Designing Artificial Heart Valves 104

3
40- to 50-minute sessions

PROJECT

ACTIVITY OVERVIEW

Students are challenged to design a prototype for a valve that could form the basis of a replacement heart valve. After some time spent trying out various ideas, students select a prototype to refine in a more systematic way. Finally, students present their prototypes and discuss which ones might warrant further development.

KEY CONCEPTS AND PROCESS SKILLS

(with correlation to NSE 5–8 Content Standards)

1. Current scientific knowledge about the heart guides investigations in artificial-heart technology. (INQUIRY: 2)
2. Disease is a breakdown in structures or functions of an organism. (LIFE SCIENCE: 1)
3. Students design, test, and redesign a solution or product. (SCIENCE AND TECHNOLOGY: 1)
4. Students communicate the process of technological design. (SCIENCE AND TECHNOLOGY: 1)
5. Students find that various factors can impose constraints on technological design. (SCIENCE AND TECHNOLOGY: 2)
6. Scientists formulate and test their explanations of nature using observations, experiments, and models (prototypes). (HISTORY AND NATURE OF SCIENCE: 2)

KEY VOCABULARY

aorta
control
prototype
valve
variable

MATERIALS AND ADVANCE PREPARATION

For the teacher

1 Transparency 104.1, "Blood Flow Through the Heart" (optional)

1 Transparency 104.2, "Replacing A Weakened Aorta"

* 1 overhead projector

* 1 prototype valve made with plastic glove material (see Figure 1 below)

* 1 prototype made with clay and a marble (see Figure 2 below)

1 transparency of Literacy Student Sheet 2, "Oral Presentations"

1 Scoring Guide: GROUP INTERACTION (GI)

1 Scoring Guide: DESIGNING INVESTIGATIONS (DI)

For the class

* 8 prototypes with triangular plastic glove (optional)

* colored pencils

* sponges

* mops

* paper towels

For each group of four students

medium non-latex glove finger(s)

medium plastic glove finger(s)

latex rubber dishwashing glove finger(s)

smaller diameter (aproximately 1.6 cm) transparent tube(s) (optional)

larger diameter (aproximately 2cm) transparent tube(s) (optional)

2 30-mL graduated cups

2 marbles

2 small sandwich bags

* 1 sponge or paper towels

1/4 stick of modeling clay

* 1 stopwatch or access to a clock with a second hand

* 1 large container (for holding water)

* additional materials supplied by students (optional)

For each pair of students

1 roll of transparent tape

1 plastic cup

* 1 pair of scissors

For each student

1 Student Sheet 104.1, "The Design Process"
1 Student Sheet 104.2, "Refining Valve Prototypes"
1 Science Skills Student Sheet 5, "Elements of Experimental Design" (optional)
1 Group Interaction Student Sheet 1, "Evaluating Group Interaction" (optional)
1 Group Interaction Student Sheet 2, "Developing Communication Skills" (optional)
1 Literacy Student Sheet 4c, "Writing Frame—DI" (optional)
1 Scoring Guide: GROUP INTERACTION (GI) (optional)
1 Scoring Guide: DESIGNING INVESTIGATIONS (DI) (optional)

**Not supplied in kit*

Masters for Scoring Guides are in Teacher Resources III: Assessment. Masters for Group Interaction Student Sheets, Science Skills Student Sheets, and Literacy Student Sheets are in Teacher Resources II: Diverse Learners.

The smaller diameter transparent tubes may also be used in Activity 108, "Getting a Hold on Design." Depending on your class size and the number of class periods you are conducting this unit, you may need to take this in to account when planning the distribution of these materials.

A limited number of large diameter tubes are included in the kit. If you anticipate needing more of these tubes, consider cutting these tubes in half.

Make prototypes based on Figures 1 and 2 below. You may want to make one for each group to use as they begin, or you may want to make one to show the entire class. Cut some extra glove fingers for replacements in case students tear their first one.

