"There are no boring subjects, only disinterested minds."
- G. K. Chesterton

Cellular Respiration, Thermoregulation, Comparative Anatomy, and Circulation

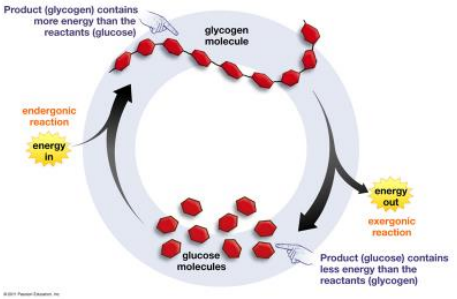
Exergonic and Endergonic Reactions

Exergonic reactions: reactants contain more energy than the products

- Energy _____
- Ex: Cellular respiration

Endergonic reactions: products contain more energy than reactants

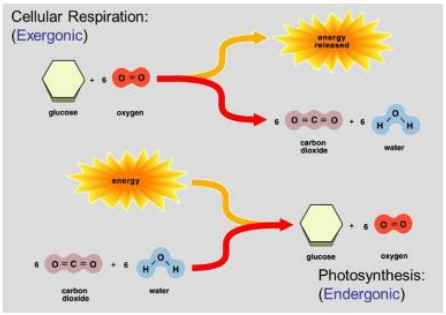
- Energy _____
- Ex: Photosynthesis



Exergonic and Endergonic Reactions

Cellular respiration: process by which all living things extract energy stored in the _____ of molecules and use it to fuel cellular processes.

Photosynthesis: conversion of solar energy to chemical energy



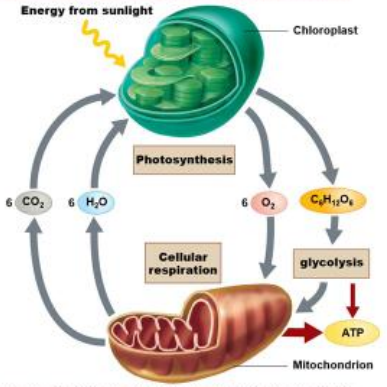
Cellular Respiration and Photosynthesis

Photosynthesis

$6H_2O + 6CO_2 \xrightarrow{\text{Light energy}} C_6H_{12}O_6 + 6O_2$

Cellular Respiration

$C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O + 36ATP$

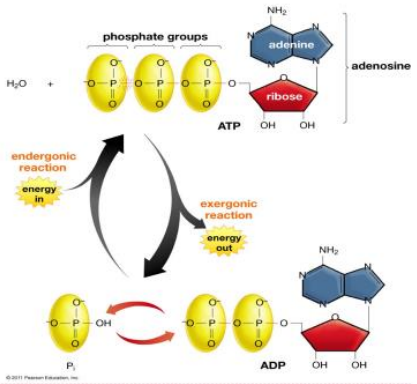


The Molecular Unit of Currency

- Adenosine triphosphate (ATP)
  - Energy transfer molecule
- Adenosine diphosphate (ADP)

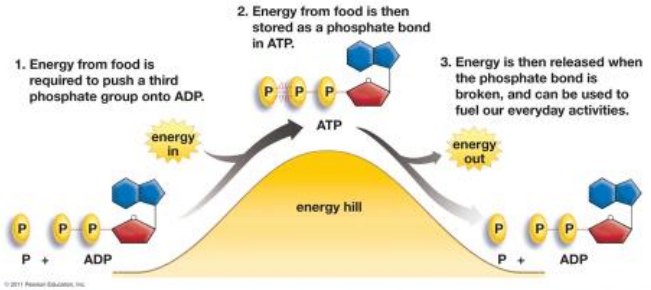
Phosphorylation: addition of a _____ to a molecule

Most important energy transfer molecule in living things!



Energizing ATP

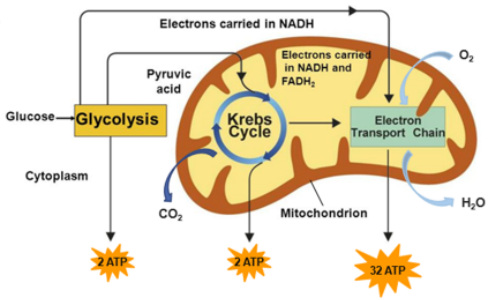
Adenosine triphosphate (ATP) and Adenosine diphosphate (ADP)



Cellular Respiration

Cellular respiration: a process where energy in the chemical bonds of glucose are converted into cellular energy in the form of ATP.

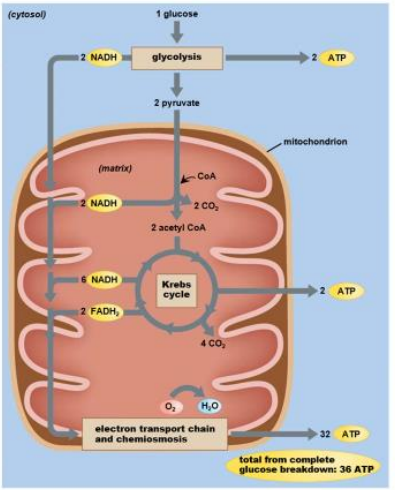
- _____ and glucose are required
- Carbon dioxide (CO_2) and water (H_2O) are by products of cellular respiration
- Occurs in the _____ of eukaryotic cells



Cellular Respiration

Four part process that converts a single glucose molecule to _____

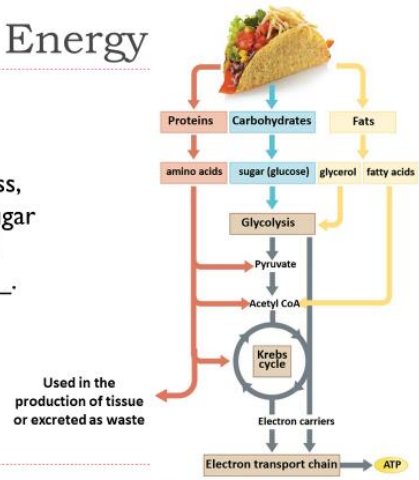
1. Glycolysis
   - 2 ATP
2. Transition Phase
   - No ATP produced
3. Krebs cycle
   - 2 ATP
4. Electron transport chain
   - 32 ATP



Macromolecules and Energy

Why do we have to eat food?

