Students design a pumping device that will effectively pump fluid through a given cardiovascular system.

**Grades 4-8**

**Estimated time: 60 minutes**

**Student Outcomes:**

1. Students will be able to design and build a device that uses pressure to move fluid.
2. Students will be able to discuss the connection between their device and the circulatory system, including the effects of too much or too little pressure.
3. Students will be able to utilize the three step design process to meet an engineering challenge.

**Next Generation Science Standards**

**Grade 4-5:** Engineering Design 3-5-ETS1-1, 3-5-ETS1-2, 3-5-ETS1-3  
**Grade 4:** Life Science 4-LS1-1  
**Grade 6-8:** Engineering Design MS-ETS1-1, MS-ETS1-2, MS-ETS1-3, MS-ETS1-4; Life Science MS-LS1-3

**Common Core Language Arts-Speaking and Listening**

**Grade 4:** SL.4.1b-d, SL.4.4a  
**Grade 5:** SL.5.1b-d, SL.5.4  
**Grade 6:** SL.6.1b-d  
**Grade 7:** SL.7.1b-d  
**Grade 8:** SL.8.1b-d

**Vocabulary:**

*Familiarity with these terms and concepts will enhance students’ experience in the activity*

- **Aorta:** Large elastic artery that carries blood away from the left ventricle and into the systemic circuit.
- **Artery:** Blood vessels that carry blood away from the heart.
- **Atrium:** Chamber of the heart from which blood is passed to the ventricles. Right atrium receives deoxygenated blood from the veins; the left atrium receives oxygenated blood from the pulmonary vein.
- **Blood Vessel:** A tubular structure carrying blood through the tissues and organs; a vein, artery, or capillary.
- **Circulatory System:** The system that circulates blood and lymph through the body, consisting of the heart, blood vessels, blood, lymph, and the lymphatic vessels and glands.
- **Pulmonary Circulation:** The portion of the cardiovascular system which carries deoxygenated blood away from the heart, to the lungs, and returns oxygenated blood back to the heart.
- **Red Blood Cells:** The individual units of blood that are responsible for the transport of oxygen and carbon dioxide throughout the system.
- **Sphygmomanometer:** Device used for measuring blood pressure.
- **Systemic Circulation:** The part of the cardiovascular system which carries oxygenated blood away from the heart to the body, and returns deoxygenated blood back to the heart.
- **Valve:** A structure within the circulatory system that temporarily closes passages to permit the movement of fluid in only one direction.
- **Vein:** Any of the tubes forming part of the blood circulation system of the body, carrying (in most cases) oxygen-depleted blood toward the heart.
- **Ventricle:** One of the large, muscular pumping chambers of the heart that discharge blood into the pulmonary or systemic circuit.
Resources:

- **NeoK12**: A website that provides educational videos, lessons, and games for K-12. Their website includes a section specifically on the circulatory system and provides a copious amount of diagrams, images, and videos on every part of the circulatory system.  [www.neok12.com/Circulatory-System.htm](http://www.neok12.com/Circulatory-System.htm)

- **E-Learning for Kids**: A website that provides an interactive platform for discovering more information about the heart and circulation.  [www.e-learningforkids.org/health/lesson/heart-and-circulation](http://www.e-learningforkids.org/health/lesson/heart-and-circulation)

- **KidsHealth**: A website maintained by Nemours that provides virtual tours of the human body. It also has separate sections for quizzes, articles, movies, activities, and word finds.  [http://kidshealth.org/kid/htbw/htbw_main_page.html](http://kidshealth.org/kid/htbw/htbw_main_page.html)

- **Example Student Projects**: Youtube has a wealth of examples of student projects that are similar to this activity. To get an idea of the possibilities visit a video posted by Iridescent, a Los Angeles based non-profit organization that brings cutting-edge science to low-income communities.  [www.youtube.com/watch?v=KYQ2vHNzXWY](http://www.youtube.com/watch?v=KYQ2vHNzXWY)

Design Challenge Process:

_The Design Challenge Process is designed so students reinforce their science, mathematics, social studies, and language arts content knowledge, through an open-ended process that results in an original, team-driven solution. Students are expected to take responsibility for assessing their own progress and incorporate peer feedback as they conceptualize and redesign their projects._

_The process consists of three interconnected steps:_

**Conceptualize**
- Identify problem, materials, and constraints
- Brainstorm ideas and possible solutions

**Construct and Test**
- Select a solution
- Design and construct
- Prototype
- Redesign or modify
- Retest

**Acquire Knowledge**
- Research
- Share solutions
- Reflect and discuss

_Through the try, fail, learn approach, students develop the skills and habits of mind of Silicon Valley innovators: creativity, problem solving, design, collaboration, leadership, risk-taking, perseverance, and learning from failure._

Materials:

**Class Materials to Share:**
- Plastic tubing (various diameters)
- Straws (different sizes)
- Balloons
- Rubber Gloves
- Empty Plastic Bottles (hole in lids)
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• Rubber Bulbs
• Plastic Bags
• Tape (masking, duct, strapping)
• Rubber Bands
• Parafilm

• Paper Clips
• Binder Clips
• Scissors
• Puncturing Device (ex. Awl, craft knife, etc.)

