

## **Cardiovascular Biomedical Engineering (Week 2)**

**Lesson Type:** Engineering

**Target Grade:** Middle School

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**Semester:** Fall 2016

### **Introduction**

Students will learn about biomedical engineering as a career and about the cardiovascular system by dissecting a sheep heart and engineering a solution to a diseased heart valve. They will learn about diseases of heart valves and what they entail, as well as current surgical solutions. By the end of the lesson, students will have practiced working in teams and using the engineering design process.

### **Teaching Goals**

- Learn about the basic parts of a heart and how blood flows through those parts
- Learn how healthy heart valves function
- Learn about diseases that affect heart valves and current surgical solutions
- Practice using the engineering design process

### **Careers and Applications**

Biomedical engineers focus on advancing human health and health care by combining their knowledge of biological principles and engineering. Other engineers, including mechanical, chemical, electrical, materials, and computer engineers can also work together with medical professionals to solve health problems. Diseases of the heart are a leading cause of death in the U.S. and therefore artificial heart valves are a leading area of research for biomedical engineers. Creating artificial heart valves involves many considerations that engineers and physicians collaborate on. For example, the valve needs to be made out of materials the human body accepts and needs to last for as many years as possible before replacement.

### **Agenda**

- **Introduction**
- **Sheep Heart Dissection**
- **Heart Valve Activity**

## Introduction

Interesting facts about the heart to start off:

- The heart beats 100,000 times a day
- The average heart pumps more than a gallon of blood a minute
- The beating sound of the heart is the clap of valve leaflets opening and closing

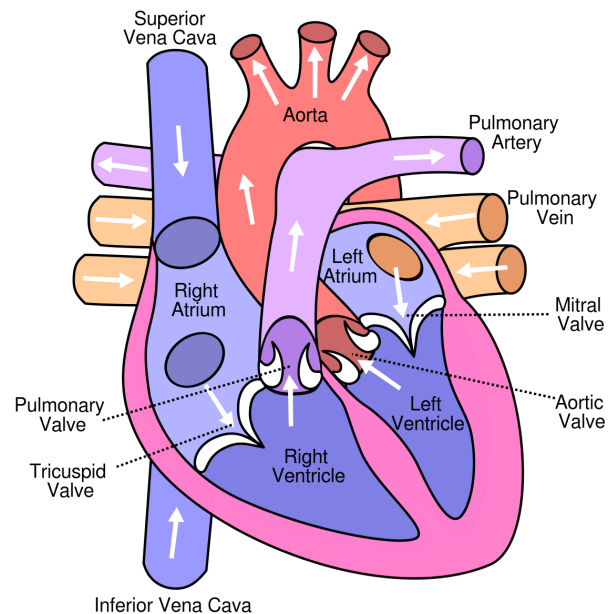
Give a quick refresher on the circulatory system from the previous week's lesson before diving into Module 1.

## Module 1: Sheep Heart Dissection

### Introduction

In this module, students will first learn a little bit about the flow of blood through the heart, as well as parts of the heart. They will then witness the dissection of a sheep heart to spur their enthusiasm about the upcoming engineering module!

Don't worry too much about the vocabulary too much, it would just be good to draw the diagram of the heart below and run through the flow of blood. The important thing is that the students understand the important function of heart valves during this part of the lesson.



The heart is a hollow, muscular organ that pumps blood throughout the body. The blood enters the heart from the body through the **superior vena cava**. Then the blood enters the **right atrium** of the heart. The blood then moves through the **tricuspid valve** (shown as two white flaps) into the **right ventricle** of the heart. Then the blood moves through the **pulmonary valve** (shown as two white flaps) into the **pulmonary artery** (one on each side of the heart). The blood re-enters the heart through the **pulmonary veins** (two on each side of the heart), and travels into the **left atrium**. The blood then passes through the **mitral valve** (shown as two

white flaps) and into the **left ventricle** chamber of the heart. The blood then moves through the **aortic valve** (shown as two white flaps) and into the **aorta**.