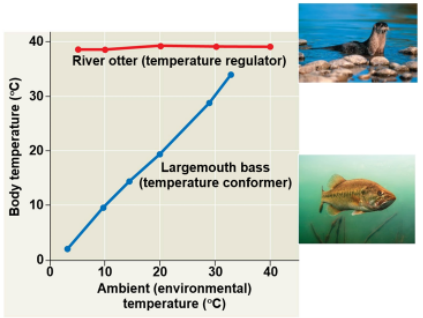
Through the cellular respiration process, stored energy in _____ of sugar and other macromolecules is captured and converted into the bonds of _____.



Homeostasis

Homeostasis: a physiological state where internal conditions are _____

- **Regulators**: use internal mechanisms to _____ external fluctuations
- **Conformers**: allow internal conditions to _____ to external fluctuations

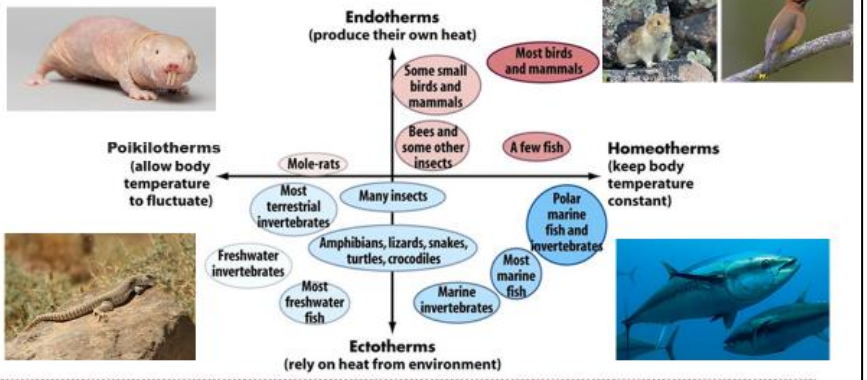


Thermoregulation

Thermoregulation: Process by which animals maintain their body temperature within a normal range

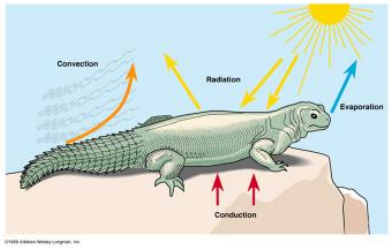
- **Endothermic**: body temperature maintained by _____
  - Birds, mammals, and some insects
- **Ectothermic**: body temperature controlled by _____
  - Most reptile, fish, and invertebrates
- **Poikilotherm**: animals whose body temperature fluctuates with the environment.
- **Homeotherm**: animals with a relatively constant body temperature

Variation in Thermoregulatory Strategies



Heat Exchange with Environment

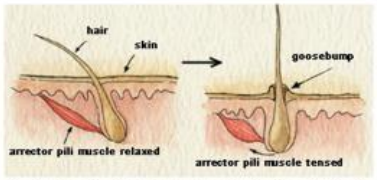
- **Conduction** - _____ of heat
- **Convection** - transfer of heat by the movement of _____ across a surface
- **Radiation** - emission of electromagnetic waves
- **Evaporation** - loss of heat from changing a liquid into a gas



Adaptations for Thermoregulation

Insulation

- Hair
- Feathers
- Fat (blubber)



Adaptations for Thermoregulation

Behavior Responses

- _____
- Huddling
- Burrowing
- Hot tubbin'

Adaptations for Thermoregulation

Evaporative heat loss

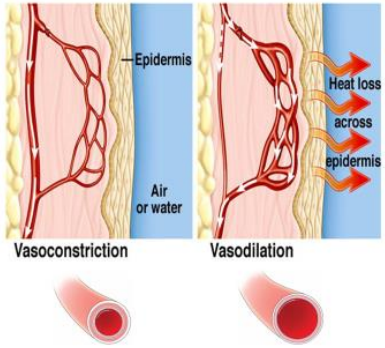
- Sweating
- Panting
- Defecating

Energy Conservation

- _____: physiological state of decreased activity and metabolism
  - **Hibernation**: long term torpor and a decreased body temperature in response to winter cold and food scarcity
  - _____: decreased metabolic rate and activity during hot summer months

Adaptations for Thermoregulation

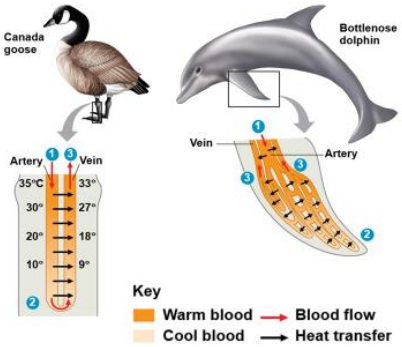
- **Vasodilation**: the widening of superficial blood vessels
  - Increases heat transfer
- **Vasoconstriction**: _____ the diameter of superficial blood vessels



