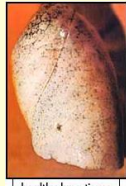




Salmon gill



healthy lung tissue



lung with emphysema

## Circulation and gas exchange

Diffusion with some help

## Overview

- Diffusion, by itself, is unable to transport essential substances throughout a “large” body
- Therefore, a circulation system is essential
- Movement of oxygen and carbon dioxide throughout bodies (**circulatory system**) plus their movement in and out of cells (**respiratory system**) are tightly connected processes essential to life

## Overview of circulatory systems

- Three components:
  - Circulatory fluid = **blood**
  - Tubes = **blood vessels**
  - Muscular pump = **heart**
- Pressure produced by the heart moves blood through vessels down a pressure gradient, and the blood eventually returns to the heart
- Two types of circulatory systems
  - **Open**
  - **Closed**

## Open circulatory system

- Arthropods and most mollusks
- Blood and interstitial fluid are not separated; form **hemolymph**
- Hemolymph pumped through **sinuses** (spaces around organs) and returned via pores

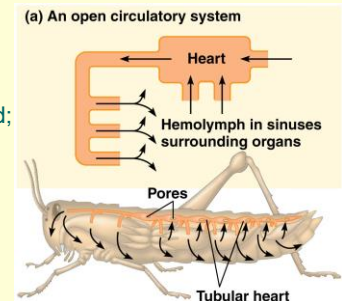


Fig. 42.3a

## Closed circulatory system

- Blood and interstitial fluid are separated
- Earthworms, squid, octopus, and vertebrates

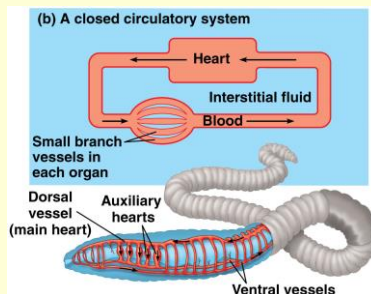


Fig. 42.3b

## A few more terms

- **Cardiovascular** system of vertebrates
- Hearts are composed of **atria** (chambers that \_\_\_\_\_ blood) and **ventricles** (chambers that \_\_\_\_\_ blood out)
- **Arteries** contain blood moving \_\_\_\_\_ from the heart and \_\_\_\_\_ capillaries
- **Veins** contain blood moving \_\_\_\_\_ the heart and \_\_\_\_\_ from capillaries
- **Single** circulation vs. **double** circulation

## Single circulation

- Bony & cartilaginous fishes
- **Two-chambered heart**
- Blood passes through heart once in each complete circuit
- **LOSES** pressure after capillary beds

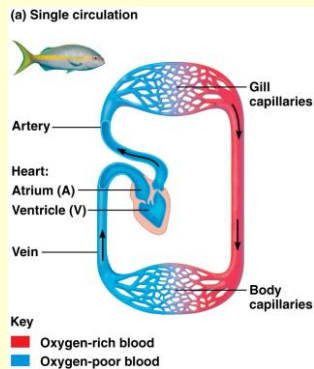


Fig. 42.4a

## Double circulation (1)

- Three- or four-chambered heart; **maintains** pressure

(b) Double circulation: amphibian

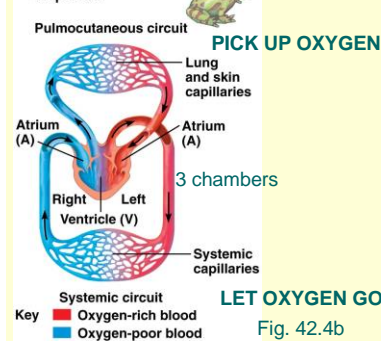


Fig. 42.4b

## Double circulation (2)

- Three- or four-chambered heart; **maintains** pressure

(b) Double circulation: amphibian

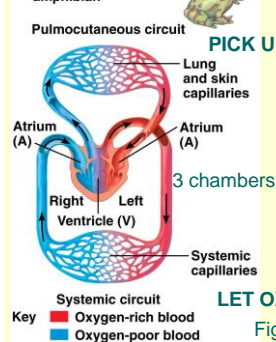
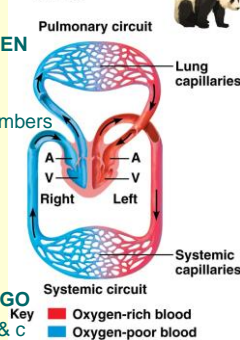


Fig. 42.4b &amp; c

(c) Double circulation: mammal



## Mammalian cardiovascular system

- Double circulation
- Right: deoxy.
- Left: oxy.
- Pulmonary = ?