### Extra Background for Mentors

*What causes the heart to pump blood?*

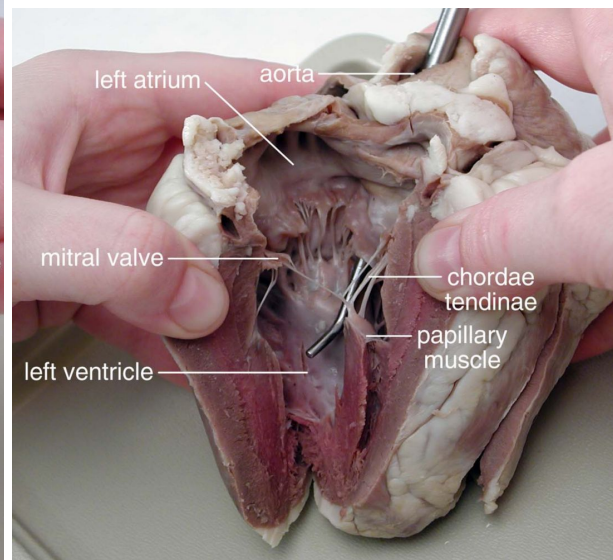
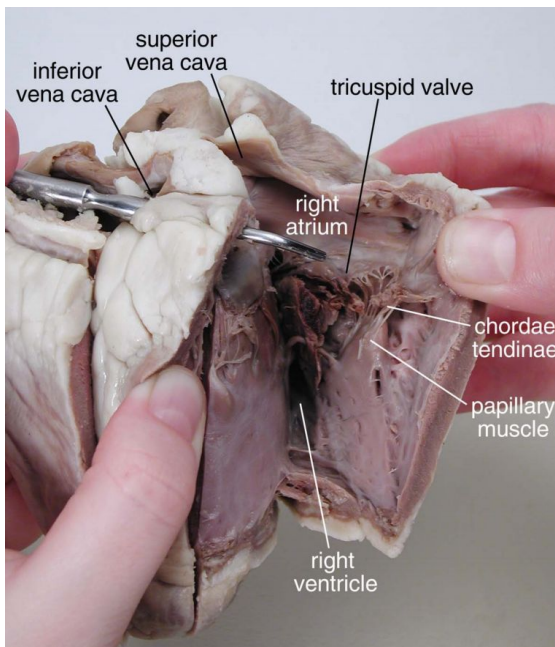
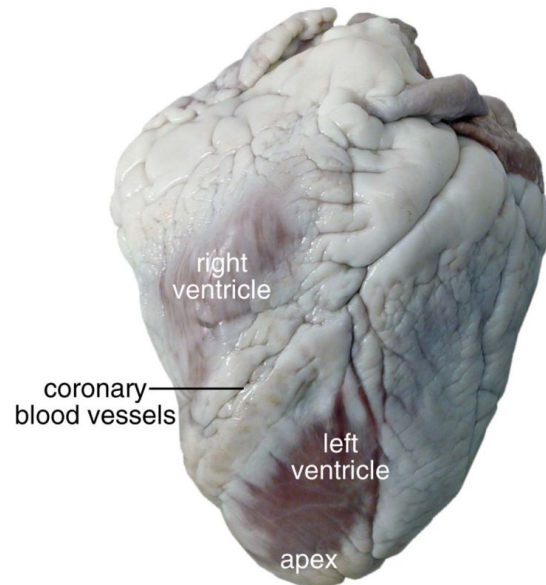
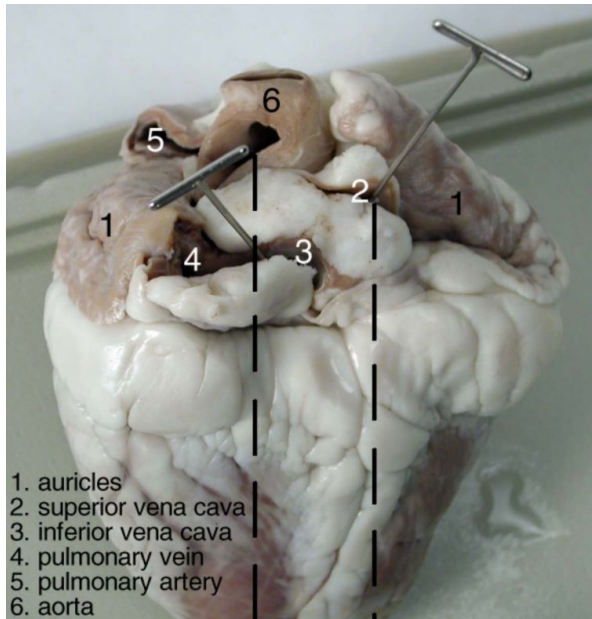
The normal rhythmical heart beat, called sinus rhythm, is established by the sinoatrial node, the heart's pacemaker. Here an electrical signal is created that travels through the heart, causing the heart muscle to contract.

