototypes by bending a knee and resting it on the prosthesis. Our goal is to provide all the important features that we talked about. Then, we'll figure out some way to connect our prostheses to a body. Since we do not have real manufacturing equipment, we will use some everyday, around-the-house materials.

PROCEDURE

Before the Activity

- Gather materials and make copies of the worksheet (pages 33), one per person.
- Review the 3 pages of images of example prototype prostheses, for how students might create their own prostheses, and ideas to address comfort and lifelikeness.

With the Students

1. Divide the class into enough teams so each has a different structural prosthetic material.
2. Lead a pre-activity discussion and brainstorming session (as described in the Assessment section) so students have a good understanding of the various prosthetic requirements and material resources to meet these needs.
3. Explain to the students that when engineers design a new or improved product, they work in groups and follow the steps of the engineering design process: 1) understand the problem or need, 2) come up with creative ideas, 3) select the most promising idea, 4) communicate and make a plan to describe the idea, 5) create or build a prototype or model of the design, and 6) evaluate what you have made.
4. Assign teams different material resources with which to construct their prostheses. Make available other materials for the students to consider incorporating into their design.
5. Hand out worksheets and have students follow along with its questions throughout the activity.
6. Have students discuss ideas within their groups, while completing the first page of the worksheet.
7. Have each group choose one teammate for whom to make the prosthesis. So that the prosthesis fits him/her, measure that student's lower leg from where it bends at the knee.
8. Have students collect other materials, such as tape and string, and begin creating their prototypes, creatively addressing the requirements of strength, stability, durability, longevity, shock absorption, lifelikeness, comfort, etc.
9. After all teams are finished, have each group present its prosthesis to the rest of the class, explaining the design concepts and material choices, as well as demonstrating the prototype's strength by having the teammate use it to walk (while bending his/her knee and wearing the prosthesis). See post-activity presentation suggestions in the Assessment section.
10. Conclude with a class discussion using the questions provided in the Assessment section.

SAFETY ISSUES

Be careful when testing prostheses. Have student "spotters" positioned around the teammate who is testing the prosthesis to catch him/her if s/he falls.

TROUBLESHOOTING TIPS

If the prostheses are not strong enough to hold the body weight, test them with heavy objects (such as books) while students hold the prosthetic steady.

Since students may be unable to cut certain materials to the correct length, advise groups with these materials to choose their "amputee" teammate by finding the person who has a lower leg length closest to the material length. Or, if the material is too long, they could adjust by elevating the opposite foot (perhaps by standing on a book or strapping an object to the foot). Engineers realize that all materials have pros and cons; if a material is difficult to work with, it is a disadvantage to ultimately choosing it to make prostheses.

ASSESSMENT

Pre-Activity Assessment

Discussion/Brainstorming: As a class, have students engage in open discussion. Solicit, integrate and summarize student responses. Give prompts as necessary. Remind students that in brainstorming, no idea or suggestion is "silly." All ideas should be respectfully heard. Take an uncritical position, encourage wild ideas and discourage criticism of ideas. Have students raise their hands to respond. Record their ideas on the board. Ask the students:

- What features would make a useful prosthetic lower leg? (Possible answers: Strength, stability, durability, longevity, shock absorption, lifelikeness, comfort.)

- How can you achieve some of these qualities, using the provided resources? (Possible answers: Use the plunger head for a comfortable knee support, use rope or duct tape for connection to the body, use tube or pipe or wood for strong and sturdy support.)

Activity Embedded Assessment

Worksheet: Have students complete the activity worksheet; review their answers to gauge their mastery of the subject.

Post-Activity Assessment

Conference Presentation: Have each group present their prosthetic lower leg as if they were presenting it at an engineering conference. Have them include the following in their presentations:

- List of materials and purpose of each

- How they came up with the design

- Important design features

- Estimated cost

- Demonstration of use

Concluding Discussion Questions: Conclude with a class discussion to gauge students' comprehension of the subject matter covered. Ask the students:

- What improvements would you make to your prototype prosthesis?

- What other materials and fasteners would help improve your design?

