I Heart BEAM

Target Grade: Elementary/Middle School
Author: Stephanie Huang *(adapted from Lindsey Zhang)*
Semester: Spring 2019

Brief Overview

Welcome to BEAM and the start of another exciting semester! At the beginning of the lesson, there will be time for ice breakers, name games, and other activities to introduce the students to BEAM, their mentors, and each other. Afterwards, students will learn about the circulatory/cardiovascular system and how to apply the engineering design process to design a biomedical device (specifically, a heart valve replacement)! By the end of the lesson, mentors/mentees should know each other's names and also a little bit about cardiovascular engineering and the engineering design process. This lesson is the first part of a two-week joint lesson on the cardiovascular system and biomedical engineering.

Teaching Goals

- Introduce BEAM! Learn the names of all mentors and mentees.
- Introduce students to the **cardiovascular system.**
    - **Cardiovascular System:** The heart and the blood vessels; this system is in charge of circulating blood throughout the body. Another name for the cardiovascular system is **circulatory system.**
- Familiarize students with the field of **biomedical engineering** and its applications.
- Practice the **engineering design process!**
    - The **engineering design process** is the process of trial and error and repeatedly testing and improving upon models.
    - There are many different ways you can design something! Engineering is not limited to one design.

Careers and Applications

As the name suggests, **biomedical engineering** is the intersection of biology, medicine, and engineering. Biomedical engineers use their engineering knowledge and apply it to solve issues in biology and medicine. This innovative field has resulted in many life-saving medical devices, such as pacemakers and insulin pumps. We will be learning more about an application of biomedical engineering, replacing a heart valve, in this lesson!

Agenda

- Introduction/Module 0: Welcome to BEAM! (15-20 min)
- Module 1: Blood Vessels (5-10 minutes)
- Module 2: Engineering Challenge - Have a Heart (Valve) (20-25 min)
- Conclusion

Module 2 is adapted from Lindsey Zhang, Fall 2016.

Introduction/Module 0: Welcome to BEAM!

Introduction

Begin the semester by playing an ice breaker or two to get to know your students by name!

Teaching Goals

1. Learn everyone's names and introduce BEAM!

Background for Mentors

Learning names is especially important for developing good relationships with the mentees because they are a lot more receptive when you call them by their name (as opposed to pointing to them or using some other generic identifier). In a few years, students may not necessarily remember the specific concepts they've learned, but they will definitely remember how they felt during their one-on-one interactions with you! Playing name games will both break the ice and allow everyone to get to know each other in a fun way.

Materials

- 2 tennis balls *per site*

Procedure

1. Introduce yourselves and what BEAM is! Your site leader will most likely decide how to do this, but some introductory questions I've liked to ask my students in the past are:
    a. What is BEAM? What do the letters in BEAM stand for?
    b. What is engineering? What do engineers do?
2. Play a name game to familiarize yourselves with your students! Here are a couple suggestions, but feel free to try other name games.
    a. Name Toss
        i. Stand in a circle and have everyone say their name.
        ii. Have a mentor start out with a tennis ball. He or she will say someone else's name and toss the tennis ball to that person.
        iii. That person will then say the name of another person and toss the ball to him or her.
        iv. The game continues until everyone has received the ball!
    b. Animal Name Game
        i. Have everyone stand in a circle (be sure that mentors are distributed among mentees). If there are too many students in your site, feel free to break this group into smaller groups. Then, go around the circle and have each mentor/mentee (1) say his or her name and (2) an animal

that starts with the same letter as their name.

ii. You can also have each mentor/mentee repeat the name/animal of each person before them. For example, say we have Evan, Amber, and Wyatt (hi to my old site ☺) in our circle:
    1. Evan starts by saying, “Elephant Evan.”
    2. Next, it’s Amber’s turn and she will say, “Elephant Evan, Anteater Amber.”
    3. Wyatt continues by saying, “Elephant Evan, Anteater Amber, Wombat Wyatt.”

