

## The Circulatory System

### Chapter 42

---

---

---

---

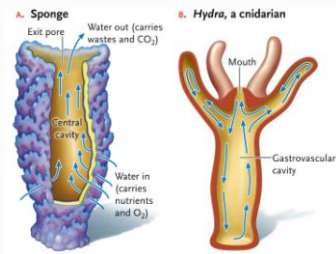
---

---

---

### Invertebrates with No Circulatory Systems

- Simple invertebrates: sponges, cnidarians, and flatworms




---

---

---

---

---

---

---

### Animal Circulatory Systems

- Muscular **heart** pumps specialized fluid (such as **blood**) through tubular **vessels**
- Blood** (in closed systems)
  - Carries O<sub>2</sub> and nutrients to body tissues
  - Carries away CO<sub>2</sub> and wastes

---

---

---

---

---

---

---

## Open and Closed Circulatory Systems

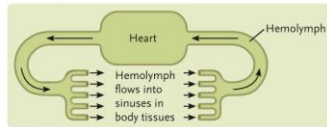
### Open circulatory system

- In most invertebrates
- Heart pumps **hemolymph** into vessels that empty into body spaces (**sinuses**) before returning to the heart

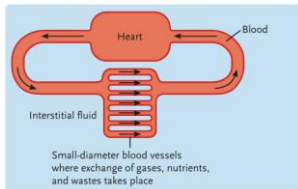
### Closed circulatory system

- In some invertebrates and all vertebrates
- **Blood** is confined in blood vessels throughout the body (**does not mix with interstitial fluid**)

a. Open circulatory system: no distinction between hemolymph and interstitial fluid



b. Closed circulatory system: blood separated from interstitial fluid



## Circulatory Systems

### Invertebrates

- **Open circulatory systems** occur in arthropods and most mollusks
- **Closed circulatory systems** occur in annelids and in mollusks such as squids and octopuses

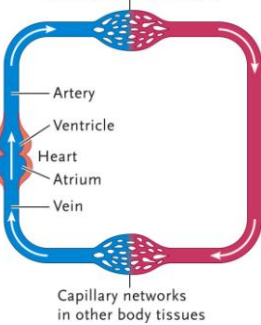
### Vertebrates

- **Closed systems** evolved from a heart with a single blood circuit (**single circulation**) to a "double" heart that pumps blood through separate **pulmonary** and **systemic circuits** (**double circulation**)

### A. Circulatory system of fishes



Capillary networks of gills



In fishes, the heart consists of a series of two chambers and pumps blood into one circuit. The ventricle pumps blood into arteries that lead to the capillary networks of the gills, where the blood releases  $\text{CO}_2$  and picks up  $\text{O}_2$ . The oxygenated blood flows through other arteries to capillary networks in other body tissues where it releases  $\text{O}_2$  and picks up  $\text{CO}_2$ . The deoxygenated blood enters veins that carry it to the atrium of the heart.

---

---

---

---

---

---

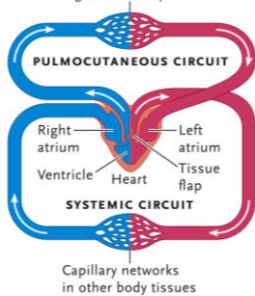
---

---

### B. Circulatory system of amphibians



Lung and skin capillaries



In amphibians, the three-chambered heart pumps blood through two circuits. Oxygenated blood from the lungs and skin enters veins that lead to the left atrium, while deoxygenated blood from the rest of the body enters the right atrium. The atria contract simultaneously, pumping oxygenated and deoxygenated blood in the single ventricle. The two types of blood remain largely (90%) separate because of a smooth pattern of flow and a small tissue flap. Contraction of the ventricle moves most of the oxygenated blood into the systemic circuit, which delivers blood to most tissues and cells of the body. Deoxygenated blood moves into the pulmocutaneous circuit, which leads to the lungs and skin where  $\text{CO}_2$  is released and  $\text{O}_2$  is picked up.

---

---

---

---

---

---

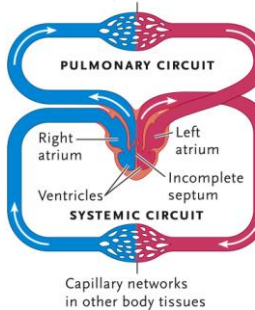
---

---

### C. Circulatory system of turtles, lizards, and snakes



Lung capillaries



In turtles, lizards, and snakes, an incomplete septum improves the separation of oxygenated blood from the lungs and deoxygenated blood from the rest of the body in the single ventricle.