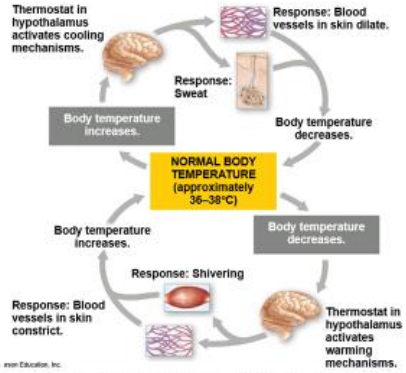
Adaptations for Thermoregulation

_____ heat exchange

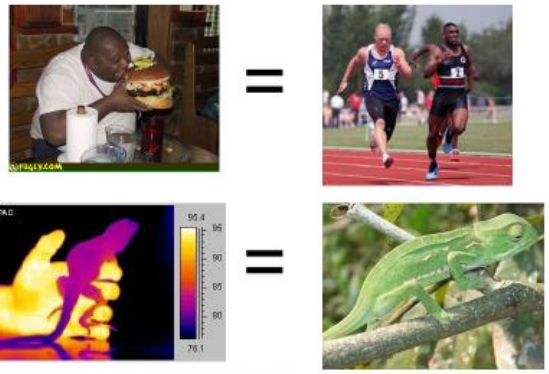
1. Warm blood in arteries from animals core comes in close contact with veins returning from extremities
2. Blood in arteries remains slightly warmer than blood in veins resulting in heat transfer
3. Returning blood almost as warm as arterial blood



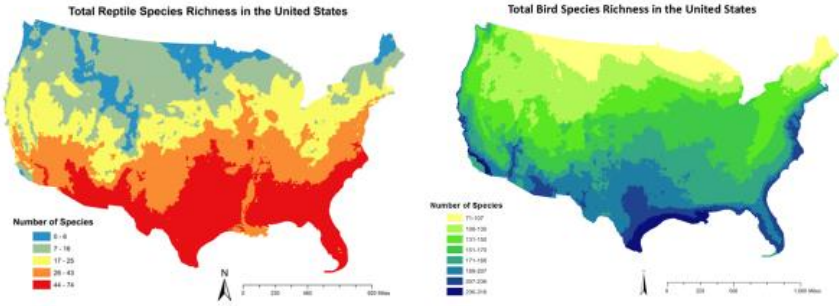
Negative Feedback Loops



Trade-offs of Thermoregulatory Strategy



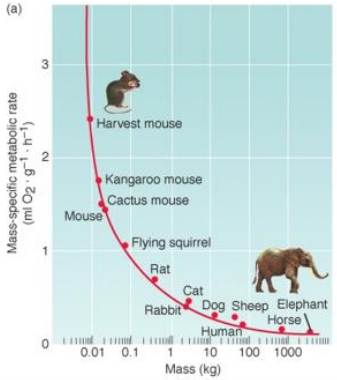
Trade-offs of Thermoregulatory Strategy



Trade-offs of Thermoregulatory Strategy

Smaller endotherms have a greater surface area to volume ratio

- Lose heat to the environment
- Must consume more energy to maintain a constant body temperature



Animal Diets

All animals are heterotrophic:

- Herbivores
- Carnivores
- Omnivores
- Insectivores

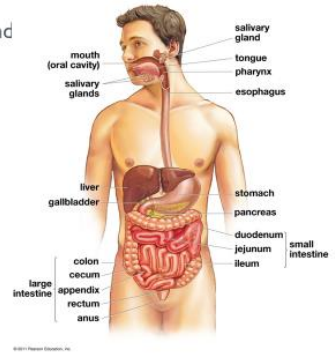
Three nutritional needs:

- _____ for cellular processes
- Organic building blocks for macromolecules
- Acquisition of _____

Digestive System

Digestive tract
- Breakdown food and absorb macro and micronutrients

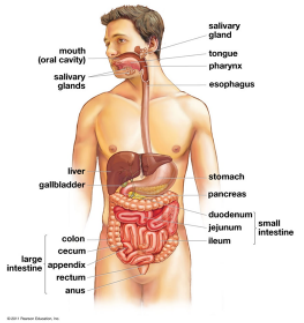
- Mouth
- Pharynx
- Esophagus
- Stomach
- Small Intestine
- Large Intestine
- Rectum



Digestive System

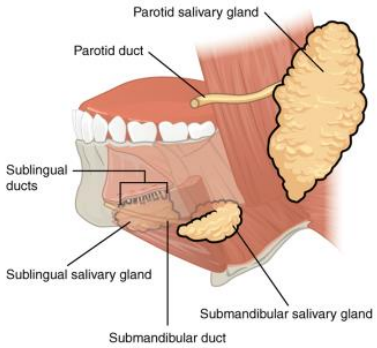
Site of Macromolecule Digestion

	Carbs	Protein	Nucleic acids	Fats
Mouth				
Stomach				
Small intestine				



The Mouth

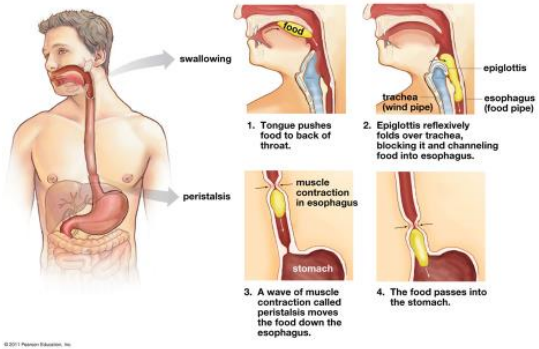
- Mechanical breakdown of food
- Release digestive enzymes
  - Salivary _____
    - Sugar breakdown
  - Lingual lipase
    - Lipid breakdown



Move It Along

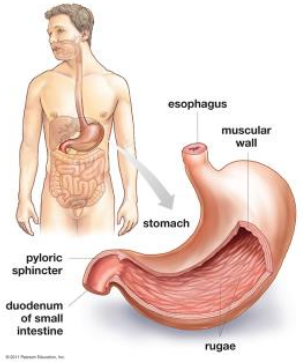
_____: waves of muscle contractions that pushes food through digestive tract

