

## The Circulatory and Respiratory Systems

### Chapter 49



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## Invertebrate Circulatory Systems

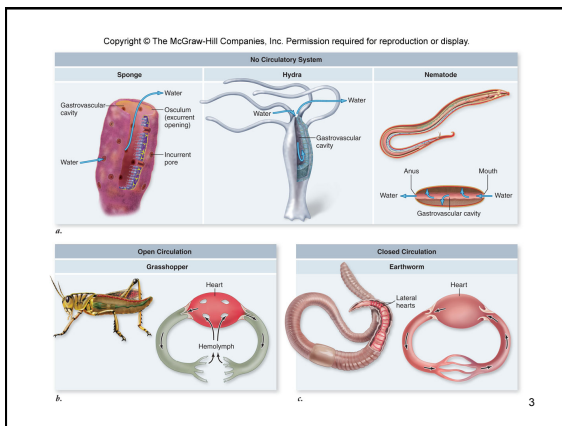
Larger animals require a separate circulatory system for nutrient and waste transport

-**Open circulatory system** = No distinction between circulating and extracellular fluid

-Fluid called **hemolymph**

-**Closed circulatory system** = Distinct circulatory fluid enclosed in blood vessels & transported away from and back to the heart

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## Vertebrate Circulatory Systems

Fishes evolved a true chamber-pump heart

-Four structures are arrayed one after the other to form two pumping chambers

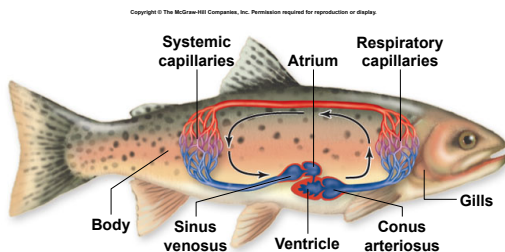
-First chamber consists of the **sinus venosus** and **atrium**, and the second, of the **ventricle** and **conus arteriosus**

-These contract in the order listed

-Blood is pumped through the gills, and then to the rest of the body

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## Vertebrate Circulatory Systems



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## Vertebrate Circulatory Systems

The advent of lungs in amphibians required a second pumping circuit, or **double circulation**

-**Pulmonary circulation** moves blood between the heart and lungs

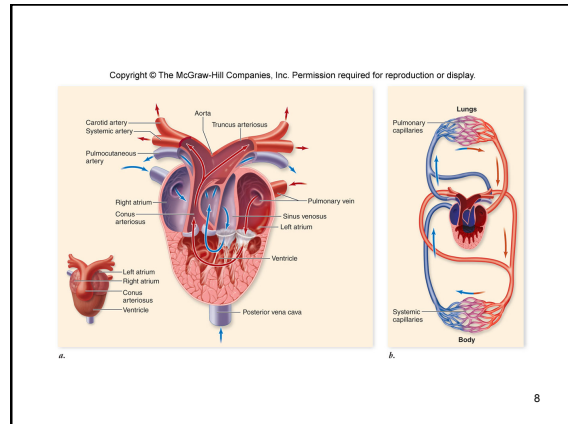
-**Systemic circulation** moves blood between the heart and the rest of the body

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## Vertebrate Circulatory Systems

- The frog has a three-chambered heart, consisting of two atria and one ventricle
- Oxygenated and deoxygenated blood mix very little
- Amphibians living in water obtain additional oxygen by diffusion through their skin
- Reptiles have a septum that partially subdivides the ventricle, thereby further reducing the mixing of blood in the heart

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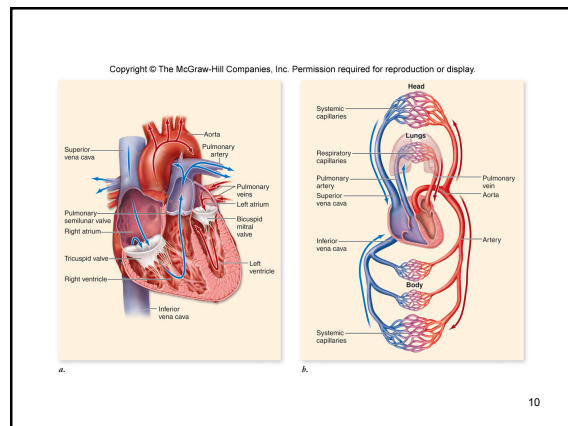


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## Vertebrate Circulatory Systems

- Mammals, birds and crocodilians have a four-chambered heart with two separate atria and two separate ventricles
- Right atrium receives deoxygenated blood from the body and delivers it to the right ventricle, which pumps it to the lungs
  - Left atrium receives oxygenated blood from the lungs and delivers it to the left ventricle, which pumps it to rest of the body

