

Principles of Animal Physiology

What is life?

“Things”organized to use energy and raw materials from their environment, maintain their integrity and reproduce.

What is physiology?

Physiology is **function**, is an integrative science.

Uses anatomy, histology, physics, chemistry, . . .

Subdisciplines of animal physiology: comparative; environmental; evolutionary; development; cell ...

Physiological subdisciplines

Developmental physiology

Structure and function changes as animals grow through the various life stages

Environmental physiology

Animal responses to environmental challenges

Evolutionary physiology

Specific physiological traits arise within lineages 血统 over the course of multiple generations

Applied physiologist (Applied Science)

Veterinary medicine — improve the health of agricultural animals and household pets

Medical physiology — understand human disease relying on other species as model systems

Comparative physiology — studies animal to explore the origins and nature of physiological diversity.

Physiological Organ Systems

- **Circulatory:** transports gases, nutrients & wastes
- **Respiration:** exchange of oxygen and carbon dioxide
- **Digestive:** obtains nutrients, water & electrolytes
- **Endocrine:** regulates processes for duration
- **Immune:** defends against foreign invaders
- **Ion and water balance**
- **Musculoskeletal:** support, protect & movement
- **Nervous:** controls rapid response of body
- **Reproduction:** perpetuation of the species

Unifying themes applying to all physiological processes

- Physiological processes obey *physical and chemical laws*
- are regulated to maintain internal constancy, known as *homeostasis* 体内平衡

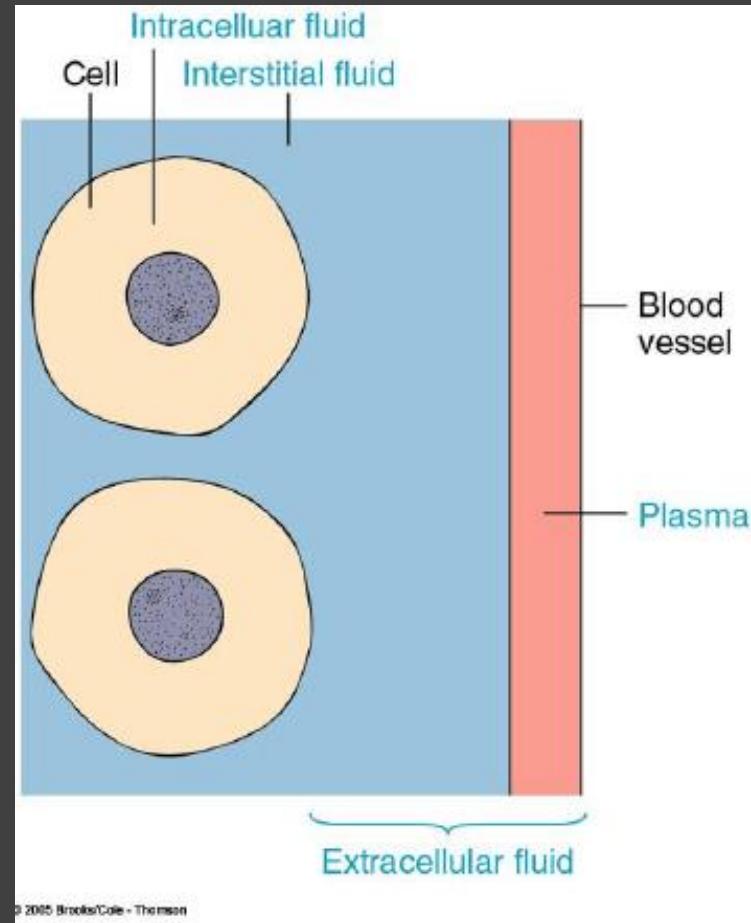
Homeostasis

The maintenance on internal constancy

Most cells are not in contact with the external environment, cannot function without other cells.

Most cells are in contact with the internal environment where they are bathed by ExtraCellular Fluid that is compatible with their survival.

The cell must obtain nutrients and discharge waste to the ECF.



Components of the ExtraCellular Fluid

Genotype and phenotype

Genotype (基因型; 遗传型) is a *product of evolutionary change* in a group of organisms-populations or species over many generations.

- Physiological traits are determined in large part by the genes of the genome (基因组) — the genotype, but also influenced by the way the genes are regulated, particularly in response to external conditions.
- A single genotype can result in multiple phenotypes, depending on the environmental conditions - phenotypic plasticity.

Phenotypes (外表型; 显型)

- The physiological properties 生理特性 (morphology, physiology, and behavior) of an animal are aspects of the animal's phenotype.
- Physiological studies examine how various processes affect the physiological phenotypes.
- Organisms may change their behavior as a result of learning, or alter physiological responses through modification of their phenotypes.
- Differential survival of animal with distinct phenotypes may result in evolutionary change in genotype of a population over many generations.

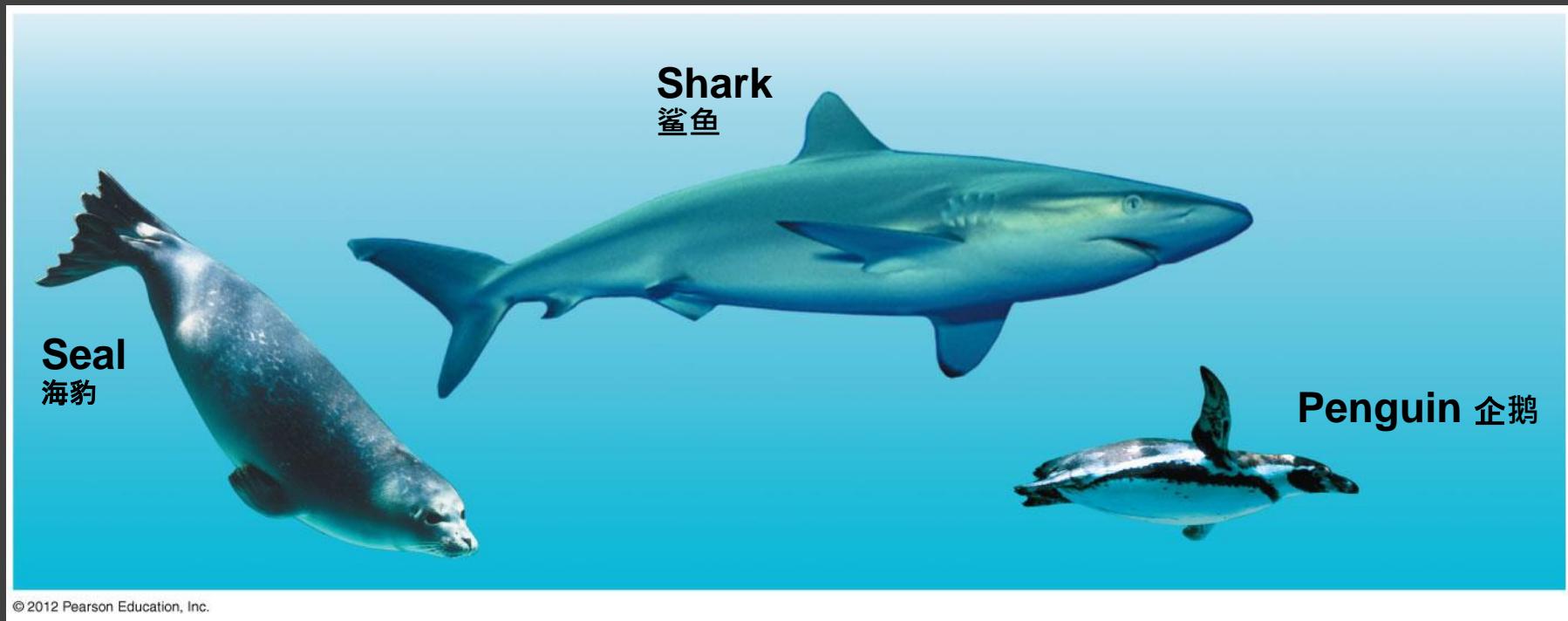
An animal's form reflects natural selection

The body plan or design of an organism 生物体

- reflects the relationship between form and function,
- results from natural selection, and
- does not imply a process of conscious invention.

EXAMPLE: Nature selection often shapes similar adaption when diverse organisms face the same environmental challenge as the resistance of water to fast swimming.

Figure 20.2



Streamlined and tapered bodies increase swimming speeds and have similarly evolved in fish, sharks, and aquatic birds and mammals, representing convergent evolution (趨同進化).

Structure fits function

- **Anatomy** is the study of structure.
- **Physiology** is the study of function.
- Animals consist of a hierarchy (层级;等级) of levels or organization (a series of ordered groupings things within a system).
 - **Tissues** are an integrated group of *similar cells* that perform a common function.
 - **Organs** perform a **specific task** and consist of **two or more tissues**.
 - **Organ systems** consist of **multiple organs** that together perform a vital **body function**.

Cellular level

Muscle cell

Function is to contract

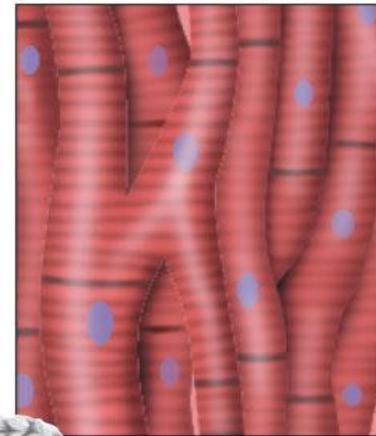
Organ level 器官

Heart

Organ system level

Circulatory system

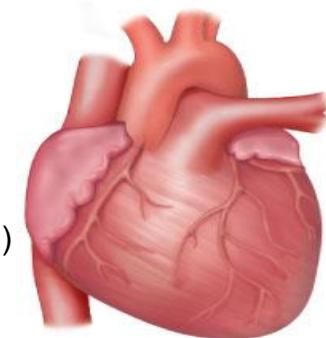
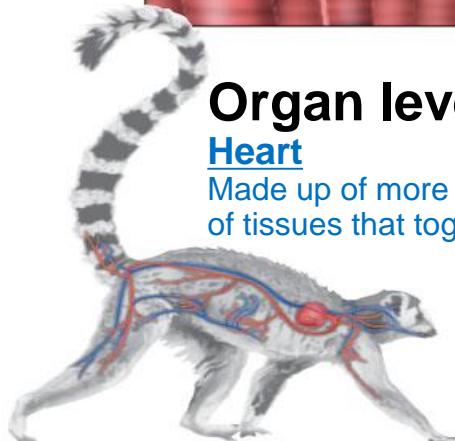
Multiple organs that together perform a vital body function including the blood, blood vessels, and nerves



Tissue level

Muscle tissue

Perform a common function



Organ level [器官]

Heart

Made up of more types of tissues that together perform a specific task

Organism level (生物體, 有机体)

Many organ systems functioning together
(Circulatory, nutrient, digestive, respiratory systems)

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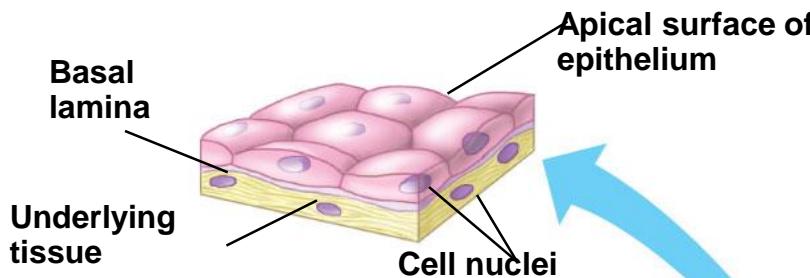
Tissues are groups of cells with a common structure and function

- Tissues
 - are an integrated group of similar cells that perform a common function and
 - combine to form organs.
- Animals have four main categories of tissues:
 1. epithelial tissue,
 2. connective tissue,
 3. muscle tissue, and
 4. nervous tissue.

Epithelial tissue covers the body and lines its organs and cavities

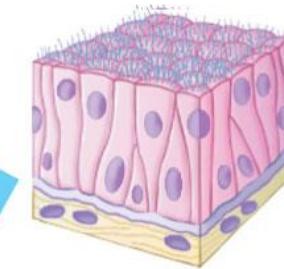
- **Epithelial tissues** (epithelia) are sheets of closely packed cells that
 - cover body surfaces and line internal organs and cavities.
 - are named according to the number of cell layers they have and shape of the cells on their apical surface
- Epithelial cells come in three shapes:
 1. Squamous 鳞状—like a fried egg,
 2. Cuboidal 立方形—as tall as they are wide, and
 3. Columnar 柱状—taller than they are wide.

The structure of each type of epithelium fits its function



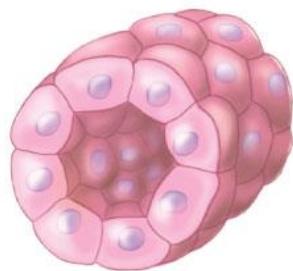
Simple squamous epithelium

is thin and leaky suitable for exchanging materials by **diffusion**



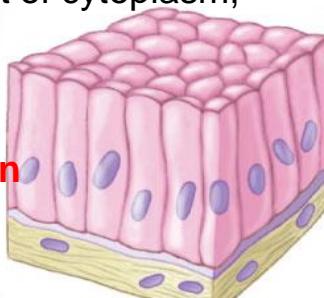
Pseudostratified ciliated columnar epithelium 假分层的有纤毛柱形上皮细胞

Lining the **respiratory tract**, manufacture secretory products, and help keep **lungs clean**



Simple cuboidal epithelium

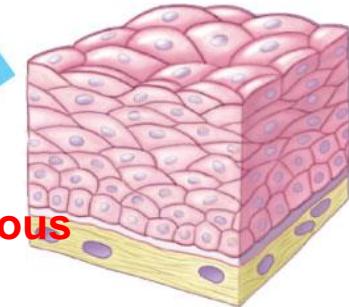
Large amount of cytoplasm, facilitating their role of **secretion or absorption** nutrients



Simple columnar epithelium



Stratified (分层的)squamous epithelium



Lining surface subject to **abrasion** (skin, mouth and esophagus), regenerates rapidly

Connective tissue binds and supports other tissues

Connective tissue consists of a sparse population of cell scattered throughout an extracellular material (nonliving matrix), can be grouped into six major types.

1. Loose connective tissue

- is the most widespread that functions as a packing material.
- consists of ropelike collagen and elastic fibers that are strong and resilient, and
- helps to join skin to underlying tissues.