- What would be different if you had to make the whole leg, including the knee?

- What design constraints or limitations might be different for biomedical engineers developing real prostheses?

ACTIVITY EXTENSIONS

Expand the design challenge to have teams make a functional prosthetic arm. For an artificial arm, the primary purpose shifts from being structural to enabling movement. Have students brainstorm ways to make the prosthetic arm move. A bonus challenge is to create a prosthetic arm and/or hand that can pick up an object.

See if your local hospital, rehab center, veteran's hospital or medical center can loan you real prosthetic devices to show students. Or, find images of the latest designs on the Internet.

Have students research gait analysis and how engineers help measure a person's gait. How would this analysis be helpful in designing prosthetic limbs?

ACTIVITY SCALING

For lower grades, instead of testing the device with the weight of an entire body, test it with heavy objects (such as books) while students hold the prototype steady. This way, the prosthetic need not be as strong or dependant on a secure leg attachment.

For upper grades, have students draw more than one design. Have them predict and explain why one of their designs would be best, and construct a prototype of that one.

Courtesy Teach Engineering: https://www.teachengineering.org/view_activity.php?url=collection/cub_/activities/cub_biomed/cub_biomed_lesson01_activity1.xml

Examples of Prototypes

Example 1:

A pipe is chosen to provide structure.

To provide some comfort for the knee, a piece of sponge is cut and taped to the top of the pipe.

For stability, a student's shoe is taped to the other end of the pipe.

The student's knee is taped to the prototype prosthesis, providing a connection to the body.

It works!

Examples of Prototypes

Example 2:

A cardboard tube is used for flexibility and lifelikeness.

A metal strip is run through it to provide structural support.

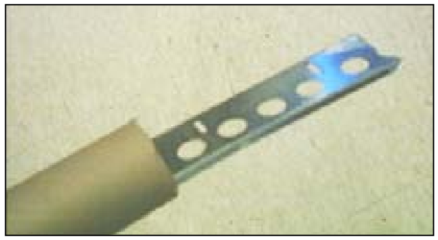
To provide some comfort, folded cardboard is duct-taped to the top of the tube.

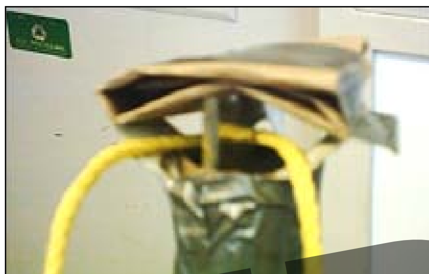
A piece of rope is threaded through a hole in the metal, providing a way to connect the prosthesis to the body.

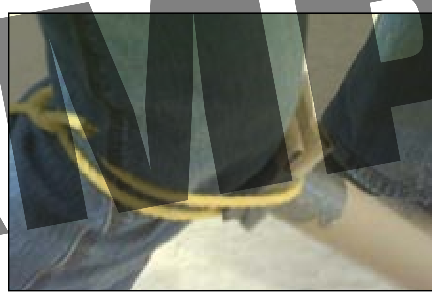
Through a hole poked in the cardboard tube, a student's shoe is tied to the other end of the tube, providing stability.

The rope ties the prosthesis to the student's knee, which rests on the cardboard tube.

Even with a flimsy cardboard tube, it works!







Examples of Prototypes

Lifelikeness:

Wrapping a piece of wood with a towel can make the prosthesis appear and feel more lifelike, especially once covered by a pair of pants!

Comfort:

Get creative to find different ways to make the prosthesis comfortable! (left to right) Perhaps a crumpled piece of paper taped to a copper pipe, a piece of bubble wrap taped to a piece of wood, or the rubber head of a toilet plunger.

Make a Prostheticfor a Classmate Worksheet

Date_______________

Names of engineers ____

____

1. **Plan:** What characteristics, qualities and features will your prosthetic lower leg possess, and how will you provide these with the available materials?

Characteristics, qualities or features	Plan: how you will provide these with the available materials

2. **Measure:** How long is the lower leg that is to be replaced by a prosthesis? __________

3. **Design:** Draw a picture of how your prosthesis will look, using your plans from above.

