Lecture 11 - Circulatory System

Introduction

The circulatory system consists of blood, a heart, and blood vessels.

Functions of the Circulatory System

The circulatory system functions with other body systems to provide the following:

Transport of materials:

Gasses transported: Oxygen is transported from the lungs to the cells. CO_2 (a waste) is transported from the cells to the lungs.

Transport other nutrients to cells - For example, glucose, a simple sugar used to produce ATP, is transported throughout the body by the circulatory system. Immediately after digestion, glucose is transported to the liver. The liver maintains a constant level of glucose in the blood.

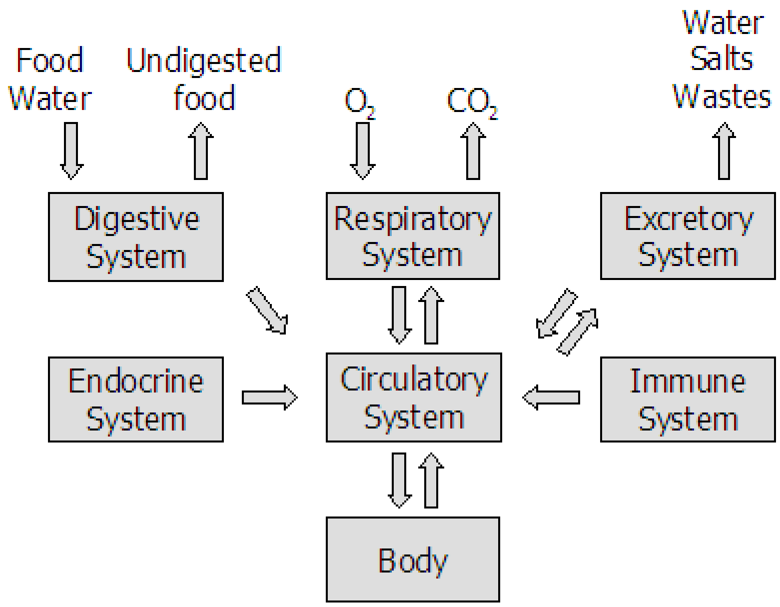
Transport other wastes from cells - For example, ammonia is produced as a result of protein digestion. It is transported to the liver where it is converted to less toxic urea. Urea is then transported to the kidneys for excretion in the urine.

Transport hormones - Numerous hormones that help maintain constant internal conditions are transported by the circulatory system.

Contains cells that fight infection

Helps stabilize the pH and ionic concentration of the body fluids.

It helps maintain body temperature by transporting heat. This is particularly important in homeothermic animals such as birds and mammals.



Large Animals

Small animals may not need a circulatory system because the interior cells are close to the surface. Oxygen absorbed from the environment by surface cells can diffuse to interior cells. Wastes produced by interior cells move a short distance to the surface and diffuse into the environment.

Most invertebrates and all vertebrates have interior cells that are too far from the body surface to exchange substances efficiently. They require a circulatory system.

A circulatory system is not needed in small, flat, or porous animals because they have a high ***surface-to-volume ratio*** and can obtain sufficient absorption directly through their skin.

Open Circulatory System

In an open circulatory system, blood is pumped from the heart through blood vessels but then it leaves the blood vessels and enters body cavities, where the organs are bathed in blood, or sinuses (spaces) within the organs.

Blood flows slowly in an open circulatory system because there is no blood pressure after the blood leaves the blood vessels. The animal must move its muscles to move the blood within the spaces.

In a closed system, blood remains within blood vessels, pressure is high, and blood is therefore pumped faster.

Arthropods and most mollusks (except cephalopods: nautilus, squid, octopus) have an open circulatory system.

Insects

The coelom of insects has been reduced to a cavity that carries blood (hemolymph). It is called a hemocoel..

dorsal heart → aorta → hemocoel

Ostia (openings in the heart) close when heart contracts. When heart relaxes, the ostia open and blood is sucked into openings.

The blood of insects is colorless because it lacks ***respiratory pigments***; it functions to carry nutrients, not gases.

