# Modeling a microvascular network with tubing

**Author(s):** Nathanael L. Rosidi, Karrie Frey, Chris B. Schaffer  
**Date Created:** 05/19/2011  
**Subject:** Biology and Physics  
**Grade Level:** 11-12  
**Standards:**  
- Standards 1, 4 and 7

## Schedule:

2 periods - 40 mins for experiments, separate period to go over questions

## Description:

Students will build a microvascular network similar to vascular networks in the body. They will analyze the parameters of the network such as fluid flow, pressure, and resistance. The goal of the lab is to understand how the dynamics of the network can change after a blockage to one of the channels.

## Objectives:

- Students will be able to apply basic math skills on a hands-on lab  
- Students will be able to understand how the blood vessel networks in the brain work  
- Students will understand concepts in biology, particularly neurobiology  
- Students will understand basic physics principles such as concepts in pressure and resistance

## Vocabulary:

- Resistance  
- Vasculature  
- Arterioles  
- Venules

## Materials:

- Light microscope w/camera  
- Flexible tubing  
- Y connectors  
- Beads  
- pump  
- Timer  
- Binder clip  

## Safety:

This lab poses no safety concerns
Science Content for the Teacher:

The microvasculature system (the portion of the circulatory system composed of the smallest vessels, such as the capillaries, arterioles, and venules) is comprised a series of vessels and networks with extensive redundant connections.

![Diagram of microvasculature system showing blood pressure, velocity, and area changes](image)

Figure 1: Branching of a typical microvasculature showing change of blood pressure, total area, and velocity.

These extensive connections are necessary to provide a high surface area for blood flow to the various organs in the body. In addition if there is an occlusion in any of these vessels e.g. a blood clot, the redundant nature of the network allows blood flow to be rerouted with minimal damage to the organ.

As a result of a blockage in the microvasculature one would expect a redistribution of flow in the neighboring vessels, a change in velocity and a change in pressure across the network.

The objective of this experiment is to characterize a simple model of the microvascular system using tubes and connectors. Students will measure flow velocities of beads (representing blood cells) within the model network before and after a blockage and track the redistribution of bead flow when a channel is occluded. Figure 2 shows a schematic a network of pipes and connectors analogous to the vasculature in the brain.
Figure 2. Schematic of microvascular network that can be made with tubing and connectors

**Classroom Procedure:**

**Materials:**
Flexible tubing
1/16” ID Tygon lab tubing – Cole Parmer – Catalog# ZW-06408-62
Connectors
Y-connectors – Cole Parmer – Catalog# ZW-30726-01
Beads
Micrometer size beads - Duke Scientific Cat # 2010A (10 micron) or 2070A (70 micron). Place few drops in a solution of water and detergent (to keep them suspended).
Binder Clip to block tubing

**Equipment:**
Pump
Light microscope with camera

**Methods:**
See Student Handout. Students will design and make their own simple network using the flexible Tygon tubing. They will predict the flow pattern/direction of bead flow, which channels have faster or slower beads. They should record their predictions. They will pump in a bead solution at a constant flow rate and watch the flow profile in each tube ‘channel’ using a microscope/camera and measure the velocity using the free software ImageJ. This will verify their predictions.

They will then block a channel and predict a new flow profile and velocity of beads. They will measure the velocity of the beads in the blocked network.
**Results and Data Analysis Expected.**

- Average velocity for each channel before and after blockage
- Prediction of flow pattern before and after channel blockage. Include the schematic. If you expect a reversal of flow support with an image of flow reversal.

**Assessment:**

A good method of assessment is for students to write a report in the format of a scientific paper.

1. Abstract
2. Introduction
3. Results
4. Discussion
5. Questions

Abstract: A synopsis of the purpose of the experiment, what method was used, and the results and conclusions obtained. (1 short paragraph)

Introduction: State the objective of the experiment and discuss the importance of the subject and what other people are doing in this area (from supplemental information given).

Results: Present the data/results in a logical manner with appropriate images and tables. Detailed calculations can go in an appendix.

Discussion: Discuss your experiments and results, your limitations and assumptions you made. Discuss what your results mean in context of the field and what would it implications be in a more complex network

Questions:

1. How would different pressures for each channel affect flow through the network?
2. What are some physiological examples of pressure changes our body undergoes?
3. Would a change in vessel diameter or vessel flow rate contribute to a greater change in pressure? What do you think our body does to compensate for changes in pressure?
4. What does a block in one channel do to network flow and direction? Is a blockage necessarily bad? Explain why it is or is not.
5. When a vessel branches, what will happen to the resistance? Pressure drop? Relate this to the picture shown in the introduction graphing pressure from arteries to the capillary beds
Acknowledgements:

Dr. Chris B. Schaffer, Dr. Shivaun Archer – Biomedical Engineering, Cornell University
Karrie Frey – Tully High School, NY
National Science Foundation Cornell GK-12 Program: DGE 0841291