Make a Prosthetic for a Classmate Worksheet (cont.)

Names of engineers ____

____

4. After creating your final design, list the materials you used and how they contribute to the function of the prosthesis.

Material	Function

5. Evaluate: While watching the group presentations, list the best feature of each group's prosthesis and what material or technique accomplished this feature.

Group	Best Feature	Material/Technique

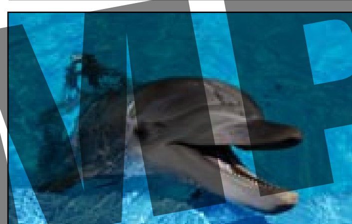
6. From the group presentations, and reflection upon your own team's design, what improvements would you make to your prototype?

BIOMEDICAL ENGINEERING ACTIVITY 2

Biomimicry: Natural Designs

SUMMARY

Students learn about biomimicry and how engineers often imitate nature in the design of innovative new products. They demonstrate their knowledge of biomimicry by practicing brainstorming and designing a new product based on what they know about animals and nature.



ENGINEERING CONNECTION

Engineers often use the natural world as inspiration for design. Biologically inspired designs include air- and sea-going vessels, navigation tools such as sonar and radar, medical imaging devices, biomedical technologies like prosthetics, and water and pollution treatment processes. Biomimicry has resulted in many creative products, such as a materials inspired by the slick leaves of the lotus plant and its natural capacity to wash away dirt particles with every rainfall, and the Velcro hook-and-loop system inspired by the prickly plant burrs that stick to our clothes.

LEARNING OBJECTIVES

After this activity, students should be able to:

- Define biomimicry.
- Explain how engineers use biomimicry to design innovative new products.
- List examples of engineered products that were inspired by nature.
- Use biomimicry to develop an idea for a new product.

MATERIALS LIST

Each student needs:

- Paper
- Pencil
- Markers or colored pencils
- Ruler

INTRODUCTION/MOTIVATION

Does anyone know what the word "biomimicry" means? Let's break down the word into more understandable parts. "Bio" means life and "mimicry" means to imitate. So, biomimicry means to imitate life or nature. Who has heard the expression, "Nature knows best"? Well, biomimicry is a way of learning from nature. It is a way to observe nature in action and use that knowledge to inspire new ideas. Engineers often use these ideas to develop cool new products or better ways to do things to help people. Today we are going to learn all about biomimicry and how engineers look at the amazing characteristics of animals and plants to create new or improved product designs.

Can anyone think of an example of biomimicry? Think of something that has been designed with nature in mind. How about Velcro®? Velcro® was invented after a man took a very close look at those little prickly seeds that stick to your clothing when you walk though a field. Water filters are designed like animal cell membranes that let certain things pass through while others are kept out. Also, though planes do not flap their wings like birds, their shapes and the principles of keeping a plane in flight are the same as bird wings. People have also created adhesives that mimic the fascinating and sticky surface of gecko or lizard's five-toed feet. Did you know that? Radar and sonar navigation technology as well as medical imaging was inspired by the echo-location abilities of bats. Also, the solar cells that make up solar panels are designed to mimic the way leaves collect energy from the sun.

Who created most of these products? Well, engineers, of course! Engineers have also used biomimicry of animals to design things like prosthetics, agriculture methods, navigation tools, and even running shoes. Darcy Winslow, the general manager of environmental business opportunities at Nike, Inc. said, "The extent to which the natural world can provide technological solutions for the types of product performance characteristics we must provide are virtually unlimited. Biomimicry still requires exploration, innovation and creativity, but by thinking like or working with a biologist we must learn to ask a different set of questions and look to nature for inspiration and learning opportunities."

Engineers definitely look to nature for inspiration and learning opportunities! Another way that engineers learn from nature is to figure out ways to address the pollution that results from making and using products. Nature has a well-defined way of taking care of its "trash," such as dead animals and leaves. Everything in nature is used, even its waste products. Sometimes natural "waste" becomes food for others animals or breaks down into soil nutrients available for reuse. This is a very important model for engineers; we can learn from nature to recycle our resources and not leave a contaminated mess behind every time we make something.