Prepare a safe storage area for the prototypes that students make. Also provide a way for students to label their prototypes. Decide whether you will allow students to use materials they supply from home; if so, provide space for them to store their materials.

To control potential spills, fill one plastic bin 1/2 full of water for each group of four students in advance. Also have sponges, mops, and paper towels available to clean up any spills.

Find out **in advance** if any of your students are allergic to latex. If so, do not provide the latex dishwashing gloves to any students in your classes.

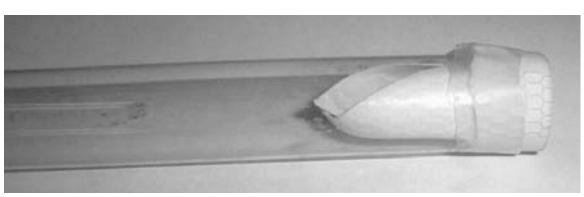


Figure 1: *This valve was constructed by cutting the finger off a rubber glove, cutting a hole in the fingertip, and taping the glove finger to the end of a plastic tube.*

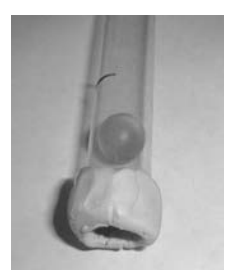


Figure 2: *This valve was created by molding clay to the end of a plastic tube and placing a marble inside the tube.*

TEACHING SUMMARY

Getting Started

1. Students review how the human heart works and how the Marfan syndrome can affect it.
2. Introduce the design project and explain the design requirements.

Doing the Activity

3. (GI ASSESSMENT) Students make, test, and draw preliminary prototypes.
4. (LITERACY, DI ASSESSMENT) Students select a design to refine using a systematic method.

Follow-Up

5. (LITERACY) Students use an interactive exhibit format to share their best designs with the class.
6. The class discusses the designs that would be most likely to work and discusses the relationship between science and engineering design.

Extension

Students research accidental discoveries.

BACKGROUND INFORMATION

The Marfan Syndrome and the Heart

The Marfan syndrome affects connective tissue throughout the human body, including the tissue that normally makes blood vessels strong and elastic. The aorta, the major artery departing from the heart, is under more stress from blood pressure than any other vessel. In Marfan patients, an aneurysm (tear) in the aorta can result in the aorta swelling and stretching. If detected in its early stages, the affected section of the aorta can be replaced by a synthetic tube; in many cases, the aortic valve must be replaced as well. An artificial valve is designed to allow blood to flow in only one direction: from the heart to the aorta, but not from the aorta back to the heart.

TEACHING SUGGESTIONS

GETTING STARTED

1. Students review how the human heart works and how the Marfan syndrome can affect it.

Teacher's Note: This activity helps students to connect the process of design to the science content in Unit D, "Genetics," in *Issues and Life Science*. If your students have not done this unit, or if you have limited time for Unit G, "Bioengineering," you may wish to skip this activity.

If your students have done Unit B, "Body Works," they can review Activity 26, "Heart Sounds," to reorient themselves to how the heart works and what happens when valves don't work properly. They may remember the swishing sounds of blood leaking backward. If you would like students to view an animation of a healthy heart pumping, go to the Activity 26, "Heart Sounds," page of *Issues and Life Science* on the SEPUP website. You may wish to show Transparency 104.1, "Blood Flow Through the Heart," to clarify the role of the aorta.

Ask students, ***How might someone feel if his or her heart valves were not closing properly?*** Responses should include that the person may feel tired because the heart cannot pump blood around the body as efficiently. Because the heart will have to work harder to make up for this lack of efficiency, the condition (faulty heart valves) will tend to worsen.

Display Transparency 104.2, "Replacing a Weakened Aorta." When the junction of the aorta with the left ventricle enlarges to more than 2 inches in diameter, the aortic valves become incompetent to prevent backflow. This stretching can put the patient in imminent danger of aortic rupture (aneurysm). The common treatment is to replace the aorta, and often the aortic valve as well, with a synthetic structure.