Epiglottis: flap of cartilage that covers the trachea when swallowing



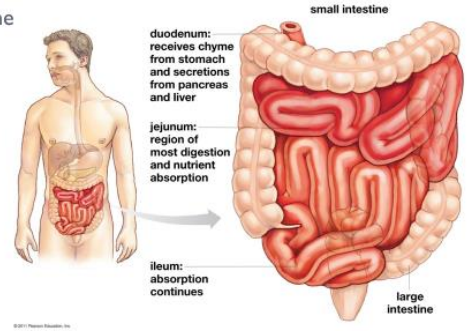
The Stomach

- Continues mechanical breakdown
- Gastric juice
  - HCl + pepsin
    - **Pepsin**: enzyme that breaks down _____
    - Acidity (pH=2) helps break down proteins and also kills bacteria
  - _____: mixture of food and gastric juices
- Food storage
  - Expanding folds known as rugae



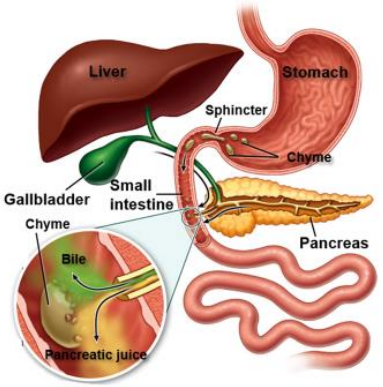
The Small Intestine

- 6m long!
  - Smaller diameter than large intestine
- 80% of nutrients absorbed
- _____
  - Receives secretions from digestive glands
    - Liver
    - Pancreas
    - Gallbladder
- Jejunum
  - Absorption
- Ileum



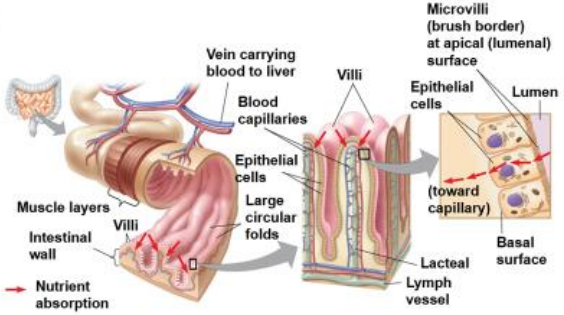
Digestive Glands

- Pancreas
  - Produces insulin
  - Secretes enzymes and buffers
    - Increase pH
- Liver
  - _____
    - Fat digestion
  - Regulates nutrients
  - Receives toxins
- Gallbladder
  - Stores bile



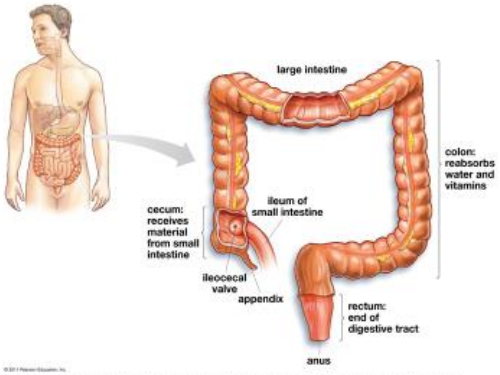
Absorption in the Small Intestine

- Intestinal folds, villi and microvilli increase surface area
  - 200-300m^2
- Monosaccharides, amino acids and monoglycerides absorbed through epithelial cells villi
- _____ carries blood with nutrients to liver
- Lipids transported through _____ system bypassing the liver



Absorption in the Large Intestine

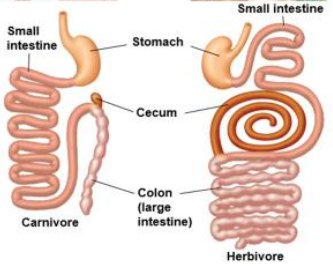
- Large intestine includes colon, cecum and rectum.
  - Absorbs water
  - Forms feces
- **Cecum**: _____ of plant material
  - Function insignificant in humans
- _____: minor role in immunity, may store "good" bacteria



Digestive Tracts of Carnivores and Herbivores

Carnivores

- Large, expandable _____
- _____ digestive tract



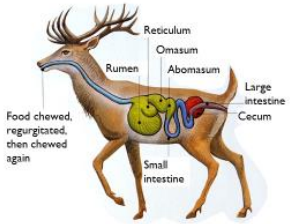
Herbivores

- Large _____ with symbiotic bacteria break down plant material
- _____ digestive tract

Digestion in Ungulates

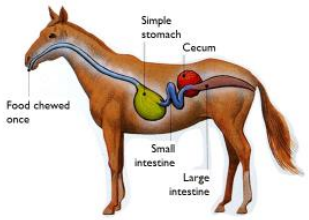
Ruminants

- Deer, antelope, bovine, camel, kangaroos
- Food chewed several times
- Complex, multi-chambered _____
- Rate of passage ~ 80 hours
- Cellulose utilization ~ ____%



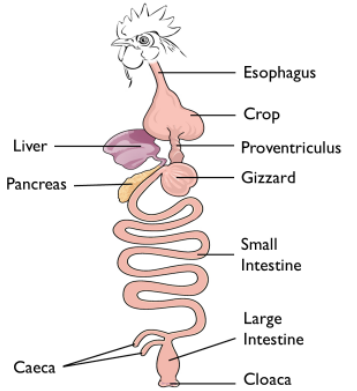
Hindgut Fermenters

- Horses, lagomorphs, rodents
- Food chewed once
- Simple stomach, large _____
- Rate of passage ~ 48 hours
- Cellulose utilization ~ ____%