c. Zap!

i. This is almost the same as the Name Toss game, except it is done without a tennis ball.
    1. Students and mentors stand in a circle.
    2. Have a mentor start out. He/she will say his/her name and then point at someone, say “Zap!” and say his/her name.
    3. That person then points to another person and says “Zap!” and his/her name.
    4. The game continues until everyone has been zapped.

d. For older students, sometimes they just don’t want to play a game. Some will think they are “too cool for a name game,” and that’s totally fine! Just make sure that everyone says their name together as a group at least once and keep finding opportunities to learn their names when you work with them more individually in the following activities.

Additional Notes for Mentors

For larger sites, be sure to stay within the time allotted for this module because there is a lot to do today! If necessary, consider splitting off into smaller groups and having a mentor lead the game for each of these groups.

Module 1: Blood Vessels

Introduction

In this module, students will be introduced to the circulatory system through a visual model of blood vessels.

Teaching Goals

1. **Circulatory/Cardiovascular System:** responsible for the movement of blood throughout the body (consists of the heart and blood vessels).
2. The heart pushes blood through arteries, which expand and contract. This process of expansion and contraction corresponds with our **heartbeat**.

Background for Mentors

The cardiovascular system is a critical part of the human body. Otherwise known as the **circulatory system**, the **cardiovascular system** is responsible for the movement of blood throughout the body. This system includes both the heart and the blood vessels.

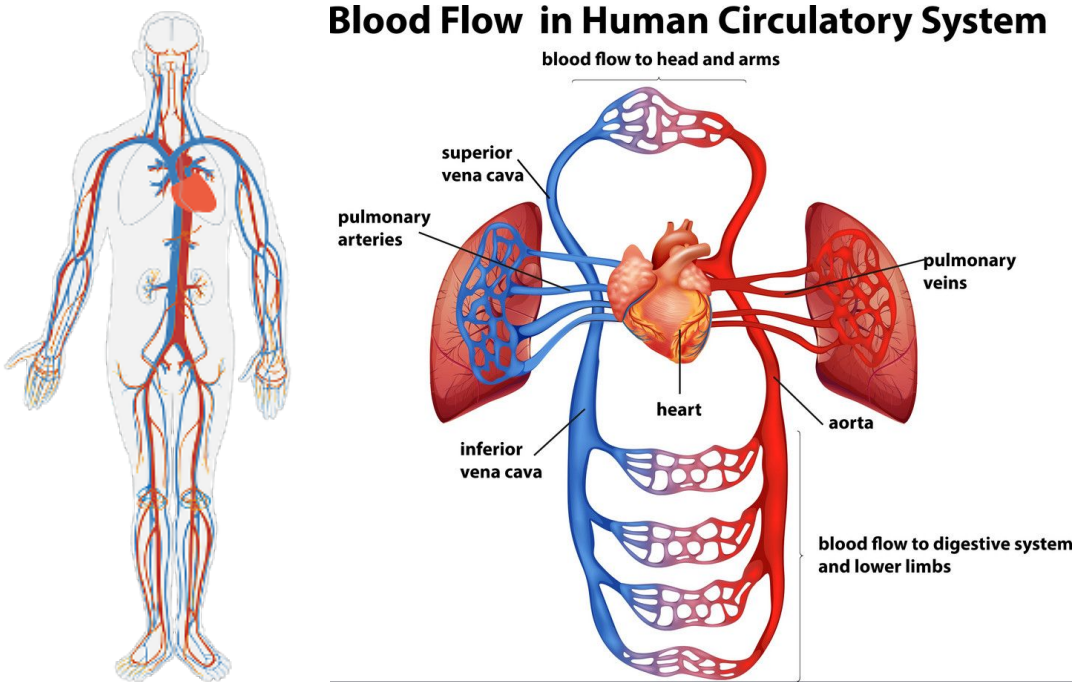


Figure 1a: Circulatory System. Pacific Medical Training.
Figure 1b: Blood Flow in Human Circulatory System. VectorStock.