2. Introduce the design project and explain the design requirements.

Tell students they are going to design initial prototypes of a heart valve. Tell them that some engineers specialize in developing biomedical technology, such as heart valves. Review the Scenario in the Student Book. To introduce the project, show students the simple prototypes you made with a glove finger and clay and a marble, or demonstrate how to make them. Students should construct a valve at the end of one plastic tube. The plastic tubes provided in the equipment kit are of two different diameters. It may be easier to test the valve by inserting one end of the smaller tube into one end of the larger tube and sealing the joint with tape or latex glove material, so that during the testing process it can be clearly seen that water collects on one side, but not the other, of a successful prototype.

DOING THE ACTIVITY

3. (GI ASSESSMENT) Students make, test, and draw preliminary prototypes.

Students will be working together on this as well as most of the remaining activities in this unit. Ideas on how to facilitate group work and foster oral language skills are in the Facilitating Group Interaction section of Teacher Resources II: Diverse Learners. You may wish to use Group Interaction Student Sheets 1 and 2 to help groups of students work more effectively with each other. Note that you may use the GROUP INTERACTION (GI) Scoring Guide to assess students on their ability to work in groups. Information on this variable is found in Teacher Resources III: Assessment.

Distribute Student Sheet 104.1, "The Design Process," and encourage students to explore as they develop their first set of two prototypes. It is important for students to have an opportunity to use the materials creatively when they begin so they can discover their properties and possibilities. Encourage them to use diagrams and words to record in their science notebooks the different designs they try, and then to record their best initial prototype on

Student Sheet 104.1. If necessary, demonstrate the testing procedure: emphasize that the goal is for water to flow freely in one direction flow very slowly in the other direction (see the Scenario on page G-17 of the Student Book).

When students have had a chance to try several approaches, stop the class and hold a discussion. Have representatives from each group share their ideas and designs with the class. Encourage collaboration at this stage, rather than competition, as it will foster a focus on learning rather than winning. Ask students to think about how they could refine their designs.

You may wish to suggest that engineers sometimes isolate and vary just one variable at a time. If the students keep all other variables the same, they will be able to draw more definitive conclusions about the effect of the one changing variable. If multiple variables are changed at once, it is often difficult to determine what effect each change had. On the other hand, in a complex design, variables may act synergistically, and it may be necessary to vary several variables at once to obtain optimum performance with an efficient use of time and materials.

4. (Literacy, DI Assessment) Students select a design to refine using a systematic method.

You may wish to use Science Skills Student Sheet 5, "Elements of Experimental Design," to assist students in designing their investigations. You may also use Literacy Student Sheet 4c, "Writing Frame—DI," with students who need additional help in structuring their plans. With the Designing Investigations (DI) Scoring Guide you may also assess the design component of students' work.

To effectively score responses with the SEPUP scoring guides, it helps to firmly establish the criteria for a Level 3 response in your mind. Below are sample criteria for the investigation.

A Level 3 response for this investigation should include:

1. a diagram of their prototype.
2. a complete procedure.
3. a description of the variable being manipulated.
4. an appropriate data table.

Pass out Student Sheet 104.2, "Refining Valve Prototypes," for students to use as they refine their prototypes, or allow students to use larger pieces of paper to illustrate their new designs. The top section of the Student Sheet encourages students to be more systematic in their investigation than they may have been so far. You may want to provide suggestions for ideas to explore, such as which type of glove or clay works best. Remind them to label clearly the differences among their prototypes. The instructions suggest that students first make two refined prototypes and test them. Then they make a second pair of refined prototypes. They may choose to continue investigating the same variable, or they may choose to investigate a different variable.

If some groups find that their prototype already meets the design requirements, suggest that they could still improve their designs. You may wish to suggest some of these goals:

- Can you get the valve to drain more quickly in one direction and to be almost completely leak-proof in the other?
- Can you make the valve work consistently every time?
- Can you make the valve more durable?
- Can you reduce the turbulence the valve produces in the flow of liquid?