Bird Digestion

- **Crop**: food storage
- **Proventriculus**: glandular stomach, secretes mucus, HCl, and pepsinogen
- _____: mechanical breakdown of food
- **Small intestine**: three sections (duodenum, jejunum and ileum). Nutrient absorption
- **Large intestine**: short, water absorption
- **Caeca**: site of fermentation in some birds
- _____: common opening for digestive, urinary and reproductive systems



Check Your Understanding

1. True or False: Water is required for cellular respiration

2. True or False: Cellular respiration is considered an endergonic reaction because it releases energy

3. True or False: Small mammals have higher metabolic rate than larger mammals

Check Your Understanding

4. An organism that maintains a constant body temperature, and whose body temperature is controlled by the environment is a:

a. ectothermic poikilotherm
b. endothermic homeotherm
c. endothermic poikilotherm
d. ectothermic homeotherm
e. warm blooded animal

Check Your Understanding

5. The initial breakdown of proteins occurs in the _____.

a. mouth
b. stomach
c. small intestine
d. large intestine

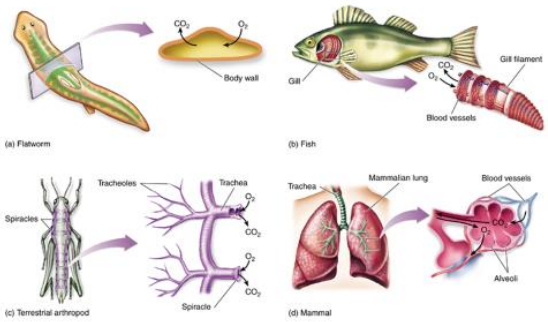
Check Your Understanding

6. In your own words, describe counter current heat exchange.

Respiratory System

Uptake O_2 from environment and discharge CO_2 into the environment

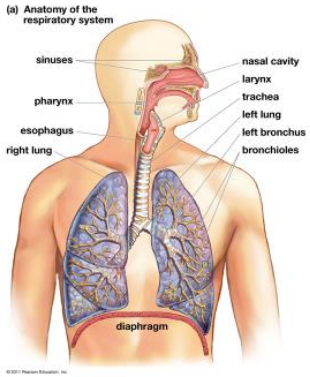
- Diffusion through skin
  - Many invertebrates, amphibians
- Gills (internal of external)
  - Some arthropods, fish
- _____ system
  - Insects
- Lungs
  - Amphibians, reptiles, birds and mammals



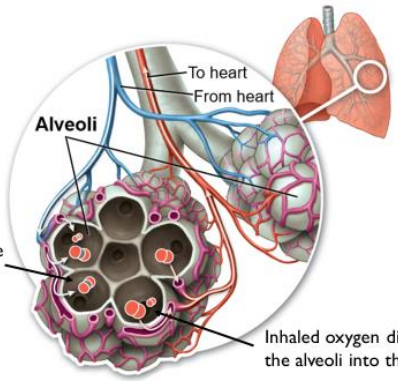
The Respiratory System

Nasal Cavity
↓
Pharynx
↓
Larynx
↓
Trachea
↓
Bronchi
↓
Bronchioles

_____: sheet of skeletal muscle that extends along the bottom of the rib cage
- Expands and contracts to force air into and out of lungs



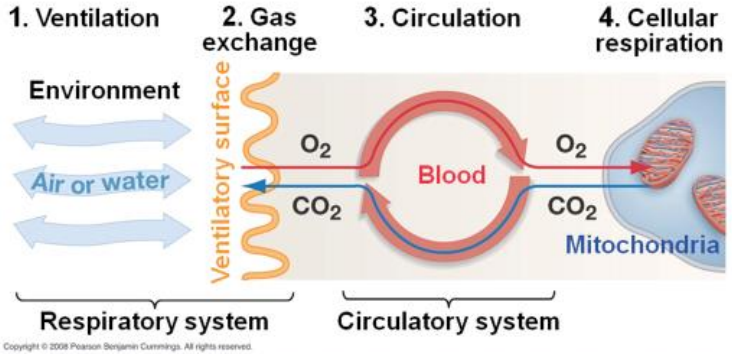
Structure of the Alveoli



Carbon dioxide diffuses from the blood into the alveoli and out of the body as exhalation occurs.

Inhaled oxygen diffuses from the alveoli into the blood.

Respiratory and Circulatory Systems



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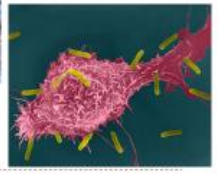
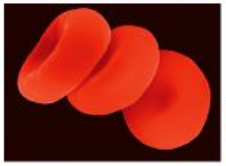
Functions of the Circulatory System

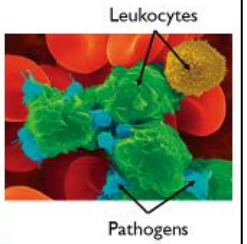
- **Transport**: transports oxygen, nutrients, waste products, immune system cells, and hormones throughout the body.
- **Temperature regulation**: helps maintain a body temperature that is optimum for metabolic function
  - Vasoconstriction and vasodilation
- **Protection**: immune system cells transported throughout the body aid in fighting foreign invaders
  - Platelets and white blood cells



What's in the Blood?