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## The Cardiac Cycle

- The heart has two pairs of valves:
- Atrioventricular (AV) valves** guard the openings between atria and ventricles
    - Tricuspid valve** = On the right
    - Bicuspid, or mitral, valve** = On the left
  - Semilunar valves** guard the exits from the ventricles to the arterial system
    - Pulmonary valve** = On the right
    - Aortic valve** = On the left

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## The Cardiac Cycle

- These valves open and close as the heart goes through the cardiac cycle of rest (**diastole**) and contraction (**systole**)
- “Lub-dub” sounds heard with stethoscope
- Right and left **pulmonary arteries** deliver deoxygenated blood from the right ventricle to the right and left lungs
- Pulmonary veins** return oxygenated blood from the lungs to the left atrium

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## The Cardiac Cycle

The **aorta** and all its branches are systemic arteries, carrying oxygen-rich blood from the left ventricle to all parts of the body

-**Coronary arteries** supply the heart muscle itself

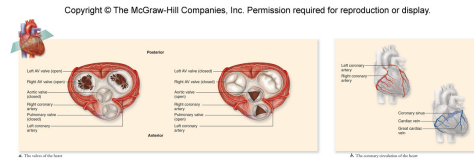
**Superior vena cava** drains the upper body

**Inferior vena cava** drains the lower body

These veins empty into the right atrium, completing the systemic circulation

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## The Cardiac Cycle



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## Contraction of Heart Muscle

Contraction of the heart muscle is stimulated by membrane depolarization

-Triggered by the **sinoatrial (SA) node**, the most important of the **autorhythmic fibers**

-Located in the right atrium, the SA node acts as a pacemaker for rest of the heart

-Produces spontaneous action potentials faster than other cells

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## Contraction of Heart Muscle

Depolarization travels to the **atrioventricular (AV) node**

-It is then conducted rapidly over both ventricles by a network of fibers called the **atrioventricular bundle**, or **bundle of His**

-Relayed to the **Purkinje fibers**

-Directly stimulate the myocardial cells of both ventricles to contract

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## Characteristics of Blood Vessels

Blood leaves heart through the **arteries**

-**Arterioles** are the finest, microscopic branches of the arterial tree

-Blood from arterioles enters **capillaries**

-Blood is collected into **venules**, which lead to larger vessels, **veins**

-Carry blood back to heart

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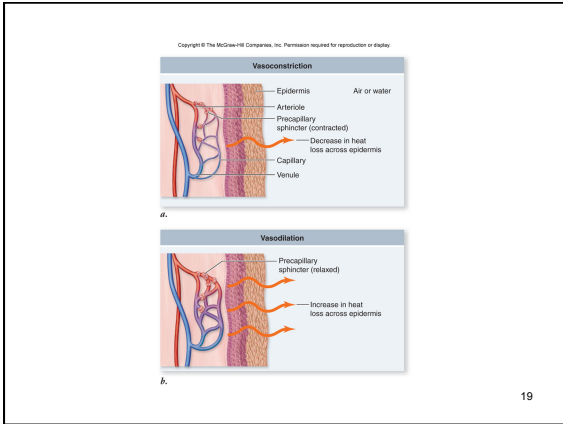
## Characteristics of Blood Vessels

### Arteries and arterioles

-Contraction of the smooth muscle layer results in **vasoconstriction**, which greatly increases resistance & decreases blood flow

-Chronic vasoconstriction can result in **hypertension** (high blood pressure)

-Relaxation of the smooth muscle layer results in **vasodilation**, decreasing resistance & increasing blood flow to organs<sup>18</sup>



## Characteristics of Blood Vessels

### Veins and venules

- Have thinner layer of smooth muscles than arteries
- Return blood to the heart with the help of skeletal muscle contractions and one-way **venous valves**

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## Cardiovascular Diseases

**Heart attacks** (myocardial infarctions)

- Main cause of cardiovascular deaths in US
- Insufficient supply of blood to heart

**Angina pectoris** (“chest pain”)

- Similar to but not as severe as heart attack

**Stroke**

- Interference with blood supply to the brain

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## Cardiovascular Diseases

### Atherosclerosis

- Accumulation of fatty material within arteries

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## The Components of Blood

**Blood** is a connective tissue composed of a fluid matrix, called **plasma**, within which are found different cells and **formed elements**

The functions of circulating blood are:

1. **Transportation** of materials
2. **Regulation** of body functions
3. **Protection** from injury and invasion

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Labels: Plasma, Red blood cells, Platelets and leukocytes, Red blood cells (erythrocytes), White blood cells, Formed elements.