Biomimicry is a process in which you ask the question, "What would nature do here?" Today we are going to be design engineers who use the biomimicry of animals to come up with a new invention! Are you ready?

PROCEDURE

Background: More on Biomimicry

People have called on nature's inspiration throughout humans' history. By observing animals, plants and natural processes, we gain insight into what works and what does not. For engineers, these observations are helpful in both the design process and inspiring new inventions using natural technologies. There are many examples of biomimicry, with one of the most well-known being Velcro® — a product designed to behave like the cockleburs that stick to animals (and people) when they brush by the plant. For more examples, see the list below as well as the resources in the References section.

Example inventions based on or inspired by animals:

- Airplanes modeled after **birds** (wing and body shapes, falcon beak)
- Morphing airplane wings that change shape according to the speed and length of a flight, inspired by birds that have differently-shaped wings depending on how fast they fly
- **Fish**-inspired scales that easily slide over each other to enable the morphing airplane wings
- Boat hulls designed after the shapes of **fish**
- Torpedoes that swim like **tuna**
- Submarine and boats hull material that imitates **dolphin and shark skin membranes**
- Radar and sonar navigation technology and medical imaging inspired by the echo-location abilities of **bats**
- Swimsuit, triathlon and bobsled clothing fabric made with woven ribbing and texture to reduce drag while maintaining movement, mimics **shark's skin**
- Adhesives for microelectronics and space applications inspired by the powerful adhesion abilities of **geckos and lizards**
- Water filters designed like **animal cell membranes** to let certain things pass through while others are kept out
- Running shoes with technology learned from studying the mechanics of **animal feet**
- Super strong and waterproof silk fibers made without toxic chemicals by **spiders**
- Ceramics and windshields, after the mother of pearl material made by **abalone mussels**
- Underwater glue for slippery surfaces, as made by **mussels**

- Anti-reflective, anti-glare film used for flat panel displays, touch screens, lamps, and phone and PDA lenses replicates the nano-structures found in the **eyes of night flying moths**
- A better ice pick for mountain climbers designed after the **woodpecker.**
- Glow sticks made with light-up chemicals, just like **fireflies**
- Very efficient pumps and exhaust fans applying the spiraling geometric pattern found in **nautilus sea shells, galaxies and whirlpools**

Example inventions based on or inspired by plants

- Hook and loop material (Velcro®) inspired by **cockleburs**
- Solar cells inspired by **plant leaves** (photosynthesis, capturing energy from sunlight)
- A wind-driven planetary rover design that maximize drag, learned from the **tumbleweed**
- Self-cleaning exterior paint, tiles, window glass and umbrella fabric inspired by the slick leaves of the **lotus flower plant** and its natural ability to wash away dirt particles in the rain
- Reduced-drag propeller designs inspired by the spiral shape of **kelp**, which moves with the current rather than fight it, so much less energy is required to move water or ship
- Filter and clean water like a **marsh**

Biomimicry can be used as a model for engineering designs that are useful to solve human problems. With the concerns for the environment, biomimicry may offer suggestions of how industrial designs can be more sustainable and appropriate for different climates and cultures.

More examples here: Biomimicry Institute: http://biomimicry.org/biomimicry-examples/#.Vgbdl3ipr8s

With the Students

1. Divide the class into pairs of students.
2. Ask the pairs to list three things both students have as common interests. These interests can be anything; examples: sports equipment, music, clothes, games, furniture, cars, etc.
3. Next, have the students agree on one of those common interests for their design topic area.
4. Tell the students they have 10 minutes to brainstorm with their partners to come up with possible ideas for designs within their interest topic using biomimicry of animals. Ask the students if they can think of any animals that remind them of their topic. What unique features do those animals have? How could they design something that uses those features? Remind students that this type of brainstorming and building on each other's ideas is an important step in engineering a new, innovative product.
5. As necessary, remind students of the brainstorming guidelines:
    - No negative comments allowed.
    - Encourage wild ideas.
    - All ideas are recorded.
    - Stay focused on topic.
    - One conversation at a time.
    - Build on the ideas of others.
6. Pass out paper, rulers, markers and colored pencils to the students.
7. Give the students 20 minutes to design and draw their new product that uses biomimicry. Have students be as detailed as possible. Ask them to label parts and materials in their design.
8. Once they have finished design, have each team make a list of the special features of their design and which animal(s) inspired those features.
9. Mount the drawing and design features onto a piece of construction paper.