2. Fibrous connective tissue

- has densely packed collagen fibers and
- forms tendons that attach muscle to bone
- Fibroblast cell synthesized an extracellular matrix that may give rise to artificial skin

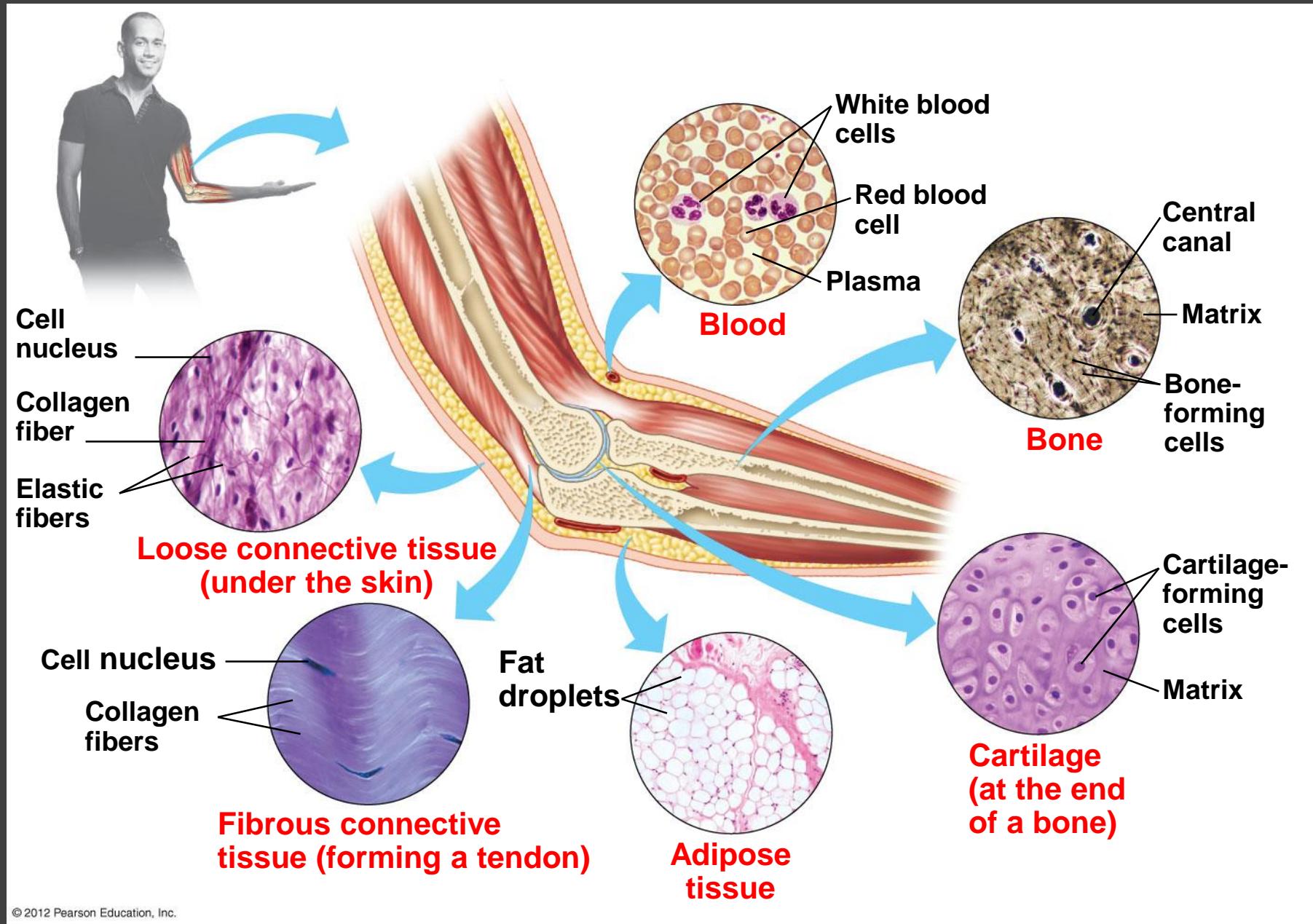
Connective tissue binds and supports other tissues

3. **Adipose tissue** stores fat in large, closely packed cells held in a matrix of fibers for energy storage. Adipose cell contains a large fat droplet that swells when fat is stored and shrinks when fat is used as fuel.
4. **Cartilage** 软骨

- is a strong and flexible skeletal material and
- commonly surrounds the ends of bones.

5. **Bone**
 - has a matrix of collagen fibers
 - embedded in a hard mineral substance containing calcium, magnesium, and phosphate.
6. **Blood** transports substances throughout the body.

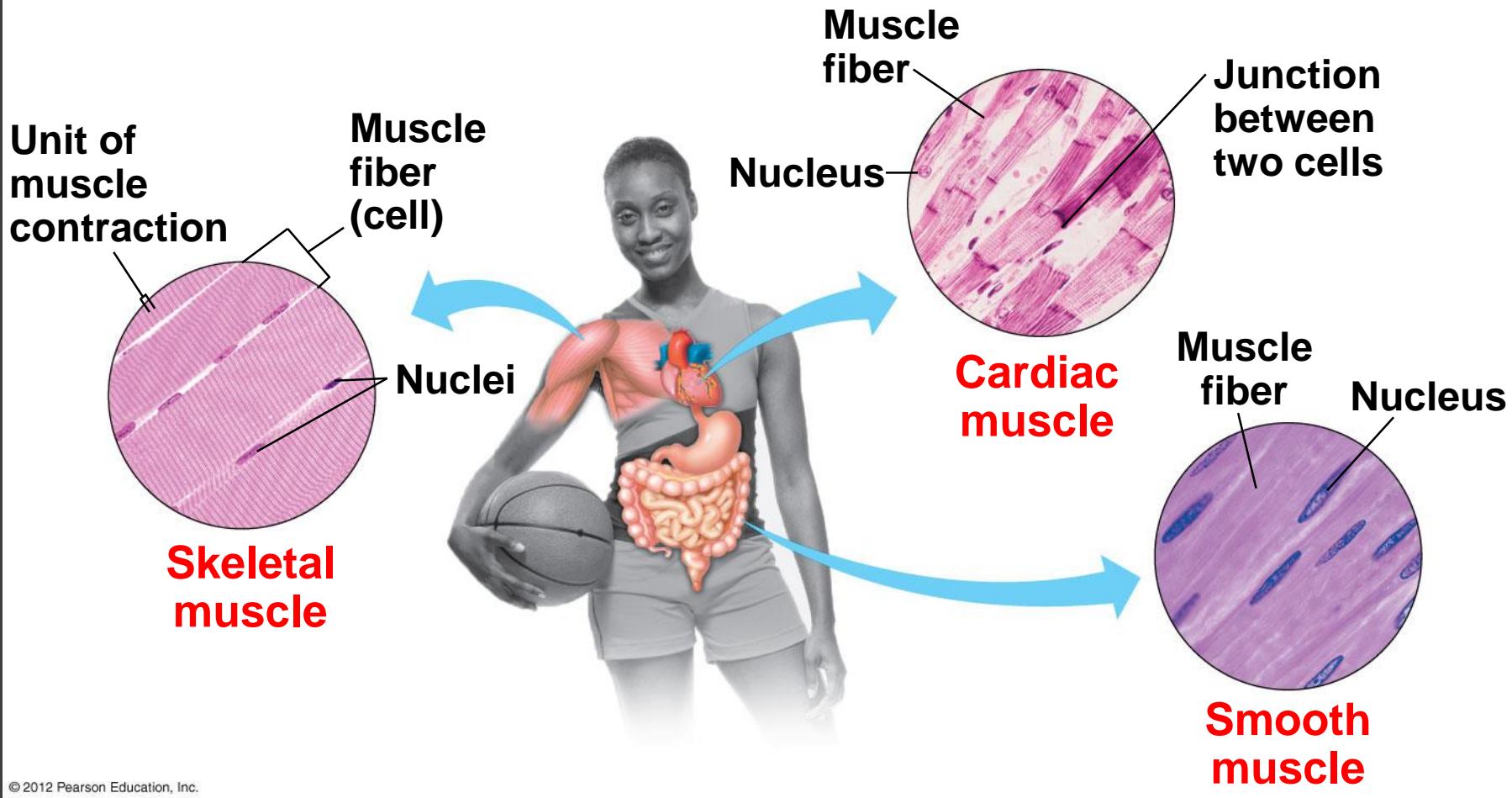
Figure 20.5



Muscle tissue functions in movement

- **Muscle tissue** is the most abundant tissue in most animals. Muscle cell has proteins that slide back and forth helping muscles to contract.
- There are three types of vertebrate muscle tissue:
 1. **Skeletal muscle** causes **voluntary** movements.
 2. **Cardiac muscle** pumps blood.
 3. **Smooth muscle** moves walls of internal organs, such as the intestines.

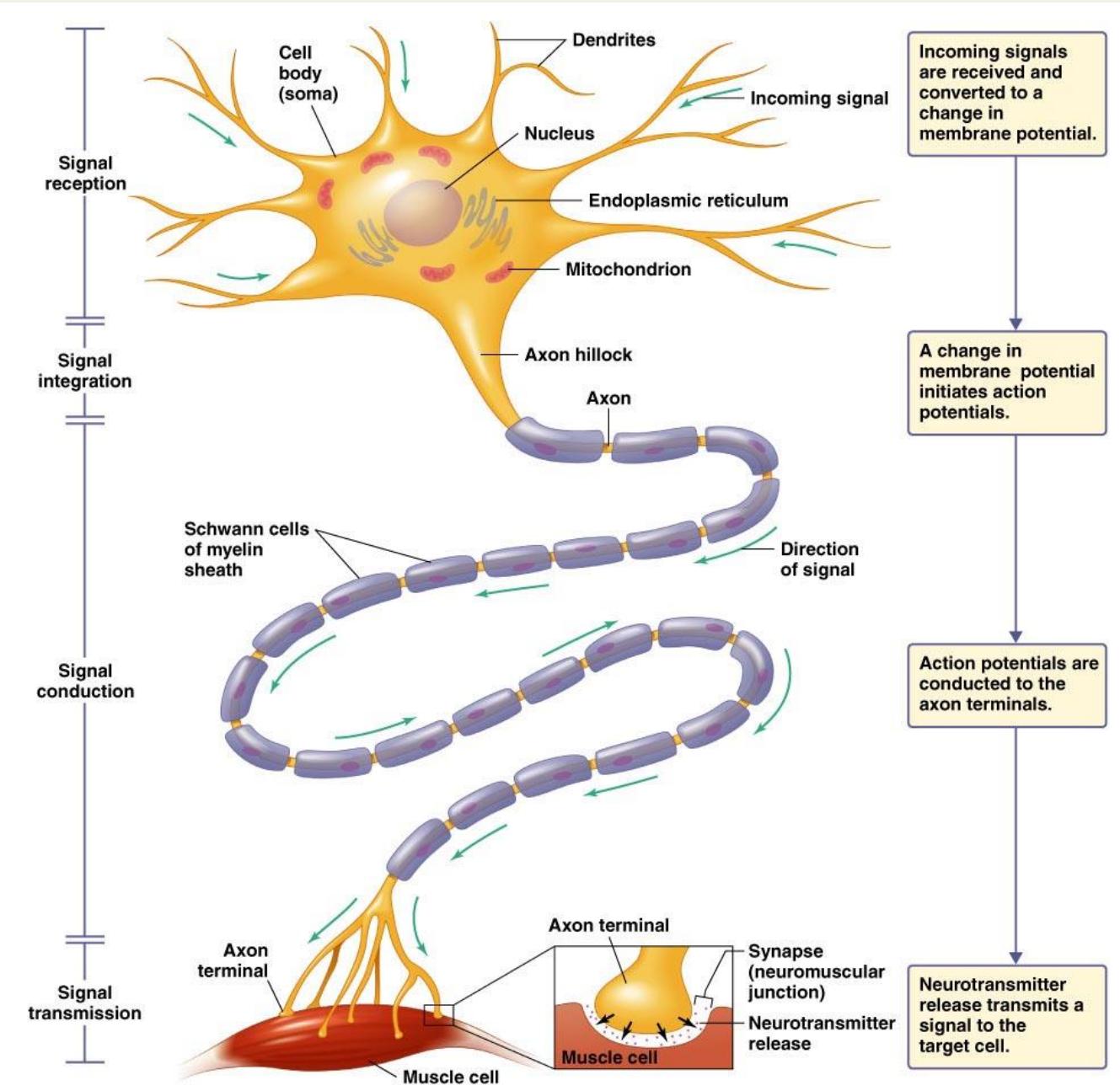
Three types of muscle tissue



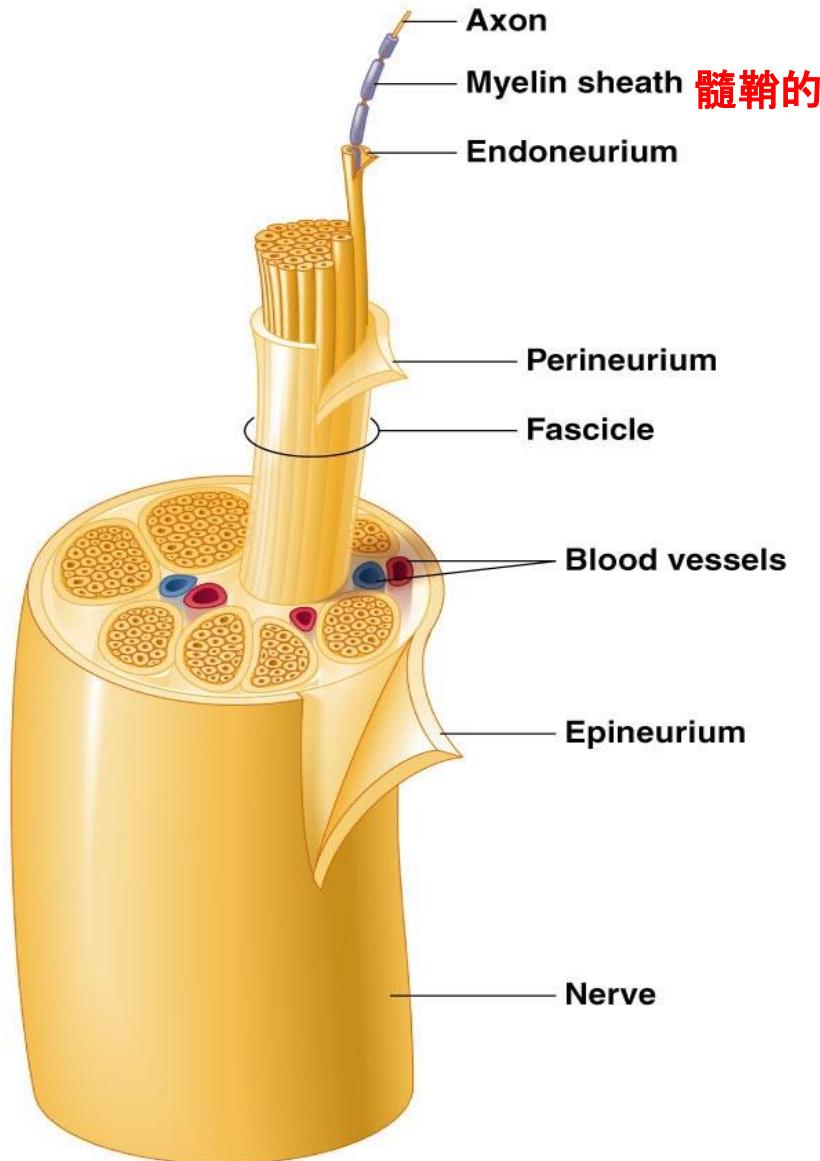
Nervous tissue forms a communication network

- **Nervous tissue**
 - senses stimuli and
 - rapidly transmits information.
- **The neuron** (神经元) is the functional unit of the nervous system. Neurons carry signals by conducting electrical impulses.
- Other cells in nervous tissue
 - insulate axons,
 - nourish neurons, and
 - regulate the fluid around neurons

