

Using Heart Models for Physiology Teaching and Learning

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Over the last few decades, there has been a shift in the classroom from a teacher-centered learning environment, with its emphasis on content delivery, to a student-centered environment focused on inquiry learning (http://www.nsta.org/docs/PositionStatement_ScientificInquiry.pdf). With the Next Generation Science Standards (NGSS, 2012) being adopted by many states, students are no longer passive listeners, but actively participate in and initiate class discussions (Weimar, 2013). Additionally, recent technological advances have allowed students to acquire information from sources such as the internet which no longer necessitates the teacher giving lectures (Silverthorn, 2006). The more student-centered learning environment allows students to better comprehend and articulate their understanding.

My Physiology and Disease course at the Illinois Mathematics and Science Academy requires that students be able to articulate their understanding of anatomy and physiology to disease conditions caused by abnormal functions of organs and organ systems. They then use their understanding to solve real life case studies. What I have observed over the years is that the students often struggle more with understanding physiology than anatomy. To help students with the more challenging concepts of physiology, students design and build a model of the human heart. In doing so, students have to think about the different parts of the heart and how they work together, as well as the reason for the different sizes, shapes, and placements of the structures in the heart. A useful resource on building a non-life size, working model of the heart is Brock (2009). This activity addresses the Next Generation Science Standards LS 1.A: structure-function relationships (NGSS, 2012).

The goal of the heart model activity is for students to gain a greater understanding of the physiology of the heart. The students are required to work in groups of two. The minimum expecta-

tion is a heart model that shows the major parts of the heart and the pathway of blood circulation. All the parts of the heart involved in blood circulation are required to be clearly labeled and the circulatory pathway clearly marked. The model is required to be life size. A working heart model is given extra credit.

Students build the model out of low-cost materials. A model design report (see Figures 1-5), including calculations of dimensions, is required and must be approved before students beginning making their models. The purpose of this report is for students to think practically about building the model and also to factor in the greater thickness of the aorta and arteries compared with veins. Since they are making the model life-like, students need to think about this. After approval of the model design report, students have two to three weeks to build the model and present it to the class. Examples of student heart models are shown in Figures 4 and 6.

Models are assessed based on accuracy, creativity, and adherence to design specifications. Students then write a reflection report (see Figure 7) on what they learned during the construction of the model, and how their understanding related to other heart laboratories and activities (heart rate, blood pressure, lung capacity). Students also reflect on how their understanding of the workings of the heart fit in with the principles of physics such as gravity, resistance, and capillary thickness. This project is a huge success in my course. Students take more responsibility for their learning and I see that the previous need to reiterate information is unnecessary given their newfound comprehension. This activity would be appropriate for other areas of physiology as well, such as the respiratory system. For the more visual learners, as well as those that take a longer time to comprehend material, building models gives students a goal to work toward while learning at the same time.

Figure 1: Heart Model Design Report. Use these questions as a guide to create your heart model design. Make sure you answer these questions in your model design report. Please note that the model design report is different from the final reflection report.

1. Describe how the human heart works to circulate blood throughout the body. Include your thoughts on how cardiac fitness and high blood pressure affect heart function.
2. Show calculations to find lengths of arteries or veins, portrayed by tubes, strings, or other materials, depending on what you use. If you are making your model work, explain what modifications you are using to make “blood” flow through your heart model.
3. Make sure that your model is the same size as a human heart and when you put the parts together, be aware of measurements of the blood vessels. There may be an element of trial and error in your design. For example, you may have to cut several pieces before you decide upon the size of blood vessels; it may not function the first time.
4. Now that you know the lengths of your elements (strings, tubes, and so forth), show a drawing of what your model will look like. Include the overall dimensions - length, width, depth - as well as the dimensions of the elements.
5. On the drawing, specify the materials that you will use.
6. Describe your procedure for how the model will be built.

Cite your references using APA style, both in-text and at the end of your report. Reports without in-text citations and a bibliography will not be scored. Use at least two scholarly references.

Figure 2: Heart model design. Drawing of a design of a heart model submitted prior to making the working model.

