Plan Category: Biology, Anatomy & Physiology

Title: Building Working Models of the Human Heart

Objective:

Few topics capture interest like human biology does, and one of its most fascinating topics is the heart. Yet how it actually works is often poorly understood. Students remember the anatomical information readily enough. But if asked to explain how the heart actually moves blood, they can seldom do more than recite the path that blood flows through the body.

To change this situation, I have created an investigation activity to help students study the physiology of the human heart and how it works. Students design and build functioning artificial "hearts" to study and to demonstrate their knowledge of the circulatory system. These physiological models reveal hidden misconceptions quickly, and they are a great way to assess student understanding about the circulatory process and related topics (e.g. blood pressure). I have had enjoyed great success with these model "hearts" over the years and think others will too.[1]

Required Equipment/Materials (per group of 2-4 students):

- 4 rubber, nitrile, or other elastic textured examination gloves
- 1-2 meters of 3/8 in. vinyl or plastic tubing
- 4 pinchcock clamps (or plastic equivalent)
- 1 tube of silicon aquarium sealant/cement or equivalent
- 1 roll of Duct tape or equivalent
- Water

Associated Costs:

- Box of Gloves = $6.00
- 10 ft. of 3/8 in. Plastic Tubing = $10.00
- Clamps = $1.50 (plastic)—$9.00 (Mohr pinchcock) per clamp
- Aquarium Cement = $5.50 per tube
- Roll of Duct Tape = $6.00

Total for First Time for Class of 28 (assuming groups of 4) = $96 (plastic clamps)—$216 (Mohr pinchcock)

Total once Initial Clamp & Tubing Investment Made = $8.75 per year for gloves, cement, & tape (which usually last at least 2 years before running out).

[1] I have published variations on this original idea of mine in *Science Activities* (vol. 37, no. 2, Summer 2000; pp. 17-20) and in *The Science Teacher* (vol.76, no. 9, Dec. 2009; pp. 36-40). The current text does not infringe on any existing copyrights.

Instruction for Execution:

Inform students that they must design and build a model of the human heart that works like the actual heart but that does not have to look like an actual heart. Inform them that their model must meet the following criteria:

- each critical structure must be present somehow (e.g. two atria, two ventricles, etc.);
- any and all required structures must be linked properly (e.g. no fluid should be able to pass directly between the atria);
- a finished "heart" must contain a closed and contiguous water solution (no “transfusions” and no “bleeding” allowed during operation);
- a "heart" must actually move fluid when working but it does not have to function by itself (i.e. students may do the pumping for themselves); and
- everything (valves, contractions, etc.) must work the same way and in the same order as they would in a real heart when the model is in operation.

Next, provide students with the list of materials outlined above and allow them to begin the brainstorming process in groups of 2-4. It will take them the equivalent of 140 class minutes to develop their solution to the problem and to build their model, and for those students who need direct instruction, literal directions are listed below. But with minimal guidance, most students are able to find their way to a solution that includes:

- having short tubing pieces between each “atrium” and its corresponding “ventricle;”
- much longer pieces to reflect the longer pathways between “right ventricle” and “left atrium” and “left ventricle” and “right atrium;” and
- valves that are placed between each “chamber.”

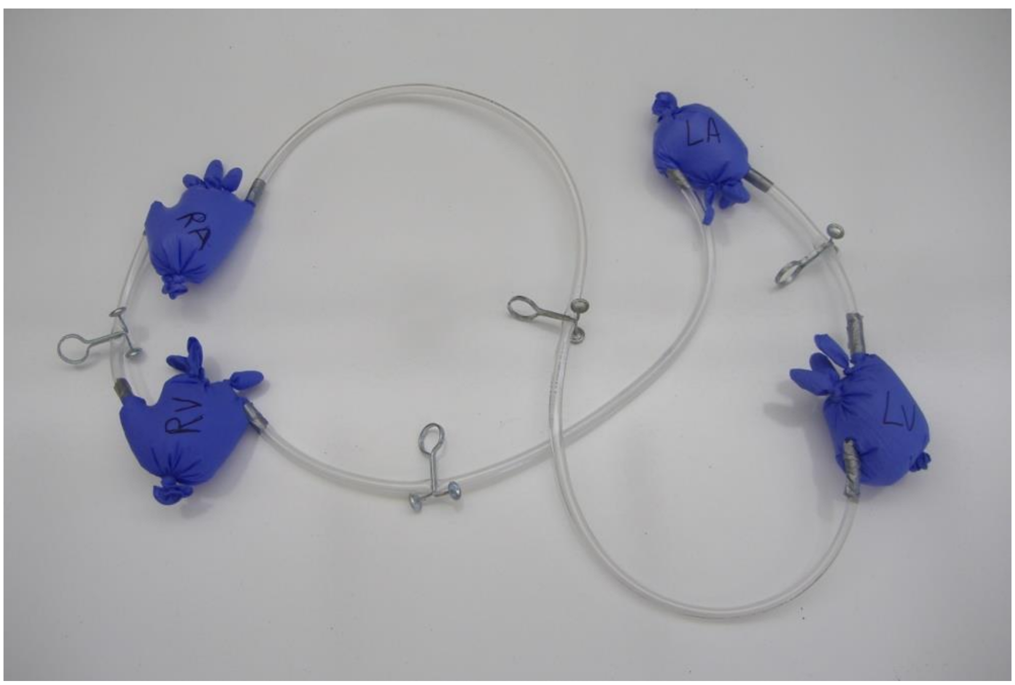
Once built, each team should demonstrate their heart for at least two full contractions according to the criteria discussed in the “Measurement of Success” section, and this process will take approximately 40 minutes for a class with 5 groups.