Blood Plasma	Red Blood Cells	Platelets
<b>Plasma proteins (7%)</b> Albumin (54%) Globulins (38%) Fibrinogen (7%) All others (1%)	4 million-6 million/ mm <sup>3</sup> blood	150,000-300,000/ mm <sup>3</sup> blood
<b>Water (91.5%)</b> Electrolytes Nutrients Gases Regulatory substances Waste products	<b>Neutrophils</b> 60-70%	<b>Eosinophils</b> 3-4%
<b>Monocytes</b> 3-8%	<b>Basophils</b> 0.5-1%	<b>Lymphocytes</b> 20-25%

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## The Components of Blood

Plasma is 92% water, but it also contains the following solutes:

- Nutrients, wastes, and hormones**
- Ions**
- Proteins**
  - Albumin**, alpha ( $\alpha$ ) & beta ( $\beta$ ) **globulins**
  - Fibrinogen**
- If removed, plasma is called **serum**

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## The Components of Blood

The formed elements of the blood include red blood cells, white blood cells and platelets

### Red blood cells (erythrocytes)

- About 5 million per microliter of blood
- Hematocrit** is the fraction of the total blood volume occupied by red blood cells
- RBCs of vertebrates contain hemoglobin, a pigment that binds and transports oxygen

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## The Components of Blood

### White blood cells (leukocytes)

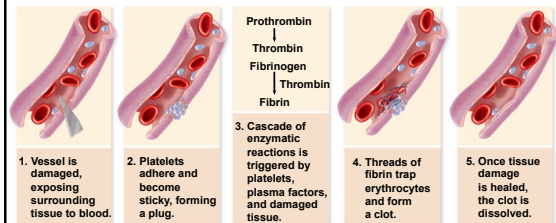
- Less than 1% of blood cells
- Larger than erythrocytes and have nuclei
  - Can also migrate out of capillaries
- Granular leukocytes**
  - Neutrophils, eosinophils, and basophils
- Agranular leukocytes**
  - Monocytes and lymphocytes

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## The Components of Blood

**Platelets** are cell fragments that pinch off from larger cells in the bone marrow

-Function in the formation of blood clots

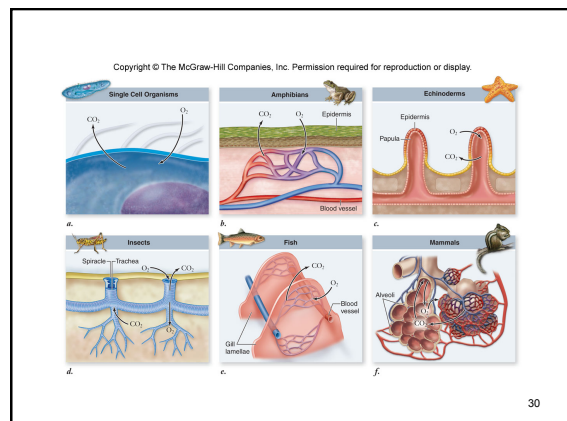


## Gas Exchange

Gases diffuse directly into unicellular organisms  
However, most multicellular animals require system adaptations to enhance gas exchange

- Amphibians respire across their skin
- Echinoderms have protruding papulae
- Insects have an extensive tracheal system
- Fish use gills
- Mammals have a large network of alveoli

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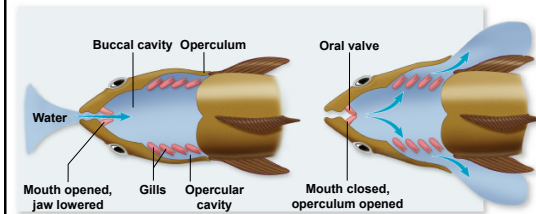
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## Gills

- Gills** are specialized extensions of tissue that project into water
- External gills are not enclosed within body structures
- Found in immature fish and amphibians
  - Two main disadvantages
    - Must be constantly moved to ensure contact with oxygen-rich fresh water
    - Are easily damaged

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## Gills

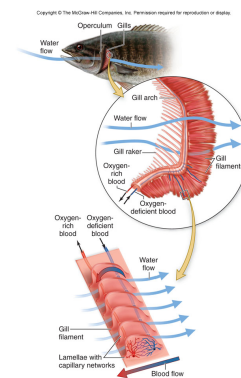


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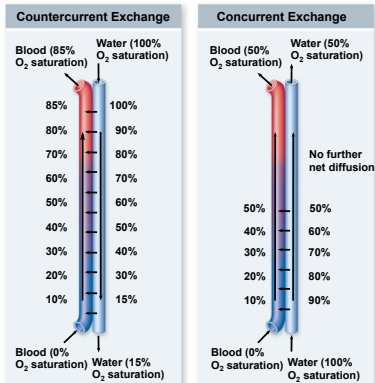
## Gills

- There are four **gill arches** on each side of a fish's head
- Each is composed of two rows of **gill filaments**, which consist of **lamellae**
    - Within each lamella, blood flows opposite to direction of water movement
    - Countercurrent flow**
    - Maximizes oxygenation of blood