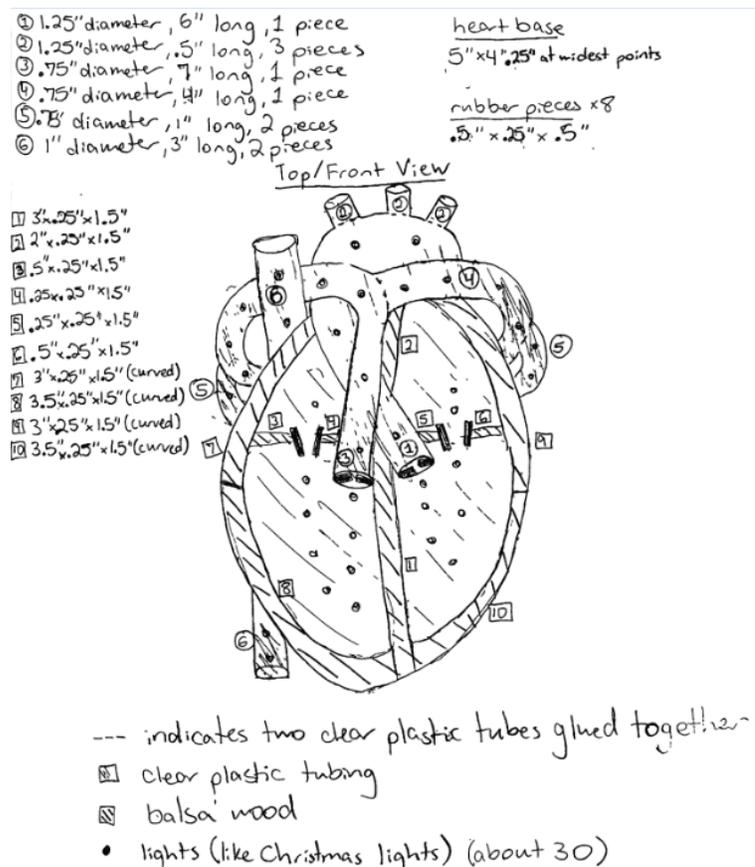


Figure 3: Excerpt From a Heart Model Design Report, Question 1.

Describe how the human heart works to circulate blood throughout the body. Include your thoughts on how cardiac fitness and high blood pressure affect heart function.

In order to circulate blood throughout the body, the heart uses two things: the intrinsic conduction system, and a blood pressure gradient. The intrinsic conduction system of the heart allows for the heart to pump blood. It is our body's own natural pacemaker. An impulse starting at the sinoatrial (SA) node goes through the atria to the atrioventricular (AV) node. This tells the atria of the heart to contract. That impulse is then carried to the bundle branches and the Purkinje fibers to tell the ventricles to contract. While the ventricles contract, the atria relax. While the ventricles relax, the atria contract, and so on and so forth. This is the cycle the heart muscle goes through to allow blood to be pumped throughout our body.

However, once the blood leaves the heart, a blood pressure gradient allows for the blood to get from one location to another. As the blood moves away from the heart to the capillaries, blood pressure is decreased, due to loss of energy. Gravity, breathing, and the contraction of skeletal muscles all also play a role in affecting blood pressure. This differing blood pressure gradient allows for blood near the heart that has a high pressure to reach the areas of the body that have a lower pressure.