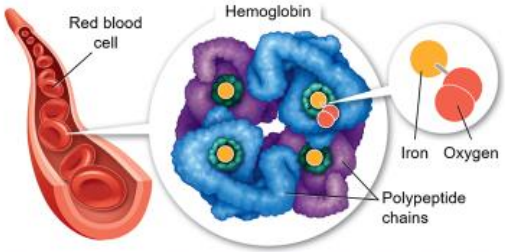
- **Red blood cells (erythrocytes)**: oxygen transport
  - Contain hemoglobin
  - Lack _____
  - 95% of all blood cells in the body
- **White blood cells (leukocytes)**: immune response to disease and foreign invaders (pathogens)
- **Platelets**: cell fragments that aid in _____





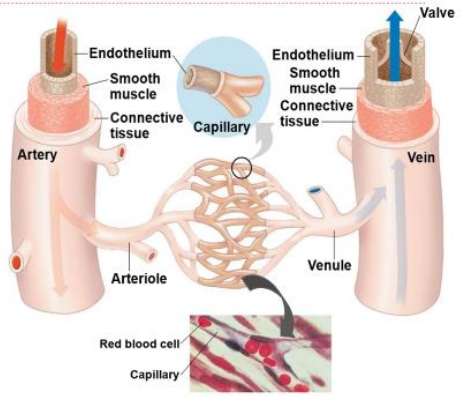
Hemoglobin

- **Hemoglobin**: an oxygen-carrying protein made up of four polypeptide chains.
  - Each hemoglobin can transport four oxygen molecules bound to seats of iron molecules
    - Approximately 250 million hemoglobin per red blood cell



Blood Vessels

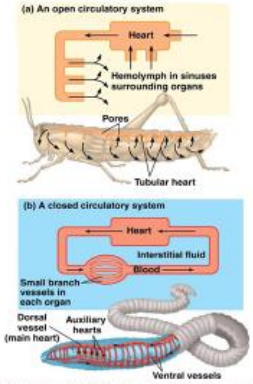
- **Blood vessel tissues:** endothelium, smooth muscle, connective tissue
- **Arteries (arterioles)**: vessels with _____ that carry blood away from the heart
- **Capillaries**: thinly walled vessels where gas, nutrient and waste _____. Lack smooth muscle
- **Veins (venules)**: vessels carrying blood back to the heart
  - Valves



Different Circulatory Systems

Open circulatory system:
_____ bathes organs directly then diffuse back into heart through sinuses

Closed circulatory system: blood transported through vessels into capillaries where diffusion of gases and nutrients occurs



Different Circulatory Systems

Open Circulatory System

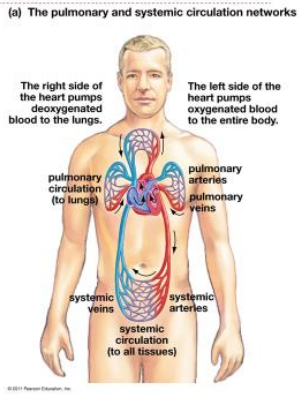
- Arthropods and mollusks
- Less efficient
- Lack of capillaries
- Hemolymph transports nutrients and wastes
- Tissues and cells _____ in hemolymph
- Slow, uncontrolled blood flow

Closed Circulatory System

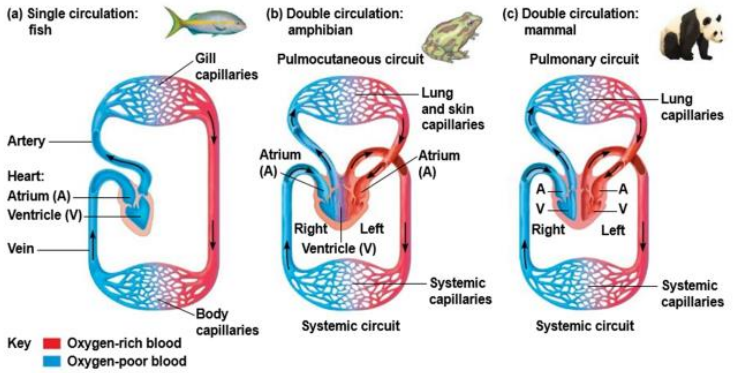
- Vertebrates and annelids
- More efficient
- _____ present
- Blood transports gases, nutrients and wastes
- Blood delivered directly to cells
- Fast, _____ blood flow

Vertebrate Circulatory System

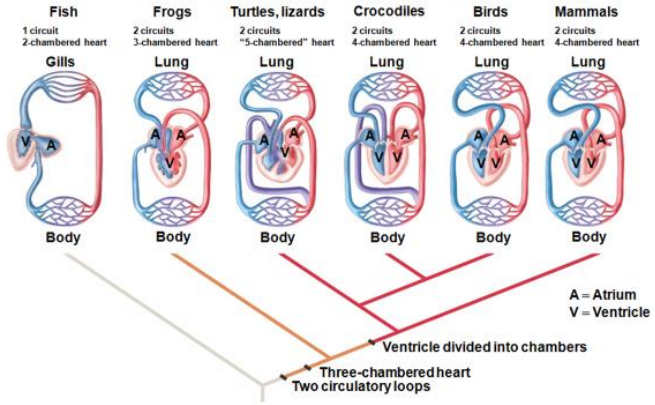
- **Cardiovascular system**: organ system that circulates blood through a network of vessels, transporting nutrients, gases and hormones to cells throughout the body
- **Heart:** hollow muscular organ that pumps blood through circulatory system by rhythmic contraction
  - _____: chambers that receive blood entering heart
  - _____: chambers that pump blood out of the heart
- **Pulmonary circuit**: circuit of blood flow between the _____
- **Systemic circuit**: circuit of blood flow between the _____



Vertebrate Circulatory Systems



Comparative Anatomy of Vertebrate Hearts



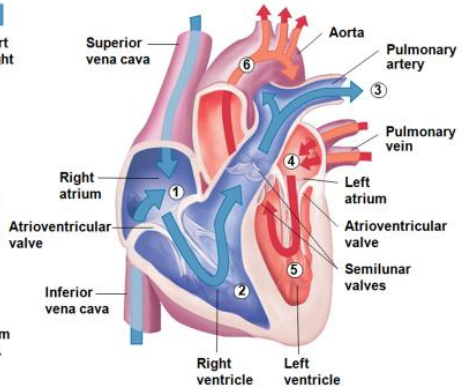
Circulation of Blood Through the Heart

Pulmonary circulation

1. Blood returns to heart from body, enters right atrium.
2. Blood enters right ventricle.
3. Blood is pumped from right ventricle to lungs.