10. If time, have students role-play engineering companies and present their biomimicry designs to the class. Post their completed designs in the classroom or school resource center to share with others.

TROUBLESHOOTING TIPS

If students have difficulty coming up with a design idea, help to steer them with suggestions. Or, assign a common class design area topic, such as sporting equipment or playground toys. After individual team presentations, have the class vote for the best design — the one they would choose invest in if they were paying clients.

ACTIVITY EMBEDDED ASSESSMENT

Thinking through the Design: Ask the students to identify which feature(s) of their design are inspired by nature. If possible, have them be specific about what type of animal or plant they are mimicking and have them describe inspiration (plant or animal characteristics, etc.).

Is It Biomimicry? Give examples of design ideas, some that are biomimicry and some that are not. Have students vote whether or not they think the designs involve biomimicry. If the design does include biomimicry, as for a volunteer to explain the natural world source of inspiration. Examples include: Airplane wing? (Answer: Yes, after bird wings.)

- iPod? (Answer: No)
- Sonar navigation? (Answer: Yes, after bats.)
- Computer printer? (Answer: No)
- Hard coatings for car windshields? (Answer: Yes, after abalone mussels' mother of pearl coating.)
- Hulls of submarines? (Answer: Yes, after dolphin and shark skins.)
- Soft cushion for a chair? (Answer: No)
- Solar cell? (Answer: Yes, after leaves.)

For additional ideas, see the Background section.

HOMEWORK

Engineering Inventors Log: Have students think about everything in the natural world (animals, plants, cycles, processes) that might inspire them to create new products. Over the next week, have them look around their environment and make journal entries of design ideas and sketches for products that an engineer might create. Let them know that engineers often think of many ideas over a long period of time before they decide on one idea to develop. Often, they keep their evolving ideas in a dated engineering or inventor's journal with details on the materials and methods they might use to produce the product.

ACTIVITY EXTENSIONS:

Biomimicry Research and Report

Have students investigate an existing product that was inspired by nature, using the Biomimicry Research and Report document (page 39).

Additional extensions can be found here.

Courtesy https://www.teachengineering.org/view_activity.php?url=collection/cub_/activities/cub_bio/cub_bio_lesson05_activity1.xml and http://www.kidsciencechallenge.com/year-four/teachers_plans_archives.php#bio

Notes

Biomimicry Research and Report

Directions: Research the technology you selected by answering the questions on this form. You might not be able to answer every question, but you should attempt to get as much information as possible. You can use any resource you want to answer the questions, but your best bet is finding information on the internet.

1. Name of the technology:

____

2. What does it do?

____

3. How does this help us?

____

4. Would you use this in everyday life, or is it designed for a special group of people or purpose? Describe this.

____

5. What animal or plant (or otherwise) inspired this technology?

____

6. How does this new technology help us to live cleaner and be sustainable?

____

7. What kind of new processes does this technology use? If the technology is fairly advanced, just do your best.

____

8. What kinds of existing technology does this make use of?

____

9. Is this technology better than the one found in nature?

____

10. How long has it been in use?

____

11. Who (what company) invented it?

____

12. In your opinion, what could be a possible future use of this technology?

____

BIOMEDICAL ENGINEERING ACTIVITY 3

Seeing and Feeling Sound Vibrations

SUMMARY

Students examine the existence of sound by listening to and seeing sound waves while conducting a set of simple activities as a class or in pairs at stations. Students describe sound in terms of its pitch, volume and frequency. They use this knowledge to discuss how engineers study sound waves to help people who cannot hear or talk.

