

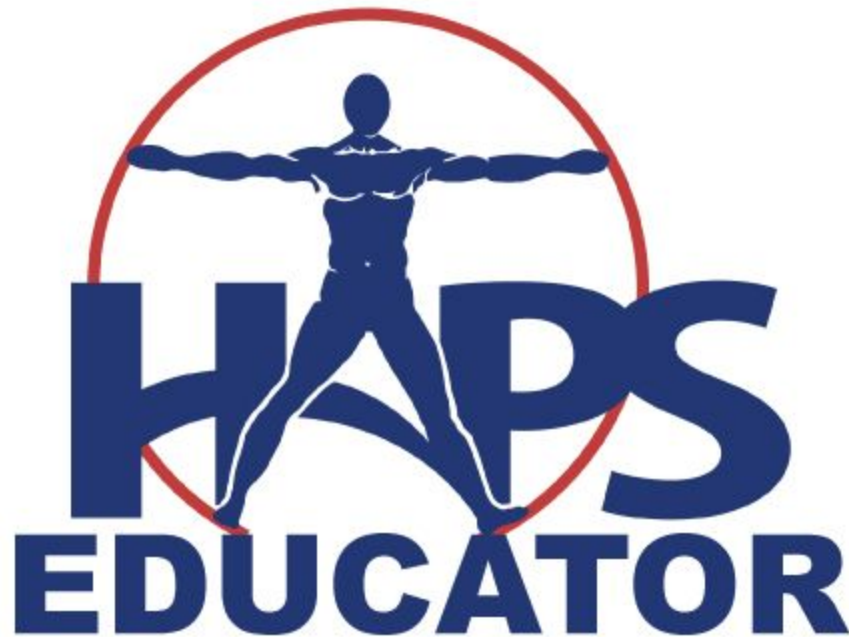
**“Stringing Together” Capillary Exchange**

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# “Stringing Together” Capillary Exchange

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## Abstract

In Anatomy and Physiology courses, students often struggle with visualizing structures, or processes, that occur at the cellular level, such as capillary exchange. Whenever available, models can be vital to students' understanding of a topic, particularly when they can be constructed by students in real time. To demonstrate capillary exchange to freshmen and sophomore Anatomy and Physiology students, a senior Health Sciences student created a simple model. The student enrolled in an independent study as a near-peer laboratory assistant. In addition to assisting the Anatomy and Physiology students learn in the lab, the near-peer student was asked to create a tool for active learning of a difficult physiological concept. Presented here are the materials and steps to create the model, recommended exercises for students to complete with the model, and example assessments that demonstrate how the activity helps students meet the relevant HAPS learning outcomes.

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**Key words:** anatomy, physiology, capillary, models, active learning

## Introduction

There are many structures and processes in Anatomy and Physiology that students find challenging to visualize and understand, particularly when concepts traditionally learned in biology, chemistry, physics or mathematics courses are involved. When these structures or processes are not easily visualized, students can experience even greater barriers to learning (Crowther 2017; Lujan et al. 2013; Rodenbaugh et al. 2012). One such process is capillary exchange. In Anatomy and Physiology courses, this topic is often introduced when studying the cardiovascular system, yet the principles are introduced very early in the Anatomy and Physiology curriculum when discussing diffusion and osmosis.

Hands-on exercises such as graphing, drawing and modeling can help students overcome barriers to learning (Crowther 2017; Hull 2016; Motz et al. 2017). In particular, models have frequently been well-received by students in Anatomy and Physiology courses, and have great potential to demonstrate structures and processes that are difficult to visualize (Breckler and Yu 2011; Dirks-Naylor 2016; Hull 2016; Motz et al. 2017). To help students visualize capillary exchange, a simple model was created by a near-peer laboratory assistant to meet the requirements of an Honors Project. The student was enrolled in a three-credit independent study, and was present at every weekly Anatomy and Physiology laboratory session. The student was eager to create an inexpensive, easy to understand model that students could use.