Nervous tissue



Structure of a Nerve

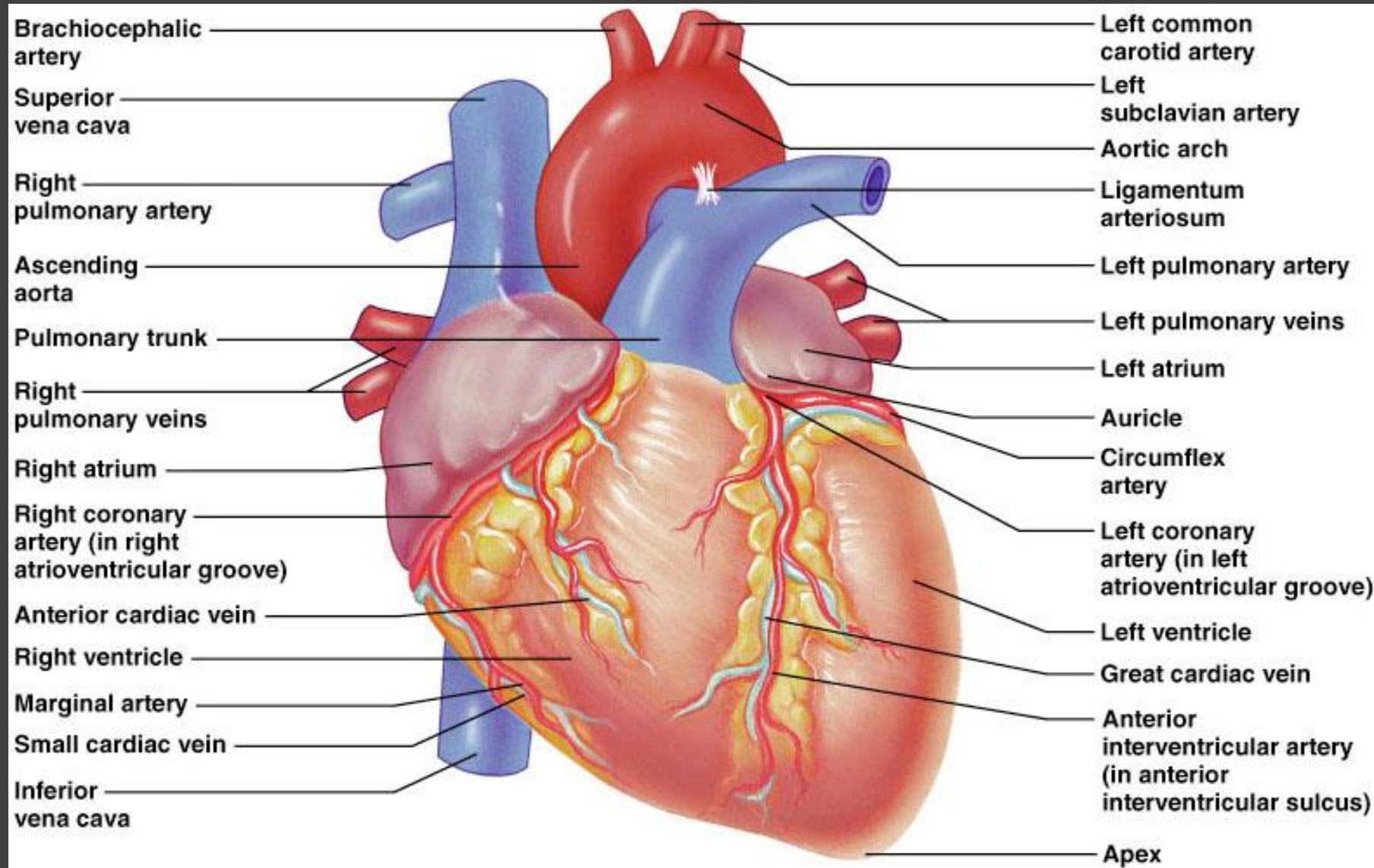


Myelin sheaths cover sections of some neurons. These neurons transmit information at a **higher rate**. **Axon** is most likely covered by a myelin sheath.

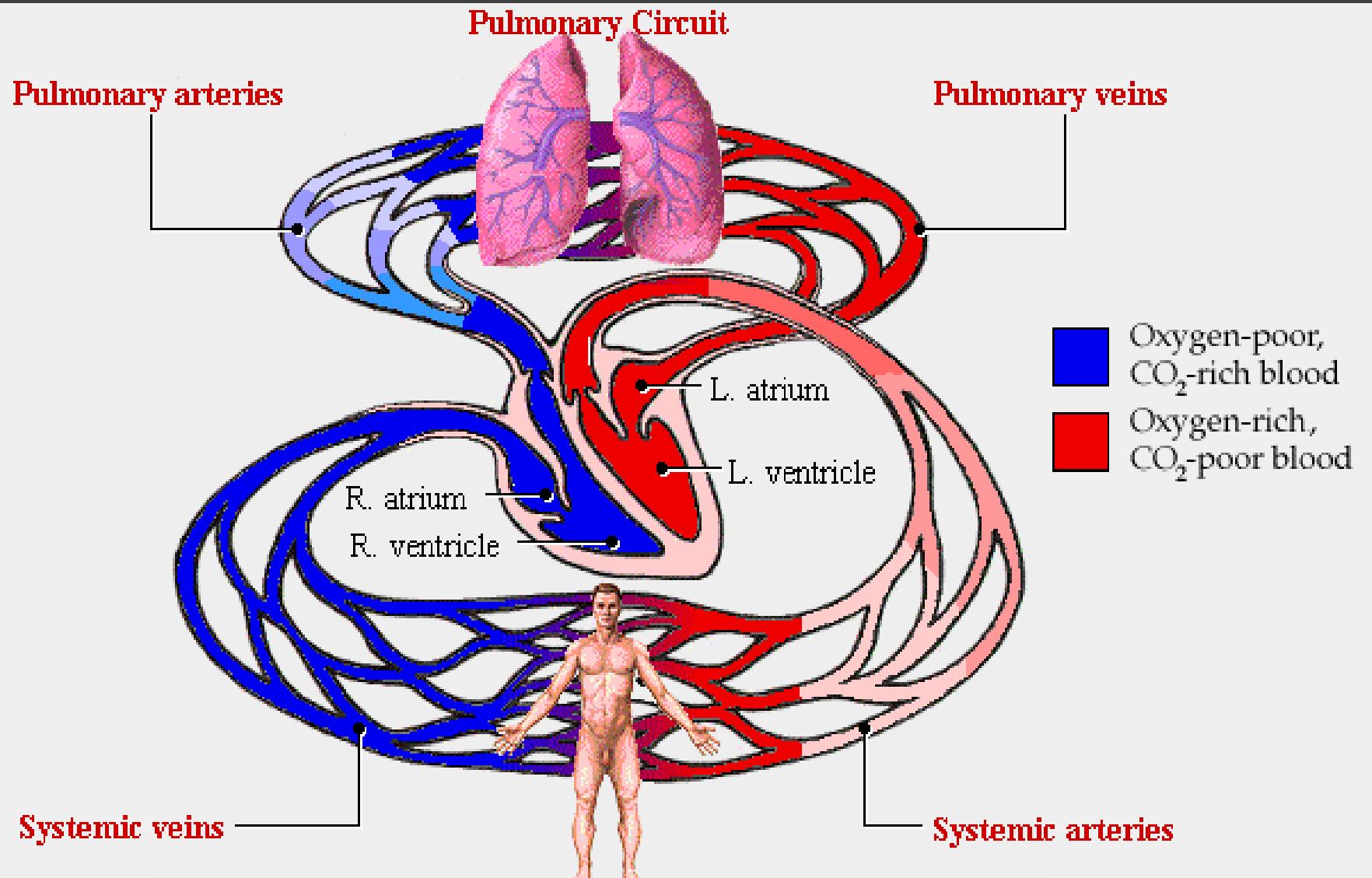
Organs are made up of tissues

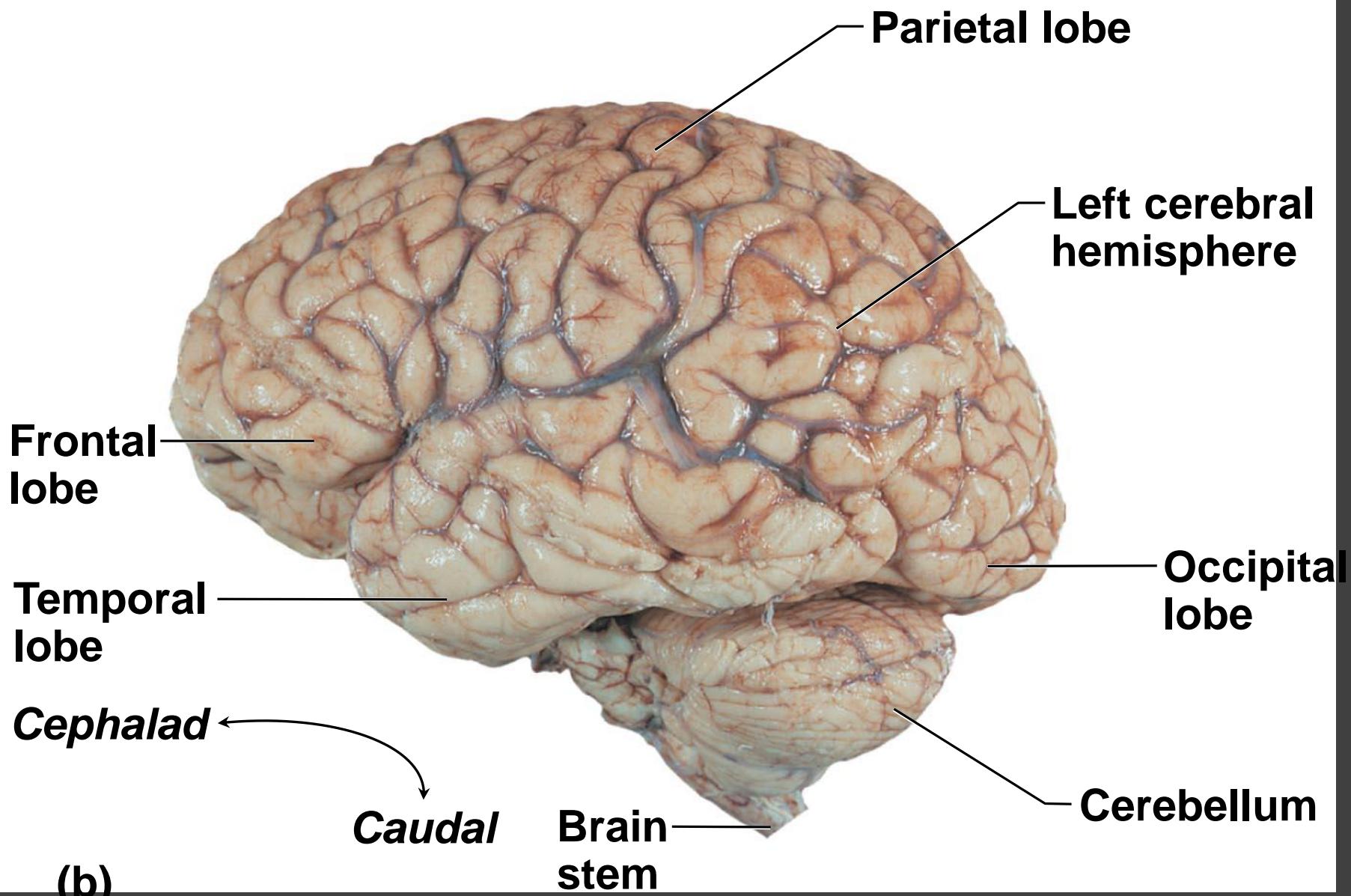
- Each tissue performs specific functions.
- The **heart** has
 - extensive muscle that generates contractions,
 - epithelial tissues that line the heart chambers,
 - connective tissues that make the heart elastic, and
 - neurons that regulate contractions.

External Heart: Anterior View



Heart: systemic circuit and pulmonary circuit

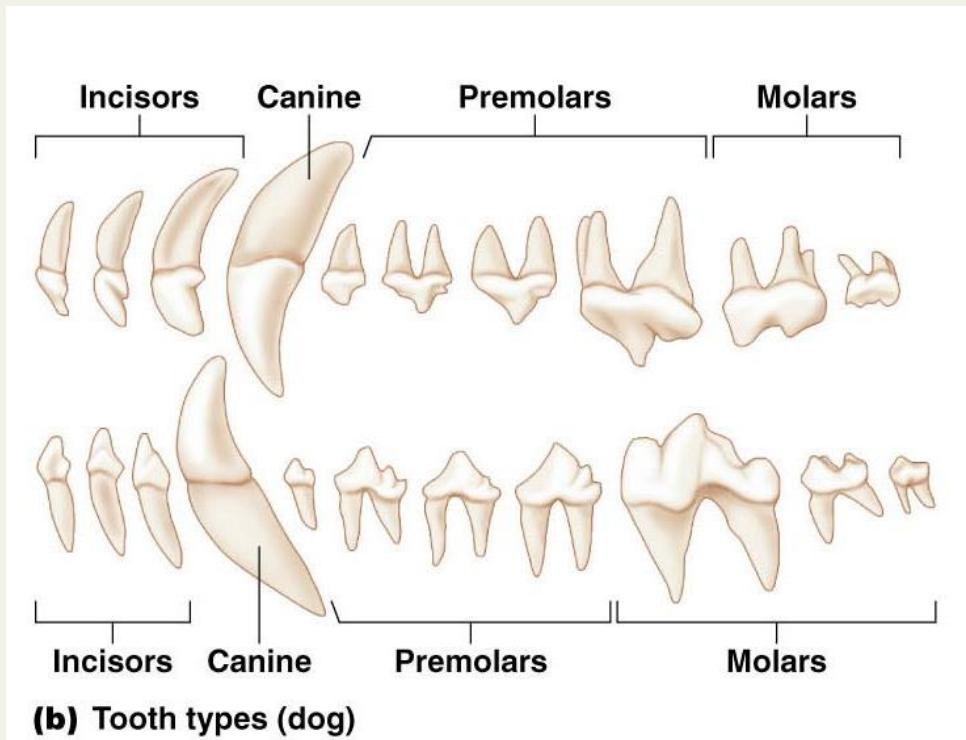




Regions of the Brain: Cerebrum

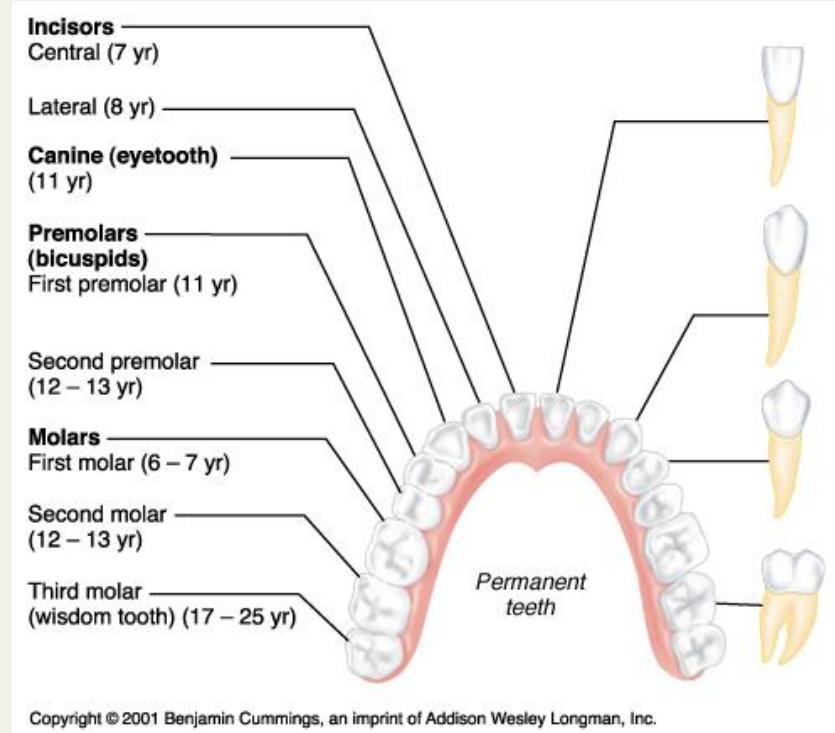
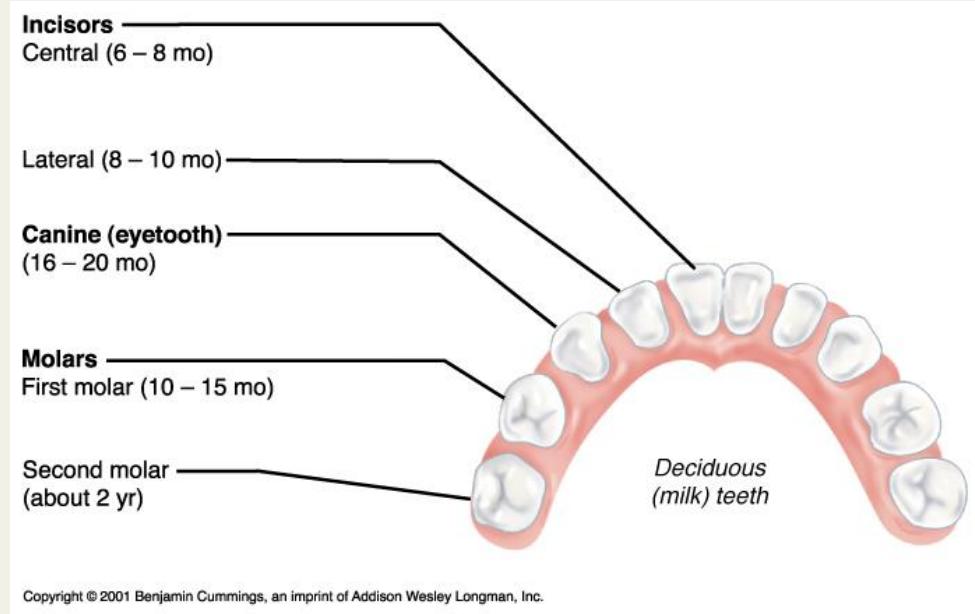
Teeth