So how does the blood in our body move? Through blood vessels! There are three main types of blood vessels: **arteries, veins, and capillaries**. The arteries carry blood away from the heart to the body while the veins from the body back to the heart. Arteries (illustrated in red in the diagrams above) carry oxygenated blood while veins (blue in the diagrams above) carry deoxygenated blood. We'll learn about these in greater detail in a later lesson, but for now, let's just focus on the arteries.

The heart is a muscle and responsible for pushing blood to the rest of the body through arteries. (Fun Fact: The heart is the strongest muscle in the body!) As the blood rushes through these arteries, the arteries expand and contract. The expansion and contraction of our arteries correlates with our **heartbeat**.

Materials

- Either toothpick or straw (1 per student)
- Modeling Clay (1 dime-sized ball per student)
- Bulb Syringe (1 per site)
- Large container of water (1 per site)
- Oblong Balloon (2 per site)

Procedure

1. **Part 1: Measuring Our Heartbeat**
    a. Before making the pulse counter, ask students to feel their heartbeat. This can be done by putting two fingers on one's wrist or neck.
    b. Now on to making the pulse counter: Give each student a toothpick/straw and a small ball of clay (dime sized). Have them stick the toothpick/straw into the lump of clay.

i. Note: if your site is running behind, you can skip making the pulse counter.

c. Have students rest the "counter" either on the inside of their wrist just below the base of the thumb or on their neck.
   i. The neck gives better results but requires kids to lay down, which may be harder to accomplish with younger students.
d. Ask the students observe the toothpick/straw as it moves. If you want, you can have them count how many times it moves in a minute to determine their pulse/heartbeat.
e. You can then have students run in place or do jumping jackets for a minute. Have them remeasure their heartbeat, do they notice any changes?
f. Follow up by asking them if any of them know the science behind a heartbeat. This will transition to Part 2 of this module, where we demonstrate vessel expansion/contraction.

Figure 2: Example of a Pulse Counter.

2. **Part 2: Vessel Expansion/Contraction DEMO**
   a. Fill up the container with water beforehand.
   b. Explain that a heartbeat basically correlates with expansion and contraction of arteries.
   c. We can now visually observe the contraction and expansion of blood vessels using a quick demo. The balloon represents a vessel (artery), the water represents blood, and the bulb syringe represents the heart.
   d. Fill the bulb syringe with water.
   e. Wrap the balloon around the bulb syringe, making sure there is no space for air to leave.
   f. Using the bulb syringe, fill up the balloon with water.
      i. **The difference between filled and unfilled balloon is very subtle, but incredibly important to show to students!**
      ii. **Please squeeze water in slowly.** If you squeeze too much water too quickly into the balloon, it makes an obnoxious farting noise due to pressure buildup. Would not recommend, your kids might go crazy if they hear it.

g. Once you get the hang of squeezing the water in and out slowly, you can do it lightly but quickly to show a heartbeat.