## Materials

Only a few simple, inexpensive materials are needed for the representation of blood capillary exchange:

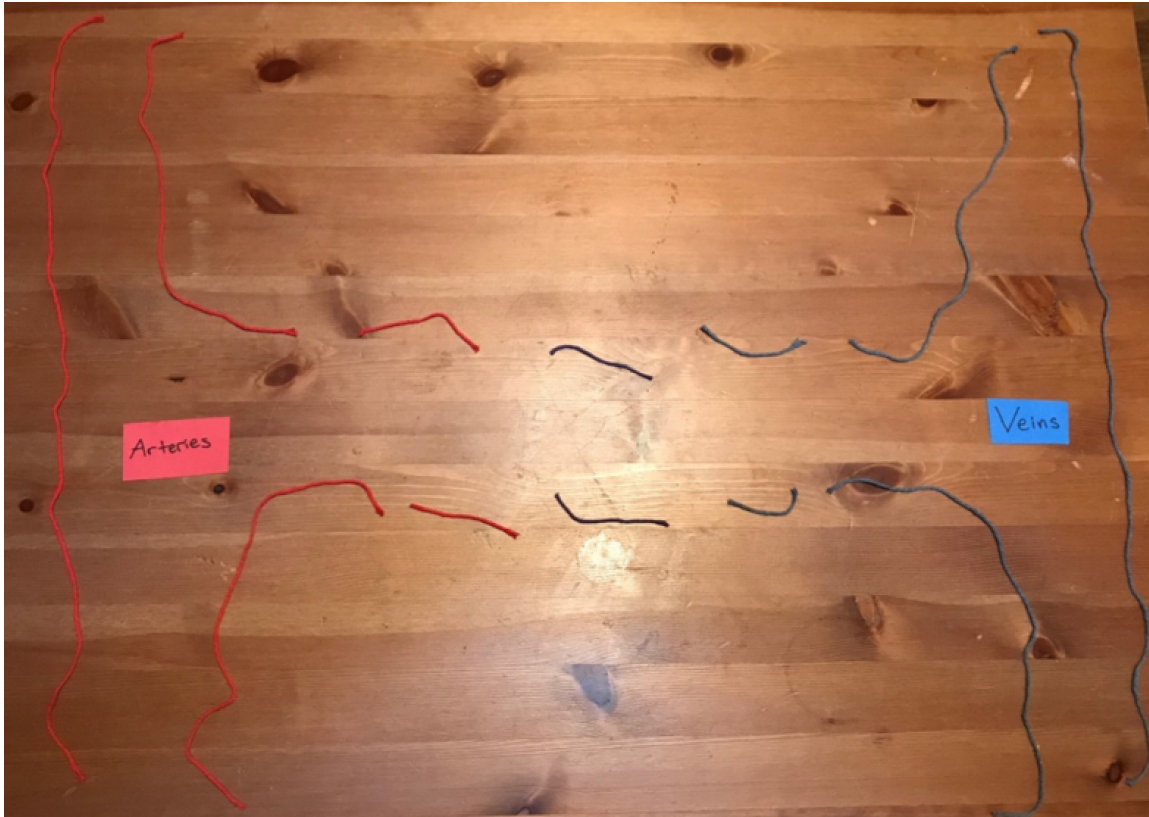
1. Red and blue string (purple string can be added to demonstrate the transition from artery to vein.)
2. Construction paper of various colors
3. Scissors

The instructor should provide the materials and instructions, but allow the students as much freedom as possible to create their own representation of the capillary system. This model can be created individually or in small groups in laboratory, recitation or lecture setting, as long as tables are accessible.

## Methods

In this assignment, students construct a visual representation of a capillary, with the goal of understanding how the various forces on the capillary wall influence exchange of materials between the blood and interstitial fluid. It is recommended to start by laying out the strands of string, using red and blue colors to represent the artery and veins. Additionally, purple strands can be incorporated to show the change from oxygenated red arteries to deoxygenated blue veins through the capillary. If any students have color vision limitations, strings with different thickness (thicker for arterial end, thinner for venous and thinnest for capillary, should be on hand.

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**Figure 1:** A basic string model of the capillary

After creating the capillary, students will create their own models of each molecule that passes through the capillary system. Key molecules to create are  $O_2$ ,  $CO_2$ ,  $H_2O$ , albumin, platelets, red blood cells, and white blood cells. These molecules can be cut in whatever shapes the students feel most comfortable with; however, it is important to emphasize the size difference in molecules to later aid in demonstrating why some molecules are able to move in and out of the capillary.