### Materials

- 1 sheep heart per class
- 1 scalpel per class
- 2 pairs of gloves
- 1 garbage bag (to perform dissection on)

### Procedure

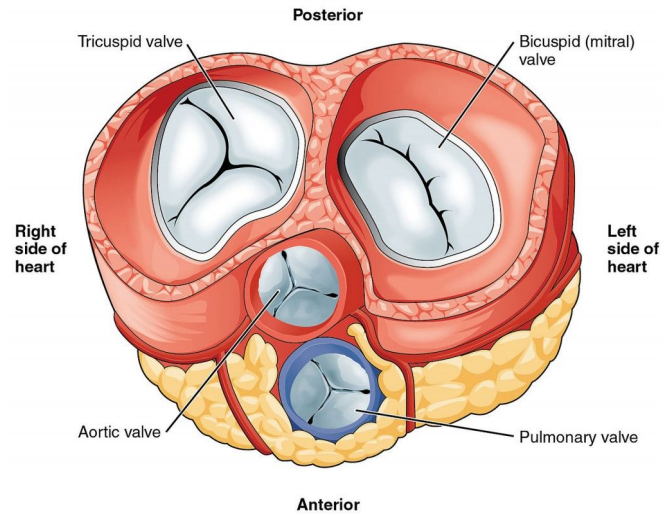
- Have two mentors perform the dissection as a “demo”
- Print out a copy of the following dissection images for reference
- Dissection Procedure (15 minutes total):
  - Before dissection, point out the outer features of the heart, including:
    - Right ventricle
    - Left ventricle
    - Aorta
    - Pulmonary artery/vein
    - Inferior/superior vena cava
  - After making two cuts along the lines shown in the diagram below, open up the right side to show
    - Right ventricle
    - Right atrium
    - Tricuspid valve
  - Then, open up the left side to show
    - Left ventricle
    - Left atrium
    - Mitral valve



## **Module 2: Heart Valve Activity**

### **Introduction**

This module will be mostly focused on the four heart valves. Each mammal has four heart valves, as shown in the diagram below. 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. Blood is pumped from high pressure areas into lower pressure areas. This pressure difference is created by the muscles of the heart.