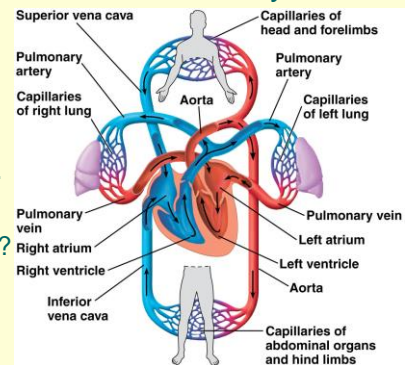


Fig. 42.5

## Mammalian heart

- Wall thickness
- Valves: AV & semilunar
- Lub-dup = valves closing
- A heart murmur is a defect in a valve

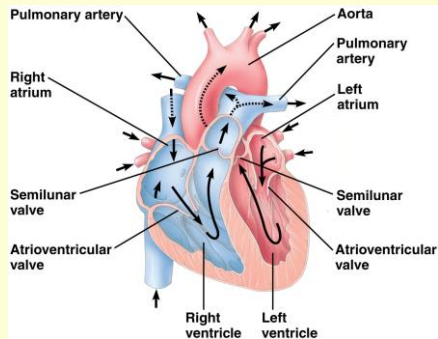
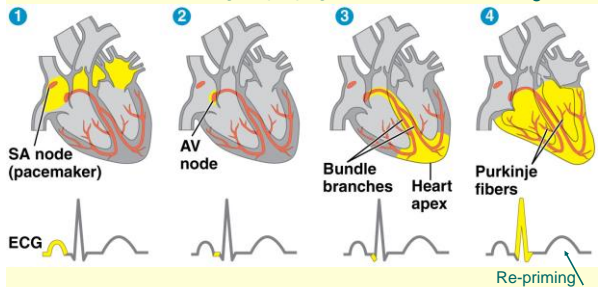


Fig. 42.6

## Heart rhythm

- Sinoatrial (SA) node and atrioventricular (AV) node
- Specialized cardiac muscle tissue
- Note direction of signal propagation

Fig. 42.8



An electrocardiogram shows the current conducted to the skin.

## Blood vessels

- 1 to 3 layers
- All: Endothelium: layer of smooth, flattened cells
- A&V: smooth muscle & connective tissue
  - Both are very elastic

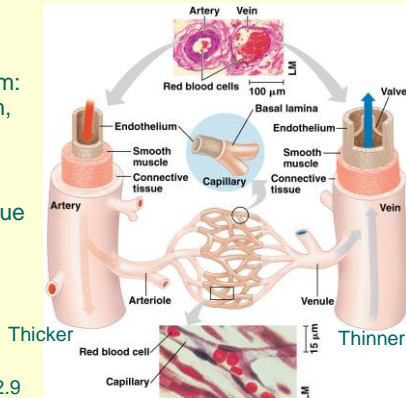
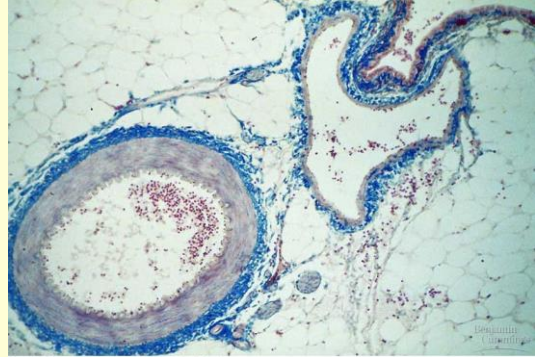


Fig. 42.9

## Arteries and veins

- Which is which?



## Blood flow

- Systole vs. diastole

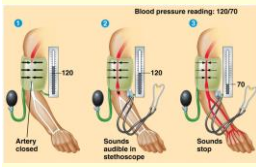


Fig. 42.11

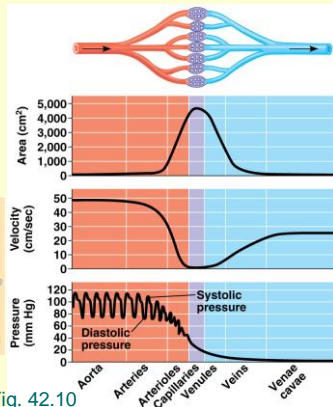


Fig. 42.10

## Blood

- Specialized connective tissue

Fig. 42.16

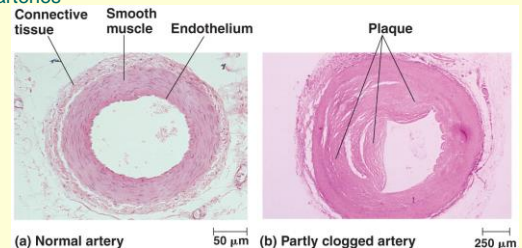
*Plasma 55%		Cellular elements 45%		
Constituent	Major functions	Cell type	Number per $\mu\text{L}$ ( $\text{mm}^3$ ) of blood	Functions
Water	Solvent for carrying other substances	Leukocytes (white blood cells)	5,000–10,000	Defense and immunity
Ions (blood electrolytes) Sodium Potassium Calcium Magnesium Chloride Bicarbonate	Osmotic balance, pH buffering, and regulation of membrane permeability	Basophils Lymphocytes Eosinophils Neutrophils Monocytes		
Plasma proteins Albumin Fibrinogen Immunoglobulins (antibodies)	Osmotic balance, pH buffering Clotting Defense	Platelets	250,000–400,000	Blood clotting
Substances transported by blood Nutrients Waste products Respiratory gases Hormones		Erythrocytes (red blood cells)	5–6 million	Transport of $\text{O}_2$ and some $\text{CO}_2$
		Hemoglobin		