- Four types of teeth
 - Incisors
 - Canines
 - Premolars
 - Molars
- Shape of the teeth reflects the type of diet



Piercing and tearing Grinding and chewing

Human Deciduous (20) and Permanent (32) Teeth

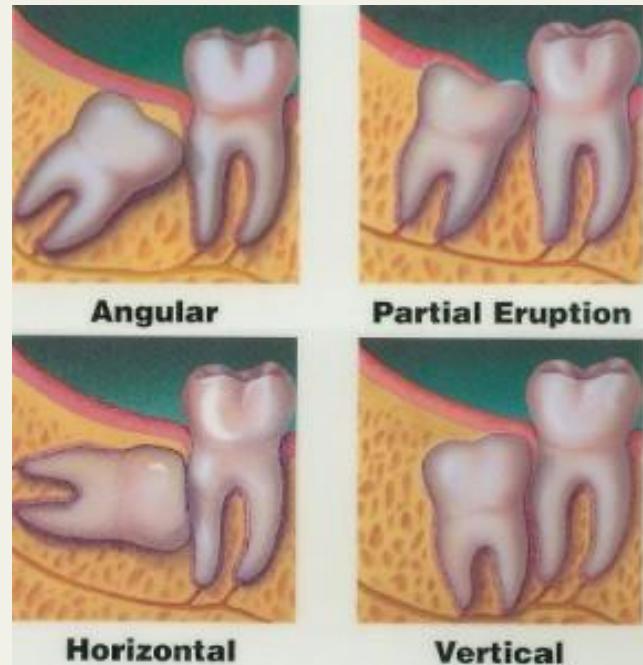


Impact teeth



X ray shows a horizontal impact tooth

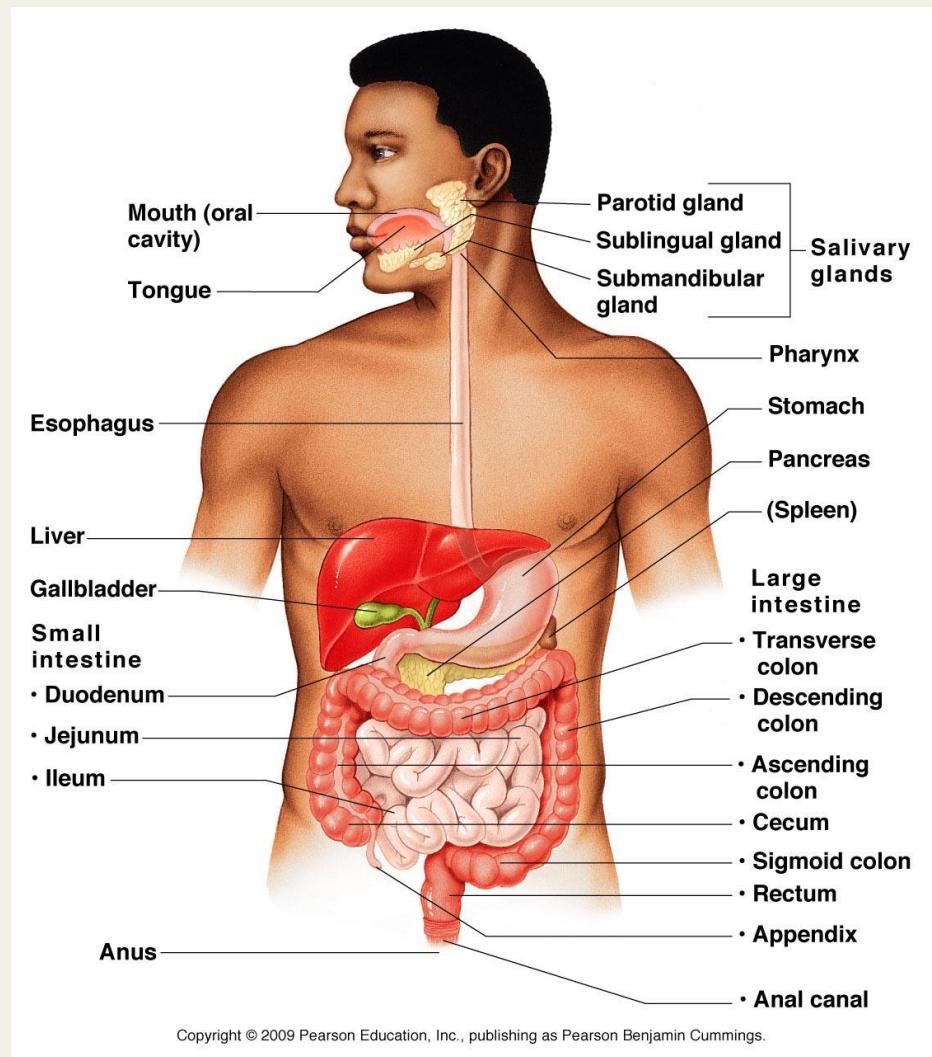
Li Y, Gu je San. Clinical analysis of mandibular impacted wisdom tooth: a report of 662 cases. *Acta Academiae Medicinae Nanjing* 4(2):105, 1984, China.



Schematic diagram for impact teeth

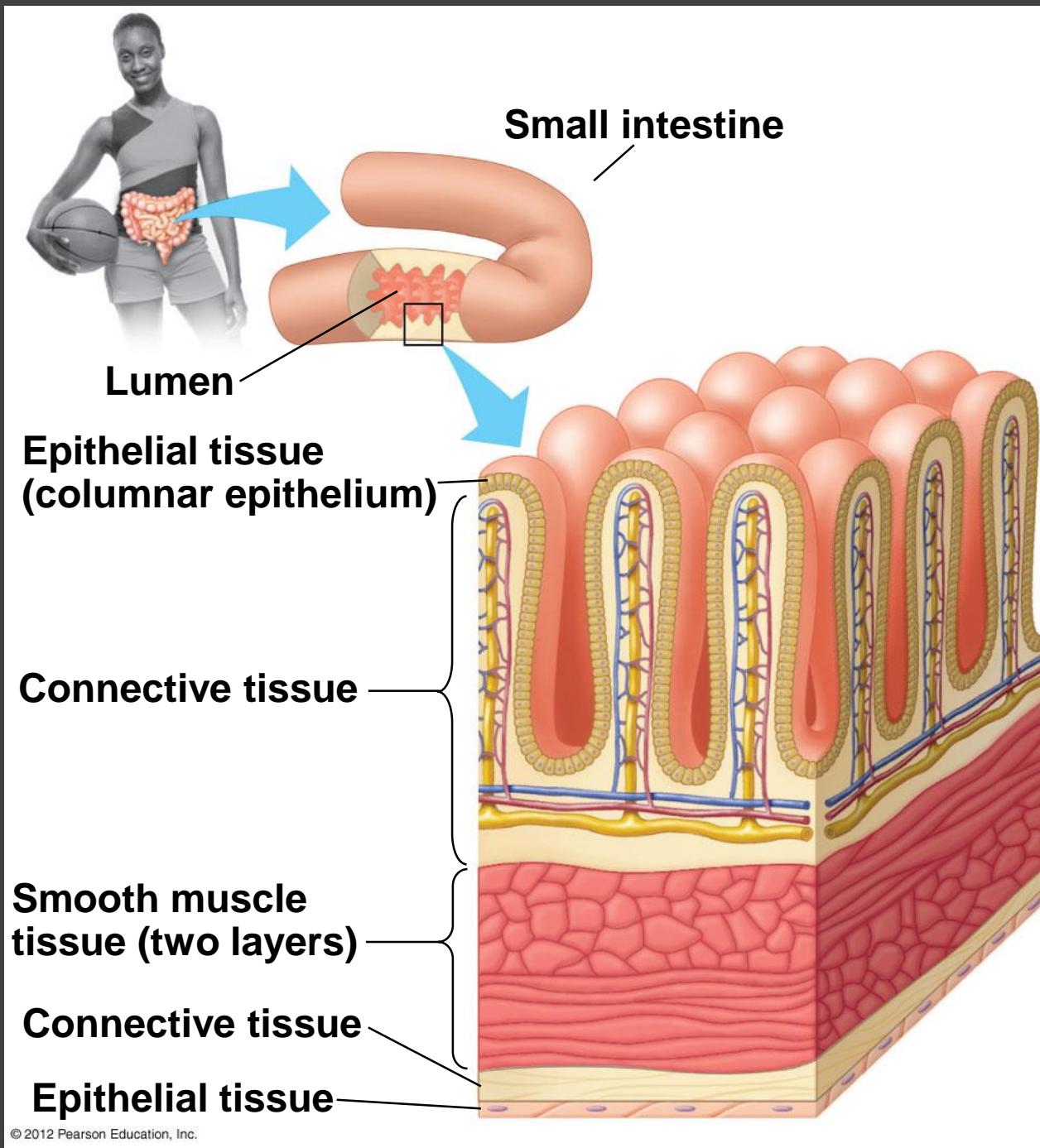
Small Intestine

- MAJOR digestive organ
- 3 subdivision
 - Duodenum
 - Jejunum
 - Ileum – meets large intestine at ileocecal valve
- Only able to process small amount of food at time, pyloric sphincter controls food movement



■ The small intestine

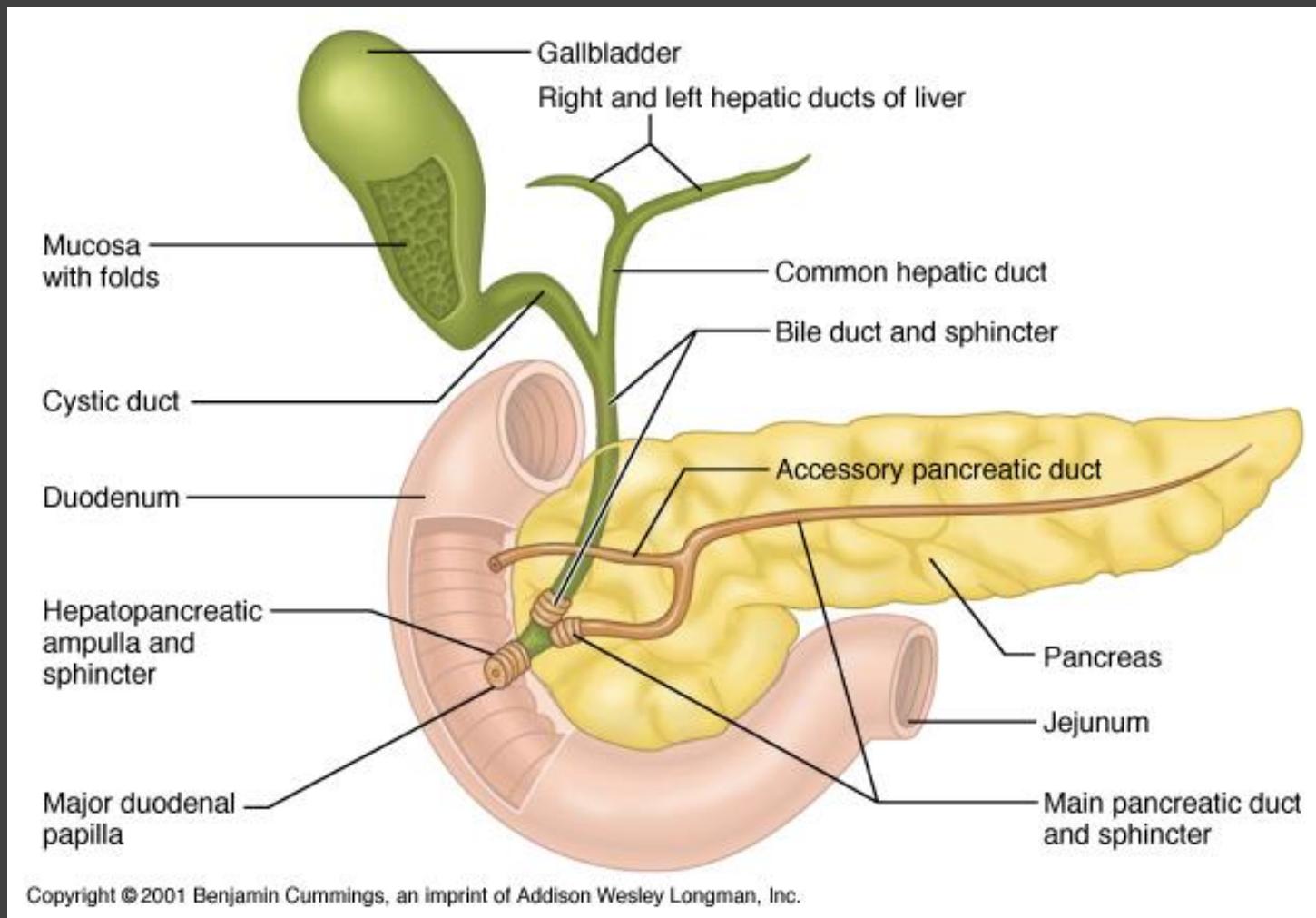
- is lined by a columnar epithelium,
- includes connective tissues that contain blood vessels, and
- has two layers of smooth muscle that help propel food.
- The inner surface of the small intestine has many fingerlike projections that increase the surface area for absorption.
- Mucous membrane secretes a substance that lubricates and keeps surface moist.