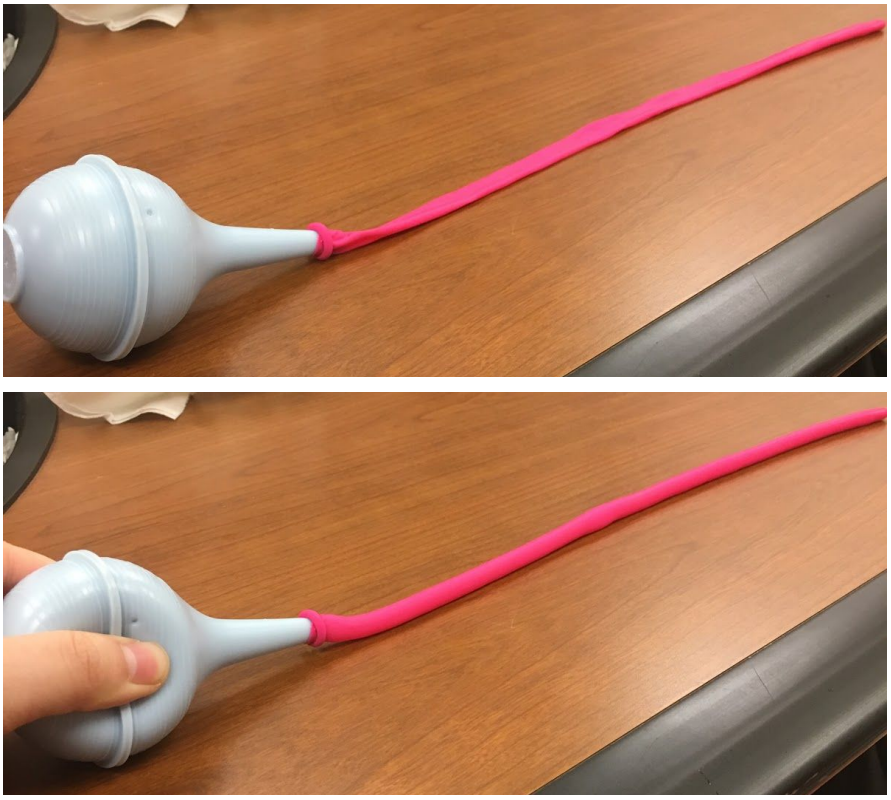


Figure 3: Vessel Expansion/Contraction Demo. top = before, bottom = after. When you squeeze water into the balloon, it expands. The difference is very subtle, but important to show to students!

Additional Notes for Mentors

If your site gets off to a slow start and spends more than the allotted time for the introduction/name game, this module may be easily adapted to accommodate. You can skip parts of or the entirety of the module, so you can have at least 20 minutes for the heart valve challenge.

Module 2: Engineering Challenge - Have a Heart (Valve)

Adapted from Lindsey Zhang, Fall 2016.

Introduction

In this activity, students will learn more about the cardiovascular system and practice the engineering design process as they build a heart valve replacement! They will be introduced to the field of biomedical engineering, one of the many fields of engineering we will explore during this semester in BEAM.

Teaching Goals

1. **Cardiovascular System:** responsible for the movement of blood throughout the body (consists of the heart and blood vessels).
2. Heart valves regulate the flow of blood by allowing it to freely flow in only one direction.
3. **Biomedical Engineering:** The integration of engineering principles in biology and medicine.

4. **Engineering Design Process:** The process of trial and error and repeatedly testing and improving upon models.

Background for Mentors

In the previous module, students were introduced to the concept of blood vessels. But how do we regulate blood flow within these arteries in the heart? Heart valves! **Heart valves** are one-way valves that allow blood to flow through it in one direction and are opened and closed using difference in pressures. An analogy for a heart valve is a doorway: you can open it one way but not the other. Blood is pumped from high pressure areas into lower pressure areas. This pressure difference is created by the muscles of the heart. Each mammal has four heart valves, as shown in the diagram below. The four heart valves are the mitral valve, tricuspid valve, aortic valve, and pulmonary valve.

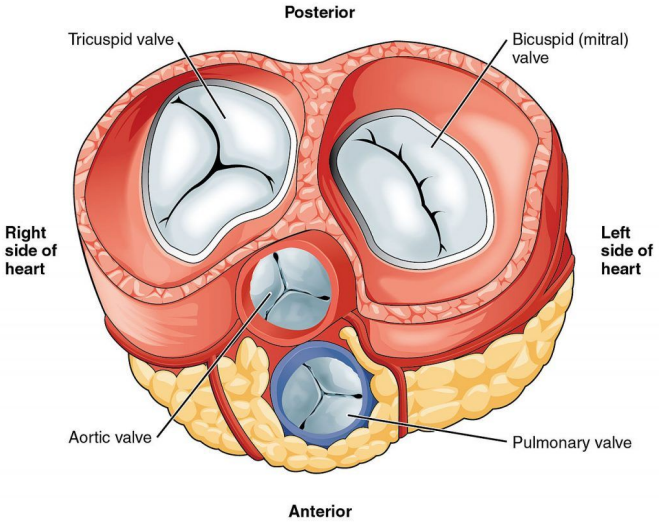


Figure 4: Heart Valve. OpenStax College.