Heart Model Instructions

1. Cut the tips off the “pinky” fingers and thumbs of all four gloves, leaving at least 2 cm of latex at the base of fingers. Tie each of the remaining fingers on the gloves with simple overhand knots so that the final knot for each finger is located where the finger meets the body of the glove.
2. Cut the plastic tubing into the following dimensions: two 10-cm pieces, one 40-cm piece, one 60-cm piece.
3. Insert one end of one of the 10-cm pieces of plastic tubing into the “pinky” finger opening of one glove, and insert its other end into the thumb opening of a second glove. Use glue to seal the tubing in place (and wrap each seal with duct tape to protect while drying).
4. Repeat step 3 for the other pair of gloves.
5. Slide a clamp into place in the middle of each piece of tubing; you have now built the two halves of the yeart.

6. Next, insert the end of the 40-cm piece of tubing into one of the remaining open fingers of one of the glove pairs and glue/tape to seal.
7. Repeat step 6 with the 60-cm piece of tubing and the other pair of gloves.
8. Now slide a clamp into place in the middle of the 40-cm piece of tubing and slide a second clamp into the middle of the 60-cm piece.
9. Finally, insert the open end of the 40-cm piece of tubing into the remaining finger opening of the other pair of gloves and vice versa with the 60-cm piece of tubing. Glue and tape both tubes in place.
10. Wait until the glue finished drying before filling the model with water.
11. To fill the model, tie off three of the gloves at their bases (where the hand would normally be inserted) with a simple overhand knot.
12. Open up all clamps, stick the remaining still open glove under a faucet and run water into the model until all chambers and tubes are full (including the one being use to fill the model).
13. Tie the remaining, 4^{th} glove off at its base with a simple overhand knot. The model is now ready to be used.

The final product should look something like this:



<u>Measurement of Success:</u>

The focus of evaluation should be on how each "heart" works, not on how it looks. This lesson is a physiology one, not an anatomy one. The "atria" do not need to be directly above the ventricles and there does not need to be a septum. Nor does there need to be any biological representation of the "body" or "lungs" since from a physiological standpoint, the heart is a closed system: it pumps blood to itself; lungs and the body are simply very large "tubes" connecting one pump to another. Hence, as long as students move the fluid in their model in the same defined pattern as that found in the real human circulatory system, it doesn't matter whether their "heart" displays every anatomical relationship. If students avoid the common error of squeezing first the right atrium, then the right ventricle, then the left atrium, and finally the left ventricle, then full credit should be given for that portion of the assignment. Again, it's a physiology lesson, not an anatomy one.

However, finished models need to have *some* structural requirements, and they are:

- four "chambers" that are properly connected (with proportional tubing lengths to exhibit the physiological demands of transporting "blood" different distances);
- "chambers" that are separated by the correct number of "valves;"
- the connection between the "right atrium" and "left ventricle" should cross over the one between the "left atrium" and "right ventricle" as shown in the picture above; and
- if resources permit, the right and left "ventricles" should be made of gloves that are larger than those used for the "atria" and the one used for the left "ventricle" should be the largest of all in order to demonstrate differences in the amount of pumping force the various chambers create.

In addition, it should be a fully closed model (no water should have to be added at any point in student demonstrations) and the "hearts" should be as water-tight as possible (given the limits of the building materials).

To assess the physiology requirements, look to make sure that students make their "hearts" work the way a real heart does. They must remember to contract first both "atria" together while opening only the valve between the "right atrium" and "right ventricle" and the valve between the "left atrium" and "left ventricle." Then they must remember to close both of these valve, open the other two valves, and contract both "ventricles" at the same time. The key is for students to match the pattern of a real heart (both atria, then both ventricles) and to work with the "valves" so that they make the fluid flow in one direction.

Detailed Rubric

Structural Components (50%)

- (4%) four "chambers"
- (4%) atria "chambers" same size
- (6%) ventricle "chambers" larger than atria "chambers" and different in size (medium & large)
- (4%) four "valves"
- (12%) four lengths of tubing (2 short, 1 medium, 1 long)
- (16%) correct arrangement of chambers, tubing, & valves (e.g. 4% for right atrium and right ventricle connected by short tube with 1 valve between them)
- (4%) water-filled

Functional Components (50%)

- (8%) students squeeze both "atria" simultaneously

- (8%) students open both valves between the “atria” and the “ventricles” before squeezing the “atria”
- (8%) students squeeze both “ventricles” simultaneously
- (8%) students open both valves between the “ventricles” and the “atria” before squeezing the “ventricles”
- (9%) degree to which valves cause water to flow one direction
- (9%) degree of leakage

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