---

---

---

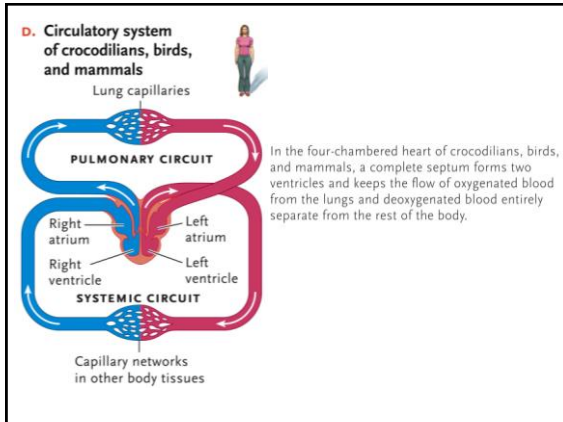
---

---

---

---

---




---

---

---

---

---

---

---

---

## Mammalian Blood

- A fluid connective tissue
  - Blood cells ([erythrocytes](#), [leukocytes](#), [platelets](#))
  - Suspended in a fluid matrix ([plasma](#))

---

---

---

---

---

---

---

---

## Plasma and Plasma Proteins

- Contains water, ions, dissolved gases ( $O_2$  and  $CO_2$ ), glucose, amino acids, lipids, vitamins, hormones, and [plasma proteins](#)
- [Plasma proteins](#)
  - [Albumins](#) (transport, osmotic balance, pH)
  - [Globulins](#) (transport, immunoglobulins)
  - [Fibrinogen](#) (blood clotting)

---

---

---

---

---

---

---

---

## Blood Cells

- **Erythrocytes**
  - Contain **hemoglobin** (transports  $O_2$  from lungs to body)
- **Leukocytes**
  - Defend body against infecting pathogens
- **Platelets**
  - Functional cell fragments that trigger clotting

---

---

---

---

---

---

---

---




---

---

---

---

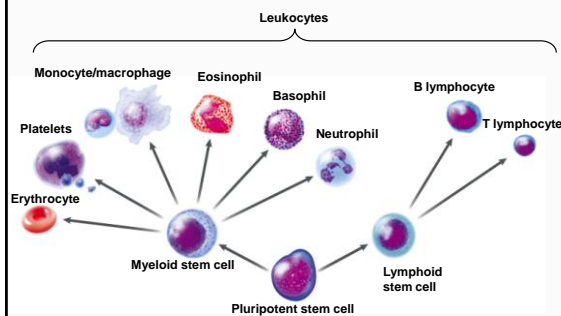
---

---

---

---

## Origins of Mammalian Cellular Components




---

---

---

---

---

---

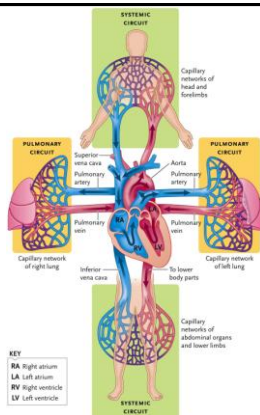
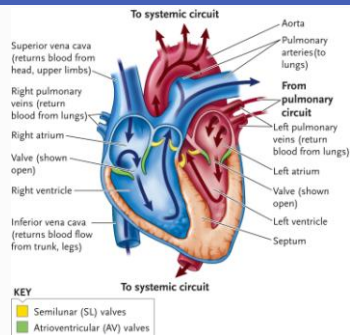
---

---

## The Mammalian Heart

- **A four-chambered pump**
  - Two **atria** at top of heart
  - Two **ventricles** at bottom of heart
  - **Atrioventricular (AV) valves** between atria and ventricles
    - **Tricuspid** and **bicuspid**
  - **Semilunar (SL) valves** between ventricles and aorta / pulmonary arteries
- Blood is pumped into **two separate circuits**
  - **Pulmonary circuit** (right heart)
  - **Systemic circuit** (left heart)

## The Human Heart



## The Cardiac Cycle

- **Systolic pressure** (systole)
  - Contraction of ventricles pushes blood into arteries at peak pressure
- **Diastolic pressure** (diastole)
  - Between contractions, blood pressure in arteries falls to a minimum pressure
- **Systole–diastole** sequence is the **cardiac cycle**

---

---

---

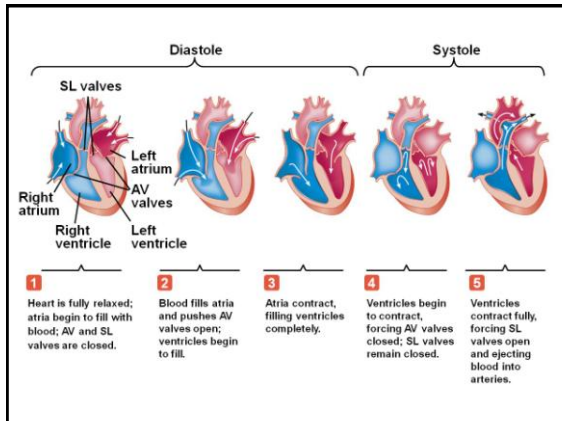
---

---

---

---

---




---

---

---

---

---

---

---

---

## Mammalian Cardiac Cycle

- Contraction of atria is initiated by signals from the **sinoatrial (SA) node** (**pacemaker cells**)
- Contraction of ventricles follows, through excitation of **atrioventricular (AV) node**
  - Via **Purkinje fibers**
- **Electrocardiogram (ECG/EKG)**
  - **SEE TEXT FOR AN EXAMPLE!**