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## Lungs

Gills were replaced in terrestrial animals because

1. Air is less supportive than water
2. Water evaporates

The **lung** minimizes evaporation by moving air through a branched tubular passage

-A two-way flow system

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## Lungs

Lungs of mammals are packed with millions of **alveoli** (sites of gas exchange)

-Inhaled air passes through the larynx, glottis and **trachea**

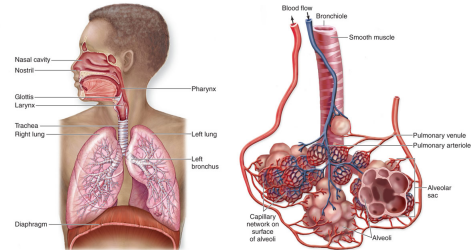
-Bifurcates into the right and left **bronchi**, which enter each lung and further subdivide into **bronchioles**

-Surrounded by an extensive capillary network

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## Lungs

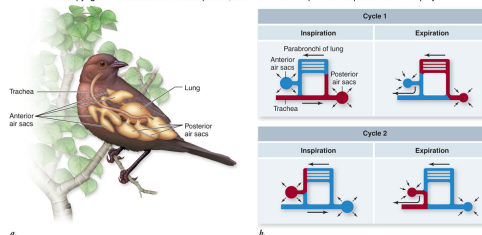
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## Lungs

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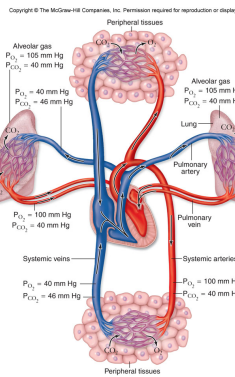
## Gas Exchange

**Gas exchange** is driven by differences in partial pressures

-As a result of gas exchange in the lungs, systemic arteries carry oxygenated blood with relatively low  $\text{CO}_2$  concentration

-After the oxygen is unloaded to the tissues, systemic veins carry deoxygenated blood with a high  $\text{CO}_2$  concentration

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## Lung Structure and Function

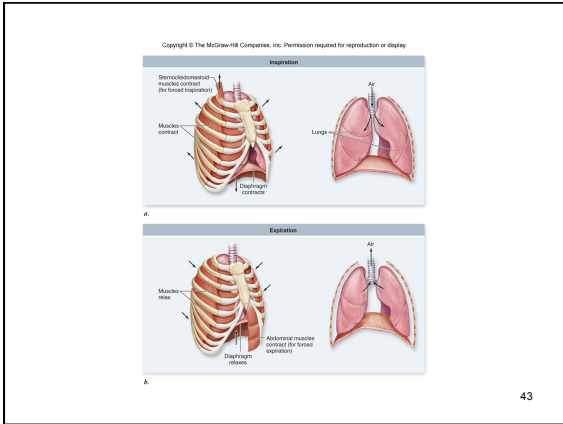
During inhalation, thoracic volume increases through contraction of two muscle sets

-Contraction of the external **intercostal muscles** expands the rib cage

-Contraction of the **diaphragm** expands the volume of thorax and lungs

-Produces negative pressure which draws air into the lungs

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## Lung Structure and Function

Each breath is initiated by neurons in a **respiratory control center** in the medulla oblongata

- Stimulate external intercostal muscles and diaphragm to contract, causing inhalation
- When neurons stop producing impulses, respiratory muscles relax, and exhalation occurs

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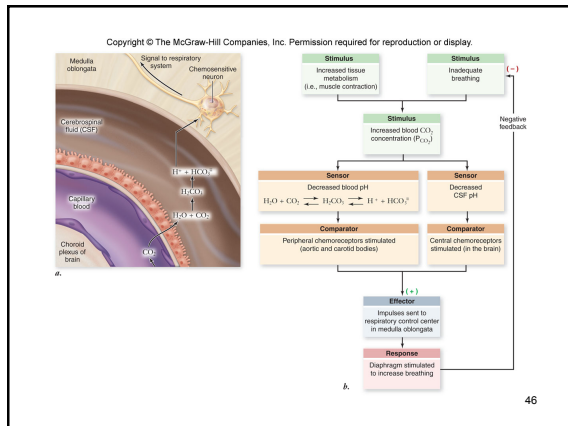
## Lung Structure and Function

Neurons are sensitive to blood  $P_{CO_2}$  changes

- A rise in  $P_{CO_2}$  causes increased production of carbonic acid ( $H_2CO_3$ ), lowering the pH
- Stimulates chemosensitive neurons in the **aortic** and **carotid bodies**
- Send impulses to control center

Brain also contains central chemoreceptors that are sensitive to changes in the pH of cerebrospinal fluid (CSF)

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## Respiratory Diseases

**Lung cancer** follows or accompanies COPD

- The number one cancer killer
- Caused mainly by cigarette smoking

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