These design considerations would be very important in designing an artificial valve for a human patient. If appropriate, explain to students that blood turbulence can stimulate blood clotting and is a major complication of heart surgery.

FOLLOW-UP

5. (Literacy) Students use an interactive exhibit format to share their best designs with the class.

One student in each team of two can demonstrate how their best valve design works, while the other circulates to see other groups' designs. Then, the students can switch places, so everyone gets a turn in both roles.

Display the transparency of Literacy Student Sheet 2, "Oral Presentations," and review it with your students. For additional guidelines on oral presentations, see Teacher Resources II: Diverse Learners.

6. **The class discusses the designs that would be most likely to work and discusses the relationship between science and engineering design.**

Use the Analysis Questions to guide discussion of the prototypes and the design process. Students may need you to clarify Question 1b. The idea is to encourage discussion of other attributes necessary for an actual artificial valve. Engineers making an actual heart valve would build on additional principles from the life and physical sciences. These would include an understanding of the properties and materials used to build the valve, the danger of turbulence promoting blood clotting, the need for a very low failure rate, and the danger of rejection by the recipient's immune system. Display Transparency 104.2, "Replacing a Weakened Aorta," to remind students that artifical valves must function inside an actual human body.

Review the design process used by the students. Engineers typically use a similar iterative design process, in which they make successive revisions to improve their design until the product meets or exceeds the minimum expectations. Even after a product is ready for use, engineers continue to make improvements and release new versions.

As you discuss Question 3, discuss the relationships among invention, technology, design, and engineering. The term *technology* can be used to describe any tools made to help solve problems or accomplish tasks. Engineers may develop inventions or may innovate and refine inventions. A large part of an engineer's education is devoted to learning to invent technological solutions to problems. Engineers usually have a background in one or more of the sciences, but also have training in the design process. Tell students that they will continue to compare and contrast engineering and other scientific work throughout the unit.

■ EXTENSION

Students research accidental discoveries.

Assign students to find some examples of "spin-off" inventions or other serendipitous discoveries in science and technology. Spin-off inventions are inventions that turn out to be useful and marketable for a purpose other than the original purpose. For example, the technology invented for space exploration has led to many spin-offs.

SUGGESTED ANSWERS TO QUESTIONS

1. *a. Which of the class's designs best met the design requirements?*

   Encourage all responses to be based on evidence that was collected during the activity.

   b. What other design requirements would be necessary for a valve to be used in a patient?

   In designing a valve to be used in the human body, scientists and engineers would consider issues such as the long-term reliability of the valve and whether the valve would be likely to be accepted by the immune system of the patient. For example, materials that cause allergies would be avoided.

   c. Which of the class's designs has the most promise to be developed into an artificial valve for use in patients with the Marfan syndrome? Explain your reasoning.

   Ask students to apply what they have learned from all the groups to discuss ways to improve their designs or the investigations that led to those designs to develop a real replacement valve. For example, students might think a valve based on the marble and clay valve is more reliable, but might realize that a different material than clay would be necessary to produce a long-lasting valve.

2. a. *What factors influenced your design?*

   Time, the materials available, and meeting the basic challenge are key factors that influenced the students' designs.

   b. *What do you think would influence a company designing and marketing an actual heart valve?*

   A company designing and marketing an actual heart valve would have a longer time period for development and a greater knowledge of and access to different materials. They would also consider factors such as the size of the product, the level of reliability needed, how well the product would function in the human body, possible side effects of the product, and the costs of developing and manufacturing the product. They would also consider the market for the product.

3. a. *How is the design process in this activity similar to other kinds of scientific work?*

   Engineering design practices are similar to scientific experimentation in that in both cases, systematic studies are conducted, an understanding of scientific principles leads to new ideas, and results are communicated with peers.