## Leukemia

- Cancer of tissues that produce blood:
  - bone marrow and lymphatic system
- Diverse cancer that is usually classified by its rate of progression and which leukocytes are affected
- Typically, many abnormal leukocytes are formed that do not function correctly and overwhelm functional blood cells
- Causes unclear, but likely due to genetic mutation and environmental factors

## Cardiovascular disease

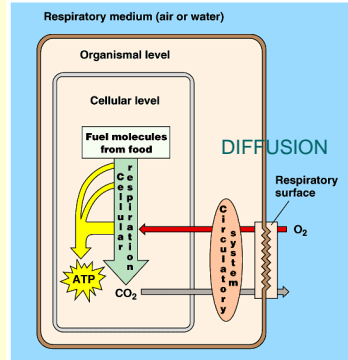
- **Heart attacks**—death of cardiac muscle due to prolonged blockage of coronary arteries (which bring oxy blood to heart)
- **Strokes**—death of nervous tissue in the brain due to blockage or rupture of arteries in head
- **Atherosclerosis**—chronic condition often leading to the above conditions; **plaques** (fibrous connective tissue + lipids) narrow arteries





## Gas exchange

- Gills
- Tracheal systems
- Lungs
- Water vs. air
  - 4 – 8 vs. 210 ml  $O_2$  per liter
  - Diffusion speed
  - Evaporation



## Gills

- Continuously pumping water

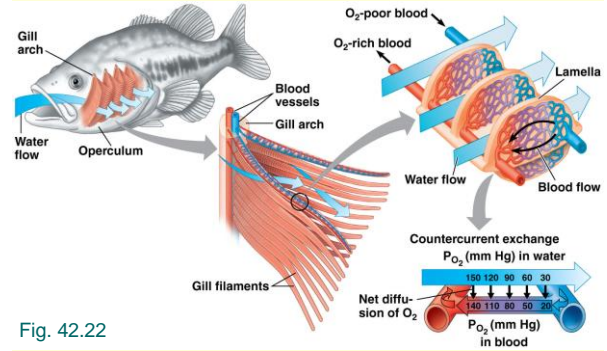


Fig. 42.22

## Tracheal systems

- Life on land
  - Small bodies
  - Trachea located throughout body

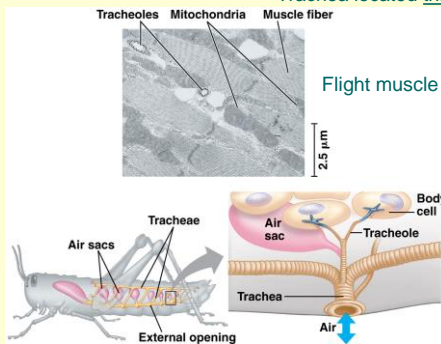


Fig. 42.23

## Lungs

- Life on land
  - Large bodies (usually)
  - Lungs localized

Note  $[O_2]$  & veins & arteries

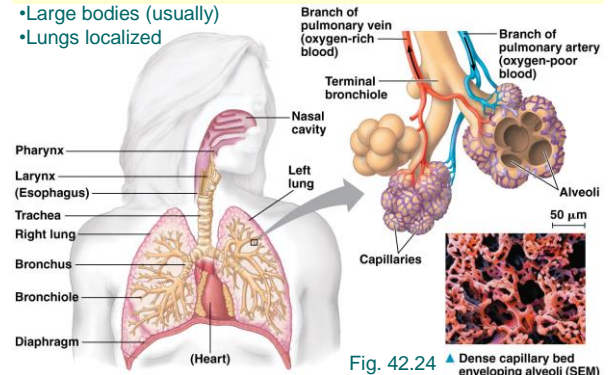


Fig. 42.24 ▲ Dense capillary bed enveloping alveoli (SEM)

## Gas loading and unloading

- Partial pressures and diffusion

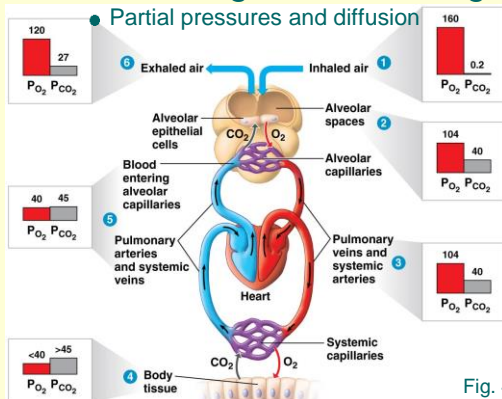


Fig. 42.29