As students build their own models, it may be helpful to provide images from the assigned textbook or learning resource to students having difficulty getting started, or to allow students to check a reference image from time to time. If time is limited, instructors may want to circulate between students or student groups to ask questions about the students' models, and ensure each part is critiqued if necessary. A recent study by Dirks-Naylor on the student construction of nephron models to facilitate understanding

of renal transporters found that students prefer confirmation from the instructor that the model was drawn correctly to increase their confidence (Dirks-Naylor 2016). If more time is allotted, students should be allowed to make mistakes in construction and rebuild, as this can be an excellent learning opportunity. In their model of the sarcomere, Rodenbaugh and colleagues stressed the importance of allotting sufficient time during active learning exercises for thinking and processing, if life-long learning is to occur (Rodenbaugh et al. 2012). Indeed, allowing students the freedom to deconstruct, reconstruct and manipulate the capillary model based on their own independent theories and conclusions puts the responsibility of learning on the student, rather than the instructor. While the length of the model and diameter of the vessels can vary, it is



**Figure 2:** Representations of the molecules involved in capillary exchange

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important to make sure that students are accurate in differentiating the sizes of certain molecules. Water and oxygen molecules should be small enough to move through the holes built in the capillary, and albumin molecules should be too large to fit through these holes.

Once the students have created all their own materials it is important to make sure they are able to explain the basics of blood capillary exchange. Emphasis should be on how hydrostatic pressures and osmotic pressures affect the movement of fluid and therefore the molecules with them. When students can confidently create and explain their own models of the blood capillary system, instructors can give each group a physiological example of how the capillary system can change, causing different movement of molecules and fluid. For example, instructors can ask students to demonstrate how high or low blood pressure, or low albumin levels, could change the exchange of molecules across their capillary model. Once the groups have been given time to model their own capillary response, it is important to then have each group take turns explaining to other groups, to allow students to learn from each other. As students begin to demonstrate a clear understanding of their models and the capillary system, there are a variety of ways the instructors can incorporate further details and information. Simple additions could include: incorporating additional strings or other material to demonstrate the different layers of the blood vessels; adding more molecules found in the blood plasma; and focusing on the different roles that ions, proteins, and cells play within the blood vessels and capillary system.

## Student Activity Instructions

An example student instruction page for the activity is provided below.

### Example of in Class Instruction

#### Part 1

In small groups, use the provided material to create a representation of the blood capillary and associated molecules to demonstrate net filtration.

Include the following molecules:

Water  
Oxygen  
Carbon Dioxide  
Red Blood Cells  
White Blood Cells  
Albumin  
Platelets  
Glucose

Once you have created your own model, notify your instructor. Demonstrate your understanding of how hydrostatic pressures and osmotic pressures affect the movement of molecules in and out of the capillary.

#### Part 2

Once your instructor has approved of your model, they will provide you with one of the following physiological events, and task you with demonstrating how it affects the capillary system:

1. Please explain and demonstrate how histamine release in the interstitial fluid will cause changes in the capillary system. Additionally, please provide an example of what will cause this histamine release to occur.
2. Please explain and demonstrate how edema can be caused and how the lymphatic and capillary systems are directly related in preventing this condition.
3. Please explain and demonstrate how low blood pressure will lead to changes in the capillary system and how the body must adapt to maintain homeostasis.

Once everyone in class has finished creating their own model, groups will take turns demonstrating and explaining their physiological event to the class.

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## Assessment

Grading of this assignment can be based on completion of the required tasks, participation, or on demonstrated understanding of the material. Specifically, for grading options, students' grades can be determined by their ability to demonstrate and clearly explain a physiological response that occurs in the capillary to the rest of the class. Students could also make a short video that can be uploaded to a learning management system, and graded by the instructor or peers.

Through this activity, students are able to achieve multiple **HAPS learning outcomes**. Students are able to comprehend how the composition of capillary walls differs from that of other blood vessels. They are able to correlate the anatomical structure of capillaries with their function through building and explaining the basics of the capillary system (**HAPS module K, topic 12, learning outcome 4a and 4c**). Creating and demonstrating the gaps in the walls of capillaries as well as using different string thickness for each blood vessel type allow students to associate the different key characteristics of each blood vessel region. Creating molecules and explaining how these molecules move across capillary walls allows students to understand the role each molecule has in the process of the exchange of gases, nutrients, and wastes across capillary walls (**HAPS module K, topic 14, learning outcome 7a**). Having students explain the process to professors or teaching assistants allows instructors to ensure that students comprehend the roles of filtration and reabsorption in capillary exchange and how net filtration pressure across the capillary wall determines movement of fluid across the capillary wall (**HAPS module K, topic 14, learning outcome 7b, 7c, and 7d**). Lastly the incorporation of specific physiological conditions will provide students with examples of how the cardiovascular system and capillaries respond to environmental changes to maintain homeostasis in the body (**HAPS module K, topic 15, learning outcome 1**).