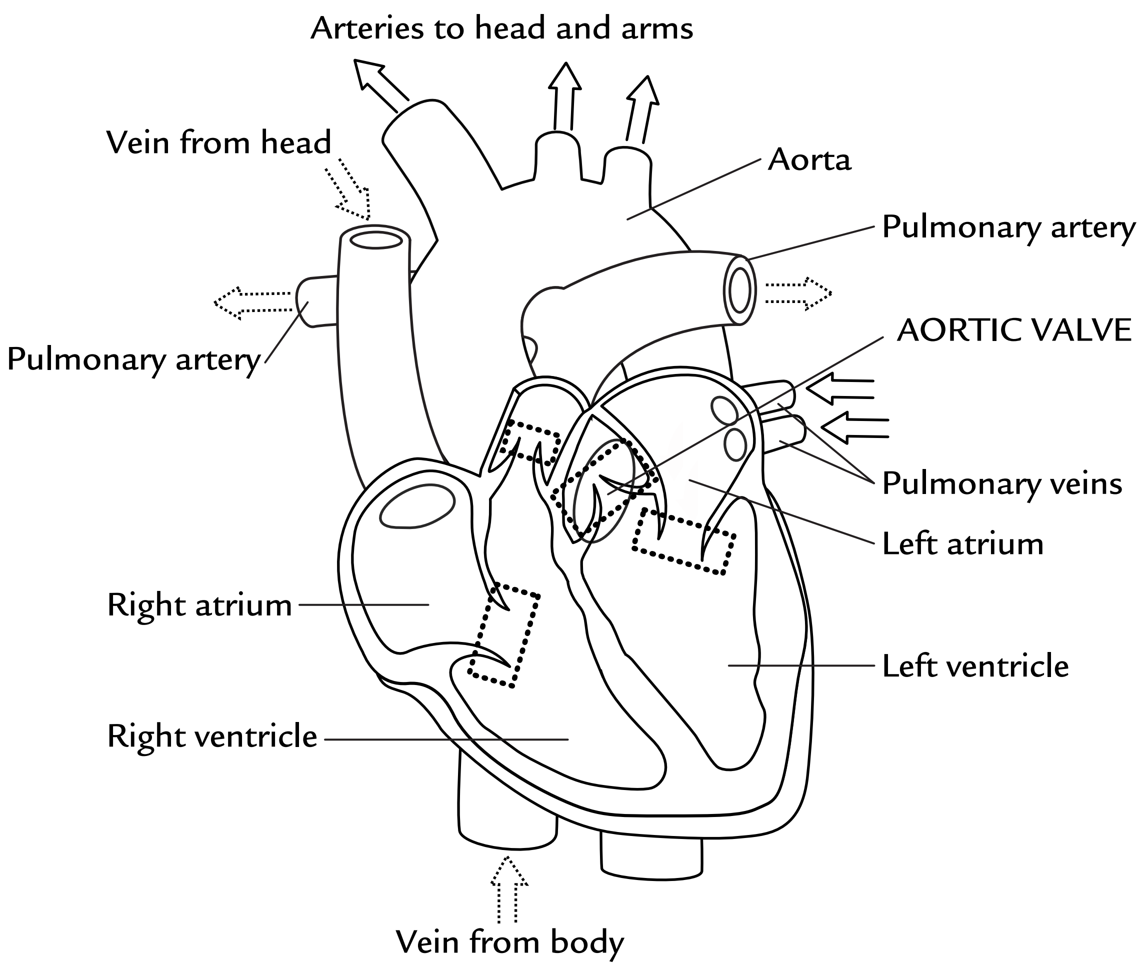
   b. *How is the design process in this activity different from other kinds of scientific work?*

   In science, the main goal is generally to understand a natural principle or phenomenon more fully; in engineering, the main goal is generally to apply a scientific principle to solve a practical problem.