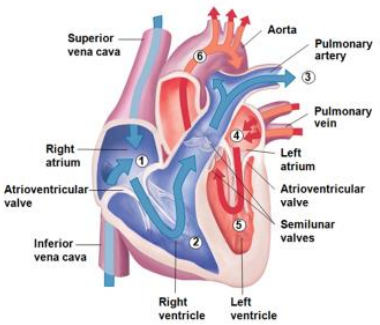
Systemic circulation

4. Blood returns to left atrium from lungs.
5. Blood enters left ventricle.
6. Blood is pumped from left ventricle to body.



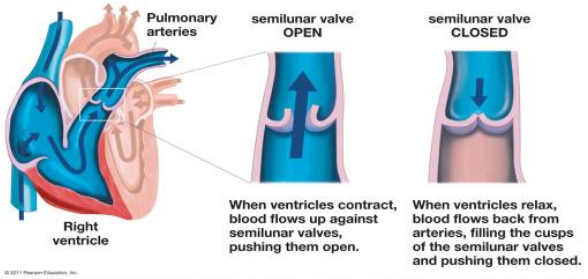
Path of Blood Through The Heart

- Superior and Inferior Vena Cava
- Right Atria
- Atrioventricular (AV) Valve
- Right Ventricle
- Semilunar Valve
- Pulmonary Arteries
- Lungs (CO_2 out, O_2 in)
- Pulmonary Veins
- Left Atria
- Atrioventricular (AV) Valve Left Ventricle
- Semilunar Valve
- Aorta
- Body (O_2 out, CO_2 in)



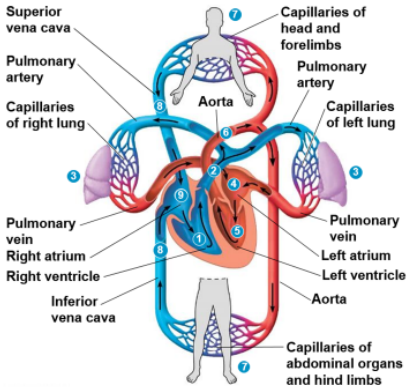
Heart Valves

- **Semilunar valve**: valve between ventricles and aorta or pulmonary artery
- **Atrioventricular valve**: valve between _____



Cardiovascular System in Humans

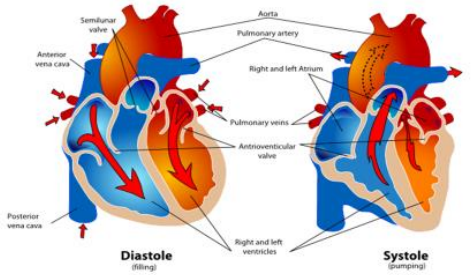
1. Right ventricle pumps blood through semi-lunar valve
2. Pulmonary arteries carry oxygen-poor blood to lungs
3. Oxygen is uploaded and carbon dioxide is unloaded in the capillary beds within the lungs
4. Pulmonary veins carry oxygen-rich blood into the left atria
5. Blood moves through the atrioventricular valve into the left ventricle
6. Oxygen rich blood is pumped through the semi-lunar valve into the aorta, where it is carried through arteries and arterioles to the capillary beds in the body
7. Oxygen is unloaded and carbon dioxide is loaded in the capillary beds in the body
8. Oxygen-poor blood is carried through the venules and veins into the right atrium through the inferior and superior vena cava
9. Oxygen-poor blood moves to the right ventricle through the atrioventricular valve



Cardiac Cycle

Diastole: period of heart _____ when the heart fills with blood

Systole: period of heart _____ when blood is forced out of the heart

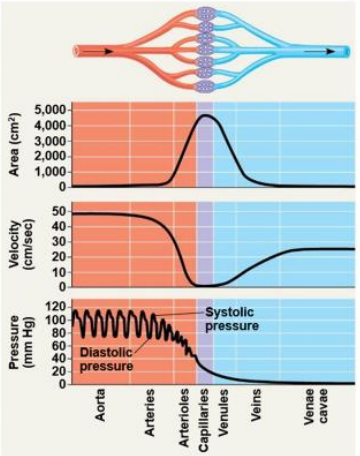


Blood Pressure

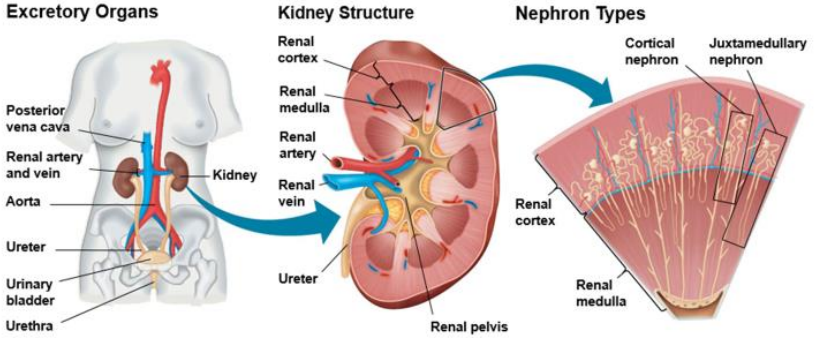
- First lets interpret the figure to the right

Interpretation:

