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

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

• Every organism must exchange materials and energy with its environment, and this exchange ultimately occurs at the cellular level.
  • Cells live in aqueous environments.
  • The resources that they need, such as nutrients and oxygen, move across the plasma membrane to the cytoplasm.
  • Metabolic wastes, such as carbon dioxide, move out of the cell.
• Diffusion is insufficient over distances of more than a few millimeters, because the time it takes for a substance to diffuse to one place to another is proportional to the square of the distance.

• For example, if it takes 1 second for a given quantity of glucose to diffuse 100 microns, it will take 100 seconds for it to diffuse 1 mm and almost three hours to diffuse 1 cm.

• The circulatory system solves this problem by ensuring that no substance must diffuse very far to enter or leave a cell.
What if you were...
Or maybe a...
Or how about a…
Or, heaven forbid, a...
Or our favorite…
• What, exactly, is blood pressure?
• What might make it rise?
• How does this affect circulation?
• How would exercise affect circulation?
• Blood volume?
• Resistance?
• Add diseases like sickle cell and atherosclerosis to this list and you have all the factors the EOC promises to ask you about.

• THIS is the EOC list of topics.
A fish heart has two main chambers, one atrium and one ventricle.
Or maybe you are waiting for a kiss to turn you back into a prince…
• Frogs and other amphibians have a three-chambered heart with two atria and one ventricle.
Or, finally, one of these specimens...
• In crocodilians, birds, and mammals, the ventricle is completely divided into separate right and left chambers.

• In this arrangement, the left side of the heart receives and pumps only oxygen-rich blood, while the right side handles only oxygen-poor blood.

• Double circulation restores pressure to the systemic circuit and prevents mixing of oxygen-rich and oxygen-poor blood.

Fig. 42.3c
• What, exactly, is blood pressure?
• What might make it rise?
• How does this affect circulation?
• How would exercise affect circulation?
• Blood volume?
• Resistance?
• Add diseases like sickle cell and atherosclerosis to this list and you have all the factors the EOC promises to ask you about.
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Students will identify factors that affect blood flow and/or describe how these factors affect blood flow through the cardiovascular system.

**Content Limits** Items may address factors such as blood pressure, blood volume, resistance, disease, and exercise.
• Arteries, veins, and capillaries are the three main kinds of blood vessels.

• What’s the difference?

• Are there any more?
• Structural differences result in the different functions of arteries, veins, and capillaries.

• Note the muscle walls. What might they do?
• The thinner-walled veins convey blood back to the heart at low velocity and pressure.
  
• Blood flows mostly as a result of skeletal muscle contractions when we move that squeeze blood in veins.
  
• Within larger veins, flaps of tissues act as one-way valves that allow blood to flow only toward the heart.
• To trace the double circulation pattern of the mammalian cardiovascular system, we’ll start with the pulmonary (lung) circuit.

• The systemic circuit, most of your blood, comes Right In and goes Left Out.

• So watch here.
• A **cardiac cycle** is one complete sequence of the heart contracting and relaxing.

• The contraction phase is called **systole**, and the relaxation phase is called **diastole**.
Cardiac output depends on two factors: the rate of contraction or **heart rate** (number of beats per minute) and **stroke volume**, the amount of blood pumped by the left ventricle in each contraction.
The cardiac cycle is regulated by electrical impulses that radiate throughout the heart.

Cardiac muscle cells are electrically connected by intercalated disks between adjacent cells.
• A sphygmomanometer, an inflatable cuff attached to a pressure gauge, measures blood pressure fluctuations in the brachial artery of the arm over the cardiac cycle.

• The arterial blood pressure of a healthy human oscillates between about 120 mm Hg at systole and 70 mm Hg at diastole; thus a blood pressure # of 120/70.
• Blood pressure is determined partly by cardiac output and partly by peripheral resistance.
  
• Contraction of smooth muscles in walls of arterioles constricts these vessels, increasing peripheral resistance, and increasing blood pressure.
  