Heart valves are critical to heart and human function. However, there are several heart valve diseases that impede the heart's ability to function efficiently. These diseases include:

- **Valve Prolapse:** Leaflets of valve become floppy or stretched out, allowing blood to flow in the wrong direction.
- **Valve Stenosis:** Calcium build up in the valve leaflets, causing them to stiffen and fail to open completely.
- **Valvulitis:** Inflammation of a valve, which leads to valve stenosis.

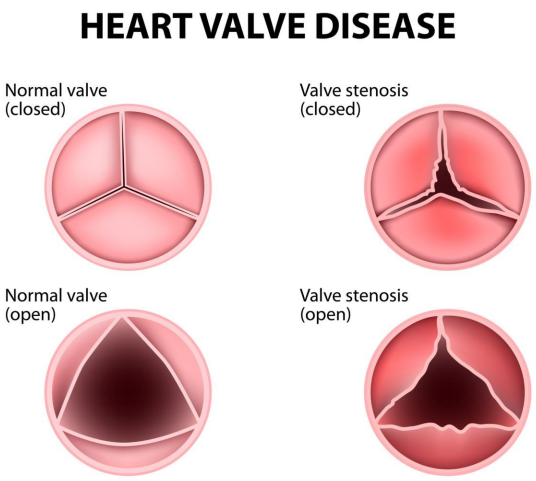


Figure 5: Heart Valve Disease. Tiny Scar Valve Surgery.

Heart valve replacement surgery is a viable option for heart valve disease. Mechanical heart valves last much longer than biological valves due to the durable materials used. However, the patient would most likely require blood thinning medication to keep clots from forming and cause a malfunction of the mechanical heart valve. Tissue valves are created from animal valves or animal tissue. These valves can last 10-20 years and usually don't require blood thinning medication.

In this module, you should introduce **biomedical engineering** and its applications:
First, explain to the students what **engineering** is**.** During this semester, we'll repeatedly explore what engineering is, so establishing a solid understanding of the concept during the first lesson is incredibly important. Ask students, how can engineering connect to medicine? For instance, do they know anyone with an artificial part of their body? **Biomedical engineering** is the application of engineering principles to medical/biological challenges (refer to the Careers and Applications section of this draft for a more detailed explanation of biomedical engineering). Some products of biomedical engineering include stethoscopes, MRIs, and prosthetics.

Engineers constantly practice the engineering design process when they design new inventions. The **engineering design process** involves prototyping and trial and error. Discuss the importance of the engineering design process (specifically trial and error and prototyping) with students. If students are still confused, you can split up the process into 5 main steps: Ask, Imagine, Plan, Create, Improve. This can be visualized in the figure below. It is fine if they do not immediately grasp this concept, as they will practice it throughout the entire semester!