Depending on available time and goals for the session, instructors can take this model even further in demonstrating hydrostatic pressure and colloid osmotic pressure. Instructors could provide the equation for net filtration pressure (NFP), give students sample values, and ask students to make a calculation, using the model to demonstrate their understanding of the correct equation answer. Allowing students to move the molecules while simultaneously discussing the factors that determine NFP could help students gain greater confidence and understanding in the relationship of these equations.

Names:		Date	
<b>Grading Rubric</b>		Score	Criteria
		1	Student met the minimum required
		2	Student met expectations
		3	Student clearly exceeded expectations
<b>Part 1</b>	Score	<b>Part 2</b>	Score
Students ability to design and model the blood capillary system		Students ability to clearly design a physiological that occurs in the Capillary system	
Students ability to understand and explain the blood Capillary system		Students ability to understand and explain their physiological response to the rest of the class	

Total Score: \_\_\_/12

**Figure 3:** Example rubric for assessment of the activity

## Student Feedback on Model

As the model was created as an Honors Project for the near-peer student, the model was not created in time to implement it in an actual laboratory or classroom setting in Anatomy and Physiology 103, the final course in the three-course sequence. However, the near-peer's mentor, the Director of the Anatomy and Physiology Curriculum, held a final exam review session for students.



**Figure 4:** Near-peer student and completed model for demonstration

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During the exam review, the near-peer student demonstrated the model to a group of ten students and described the proposed activity to them as described in this paper. Every student agreed that this would have been an excellent activity in lab, small groups during lecture, or for the lecture instructor to demonstrate capillary exchange in class. One student commented "I wish I saw this before the midterm!" which was when the topic was first introduced. She reported being very focused on memorizing the values for net filtration pressure at the arterial and venous end, but struggled to understand how those pressures were created. After demonstrating the model, each student was able to move the molecules in the correct directions under normal conditions, and then in the proposed physiological conditions in the activity: low albumin, histamine release, and low blood pressure. When the near-peer student attached the histamine molecule to the capillary and widened the gaps between the strings, a visible "aha" moment occurred in the group. The students were able to see how white blood cells could reach interstitial tissue. Next year, the activity will be included in the laboratory that focuses on the heart and blood vessels.

### Limitations and Future Directions

A simple model using only string and paper can be used to demonstrate the basic forces influencing flow across the capillary wall. Once students have a solid understanding of what is exchanged across the capillary, and why, they can better apply the equations to calculate net filtration pressure. Models have the potential to be even more useful for students when created by former students who were successful in their Anatomy and Physiology courses. Broader implementation of the model is necessary to fully demonstrate the effectiveness of the model as a teaching and active learning tool. While students may be excited and engaged by the activity, that does not necessarily mean that the activity achieves higher-order thinking or understanding of a concept, which is a primarily goal of active learning strategies. Motz and colleagues' soda bottle model of a nephron was met with great student enthusiasm, and helped students understand glomerular filtration, but still required instructor explanation for the forces behind reabsorption and secretion in the tubule (Motz et al. 2017). Instructors may assume that because students give positive feedback about a model, it is helping them better meet the desired learning outcomes. A 2017 literature review of active learning strategies by Hopper found that the success of active learning strategies is variable, and recommends instructors critically evaluate the effectiveness of their classroom activities with an evidence-based approach (Hopper 2017).

It is also important to recognize that very simple educational models such as the one presented here have limitations. For example, no fluid can "flow" through a capillary to demonstrate the real-time effects of varied hydrostatic and osmotic pressures in the capillary and surrounding extracellular fluid. However, this model could be an excellent starting point, particularly for students with no prior

knowledge or exposure to the information. Instructors could then provide students with more detailed illustrations, or videos, demonstrating capillary exchange. There are a great number of potential clinical applications students can use the model to demonstrate, many of which they would routinely see in clinical practice. Finally, the Anatomy and Physiology students in the laboratories with near-peers regularly expressed excitement and awe that the near-peers had been in their shoes a year prior. Therefore, models may be even more beneficial to students when developed by their near-peers who were successful in the course, as they are closer to them in terms of knowledge and experience.

### About the Authors

Alejandro Quinonez, BS, is a recent graduate of the Drexel University Bachelor of Health Sciences Program. In the spring of 2019 he served as a near-peer assistant in the Anatomy and Physiology laboratories.

Krista Rompolski, PhD, is an Associate Professor in the Health Sciences Department at Drexel University. She supervised the near-peer students in the Anatomy and Physiology laboratories for the 2018-19 school year.

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