Animals with open circulatory systems generally have limited activity due to limitations in the oxygen delivery capability of the system. Insects are able to be active because gas exchange is via a tracheal system.

Closed Circulatory System

In a closed circulatory system, blood is not free in a cavity; it is contained within blood vessels. Valves prevent the backflow of blood within the blood vessels.

This type of circulatory system is found in vertebrates and several invertebrates including annelids, squids and octopuses.

The blood of animals with a closed circulatory system usually contains cells and plasma (liquid). The blood cells of vertebrates contain hemoglobin.

Earthworms

Earthworms have a dorsal and ventral blood vessel that runs the length of the animal. Branches from these vessels are found in each segment.

There are five vessels that pump blood from the dorsal vessel to the ventral vessel.

Earthworms have red blood (due to the pigment hemoglobin) but they have no cells. Hemoglobin binds with oxygen to carry it to the tissues.

Blood Vessels

heart → arteries → arterioles → capillaries → venules → veins → heart

Arteries

Arteries carry blood away from heart.

Arteries have a thick, elastic layer to allow stretching and absorb pressure. The wall stretches and recoils in response to pumping, thus peaks in pressure are absorbed.

The arteries maintain pressure in the circulatory system much like a balloon maintains pressure on the air within it. The arteries therefore act as pressure reservoirs by maintaining (storing) pressure.

The elastic layer is surrounded by circular muscle to control the diameter and thus the rate of blood flow. An outer layer of connective tissue provides strength.

Arterioles

Smooth muscle surrounding the arteries and arterioles controls the distribution of blood. For example, blood vessels dilate when O_2 levels decrease or wastes accumulate. This allows more blood into an area to bring oxygen and nutrients or remove wastes.

Capillaries

The smallest blood vessels are capillaries. They are typically less than 1 mm long. The diameter is so small that red blood cells travel single file.

The total length of capillaries on one person is over 50,000 miles. This would go around the earth twice.

Not all of the capillary beds are open at one time because all of them would hold 1.4 times the total blood volume of the all the blood in the body. ***Vasodilation*** and ***vasoconstriction*** refer to the dilation and constriction of blood vessels. The diameter is controlled by neural and endocrine controls. Sphincter muscles control the flow of blood to the capillaries.

The total cross-sectional area of the capillaries is greater than that of the arteries or veins, so the rate of blood flow (velocity) is lowest in the capillaries. Blood pressure is highest in the arteries but is considerably reduced as it flows through the capillaries. It is lowest in the veins.

Interstitial fluid

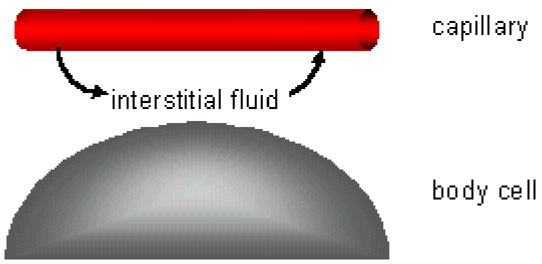
The exchange of substances between blood and the body cells occurs in the capillaries. Capillaries are specialized for exchange of substances with the *interstitial fluid*. No cell in the body is more than 100 micrometers from a capillary. This is the thickness of four sheets of paper.

Interstitial fluid surrounds and bathes the cells. This fluid is continually being replaced by fresh fluid from blood in the circulatory system.

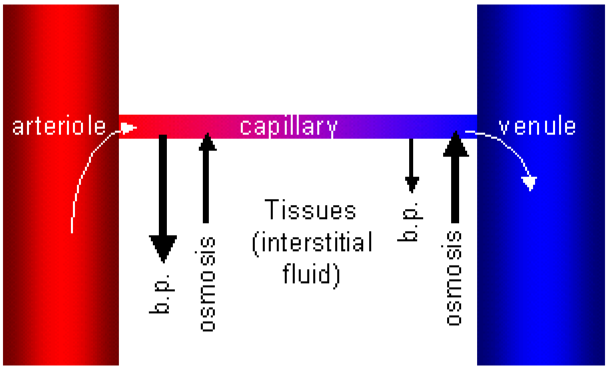
Body cells take up nutrients from the interstitial fluid and empty wastes into it.