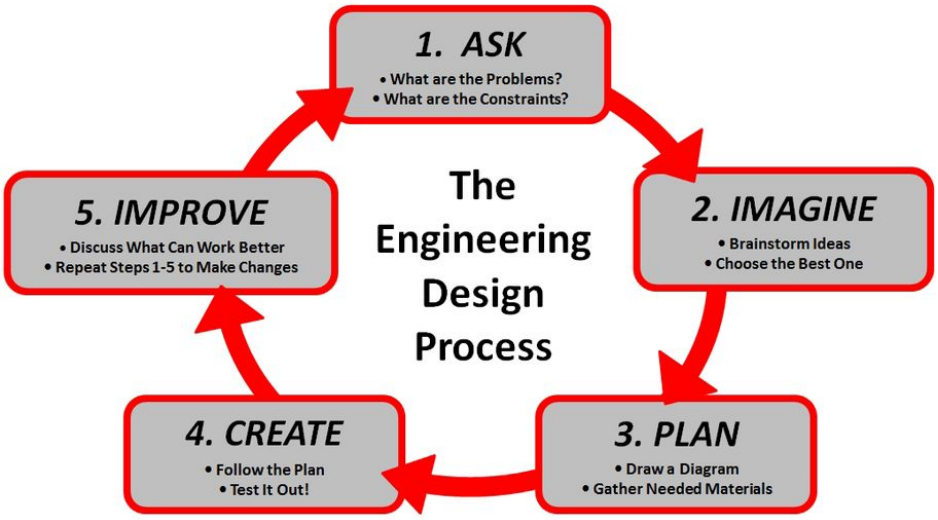


Figure 6: Engineering Design Process. Mr. Fleming Science.

Ultimately, the takeaway from this is that **there are many different ways you can design something**! In engineering, there is no set one answer, but rather a variety of different options and ideas engineers may explore. There is no end to your student's creativity, harness it to its true potential!

Materials

(For groups of 3-4 students.)

- Modeling Clay (1 tub per site)
- Plastic box with middle valve setup (1 per group)
    - Middle Valve setup can be customized for difficulty using clay or cardboard.
- Marbles (30 per site, allow marbles to be split among groups for testing while building)
- Construction paper (3 sheets per group)
- Popsicle sticks (5 per group)
- Toothpicks (5 per group)
- Scrap pieces of cardboard (2 pieces per group)
- Scissors (1 pair per group)
- Tape (2-3 rolls per site)
- String (1-2 rolls per site)

Procedure

1. Split students up into small groups of 3-4.
2. Introduce the engineering challenge. The marbles represent blood and the box represents the blood vessel. Students must design a heart valve that allows blood to only move in one direction. **(The marbles should flow one way but not the other!)**
    a. <u>You can customize the middle valve setup for difficulty based on the age/skill level of your students using modeling clay!</u> There can be a few different passages the valves must be made to fit in. For example, when assembling the initial valve setup (prior to starting the activity), you could place clay on the

bottom such that marbles have to go over it. It could be as simple as an obstacle marbles have to go over, something the have to go over, a hole they must go through, etc. Pictures of possible challenges are included below!

