Circulation and Gas Exchange

Doç. Dr. M. Borga Ergönül

Exchange with the surroundings

- The exchange of substances between an animal and its surrounding ultimately occurs at the cellular level. The resources that an animal cell requires, such as nutrients and oxygen (O2), enter the cytoplasm by crossing the plasma membrane. Metabolic by-products, such as carbon dioxide (CO2), exit the cell by crossing the same membrane.

Doç. Dr. M. Borga Ergönül

In unicellular organisms, exchange occurs directly with the external environment. For most multicellular organisms, however, direct transfer of materials between every cell and the environment is **not** possible. Instead, these organisms rely on special systems that carry out exchange with the environment and transport materials to rest of the body. For example; gills are specialized exchange system in many aquatic animals.

Doç. Dr. M. Borga Ergönül

Internal transport and gas exchange are functionally related in most animals.

Material exchange

Small molecules, including O2 and CO2, can move between cells and their immediate surroundings by diffusion. When there is a concentration gradient, diffusion can result in net movement. But such movement is very slow for distances of more than a few millimeters. That's because the time it takes for a substance to diffuse from one place to another is proportional to the *square* of the distance. For example, a quantity of glucose that takes 1 second to diffuse 100 µm will take 100 seconds to diffuse 1000 µm.

Doç. Dr. M. Borga Ergonul

In multicellular animals (except Cnidaria and Platyhelminthes) an internal transport system is needed to move fluid between each cell's immediate surroundings and the body tissues.

Open and Closed Circulatory Systems

- More complex animals have either open or closed circulatory systems.
- Both systems have three basic components:
  - A circulatory fluid = blood or hemolymph.
  - A set of tubes = blood vessels.
  - A muscular pump = the heart.

Doç. Dr. M. Borga Ergönül

- In insects, other arthropods, and most molluscs, blood bathes the organs directly in an open circulatory system.
- In an open circulatory system, there is no distinction between blood and interstitial fluid, and this general body fluid is more correctly called hemolymph.
- Heart contraction pumps the hemolymph through the circulatory vessels into interconnected sinuses, spaces surrounding the organs. Within the sinuses, chemical exchange occurs between the hemolymph and body cells. Relaxation of the heart draws hemolymph back in through pores, which are equipped with valves that close when the heart contracts. Body movements periodically squeeze the sinuses, helping circulate the hemolymph.

Doç. Dr. M. Borga Ergonul

- In a closed circulatory system, the blood is confined to vessels and is distinct from the interstitial fluid. One or more hearts pump blood into large vessels that branch into smaller ones that infiltrate the organs. Chemical exchange occurs between the blood and the interstitial fluid, as well as between the interstitial fluid and body cells.
- Closed systems are more efficient at transporting circulatory fluids to tissues and cells. (annelids, cephalopods and vertebrates)

Doç. Dr. M. Borga Ergönül

Vertebrate Closed Circulatory System

- Humans and other vertebrates have a closed circulatory system, often called the cardiovascular system.
- Blood circulates to and from the heart through an amazingly extensive network of vessels. The three main types of blood vessels are:

  arteries - away from the heart.

  veins - toward the heart.

  capillaries - exchange with body cells.

Doç. Dr. M. Borga Ergönül

Double Circulation

- Amphibian, reptiles, mammals and birds have **double circulation.**
- Oxygen-poor (right) and oxygen-rich (left) blood are pumped separately from the right and left sides of the heart.

Doç. Dr. M. Borga Ergönül

- In animals with double circulation, the pumps for the two circuits are combined into a single organ, the heart. Having both pumps within a single heart simplifies coordination of the pumping cycles.
- One pump, the right side of the heart, delivers oxygen-poor blood to the lungs. This part of the circulation is called a ***pulmonary circuit*** if the capillary beds involved are all in the lungs, as in reptiles and mammals. It is called a *pulmocutaneous circuit* if it includes capillaries in both the lungs and the **skin**, as in many amphibians .

Doç. Dr. M. Borga Ergönül

After the O2-enriched blood leaves the gas exchange tissues, it enters the other pump, the left side of the heart. Contraction of the heart propels this blood to capillary beds in organs and tissues in the body. Following the exchange of O2 and CO2, as well as nutrients and waste products, the oxygen-poor blood returns to the heart, completing the **systemic circuit**.

Doç. Dr. M. Borga Ergönül

Double circulation maintains higher blood pressure in the organs than does single circulation.

Amphibians:

- Frogs / amphibians have a three-chambered heart: 2 atria and 1 ventricle.
- The ventricle pumps blood into a forked artery that splits the ventricle's output into the pulmocutaneous circuit and the systemic circuit.
- Underwater, blood flow to the lungs is nearly shut off.

Doç. Dr. M. Borga Ergönül

Reptiles (Except Birds)

- Reptiles also have double circulation, with a pulmonary circuit - lungs and a systemic circuit.
- Turtles, snakes, and lizards have a three-chambered heart: two atria and one ventricle.
- In alligators, caimans, and other crocodilians a septum - partially or fully divides the ventricle.

Doç. Dr. M. Borga Ergönül

- Blood begins its flow with the right ventricle pumping blood to the lungs. In the lungs, the blood loads O_2 and unloads CO_2.
- Oxygen-rich blood from the lungs enters the heart at the left atrium and is pumped through the **aorta** to the body tissues by the left ventricle. The aorta also provides blood to the heart through the coronary arteries.

Door Dr. Ali Borga Erdönül

Blood returns to the heart through the superior **vena cava** (deoxygenated blood from head, neck, and forelimbs) and inferior vena cava (deoxygenated blood from trunk and hind limbs). The superior vena cava and inferior vena cava flow **into** the Right Atrium.

Doç. Dr. M. Borga Ergönül

Blood Pressure

Blood pressure is a hydrostatic pressure that blood exerts against the wall of a vessel.

In rigid vessels blood pressure is maintained; less rigid vessels deform and blood pressure is lost. A **pulse** is the rhythmic bulging of artery walls with each heartbeat.

Doç. Dr. M. Borga Ergönül

Capillary Function

- Capillaries in major organs are usually filled to capacity. However, blood supply in many other sites may change.
- Two mechanisms regulate distribution of blood in capillary beds:
  - *Contraction of the smooth muscle* layer in the wall of an *arteriole* constricts the vessel.
  - *Precapillary sphincters* control flow of blood between arterioles and venules.

Doç. Dr. M. Borga Ergönül

- The critical *exchange of substances between the blood and interstitial fluid* takes place across the thin endothelial walls of the *capillaries*.
- The *difference between blood pressure and osmotic pressure* drives fluids out of capillaries at the arteriole end and into capillaries at the venule end.

Doç. Dr. M. Borga Ergönül