By maintaining a constant pH and ionic concentration of the blood, the pH and ionic concentration of the interstitial fluid is also stabilized.

Although fluid leaves and returns to the capillaries, blood cells and large proteins remain in the capillaries.



At the arterial end of capillaries (the left side of the diagram below), blood pressure forces fluid out and into the surrounding tissues. As blood moves through the capillary, the blood pressure decreases so that near the veinule end, less is leaking into the surrounding tissues.



As blood flows through the capillary and fluid moves out, the blood that remains behind becomes more concentrated. The osmotic pressure in the capillary is therefore greater near the veinule end and results in an increase in the amount of fluid moving into the capillary near this end.

The arrows on the diagram above represent the movement of blood into and out of the capillary. Long and thick arrows are used to represent a large amount of fluid movement. The total amount of movement out of the capillary is approximately equal to the amount of movement into the capillary. Notice that more blood tends to leave the capillary near the arteriole end and more tends to enter it near the veinule end.

The lymphatic capillaries collect excess fluid in the tissues.

Venules

Capillaries merge to form venules and venules merge into veins.

Venules can constrict due to the contraction of smooth muscle. When they are constricted there is more fluid loss in the capillaries due to increased pressure.

Veins

The diameter of veins is greater than that of arteries.

The blood pressure in the veins is low so valves in veins help prevent backflow.

The contraction of skeletal muscle squeezes the veins and assists with moving blood back to the heart.

The vena cava returns blood to the right atrium of the heart from the body. In the right atrium, the blood pressure is close to 0.

Varicose veins develop when the valves weaken.

Veins act as blood reservoirs because they contain 50% to 60% of the blood volume.

Smooth muscle in the walls of veins can expand or contract to adjust the flow volume returning to the heart and make more blood available when needed.

Portal Veins

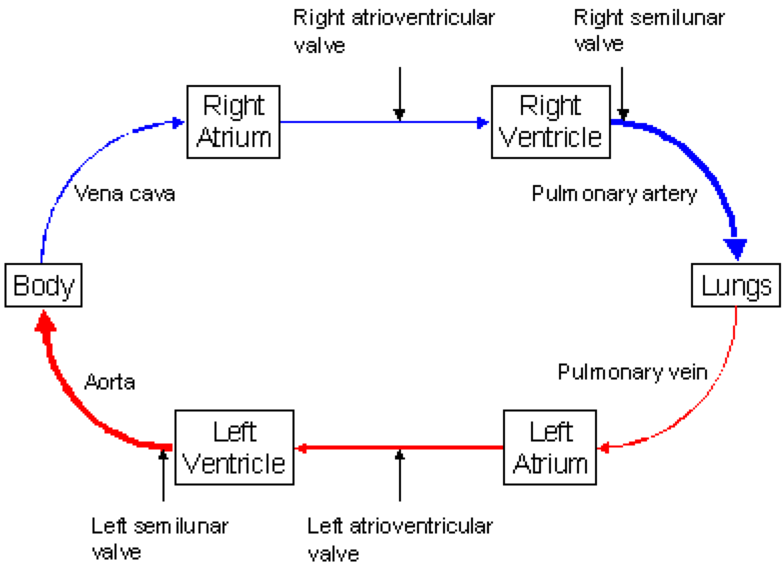
Portal veins connect one capillary bed with another.

The hepatic portal vein connects capillary beds in the digestive tract with capillary beds in the liver.

<u>Human Circulation</u>

Chambers of the heart

The heart is actually two separate pumps. The left side pumps blood to the body (systemic circulation) and the right side pumps blood to the lungs (pulmonary circulation). Each side has an atrium and a ventricle. See the diagram below



The atria function to receive blood when they are relaxed and to fill the ventricles when they contract.