• Stress, both physical and emotional, can raise blood pressure by triggering nervous and hormonal responses that will constrict blood vessels.
• Cardiac output is adjusted in concert with changes in peripheral resistance.
  • For example, during heavy exercise the arterioles in the working muscles dilate, admitting a greater flow of oxygen-rich blood to the muscles and decreasing peripheral resistance.
  • At the same time, cardiac output increases, maintaining blood pressure and supporting the necessary increase in blood flow.
  • Pressure, resistance, exercise – all affect circulation.
10. Cardiovascular diseases are the leading cause of death in the U.S. and most other developed nations

- More than half the deaths in the United States are caused by cardiovascular diseases, diseases of the heart and blood vessels.

- The final blow is usually a heart attack or stroke.
  
  - A heart attack is the death of cardiac muscle tissue resulting from prolonged blockage of one or more coronary arteries, the vessels that supply oxygen-rich blood to the heart.

  - A stroke is the death of nervous tissue in the brain.
• The suddenness of a heart attack or stroke belies the fact that the arteries of most victims had become gradually impaired by a chronic cardiovascular disease known as **atherosclerosis**.

• Growths called plaques develop in the inner wall of the arteries, narrowing their bore, *decreasing circulation*.  

![Fig. 42.17](image)
• At plaque sites, the smooth muscle layer of an artery thickens abnormally and becomes infiltrated with fibrous connective tissue and lipids such as cholesterol.

• In some cases, plaques also become hardened by calcium deposits, leading to arteriosclerosis, commonly known as hardening of the arteries.

• The smaller and harder vessels INCREASE resistance and slow circulation – the heart has to work harder.
• **Hypertension** (high blood pressure) promotes atherosclerosis and increases the risk of heart disease and stroke.

• According to one hypothesis, high blood pressure causes chronic damage to the endothelium that lines arteries, promoting plaque formation.

• Pressure on these cells seems to cause them to respond in a way that will make them less easy to push – stick some stuff to your surface to make it less flexible.

• Hypertension is simple to diagnose and can usually be controlled by diet, exercise, medication, or a combination of these.
• To some extent, the tendency to develop hypertension and atherosclerosis is inherited.

• Nongenetic factors include smoking, lack of exercise, a diet rich in animal fat, and abnormally high levels of cholesterol in the blood.

• One measure of an individual’s cardiovascular health or risk of arterial plaques can be gauged by the ratio of low-density lipoproteins (LDLs) to high-density lipoproteins (HDLs) in the blood.

  • LDL is associated with depositing of cholesterol in arterial plaques. Watch 1:00 and Watch here. 2:00
  
  • HDL may reduce cholesterol deposition, as these transport cholesterol out of blood and into cells.
EOC notes regarding circulation

- The EOC may ask you about how the following affect blood flow:
  - Pressure
  - Volume
  - Resistance
  - Disease
  - Exercise
8. The lymphatic system returns fluid to the blood and aids in body defense

- Fluids and some blood proteins that leak from the capillaries into the interstitial fluid are returned to the blood via the **lymphatic system**.
• Lymph vessels, like veins, have valves that prevent the backflow of fluid toward the capillaries.
• Rhythmic contraction of the vessel walls help draw fluid into lymphatic capillaries.
• Also like veins, lymph vessels depend mainly on the movement of skeletal muscle to squeeze fluid toward the heart.
• Lymph has white cells in it but not red cells.
9. Blood is a connective tissue with cells suspended in plasma

- However, blood in the closed circulatory systems of vertebrates is a specialized connective tissue consisting of several kinds of cells suspended in a liquid matrix called plasma.
**Plasma 55%**

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Major functions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>Solvent for carrying other substances</td>
</tr>
<tr>
<td>Ions</td>
<td></td>
</tr>
<tr>
<td>Sodium</td>
<td></td>
</tr>
<tr>
<td>Potassium</td>
<td></td>
</tr>
<tr>
<td>Calcium</td>
<td></td>
</tr>
<tr>
<td>Magnesium</td>
<td></td>
</tr>
<tr>
<td>Chloride</td>
<td></td>
</tr>
<tr>
<td>Bicarbonate</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Plasma proteins</td>
<td></td>
</tr>
<tr>
<td>Albumin</td>
<td></td>
</tr>
<tr>
<td>Fibrinogen</td>
<td></td>
</tr>
<tr>
<td>Immunoglobulins (antibodies)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Substances transported by blood</td>
<td></td>
</tr>
<tr>
<td>Nutrients (e.g., glucose, fatty acids, vitamins)</td>
<td></td>
</tr>
<tr>
<td>Waste products of metabolism</td>
<td></td>
</tr>
<tr>
<td>Respiratory gases (O_2 and CO_2)</td>
<td></td>
</tr>
<tr>
<td>Hormones</td>
<td></td>
</tr>
</tbody>
</table>

