Circulation and Gas Exchange
Chapter 42

Circulatory systems link exchange surfaces with cells throughout the body
- Diffusion is only efficient over small distances
- In small and/or thin animals, cells can exchange materials directly with the surrounding medium
- Cells exchange materials with the environment via a fluid-filled circulatory system in most animals

Gastrovascular cavities
- Digest and distribute substances
- Can have large surface area to volume ratio

Circulatory systems minimize diffusion distances
- A circulatory system has
  - A circulatory fluid
  - A set of interconnecting vessels
  - A muscular pump
- Connects the fluid that surrounds cells with the organs that exchange gases, absorb nutrients, and dispose of wastes

Open circulatory systems
- Blood bathes the organs directly
  - General body fluid is called hemolymph
- Insects, other arthropods, and most molluscs,

Closed circulatory systems
- Blood is confined to vessels and is distinct from the interstitial fluid
- Annelids, cephalopods, and vertebrates
Vertebrate circulatory systems

- Closed circulatory system called the cardiovascular system.
- The three main types of blood vessels are arteries, veins, and capillaries.
- Arteries branch into arterioles and carry blood away from the heart to capillaries.
- Capillary beds are the sites of chemical exchange between the blood and interstitial fluid.
- Venules converge into veins and return blood from capillaries to the heart.

Single Circulation

- Bony fishes, rays, and sharks have single circulation with a two-chambered heart.
- In single circulation, blood leaving the heart passes through two capillary beds before returning.

Double circulation

- Oxygen-poor and oxygen-rich blood are pumped separately.
- Amphibians have a three-chambered heart.
- When underwater, blood flow to the lungs is shut off.

Double Circulation

- Mammals and birds have a four-chambered heart.
- The left side of the heart pumps and receives only oxygen-rich blood, while the right side receives and pumps only oxygen-poor blood.
- Endotherms require more oxygen.

Cardiac cycle

- The contraction, or pumping, phase is called systole.
- The relaxation, or filling, phase is called diastole.
- The heart rate is the number of beats per minute.
- The stroke volume is the amount of blood pumped in a single contraction.
- The cardiac output is the volume of blood pumped into the systemic circulation per minute and depends on both the heart rate and stroke volume.
- Four valves prevent backflow of blood in the heart.

- Velocity slowest at capillaries
- Blood flows from areas of higher pressure to areas of lower pressure.
Gas exchange occurs across specialized respiratory surfaces
- A gas diffuses from a region of higher partial pressure to a region of lower partial pressure
- Gases diffuse down pressure gradients in the lungs and other organs as a result of differences in partial pressure

Respiratory media and surfaces
- Animals require large, moist respiratory surfaces for exchange of gases between their cells and the respiratory medium, either air or water
  - Less oxygen in water than in air
- Gas exchange across respiratory surfaces takes place by diffusion
- Respiratory surfaces include the outer surface, skin, gills, tracheae, and lungs
Gills in aquatic animals

- Gills are outfoldings of the body that create a large surface area for gas exchange.

Tracheal systems in insects

- Supply O₂ directly to body cells.
- Larger insects must ventilate their tracheal system to meet O₂ demands.

Mammalian lungs

- Gas exchange takes place in alveoli, air sacs at the tips of bronchioles.
- Gases diffuse through the moist film of the epithelium and capillaries.
- Alveoli lack cilia and are susceptible to contamination.
- Secretions called surfactants coat the surface of the alveoli.

Breathing ventilates the lungs

- The process that ventilates the lungs is breathing, the alternate inhalation and exhalation of air.
- An amphibian such as a frog ventilates its lungs by positive pressure breathing, which forces air down the trachea.
• Birds have multiple air sacs that keep air flowing through the lungs
• Air passes through the lungs in one direction only

Mammals ventilate their lungs by negative pressure breathing, which pulls air into the lungs
• Lung volume increases as the rib muscles and diaphragm contract

Respiratory Pigments
• Respiratory pigments, proteins that transport oxygen, greatly increase the amount of oxygen that blood can carry
• Arthropods and many mollusks have hemocyanin with copper as the oxygen-binding component
• Most vertebrates and some invertebrates use hemoglobin
• In vertebrates, hemoglobin is contained within erythrocytes

Respiratory adaptations of diving mammals
• Have a high blood to body volume ratio
• Stockpile O₂ and deplete it slowly
• Diving mammals can store oxygen in their muscles in myoglobin proteins
• Diving mammals also conserve oxygen by
  ▪ Changing their buoyancy to glide passively
  ▪ Decreasing blood supply to muscles
  ▪ Deriving ATP in muscles from fermentation once oxygen is depleted