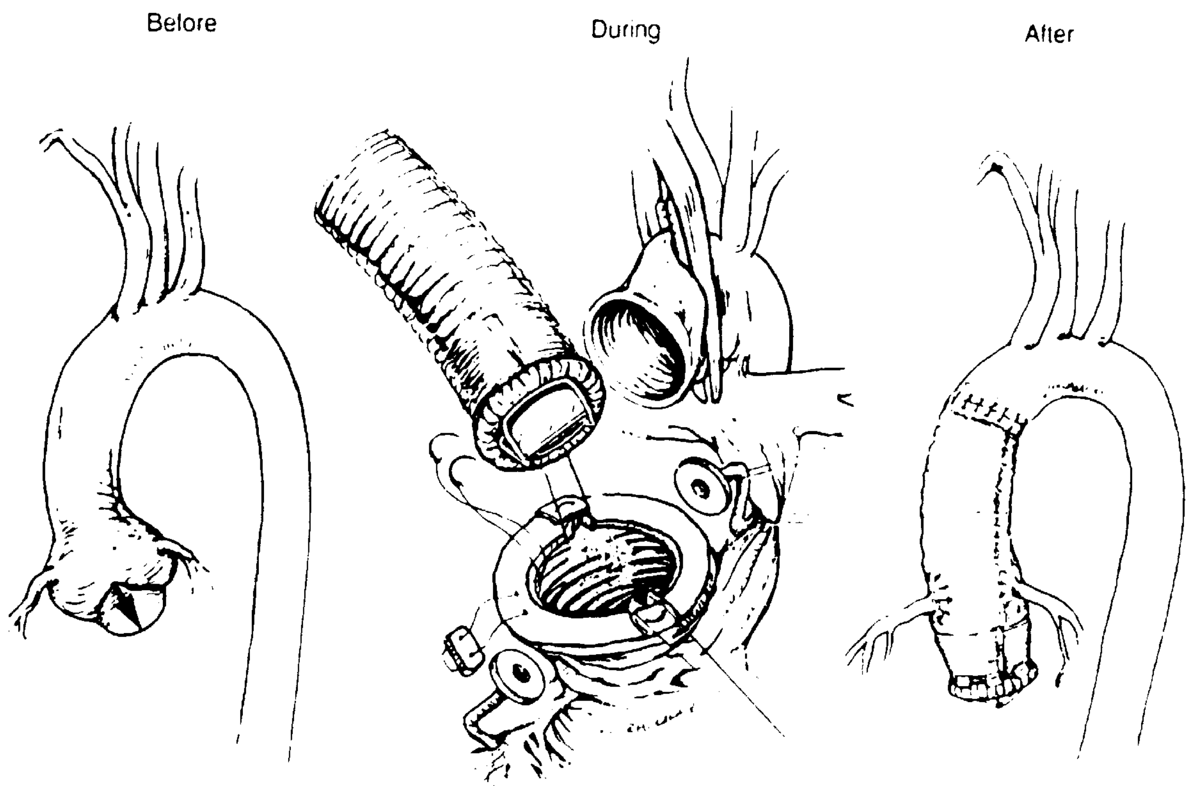
4. ***Reflection:*** *What did you learn from this activity about being an inventor?*

   Students may mention the parallels with other scientific work or comment on whether they enjoyed the design process or whether the activity seemed relevant.

Blood Flow Through the Heart



Replacing a Weakened Aorta



Name ______________________________ Date ____________

The Design Process

Design and make a valve that allows fluid to pass quickly in one direction, but allows less than 30 mL through every 10 seconds in the other direction.

Draw and label your prototype so someone else could follow your blueprint.

Prototype 1

How well did your prototype meet the design requirements?

Ideas for improving the prototype:

Name ______________________________ Date ____________

Refining Valve Prototypes

Make a list of the variables in your design process. Circle the ones that you are controlling.

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Draw and label diagrams below that show the materials and amounts used for each prototype.

Prototype 2a **Results:**	**Prototype 2b** **Results:**
Prototype 3a **Results:**	**Prototype 3b** **Results:**