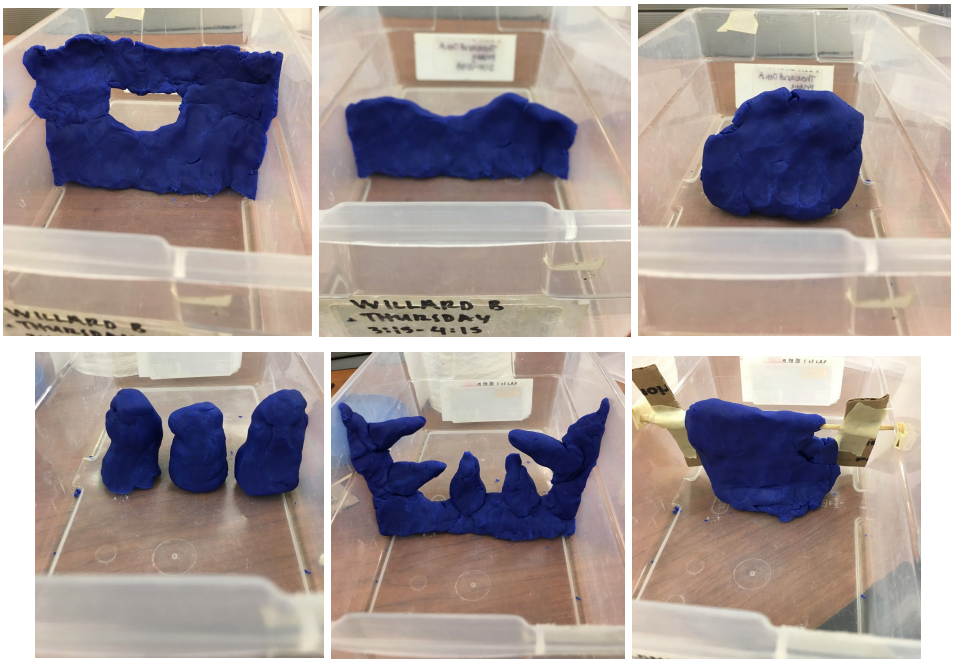


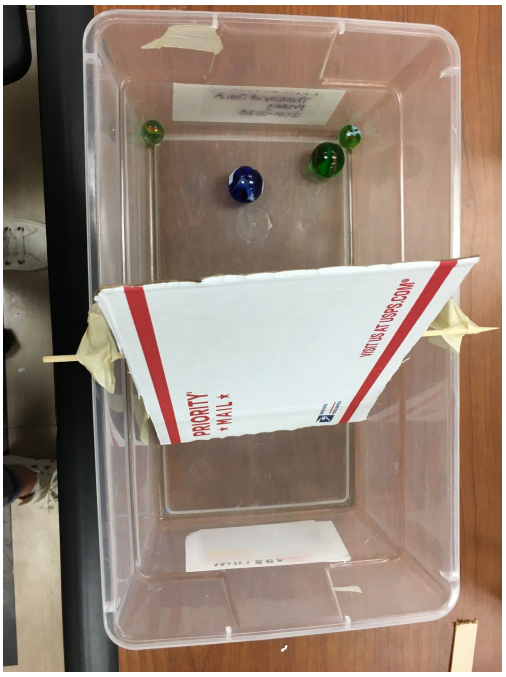
Figure 7a-f: Examples of different challenges made of modeling clay that students can design a heart valve around. Figure 6f includes both the challenge and a possible solution engineered using cardboard and wooden sticks.

3. Have each groups brainstorm some ideas for heart valve design.
4. Once each group has come up with an idea, distribute materials.
    a. If your site is more advanced, you can give incentives for using less materials. Engineers aim to make practical designs that use the least amount of resources.
5. Groups build their heart valve and test this in their own test artery (site box with marbles).
6. To motivate students, you can can turn this into a competition! One by one, groups test their artificial valves in front of everyone else, 30 marbles are placed on the starting side of the heart and the box is tilted to mimic pumping blood so that they slide through the valve area. Then, the box is tilted backwards to see if any marbles flow backwards through the valve. The winning group has the most marbles on the correct side of the valve with a relatively low amount of materials (allow mentors to decide on this).

Additional Notes for Mentors

MAKE SURE TO ESTABLISH CONTROL OF THE PLAY-DOH! Kids really love Play-Doh and will try to keep it, but they can't because we need these for later sites.

Here are some examples of possible designs that you can refer to in case a student is stuck. Note that some designs are better than others. You are of course not limited to these following designs, they are only a couple of the ones we came up with while lesson testing!