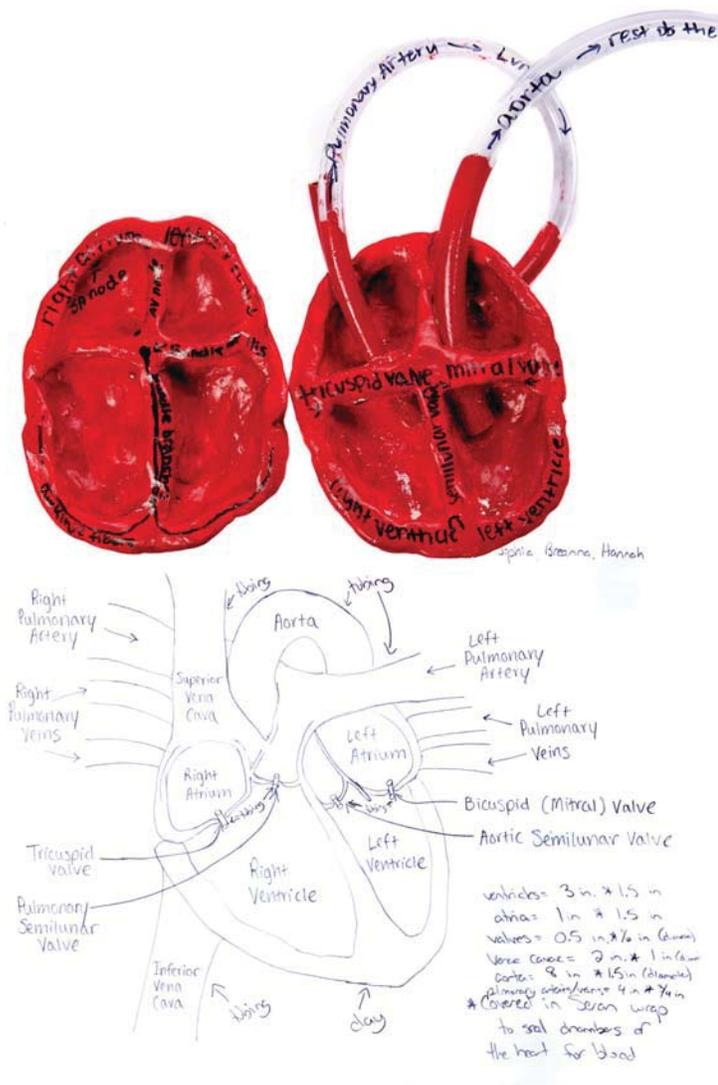


Figure 4: Model and diagram. A heart model made of clay, with the corresponding submitted design.

Figure 5: Excerpt From a Heart Model Design Report

We will use 3” of $\frac{3}{4}$ ” diameter clear plastic tubing for both the superior vena cava and inferior vena cava, to indicate where they flow into the heart. We will use 7” of $1\frac{1}{4}$ ” diameter clear plastic tubing for the aorta because it will cover 4” of the front of the model where it connects to the left ventricle, and we will allow 3” for it to wrap behind the top of the heart.

From the top of the aorta, we will attach three separate $\frac{1}{2}$ ” long pieces of the same diameter tubing to indicate the branches of the aorta located above the heart. For the pulmonary vein/artery tubing, we will use 16” of $\frac{3}{4}$ ” diameter clear plastic tubing, 7” for each pulmonary circuit from the right ventricle to the right lung, 5” to the right lung and 2” for the additional branch on each side that empties into the left atrium.

We will make our model work by drilling holes in the wood back of the heart model and in the clear plastic tubing and inserting small lights that light up in the order of blood flow through the heart. The whole actual heart will be 5” long and 4” wide at their widest points. We will make the 3D heart walls $1\frac{1}{2}$ ” tall. We will connect the pieces of wood, plastic tubing, and lights with hot glue/super glue. We will tilt the heart forward for easier viewing with a 2” wood stilt behind it, both sitting on a wooden 6”x6” base.