**Cellular elements 45%**

<table>
<thead>
<tr>
<th>Cell type</th>
<th>Number (per mm(^3) of blood)</th>
<th>Functions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Erythrocytes (red blood cells)</td>
<td>5–6 million</td>
<td>Transport oxygen and help transport carbon dioxide</td>
</tr>
<tr>
<td>Leukocytes (white blood cells)</td>
<td>5000–10,000</td>
<td>Defense and immunity</td>
</tr>
<tr>
<td>Basophil</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eosinophil</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Neutrophil</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lymphocyte</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Monocyte</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Platelets</td>
<td>250,000–400,000</td>
<td>Blood clotting</td>
</tr>
</tbody>
</table>

Fig. 42.14
Suspended in blood plasma are two classes of cells: **red blood cells** which transport oxygen, and **white blood cells**, which function in defense.

A third cellular element, **platelets**, are pieces of cells that are involved in clotting.

Red blood cells, or **erythrocytes**, are by far the most numerous blood cells.
• Mammalian erythrocytes lack nuclei, an unusual characteristic that leaves more space in the tiny cells for **hemoglobin**, the iron-containing protein that transports oxygen.

• Red blood cells also lack mitochondria and generate their ATP exclusively by anaerobic metabolism.
• Erythrocytes, leukocytes, and platelets all develop from a single population of cells, pluripotent stem cells, in the red marrow of bones, particularly the ribs, vertebrae, breastbone, and pelvis.

• “Pluripotent” means that these cells have the potential to differentiate into any type of blood cells or cells that produce platelets.

• This population renews itself (by mitosis) while replenishing the blood with cellular elements.
Fig. 42.13

- Lymphoid stem cells
- Pluripotent stem cells (in bone marrow)
- Myeloid stem cells
  - Erythrocytes
  - Platelets
  - B cells
  - T cells
  - Lymphocytes
  - Monocytes
  - Neutrophils
  - Basophils
  - Eosinophils
• Blood contains a self-sealing material that plugs leaks from cuts and scrapes.

• A clot forms when the inactive form of the plasma protein **fibrinogen** is converted to **fibrin**, which aggregates into threads that form the framework of the clot.

• The clotting mechanism begins with the release of **clotting factors** from platelets.

• An inherited defect in any step of the clotting process causes **hemophilia**, a disease characterized by excessive bleeding from even minor cuts and bruises.

• Remember Queen Victoria, Rasputin, sex-linked recessive, etc.?
1. Injury to lining of blood vessel exposes connective tissue; platelets adhere

2. Platelet plug forms

3. Fibrin clot with trapped cells

Collagen fibers

Platelet releases chemicals that make nearby platelets sticky

Platelet plug

Clotting factors from:
- Platelets
- Damaged cells
- Plasma (factors include calcium, vitamin K)

Prothrombin → Thrombin

Fibrinogen → Fibrin

Fibrin
Which of these transport blood from the heart to the rest of the body?

A. Veins
B. Arteries
C. Capillaries
D. Bronchial tubes
Many factors affect blood flow throughout the body, including stress, exercise, and the buildup of plaque in the blood vessels. Which statement best describes how the buildup of plaque in blood vessels affects the body?

A. It widens blood vessels, causing a decrease in heart rate and depriving issues of the blood they need.

B. It narrows blood vessels, causing a decrease in heart rate and depriving some cells of the nutrients and oxygen they need.

C. It narrows blood vessels, causing the heart to work harder to move enough blood to cells that are in need of nutrients and oxygen.

D. It widens blood vessels, causing the heart to beat rapidly and exert a strong force on the walls of the blood vessels.
A doctor determines that a patient has low blood flow. Which of the following can reduce the flow of blood through the cardiovascular system?

A. A buildup of plaque inside the blood vessels  
B. An increase in heart rate due to exercise  
C. A thinning of the blood due to medication  
D. A feeling of stress due to danger or excitement
Which of the following can interfere with blood flow throughout the body?

A. Moderate exercise
B. Reduction in heart rate
C. The narrowing of blood vessels
D. Normal blood cholesterol levels