Testing Materials:
• Outline of human body
• Big towel or mop
• Colored fluid

Special Considerations:
• DO NOT work in a carpeted or other areas where floors may easily be stained or absorb liquids!
• DO work in an area with easy access to a sink.
• DO give safety instructions and demonstrate proper use of any sharp tools that students may utilize to punch holes in materials.

Lesson Plan:

Introduction (2 minutes)

Hold your hand and make a fist; now place that fist in the center of your chest. Your heart (as a kid) is the size of your fist, and is almost in the center of your chest, in between your two lungs. If you listen closely you can hear your heart make two sounds – “lub-DUB” – as the valves of your heart open and close to let blood in and out. Everyday your heart beats 100,000 times in order to pump the 5.6 liters of blood through your entire body three times every minute! As the engine of this system, your heart is responsible for moving the oxygenated blood to the different parts of your body, and transporting the carbon dioxide out. Today you’re going to recreate this vital life system.

Design Challenge (33 minutes)

1. Introduce the Challenge: Build a circulatory system and bypass pump in order to send blood through the heart, to the lungs and one other part of the body, and then back to the heart of the paper person.
2. Introduce the Constraints:
   • Only the provided materials may be used.
   • All leaking should be minimized.
   • The circulatory system must be attached to the paper person.
   • All parts of your circulatory system must be clearly labeled.
   • The fluid should flow through the system with one or more pumps of the bypass pump.
   • Your system must have a drainage valve and a way to catch the drained fluid.
   • All members or your engineering team must be included.
3. Build: Give students about 30 minutes to build and test. The instructor should ask open-ended questions to help guide students through the design process, but should also allow students space to tinker. Optional: Provide teams with a reference sheet that includes a diagram of the circulatory system. A possible handout is included at the end of the Lesson Plan.
Demonstration and Reflection (25 minutes)

1. **Demonstration:** Have students demonstrate their devices one team at a time. Engineering teams should present from their table and describe how their system works. The instructor should ask questions to help guide teams toward the teaching points.
   - **Teaching Points:**
     - The heart generates blood pressure through each contraction (or beat). Too much pressure can cause problems on the rest of the system. Pressure increases as the tube (or blood vessel) becomes constricted.
     - The heart must function properly to pump blood completely through the circulatory system.
   - **Questions:**
     - What was the most challenging part in creating a pumping device to pump the fluid through the circulatory system? How did you resolve this/these problems?
     - How is your device like a heart? How is it different?
     - Can gravity help the process?
     - Did you experience any leaking? Why do you think it leaked? What can/did you do to stop the leaking?
     - What happened if your pumping device couldn't work as hard as it does now?
     - Why do you think it is important to keep the heart healthy and strong?
     - What changes would you make to your bypass pump if you added additional arteries and veins to your system?
     - If you were given more time what would you add, subtract, or change about your system?

2. **Discussion:** Discuss how scientists and engineers go through this Design Challenge process on a daily basis; learning from their mistakes, reflecting and improving upon what they have designed.

Extensions

1. Have different engineering teams construct circulatory systems for fish, most reptiles, and crocodilians/birds/mammals. Then have students compare and contrast the systems.
2. Repeat the design challenge but have students modify their model for additional parts of the systemic system. Encourage students to think about what changes need to be made to their pumping device and why.
Pump It Up!
Design Challenge Learning

PROJECT OVERVIEW

CHALLENGE:
Build a circulatory system and bypass pump in order to send blood through the heart, to the lungs and one other part of the body, and then back to the heart of the paper person.

CONSTRAINTS:
- Only the provided materials may be used.
- All leaking should be minimized.
- The circulatory system must be attached to the paper person.
- All parts of your circulatory system must be clearly labeled.
- The fluid should flow through the system with one or more pumps of the bypass pump.
- Your system must have a drainage valve and a way to catch the drained fluid.
- All members of your engineering team must be included.

THINGS TO CONSIDER:
- What problem are you having? Why are you having that problem? How can you fix that problem?
- Did you experience any leaking? Why do you think it leaked? What can/did you do to stop the leaking?
- How much pressure do you have to apply to your pump in order to get the fluid to flow? What would you do to minimize the pressure needed? What would you do to maximize the pressure needed?
- What path does the “blood” take through your circulatory system? Is this an accurate representation of the circulatory system?
- What would you add, subtract, or change about your system if you were given additional time?
- How would you need to change your pumping device if you added additional veins and arteries?

DIAGRAM: