Benchmark SC.912.L.14.36 Describe the factors affecting blood flow through the cardiovascular system.

Benchmark Clarification Students will identify factors that affect blood flow or describe how these factors affect blood flow through the cardiovascular system.

Content Limit Items may address factors such as blood pressure, blood volume, resistance, blood viscosity, disease, and exercise.

Mr. Stone's notes on the stuff your book doesn't explain so well:

So, you have to run the mile in PE. How does your body adjust to the increased demand for oxygen? A few things have to happen in order for your heart rate to increase and supply your cells with the oxygen they need.

1) As your cells burn sugars for fuel, they produce carbon dioxide (remember cellular respiration).

2) The carbon dioxide diffuses out of your cells and into your blood, where the carbon dioxide reacts to form carbonic acid.

$$CO_2 + H_2O \rightleftharpoons H^+ + HCO_3^- \rightleftharpoons H_2CO_3$$

Carbon dioxide and water react to make carbonic acid.

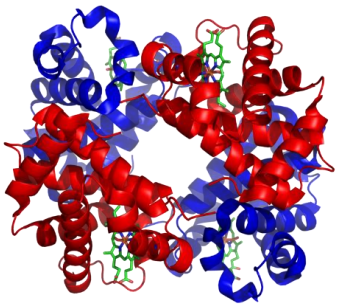
3) Chemoreceptors in the medulla detect the change in ρH, and signal the heart to beat faster.

4) But your heart doesn't just beat faster, it also beats harder, which is called the Stroke Volume; it increases the volume of blood pumped with each beat.

Cardiac output (mL/minute)	=	Heart rate (beats/minute)	×	Stroke volume (mL/beat)

5) The product of your heart rate and stroke volume is the Cardiac Output, a measure of blood flow in milliliters per minute.

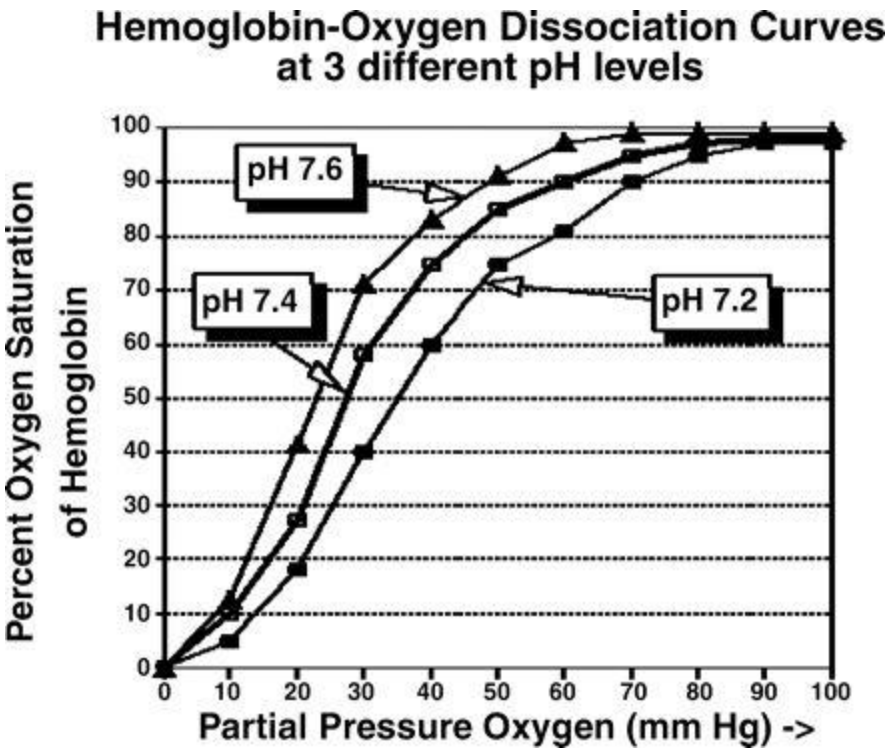
When you run the mile your breathing rate increases, too, and facilitates the rapid exchange of gasses between the alveoli of your lungs and the atmosphere. As carbon dioxide diffuses out of the pulmonary circuit and into your lungs, oxygen diffuses from the atmosphere into the pulmonary circuit.



Hemoglobin

Unfortunately, oxygen dissolves poorly in water and blood. You would never have enough oxygen to nourish your cells without the carrier protein hemoglobin, which is in your red blood cells. Hemoglobin is a protein with four iron "heme" groups. The iron atoms bind oxygen molecules (O_2), which allows more oxygen to diffuse into the blood. Hemoglobin has a very strong attraction to oxygen, but at some point it has to be able to release the oxygen so the oxygen can reach your cells. How does this happen?

You can probably imagine that the further away you get from the left ventricle in the systemic circuit, the more loaded with carbonic acid the blood is from cells excreting waste. Remarkably, the same acidity that triggers your increasing heart rate and breathing rate also decreases hemoglobin's affinity for oxygen. Therefore, as oxygen rich red blood cells make their way through the systemic circuit, they release oxygen to the tissues that are producing the most carbon dioxide, and which are therefore the most in need of oxygen.



This graph shows how a more acidic ρH causes hemoglobin to carry less oxygen.

With an atmospheric pressure of 60mm Hg and blood ρH = 7.6, there is approximately 97% saturation. Saturation decreases to 90% when blood ρH = 7.4, and decreases to 81% when blood ρH = 7.2.

If running the mile is a pain, it's much worse if you are out of shape and suffer from atherosclerosis, a hardening and narrowing of the arteries and veins. Why is the buildup of cholesterol plaque so bad for your heart? It slows down the flow rate of blood through your circulatory system, i.e. it decreases your cardiac output. Now your cardiac muscle will be strained to achieve the same cardiac output, measured in mL/minute.

$$\text{Flow rate} = (P_{in} - P_{out}) \left(\frac{\pi}{8}\right)\left(\frac{1}{\eta}\right)\left(\frac{r^4}{l}\right)$$

...where P is pressure, η is the viscosity of the fluid, *r* is the radius of the tube, and *l* is the length of the tube.

$$\text{Flow rate} = \frac{\Delta P}{R}$$

...and in this equation R stands for "resistance," which is a measure of resistance to flow. Increasing blood viscosity increases resistance. Conversely, decreasing radius of the blood vessel also increases resistance.

By what % does flow rate decrease if vessel radius decreases by 10%?

Sample EOC question:

The rate at which blood flows through the human body changes in response to many factors. Which statement describes one of these factors and its effect on blood flow?

A. The narrowing of blood vessels increases pressure and leads to faster blood flow.

B. High blood viscosity increases the resistance in the blood vessels and leads to slower blood flow.

C. Low blood pH decreases the rate of diffusion through the blood vessels and leads to slower blood flow.

D. The changing of the shape of red blood cells to a crescent shape decreases resistance and leads to faster blood flow.