MATERIALS LIST

Each student needs: Seeing Sounds Worksheet (page 43)

For each pair of students or activity station:

- **Tuning Fork Station:** Tuning fork (available at a musical instruments store), cup of water (or ping pong ball)
- **Spatula Blade Station:** Spatula (metal or plastic)
- **Rubber Band on Doorknob Station:** Rubber bands, doorknob on a door
- **Boom Box Station:** Boom box, balloons, paper plate, small pieces of paper

ENGINEERING CONNECTION

Biomedical engineers are especially interested in sound waves because they design devices such as hearing aids or computerized voices that help people who cannot speak or hear be able to create or identify these sound waves. Engineers also design many types of imaging devices that change ultrasonic and infrasonic sound energy into visual images. For example, some medical equipment uses sound energy to create screen images of what is going on, unseen, in the human body. And, ocean navigation equipment includes sound imaging equipment so ships can determine the unseen terrain of an ocean floor.

LEARNING OBJECTIVES

After this activity, students should be able to:

- Describe how sound is created by the vibration of certain objects. As the vibration changes, so does the sound.
- Relate that sound energy can be seen as well as heard.
- Describe sound in terms of volume, pitch and frequency.
- Explain how engineers use their knowledge of sound waves to create devices to help people hear.

INTRODUCTION/MOTIVATION

We are going to explore three characteristics of sound energy today — pitch, volume and frequency. Volume is how loud a sound is (greater amplitude), pitch is how high a sound is (short wavelength = high pitch), and frequency is how fast a sound wave is moving (high frequency = short wavelength = high pitch). These three properties really help us describe sound energy.

Can you see sound energy? Can you feel sound energy? Well, let's find out! Everybody stand up! Now shake your body! Shake all your body parts as much as you can! When something moves back and forth, it is said to vibrate. Can you see your neighbor's body vibrating? Well, sound is made by vibrations that are usually too fast to see.

Have the students hum their favorite song while gently placing their fingers on their throat. What do they feel? (Answer: They are feeling the vibrations of their vocal chords, which vibrate to make sound.)

The vibrations you feel when you hum are how we make and hear sound. Biomedical engineers are especially interested in sound energy; they design devices that help people who cannot speak or hear be able to create or identify sound waves. You may be familiar with hearing aids, which are devices created by engineers. Using their understanding of sound energy, engineers create equipment to help people hear.

In today's activity, we are going to examine how we can see and feel sound energy using pitch, volume and frequency.

Pre-Activity Assessment
Brainstorming: As a class, have the students engage in open discussion. Remind them that in brainstorming, no idea or suggestion is "silly." All ideas should be respectfully heard. Take an uncritical position, encourage wild ideas and discourage criticism of ideas.

Ask the students:
What is sound energy?
In what places have you heard sounds?
What creates these sounds?
Sound Drawing: After each student has drawn a picture of a noisy place they have been, have them describe all the noises to the class.

PROCEDURE

Before the Activity

- Gather the materials for each station.
- Make copies of the Seeing Sounds Worksheet (page 43), one per student.

This may be either an entire class demonstration or a student team activity. Either have the class perform each activity station together, or set up stations around the room and have students conduct each activity station in small groups.

With the Students

Tuning Fork

1. Strike a tuning fork and place one of its tines against a cup of water or ping-pong ball.
2. Discuss what happened to the ping-pong ball. Why did it move?

Spatula Blade

1. Place the tip of a spatula blade on a desk or table with the handle extending over the side.
2. Pull the handle down and let go.
3. Discuss what happens when the handle is let go? What does the spatula look like? Do you hear anything? Describe the volume, pitch and frequency of what you observe. These vibrations are similar to what goes on in your vocal chords when you talk.

Rubber Bands on Doorknob

1. Fasten a rubber band to a doorknob, pull it taut, and pluck it.
2. Discuss what happens when the rubber band is plucked. What does the rubber band look like? Do you hear anything? Describe the volume, pitch and frequency of what you observe when you change how much you stretch the rubber band. These vibrations are similar to what goes on in your vocal chords when you talk.