The ventricles function to pump blood to the body (left ventricle) or to the lungs (right ventricle).

Valves

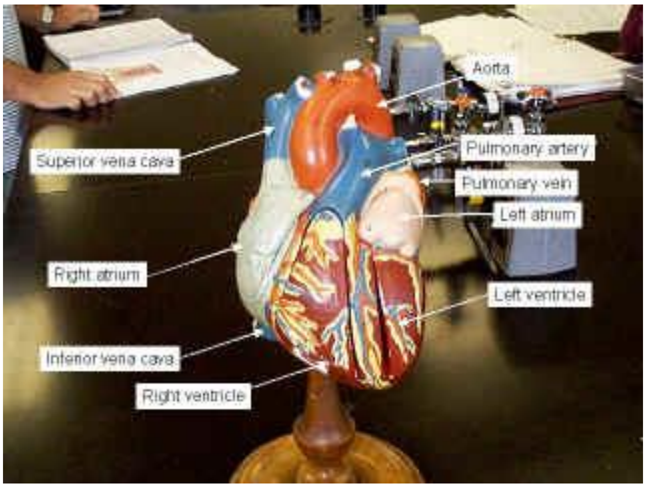
Valves allow blood to flow through in one direction but not the other. They prevent backflow.

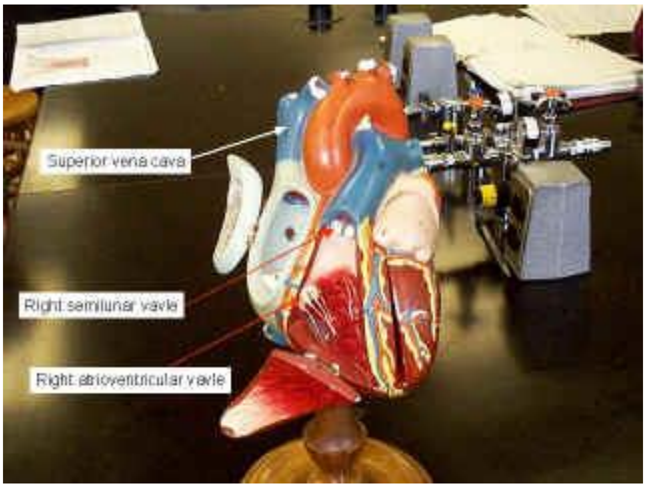
Atrioventricular* valves** (diagram above) are located between the atria and the ventricles. They are held in place by fibers called ***chordae tendinae. The left atrioventricular valve is often called the bicuspid or mitral valve; the right one is also called the tricuspid valve.

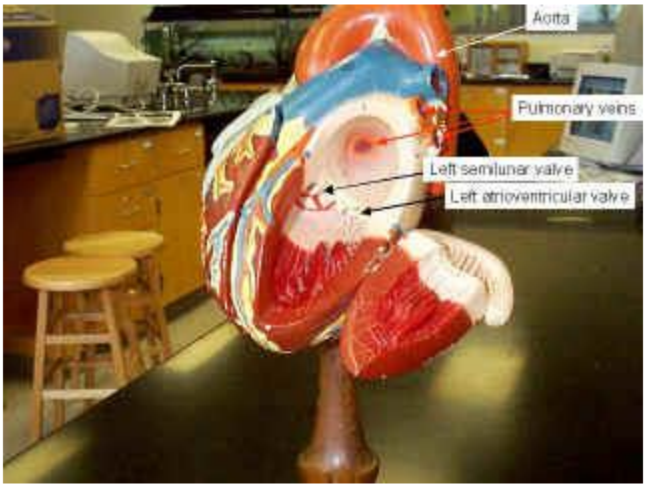
The ***semilunar valves*** (diagram above) are between the ventricles and the attached vessels.

The heartbeat sound is produced by the valves closing.

Below: The structure of the mammalian heart is summarized using a model.




Superior vena cava
Right semilunar vavle
Right atrioventricular vavle


Aorta
Pulmonary veins
Left semilunar valve
Left atrioventricular valve