Accessory Organs Associated with Duodenum

- Pancreas – enzymes that complete food digestion, ducted to duodenum via pancreatic ducts
- Gallbladder and liver – bile (formed by liver) enters via bile duct
- Bile duct and pancreatic duct form hepatopancreatic ampulla and duodenal papilla

The Duodenum and Related Organs



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Liver

- One of body's most important organs and largest gland
- Four lobes, suspended from diaphragm and abdominal wall by falciform ligament 镰状韧带
- **Dual blood supply**

Hepatic portal vein 肝门静脉

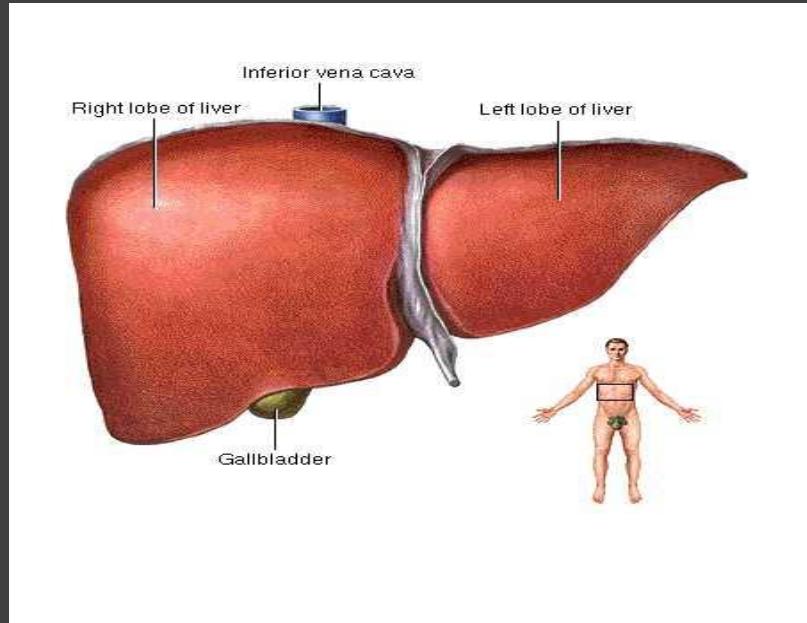
- Direct input from small intestine

PORTAL HYPERTENSION
in the Patients with cirrhosis

Hepatic artery/vein

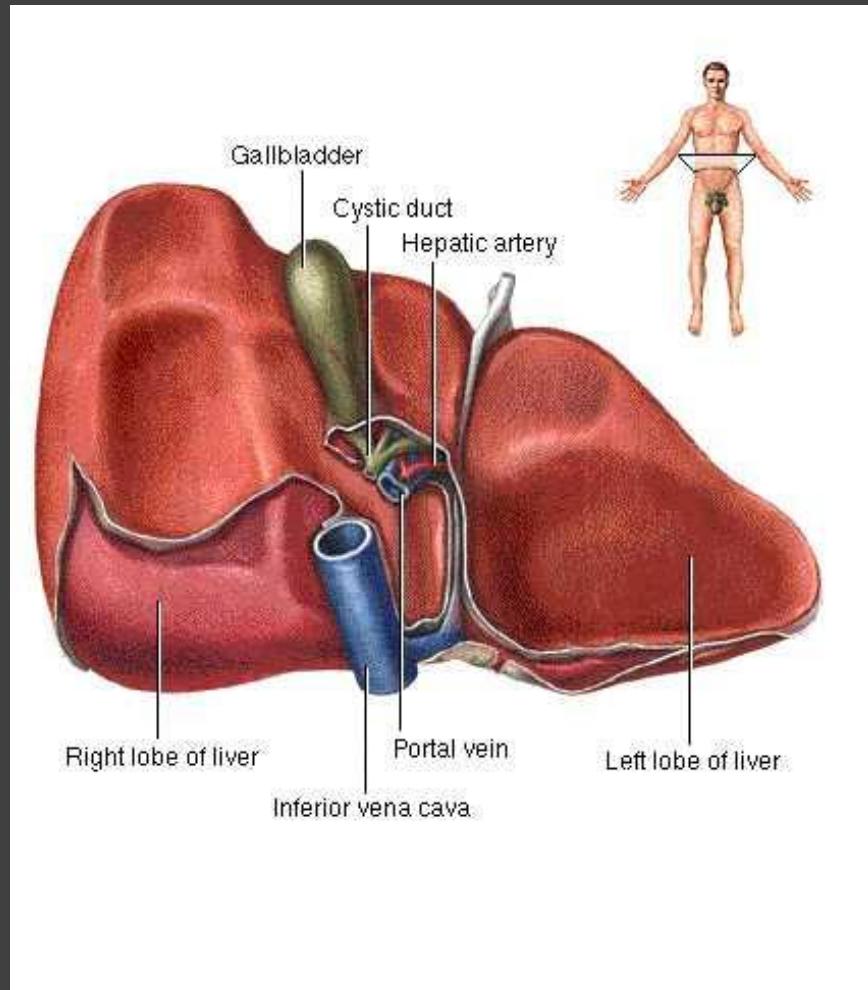
- Direct links to heart

Digestive function – produce bile



Liver

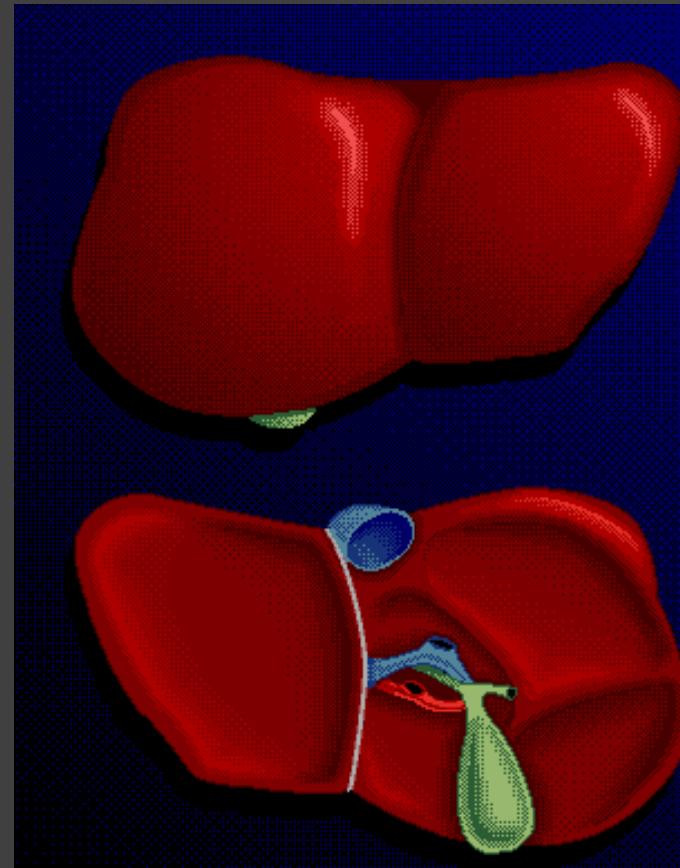
- Detoxifies/removes
 - Drugs
 - Alcohol
- Stores
 - Glycogen
 - Vitamins (A, D, E, K)
 - Fe and other minerals
 - Cholesterol
- Activates vitamin D
- Fetal RBC production
- Phagocytosis
- Metabolizes absorbed food molecules
 - Carbohydrates
 - Proteins
 - Lipids



Liver

■ Functions

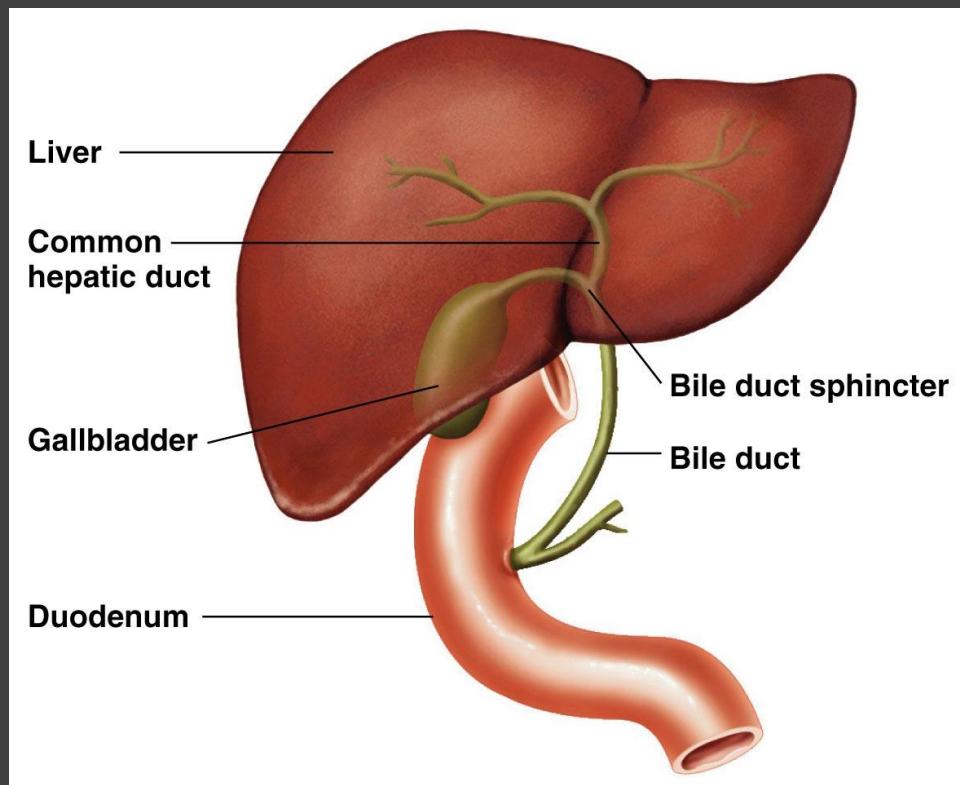
- Makes bile
 - Detergent – emulsifies fats
 - Release promoted by:
 - Vagus n.
 - CCK
 - Secretin
 - Contains
 - Water
 - Bile salts
 - Bile pigments
 - Electrolytes
 - Cholesterol



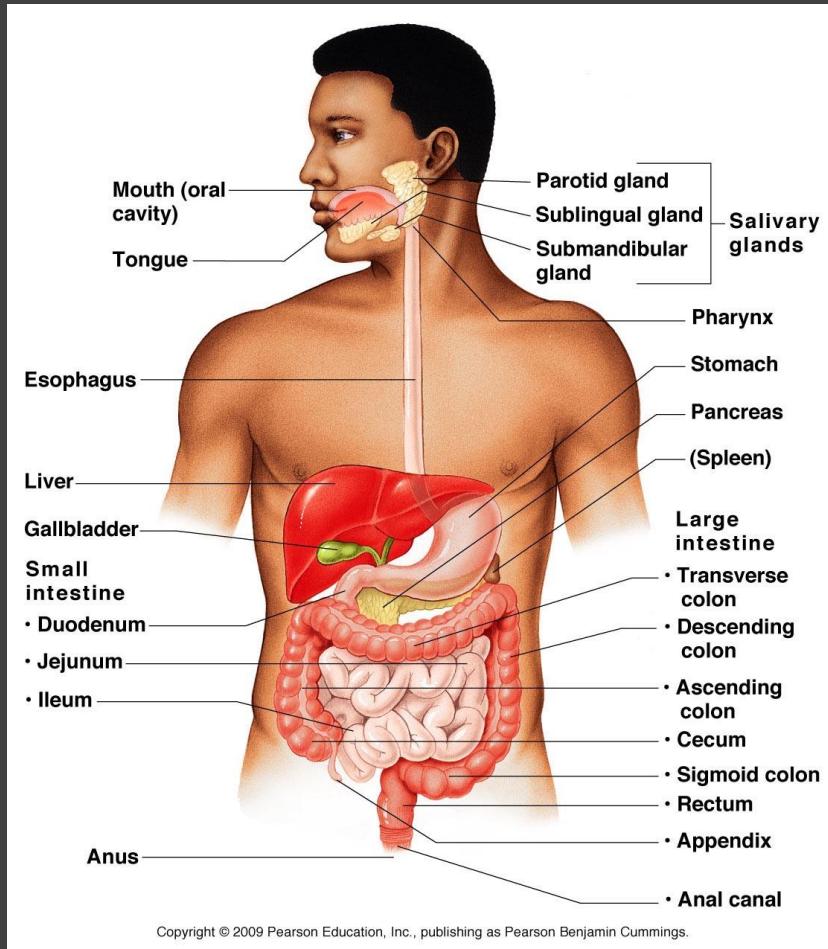
Exocrine Secretions into the Intestine

- **Bile** 胆汁

- Produced in the liver and stored in the gallbladder
- Solution of digestive chemicals and liver waste products
- Phospholipids
 - Aid in the uptake of lipids
- Bile salts
 - Emulsify fats
- Bile duct opens into small intestine



Gall Bladder



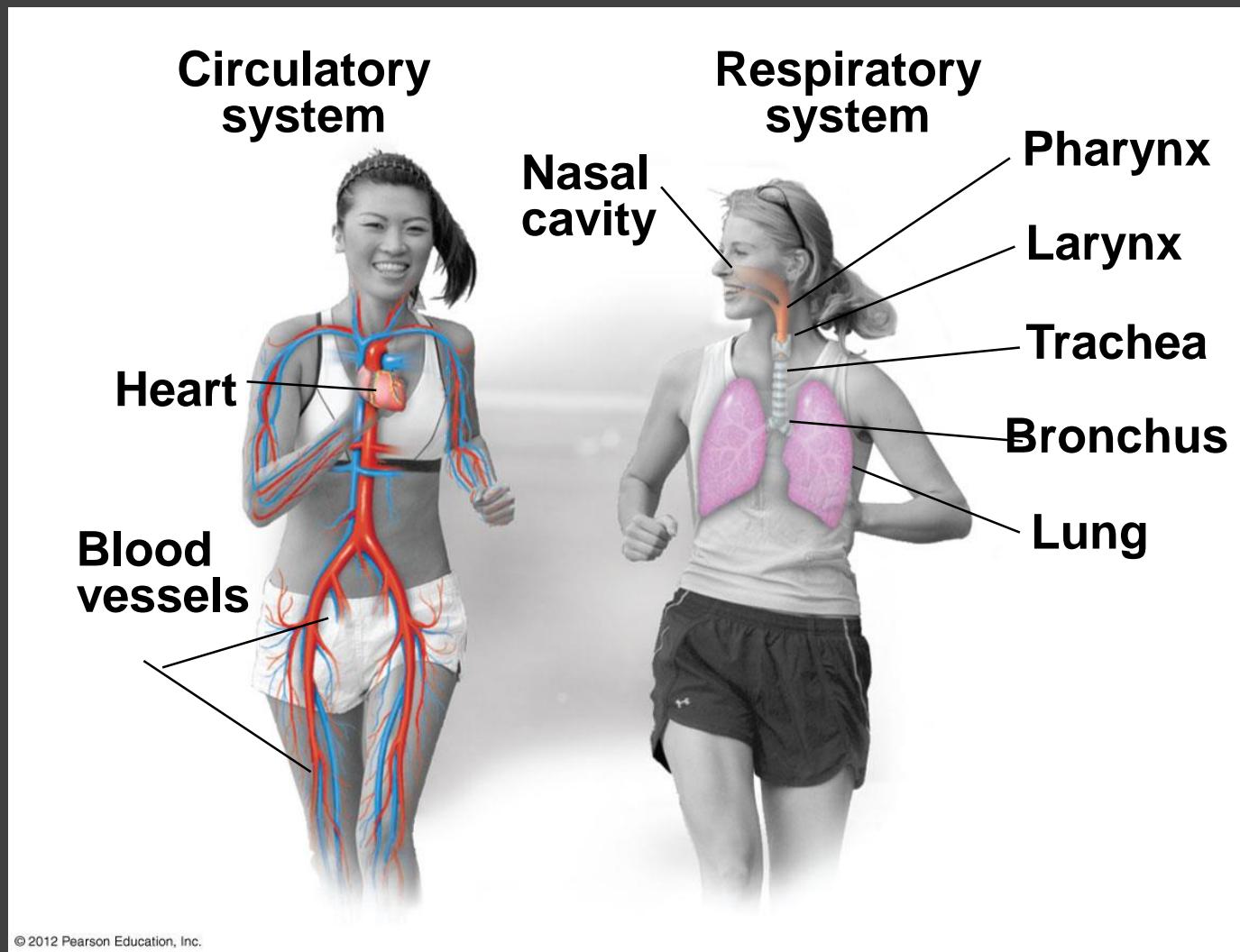
- Thin walled green sac
- When not eating bile stored here
- Concentrated by water removal
- Fatty meal enters duodenum, bile released due to hormonal stimulus

Organ systems work together to perform life's functions

Each organ system

- typically consists of many organs,
- has one or more functions, and
- works with other organs together in a systems to collectively perform a vital body function.