---

---

---

---

---

---

---

---

## Blood Vessels of the Circulatory System

- Blood leaves the heart in large **arteries**
  - Branch into smaller **arterioles**
- **Arterioles** deliver blood to **capillary networks**
  - **Capillaries** exchange substances between blood and interstitial fluid
- Small **venules** collect blood from capillaries
  - Join into larger **veins** that return blood to heart

---

---

---

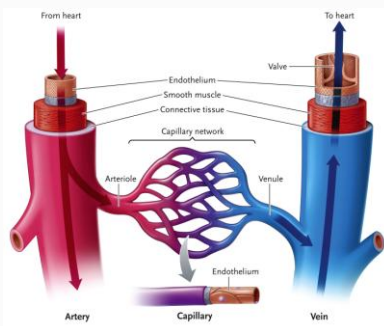
---

---

---

---

## Blood Vessel Structure




---

---

---

---

---

---

---

## Arteries

- Artery walls
  - Inner endothelial layer
  - Middle layer of smooth muscle
  - Outer layer of elastic fibers
- Arterioles (smallest arteries) constrict and dilate
  - Regulate flow and pressure of blood into capillaries

---

---

---

---

---

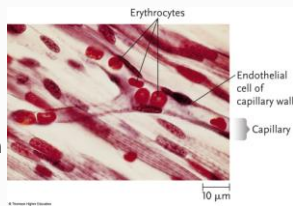
---

---

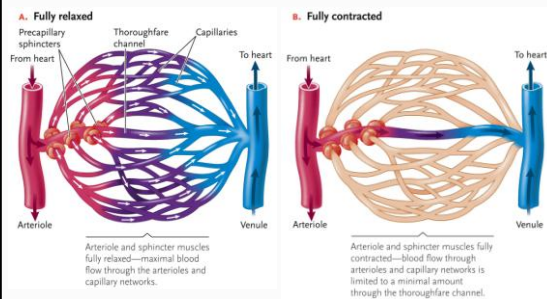


## Capillaries

- Capillary walls
  - Single layer of endothelial cells
- Variation in contraction of smooth muscles of arterioles and **precapillary sphincters** controls blood flow through capillaries



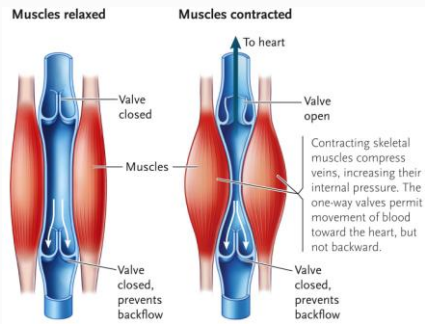
## Control of Blood Flow in Capillary Networks



## Veins

- Veins have thinner walls than arteries
  - Allows vessels to expand and contract
  - Veins act as blood reservoirs as well as conduits
- Pressure from movements of skeletal muscles and respiration help return blood to heart
- One-way valves** prevent blood from flowing backward

## Valves in Veins




---

---

---

---

---

---

---

---

## Maintaining Blood Flow and Pressure

- Regulated by controlling
  - Cardiac output ( $HR \times SV$ )
  - Degree of constriction of blood vessels (arterioles)
  - Total blood volume
- **Autonomic nervous system** and **endocrine system** interact to coordinate these mechanisms

---

---

---

---

---

---

---

---

## The Lymphatic System

- Extensive network of vessels
  - Collects excess interstitial fluid (becomes *lymph*)
  - Returns it to the venous blood
- AND a key component of the immune system

---

---

---

---

---

---

---

---

## Tissues and Organs of the Lymphatic System

- Lymph nodes, spleen, thymus, tonsils
- Remove viruses, bacteria, damaged cells, and cellular debris from lymph and bloodstream
- Defend the body against infection and cancer

---

---

---

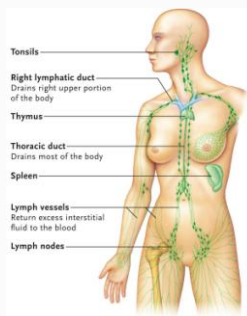
---

---

---

---

## The Lymphatic System



---

---

---

---

---

---

---