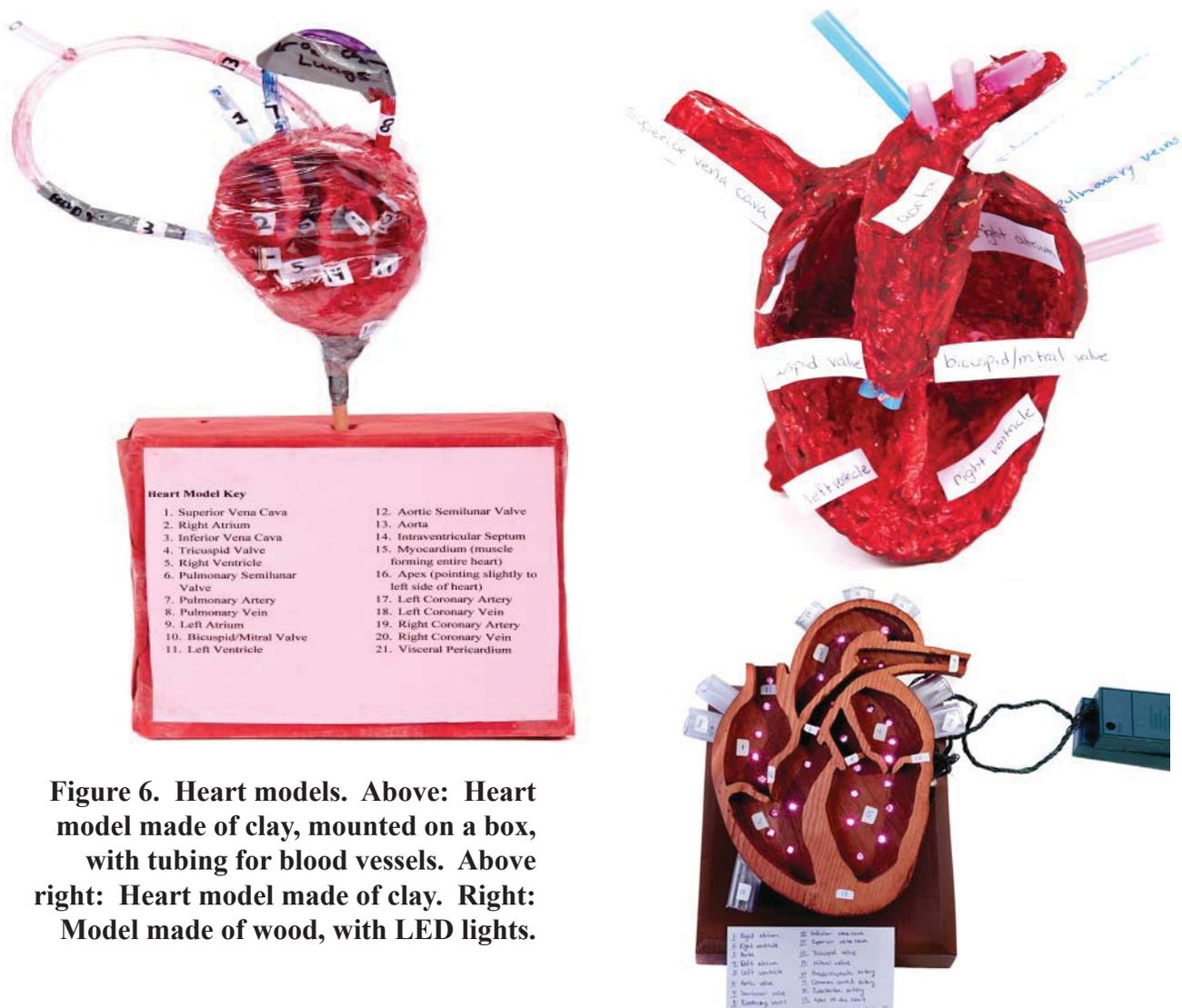


Figure 6. Heart models. Above: Heart model made of clay, mounted on a box, with tubing for blood vessels. Above right: Heart model made of clay. Right: Model made of wood, with LED lights.

Figure 7: Excerpt From a Heart Model Reflection Report

To replicate the human heart, my partner and I decided to “think out of the box” and create a working heart model out of wood. We decided to make a cross section of the heart that would work by flashing lights, indicating the blood circulation in the heart. If one looks at our original design, it can be seen that there are some differences in our actual model and the design. First and foremost, it can be seen that the actual model is bigger than an actual human heart. There are very good reasons for this. When trying to make a heart model that small, carving out intricate details such as the mitral and tricuspid valve was very difficult and it actually cracked the wood. Although we understand that our model is a blown up version of a real human heart, the attention to detail that we achieved with making the bigger heart was more valued to us, for it was more accurate in displaying the unique characteristics of a human heart. I also personally think that by making our heart bigger, it made the final piece tidier and cleaner. Also, we changed the fact that our pulmonary artery and aorta were made out of wood in the final model. If I was to change anything for the next time, I would definitely try to make the entire piece out of wood without the use of plastic tubing. Additionally, I would do this from a thinner wood slab, because the one we used was way too thick, and had to be sanded down so that the saw would cut through it. Furthermore, I would more carefully carve the left pulmonary artery because in the current model, it is not very distinguishable that the pulmonary artery splits up into the left pulmonary artery as well, not just the right one. I would also get smaller bulbs for the lights because putting the lights on the back of the heart proved to be difficult because of their size. Moreover, I would change the lights so that they synchronize with the actual heartbeats of the heart. And lastly, in the future, I would start staining the wood early in the day. This is because it took 7 hours for the wood to completely stain to the desired color; I should have not started at 4 pm, because it took up my whole day!

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