The **circulatory system** delivers O₂ and nutrients to body cell and transports CO₂ carbon dioxide 二氧化碳 to the lungs and metabolic wastes to the kidneys.



The **respiratory system** exchanges gases with the environment, supplying blood with O₂ and disposing CO₂.

Blood Pressure

- Measurements by health professionals are made on the pressure in large arteries
 - Systolic—pressure at the peak of ventricular contraction
 - Diastolic—pressure when ventricles relax
 - Write systolic pressure first and diastolic last (120/80 mm Hg)
- Pressure in blood vessels decreases as distance from the heart increases

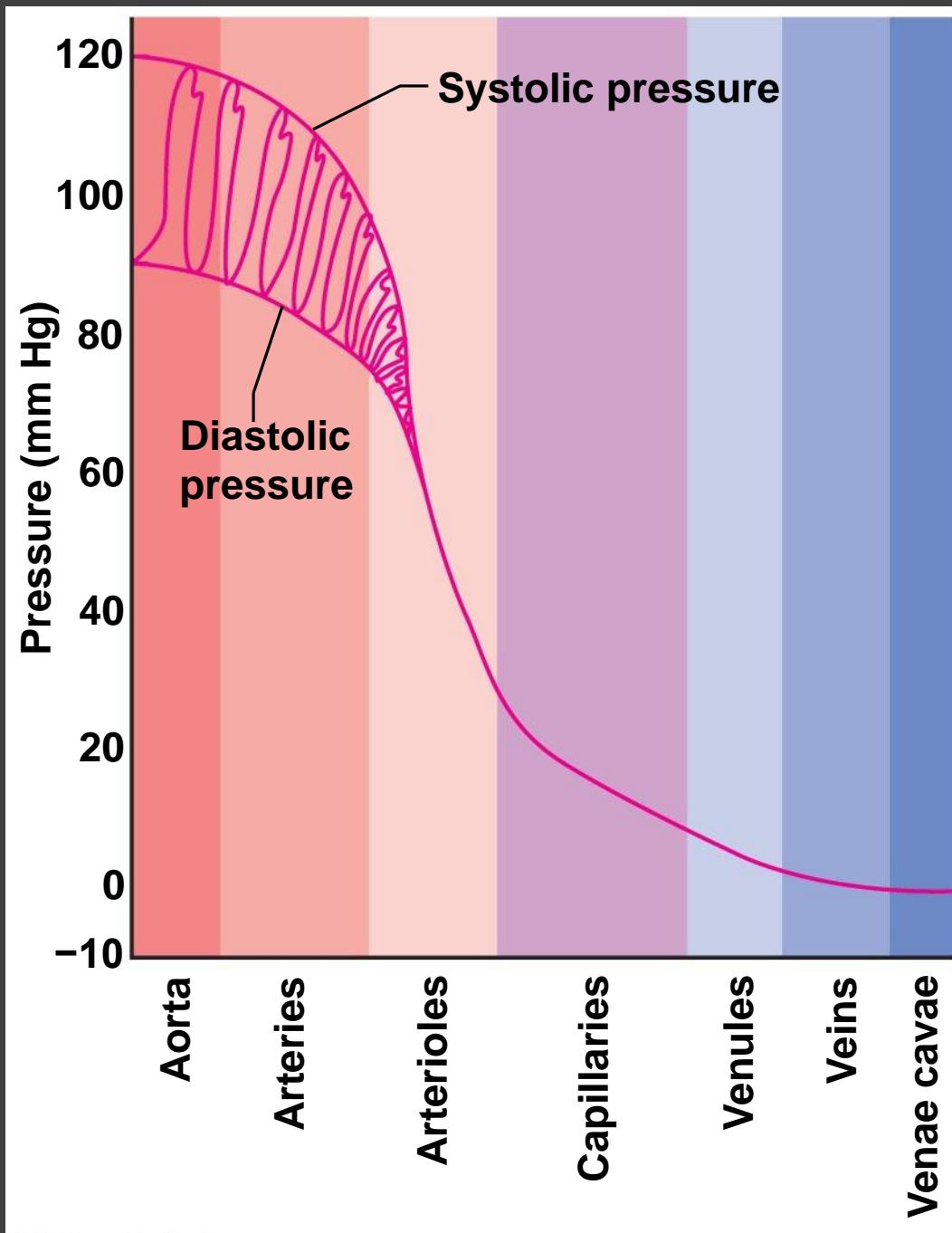
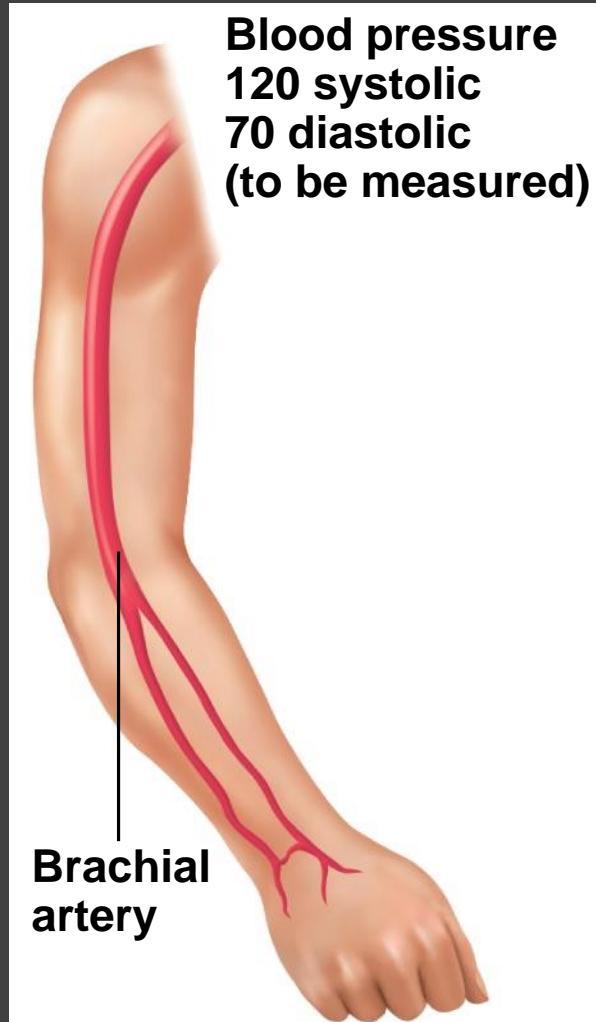


Figure 11.20



(a) The course of the brachial artery of the arm. Assume a blood pressure of 120/70 in a young, healthy person.

Figure 11.21a

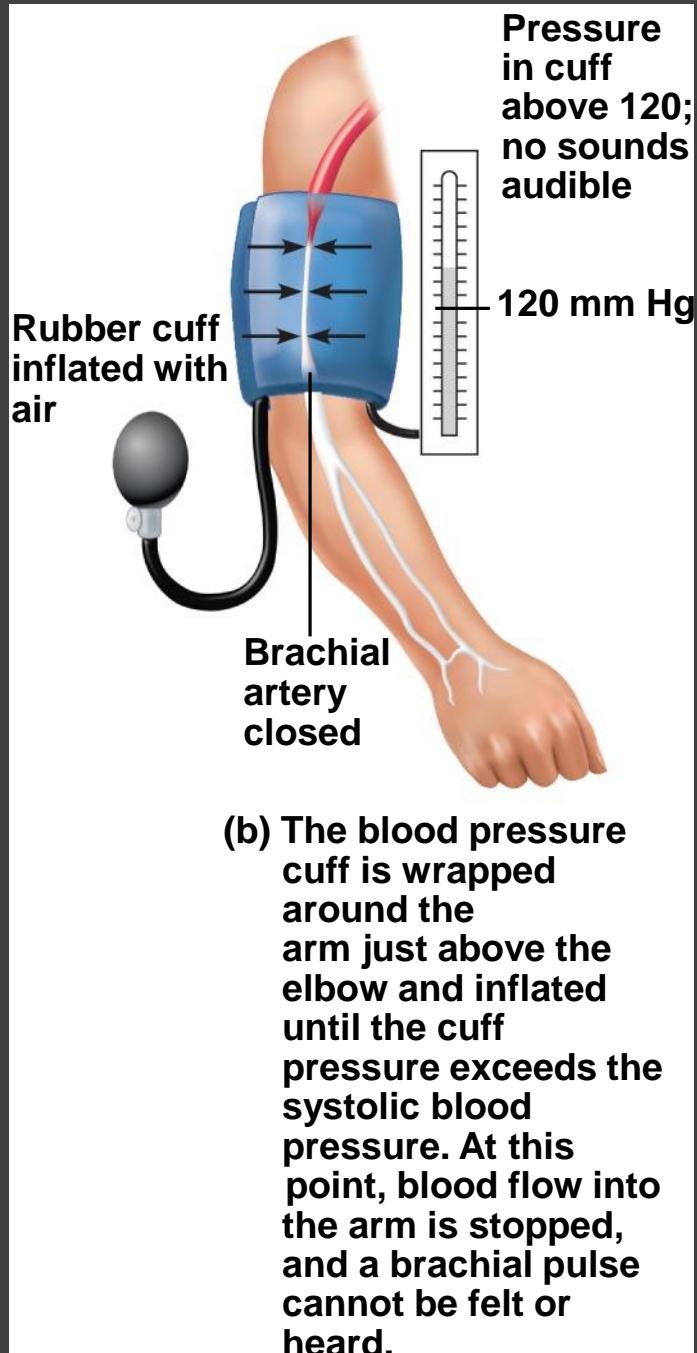
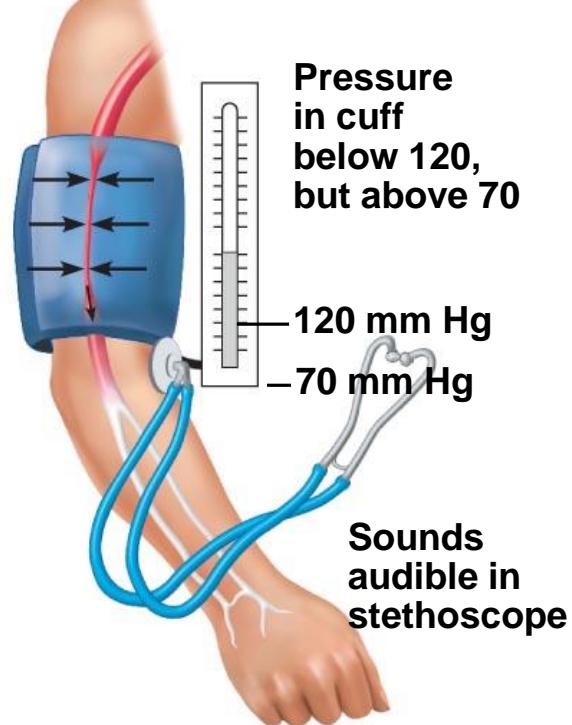
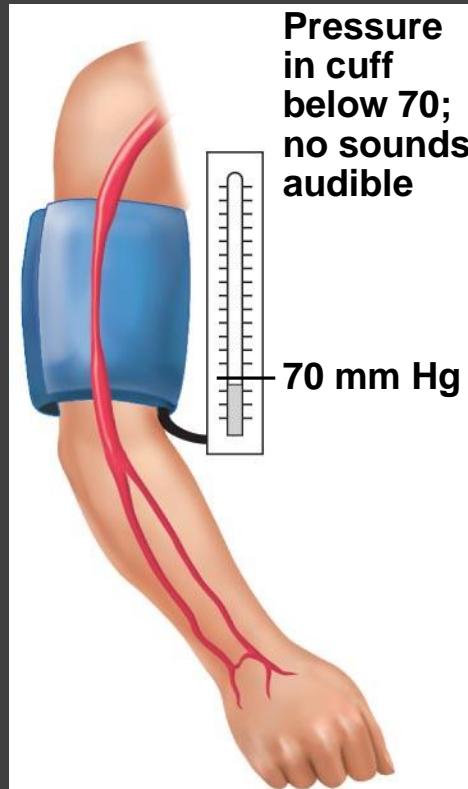


Figure 11.21b



(c) The pressure in the cuff is gradually reduced while the examiner listens (auscultates) for sounds in the brachial artery with a stethoscope. The pressure read as the first soft tapping sounds are heard (the first point at which a small amount of blood is spurting through the constricted artery) is recorded as the systolic pressure.

Figure 11.21c



(d) As the pressure is reduced still further, the sounds become louder and more distinct; when the artery is no longer constricted and blood flows freely, the sounds can no longer be heard. The pressure at which the sounds disappear is recorded as the diastolic pressure.

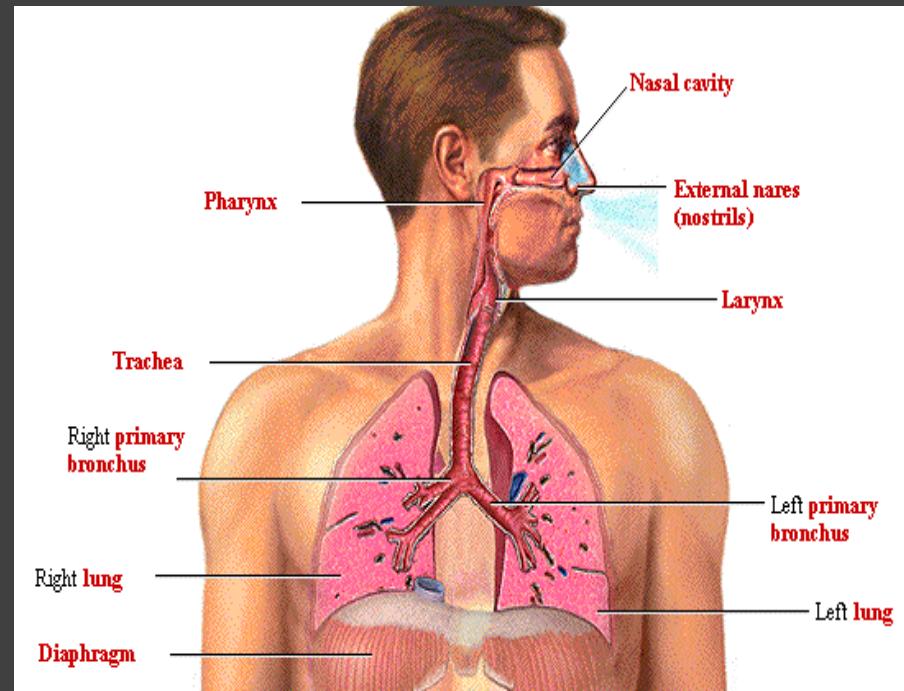
Figure 11.20d

- **Upper respiratory tract**
 - Mouth, nasal cavity, pharynx, trachea
- **Lower respiratory tract**
 - Bronchi and gas exchange surfaces (alveoli)
- **Alveoli are the site of gas exchange**