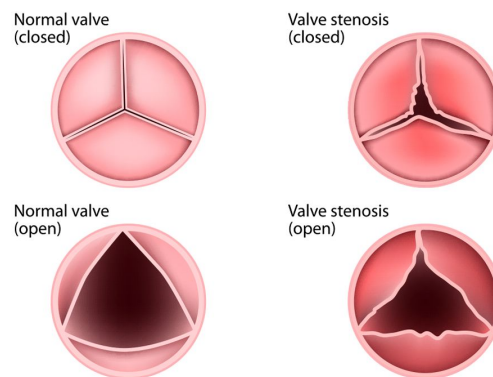


### Heart Valve Diseases:

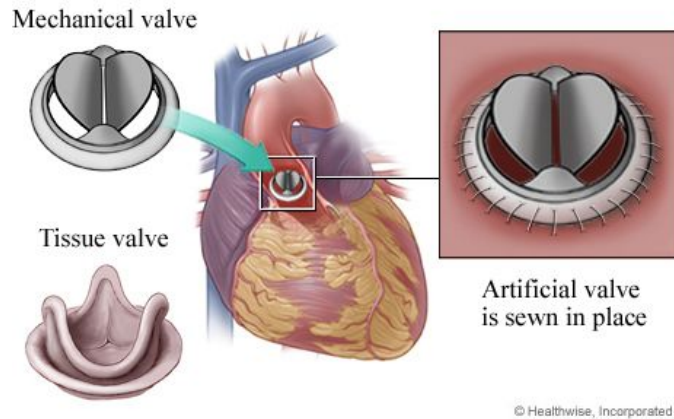
There are several heart valve diseases that impede the heart's ability to function efficiently. These diseases include:

- **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

## Heart Valve Disease



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.



### Extra Background for Mentors

More detailed definitions of the four valves:

- **aortic valve:** The valve between the left ventricle and the aorta, normally with three leaflets.
- **mitral valve:** The valve between the left atrium and left ventricle, with two leaflets. Also known as the bicuspid valve because it is the only valve in the human heart with just two flaps.
- **pulmonary valve:** The valve between the right ventricle and the pulmonary artery, with three cusps or leaflets.
- **tricuspid valve:** The valve between the right atrium and right ventricle, normally with three leaflets and three papillary muscles.

### Materials

This is the list of total materials that should be provided depending on the size of the class but keep in mind that groups will be using points to “purchase” the materials themselves.

- Plastic box with middle valve setup (1 per group)
- 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)
- String
- Tape

### Procedure

- Students should split into groups of 4
- Brainstorm ideas on paper (5 minutes)
- Allow groups to come up one at a time to “purchase” materials (5 minutes)
  - Keep track of how many points they spend based on the attached materials list and point values

- Groups build their heart valve and test on their own test artery, allow students to “purchase” more materials as necessary (15 minutes)
- 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 reasonably low point expenditure (allow mentors to decide on this). (10 minutes)

## **References**

- [https://www.teachengineering.org/activities/view/cub\\_heartvalves\\_lesson01\\_activity1](https://www.teachengineering.org/activities/view/cub_heartvalves_lesson01_activity1)

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## **Summary Materials Table**

<b>Material</b>	<b>Amount per Group</b>	<b>Expected \$\$</b>	<b>Vendor (or online link)</b>
Sheep Hearts	1 per site	~\$5 each	
Gloves	2 pairs per site	\$9 a box	<a href="https://www.amazon.com/SAFE-GUARD-Latex-Powder-Gloves-Medium/dp/B00ATJUEJ4/ref=sr_tnr_p_9_15755321_1_a_it?ie=UTF8&amp;qid=1478561743&amp;sr=8-9&amp;keywords=gloves">https://www.amazon.com/SAFE-GUARD-Latex-Powder-Gloves-Medium/dp/B00ATJUEJ4/ref=sr_tnr_p_9_15755321_1_a_it?ie=UTF8&amp;qid=1478561743&amp;sr=8-9&amp;keywords=gloves</a>
Scalpels	2 per site	\$6.50 for 6	<a href="https://www.amazon.com/Premiere-9411-Disposable-High-Carbon-Individually/dp/B00EP0T1HY/ref=sr_1_1?ie=UTF8&amp;qid=1478561783&amp;sr=8-1&amp;keywords=scalpel">https://www.amazon.com/Premiere-9411-Disposable-High-Carbon-Individually/dp/B00EP0T1HY/ref=sr_1_1?ie=UTF8&amp;qid=1478561783&amp;sr=8-1&amp;keywords=scalpel</a>
Trash bag	1 per site	--	
Plastic boxes	1 box per group	--	
Marbles	30 per site	--	
Construction Paper	3 sheets per group	--	

Popsicle Sticks	5 per group	--	
Toothpicks	5 per group	--	
String	Enough for site	--	
Tape	Enough for site	--	

Material	"Cost"
Construction Paper	2 points per sheet
Popsicle Sticks	1 point per
Toothpicks	1 point per two
String	1 points per foot
Tape	2 points per foot