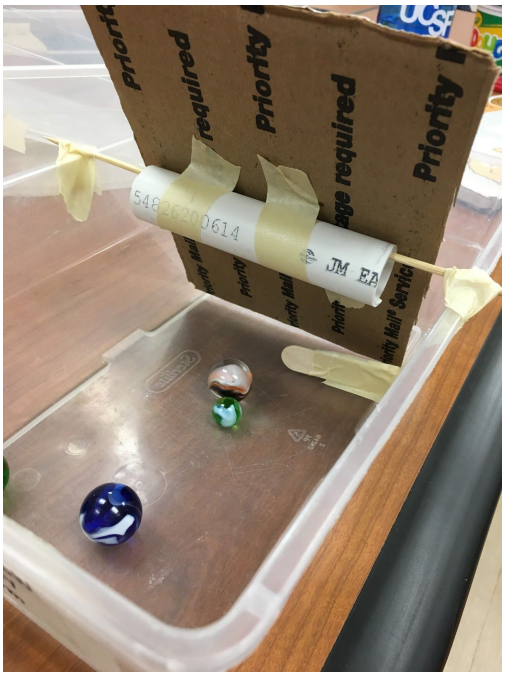


Figure 8a and 8b: Example 1: The piece of cardboard rotates around the axis. A popsicle stick stops the cardboard from rotating in the opposite direction.

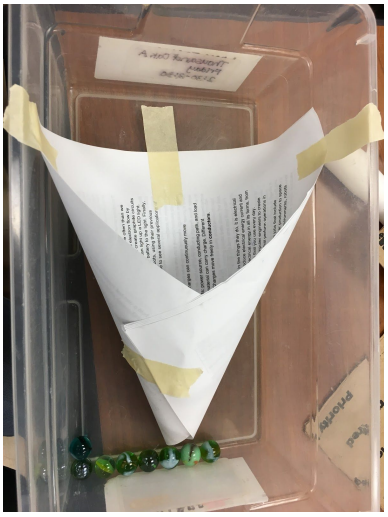



Figure 9 (left): Example 2: Using a piece of paper rolled up as a cone with a small opening.
Figure 10 (right): Example 3: Using 2 pieces of cardboard that almost connect diagonally.

Conclusion

Biomedical engineering is an incredibly diverse field, and there are huge implications of creating devices that could potentially repair function in the human body. As we saw in this lesson, even a design built with materials you can find at home can mimic the function of a heart valve. With growing technologies and more resources, biomedical engineering is on the forefront of innovation in medicine.

At site, ask students what they have learned about biomedical engineering is and ask for some examples of biomedical devices. What must biomedical engineers consider when they design these devices? What is the engineering design process like? How did the students practice the engineering design process today? Ultimately, what does the work of biomedical

engineers accomplish?

References

- Cardiovascular Biomedical Engineering (Week 2), Lindsey Zhang, Berkeley Engineers and Mentors. http://beam.berkeley.edu/lessons_archive/heart.pdf
- Prostheses, Stephanie Huang and Soumita Bose, Berkeley Engineers and Mentors. http://beam.berkeley.edu/lessons_archive/a_handful_of_fun.pdf
- Marshmallow Catapults, Matthew Sit, Berkeley Engineers and Mentors. https://drive.google.com/file/d/0B9MnMPcXYKHWWTRBTHJ0TENqVmc/view?usp=sharing
- My Body: Circulatory System, Henry County Public Schools Curriculum. http://www.henry.k12.ga.us/cur/mybody/circ_lessons.htm
- The Ins and Outs of the Cardiovascular System, Ana Solbes, Alex Renn, Kelly Chang, Berkeley Engineers and Mentors. http://beam.berkeley.edu/lessons_archive/featured_final_lessons/the_cardiovascular_system.pdf

Summary Materials Table

Material	**Amount per Group**	**Expected $$**	**Vendor (or online link)**
Either toothpick or straw	1 per student		Inventory
Modeling Clay	1 tub per site		Inventory (only 2 tubs) Amazon link
Bulb Syringe	1 per site	3 for $4.99	Amazon
Ooblong Balloon	2 per site		Inventory
Plastic Box	1 per group of 3-4 students		Inventory
Marbles	30 per site		Inventory
Construction Paper	3 sheets per group of 3-4 students		Inventory
Popsicle Sticks	5 per group of 3-4 students		Inventory
Toothpicks	5 per group of 3-4 students		Inventory
Tape	2-3 rolls per site		Inventory
String	1-2 rolls per site		Inventory

Scrap Pieces of Cardboard	2 pieces per group of 3-4 students		Inventory
Scissors	1 pair per group of 3-4 students		Inventory