Thin wall of type I alveolar cells

Type II surfactant cells secrete fluid

Outer surface of alveoli are covered in capillaries

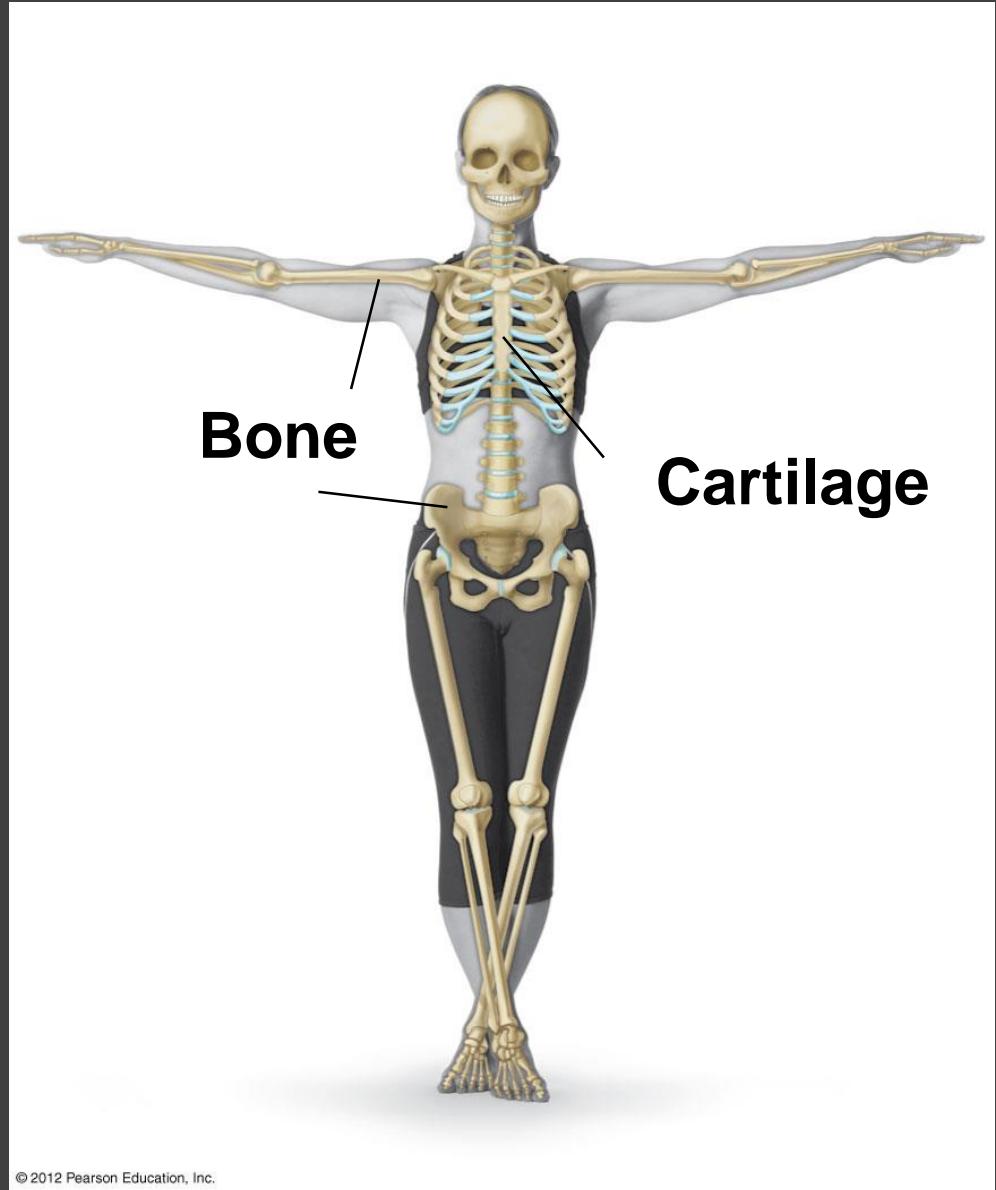


The **integumentary system** covers the body against injury, infection, excessive heat or cold, and drying out.



Skeletal system

The **skeletal systems** support the body, protects organs (brain, lungs) and provides the framework for muscles to produce movement

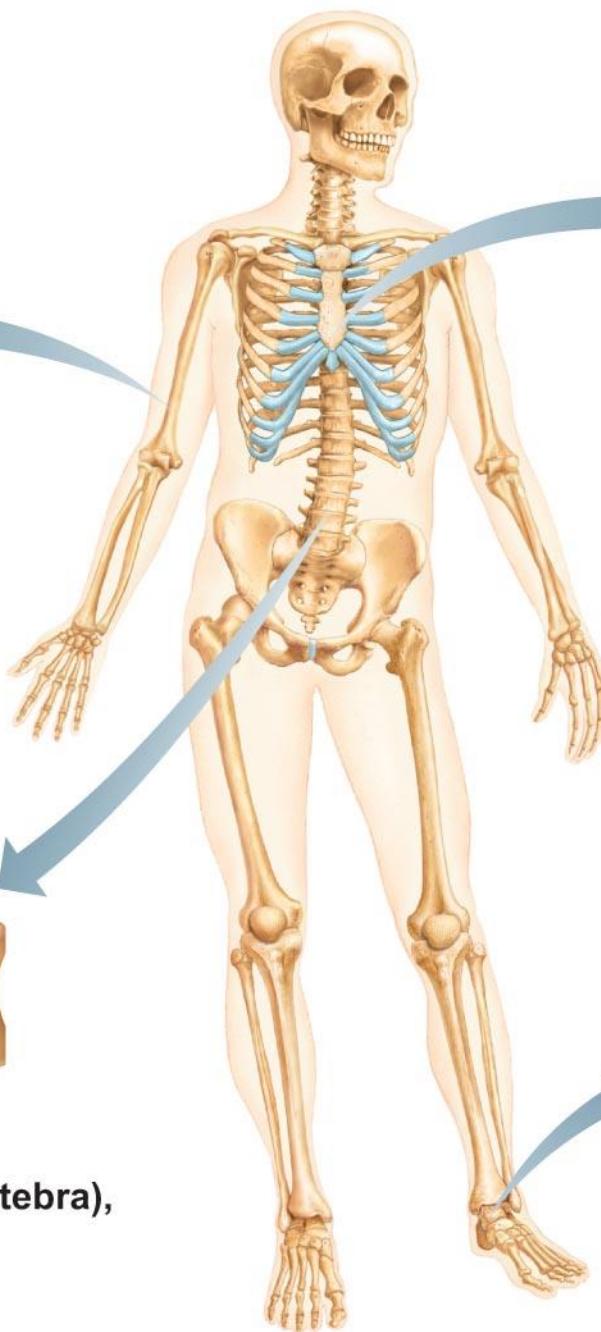




(a) Long bone
(humerus)



(b) Irregular bone (vertebra),
right lateral view



(c) Flat bone (sternum)

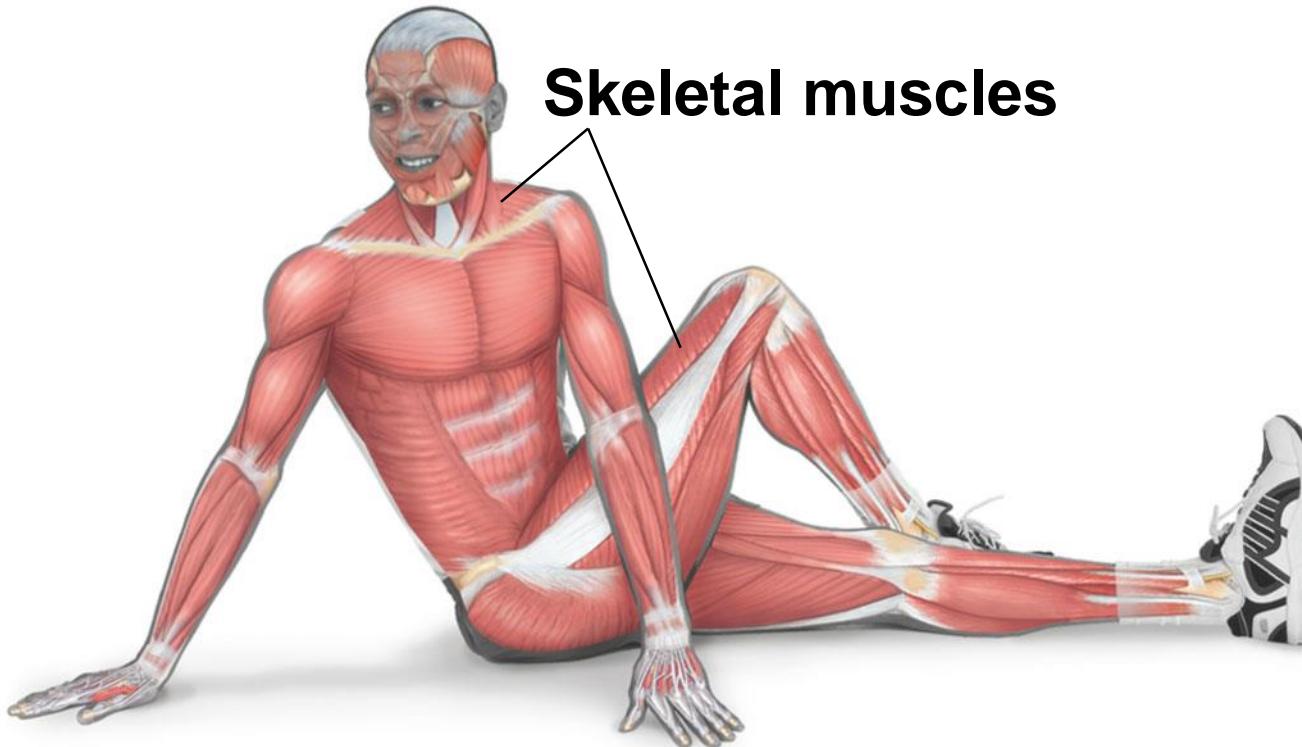


(d) Short bone (talus)

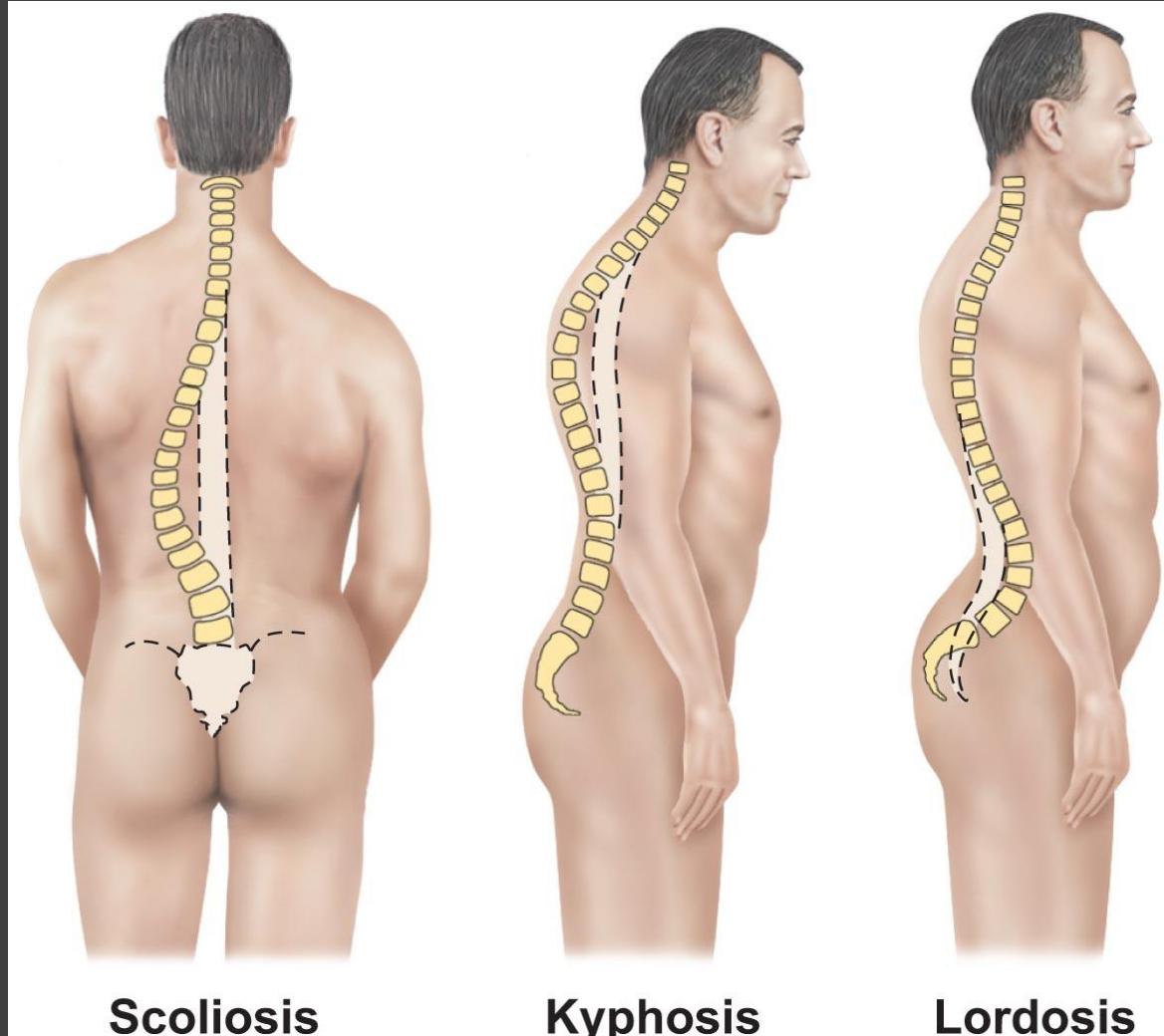
The **muscular system** moves your body,
maintains posture, and produces heat