- Blood pressure and velocity decreases in the arterioles and capillaries
- Blood flow is slowest in capillaries where exchange of gases, nutrients and waste occurs
- Blood flow (velocity) increases in venules and veins



Human Excretory System



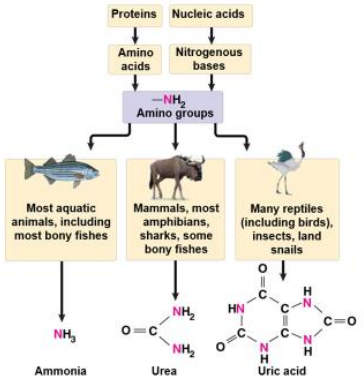
Excretory System

Disposal of _____-containing metabolites and other waste products (nitrogenous wastes)

- Ammonia
  - Toxic, but low energetic costs to produce
- Urea
  - Less toxic, with some energetic costs
- Uric acid
  - Low toxicity, but energetically costly to produce

Excretory System:

- Filtration
- Reabsorption
- Secretion
- Excretion

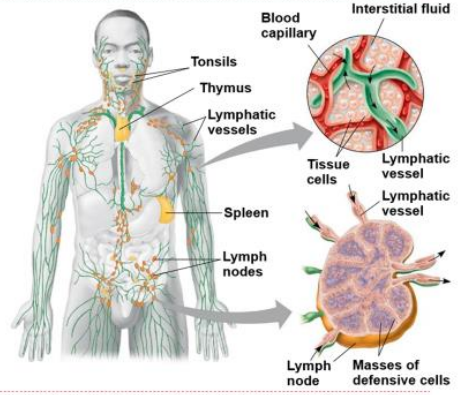


Lymphatic System

Lymphatic system: system of vessels and nodes that returns fluid, proteins, and cells back to the blood.

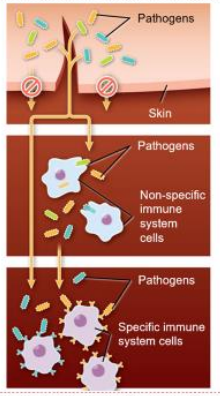
- Separate from circulatory system

- _____: fluid of lymphatic system
- **Lymph nodes**: lymphatic organs that filter lymph and contain _____ cells that fight disease



Divisions of the Immune System

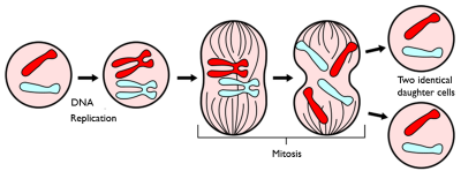
- **Physical barriers**: skin, mucus-membranes, sweat glands, hair, and associated secretions that prevent pathogens from entering the body
  - **Lysozyme**: enzyme in sweat, saliva, and tears that destroys cell wall of bacteria
- **Non-specific (innate) immunity**: immune system cells that quickly recognize and destroy all pathogens that enter the body
  - Responds to all pathogens the same
  - Found in plants, fungi, insects, and other non-vertebrate animals
- **Specific (adaptive) immunity**: immune system cells that recognize and destroy specific pathogens, and can also remember previous pathogens
  - B-cells and T-cells target specific pathogens
  - Found only in _____



Types of Reproduction

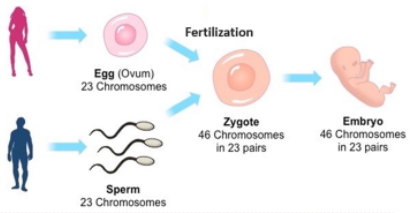
Asexual reproduction: reproduction without recombining DNA with another individual of the same species

- Offspring are genetically identical to the parent
- Common in single-celled organisms



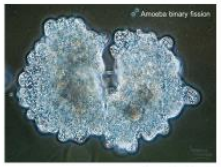
Sexual reproduction: the formation of offspring as a result of the fusion of _____ (egg and sperm), which develop into an embryo

- Offspring are genetically _____ from the parent
- Common multicellular organisms



Types of Reproduction

- Examples of asexual reproduction



Types of Sexual Reproduction

External fertilization (spawning): release of gametes (egg and sperm) into the water where fertilization occurs

- Occurs in _____ organisms
- Parents have no further interaction with offspring

Types of Sexual Reproduction

Internal fertilization: sperm is directly transferred from male to female and fertilization occurs in the female.

- Females can either lay eggs (internally or externally) or give live birth
- Some parents provide parental care for young

Modes of Sexual Reproduction

- **Ovuliparity**: female lays unfertilized eggs, which are externally fertilized by the male
  - Most bony fish and some amphibians
- _____: the mother deposits internally fertilized eggs that develop and hatch outside of mother's body
  - Some bony fish and sharks, most reptiles and all birds
- **Viviparous**: young develop within mother's uterus and receive nourishment via the placenta, uterus or by eating other eggs, before being born (live birth)
  - Some sharks and fish, some reptiles, most mammals

Check Your Understanding

True or False: All organisms that reproduce through internal fertilization also give live birth.

True or False: Vertebrates are the only group of organisms with an innate immune response

True or False: Asexual reproduction results in offspring that are genetically different from the parents.

Check Your Understanding

4. Gas exchange occurs at which of the following sites?

a. Capillaries
b. Aorta
c. Alveoli
d. Veins
e. Gas exchange occurs at more than one of the above locations.

Check Your Understanding

5. Blood returning from the lungs enters which of the following?

a. Left ventricle
b. Right atrium
c. Left atrium
d. Right ventricle
e. Aorta

Check Your Understanding

6. Birds and Reptiles produce which of the following nitrogenous wastes?

a. Pee pee
b. Urea
c. Ammonia
d. Uric acid