Boom Box

1. Hold a blown-up balloon in front of a boom box speaker and turn up the volume.
2. Observe what happens to the balloon when the volume is turned up.
3. Place a paper plate with small pieces of paper on it on top of the boom box.
4. Observe what happens to the pieces of paper as you turn up the volume.

CONCLUSION

Discuss with the students what they have seen and felt. Come to a class consensus: Can you see and feel sound energy? Sound energy is a useful form of energy for sensing and detecting vibrations. Engineers use sound energy to help people see and feel things that they would not otherwise be able to, like what is going on deep inside a human body, far under the surface of the Earth, and deep below the sea to the ocean floor. Engineers also design medical devices, such as hearing aids, that help people hear things they may not be able to normally hear.

SAFETY ISSUES

Remind the students that loud noises can damage their ears. They should be as quiet as possible, especially when experimenting with the boom box.

TROUBLESHOOTING TIPS

If the class period is too short to complete all the activities, just do one or two.

This activity may get loud. To avoid disturbing other classes, consider going outside.

ASSESSMENT

Worksheet: Have the students use the Seeing Sounds Worksheet to guide them as they rotate through the activity stations and as a place to record their observations. Review their answers to gauge their mastery of the subject.

Post-Activity Assessment

Ask the class: How many different things can you think of that use sound energy? (Possible answers: Radio, television, car horn, telephone, crosswalk signal, smoke alarm, oven timer, etc.)

Activity Extensions

Have students conduct an Internet or library search to learn more about ultrasound and infrasonic sound and the engineering products created from using these types of sound.

Have students investigate how a hearing aid works, and how they have improved over time.

Have students describe the sound that comes from using various instruments such as a guitar or a drum. On a guitar, how do you make the sound change in pitch? Does it relate to the frequency of the sound wave?

Activity Scaling

For lower grades, conduct these activities as a class demonstration, instead of individual stations. They are fun to do together.

For lower grades, have students draw pictures of their observations.

Courtesy Teach Engineering: https://www.teachengineering.org/view_activity.php?url=collection/cub_/activities/cub_energy2/cub_energy2_lesson05_activity1.xml

Notes

Seeing Sounds Worksheet

Date______________________________

Name of engineer ____

Tuning Fork Station

1. Strike a tuning fork and place one of its tines against a cup of water or a ping pong ball.

2. What happened to the water (or ping pong ball)? ___________________________________

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Object	Volume Was the sound **loud** or **soft?**	Pitch Was the sound **high** or **low?**	Frequency Did the water or ping pong ball vibrate **fast** or **slow?**
Tuning fork			

Spatula Blade Station

1. Place the tip of a spatula blade on a desk or table with the handle extending over the side.

2. Pull the handle down and let go.

3. What happens when the handle is let go? Do you hear anything? These vibrations are similar to what goes on in your vocal chords when you talk.

Object	Volume Was the sound **loud** or **soft?**	Pitch Was the sound **high** or **low?**	Frequency Did the spatula vibrate **fast** or **slow?**
Spatula			

Seeing Sounds Worksheet

Name ___________________________________

Rubber Bands on Doorknob Station

1. Fasten a rubber band to a doorknob, pull it taut, and pluck it.

2. What happens when the rubber band is plucked? Do you hear anything? These vibrations are similar to what goes on in your vocal chords when you talk.

Object	Volume Was the sound **loud** or **soft**?	Pitch Was the sound **high** or **low**?	Frequency Did the rubber band vibrate **fast** or **slow**?
Rubber band			

Boom Box Station

1. Hold up a blown-up balloon in front of a boom box speaker and turn up the volume.

2. Place a paper plate with small pieces of paper on it on top of the boom box.

3. What happens to the balloon when the volume is turned up? What happens to the pieces of paper as you turn up the volume?

Object	Volume What happened to the object when the volume was **turned up**?	Pitch Did the objects change when the sound was **high** or **low**?	Frequency Did the object vibrate **fast** or **slow**?
Balloon			
Paper			

Conclusion

1. Can you see or hear sound energy? ____

2. How would this help an engineer designing something? ___________________________

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