Muscular system

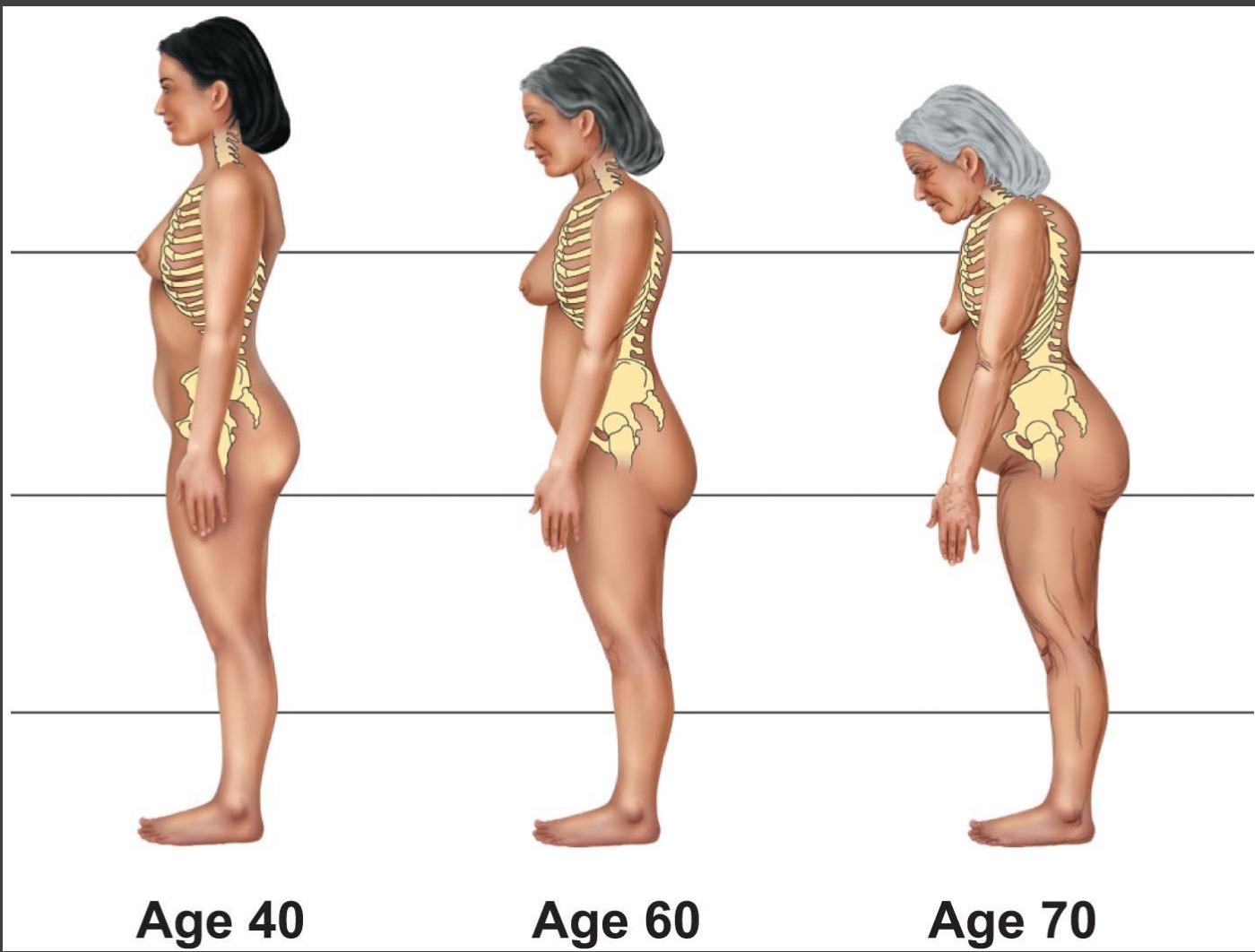
Skeletal muscles



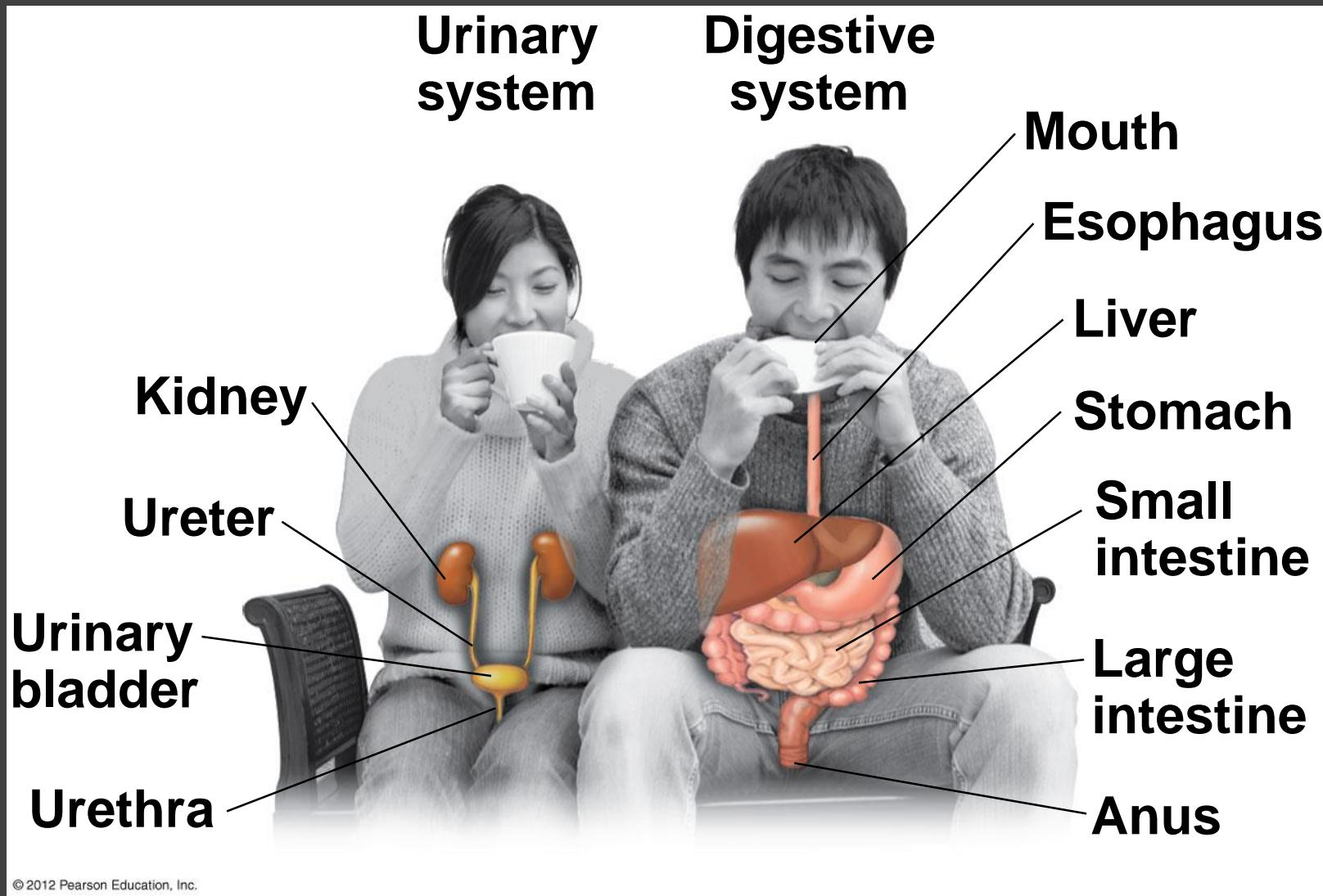
Abnormal spinal curvatures (scoliosis 脊柱侧凸 and lordosis 脊柱前弯症), kyphosis 驼背 are often congenital



Skeletal Changes Throughout Life



The **digestive systems** ingested and digests food, absorbs nutrients, and eliminated undigested materials



The **urinary system** disposes of wastes from blood an excretes urine, and also regulates the PH and water balance of your blood

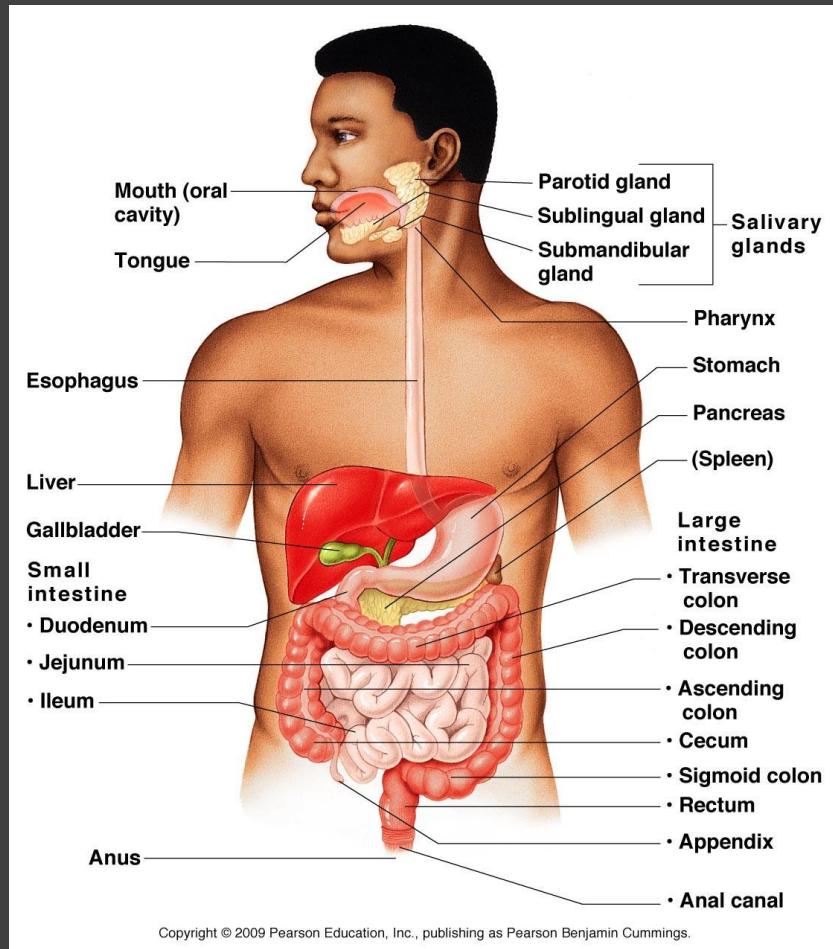
Human Digestive System

– Alimentary canal (GI Tract)

- Ingestion, digestion, absorption, defecation
- Continuous, coiled muscular tube through body
- Open at both ends
- Food outside body

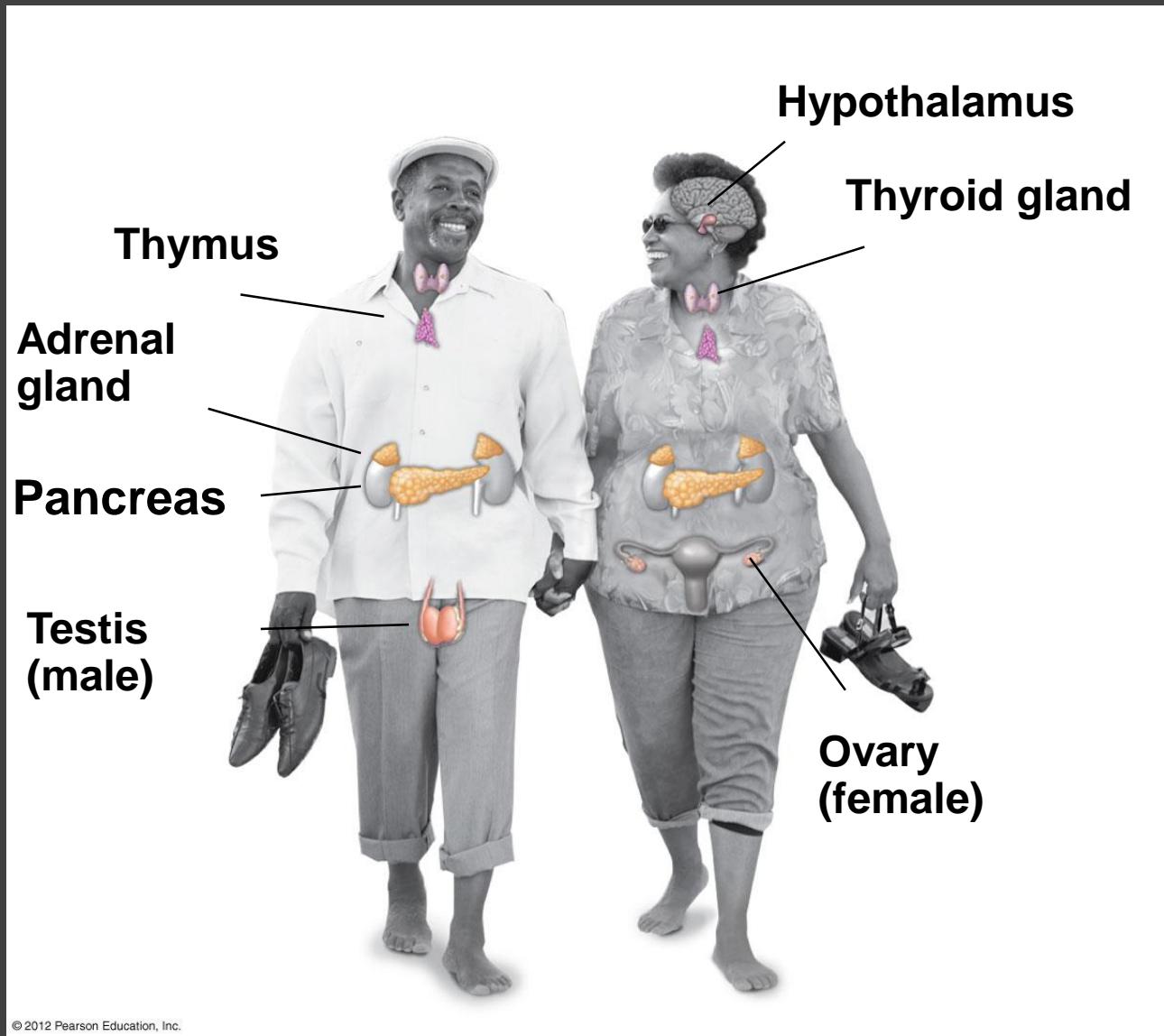
– Accessory digestive organs

- Assist digestive breakdown

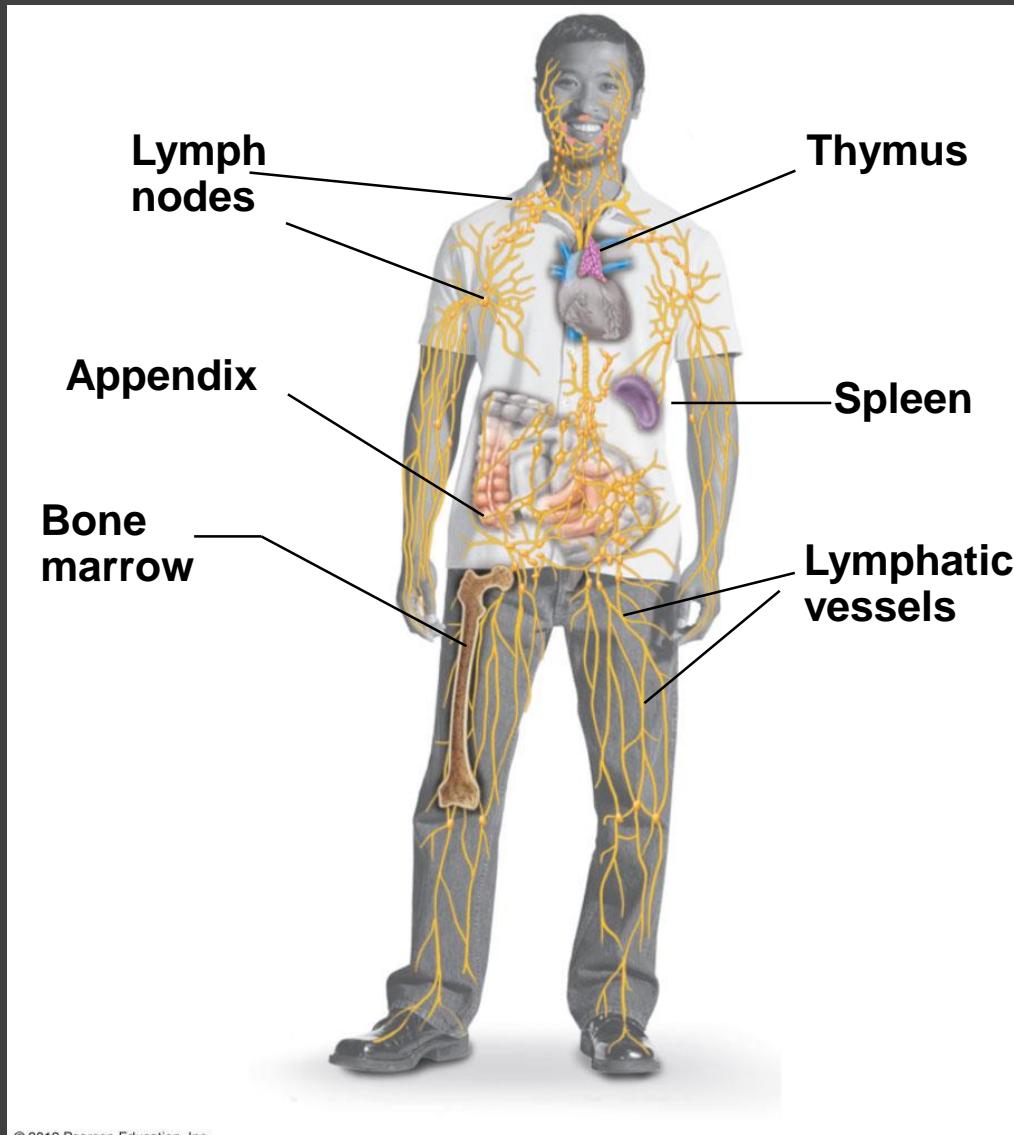


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Endocrine system secretes hormones that regulate the activity of body, and maintaining an internal steady state called homeostasis

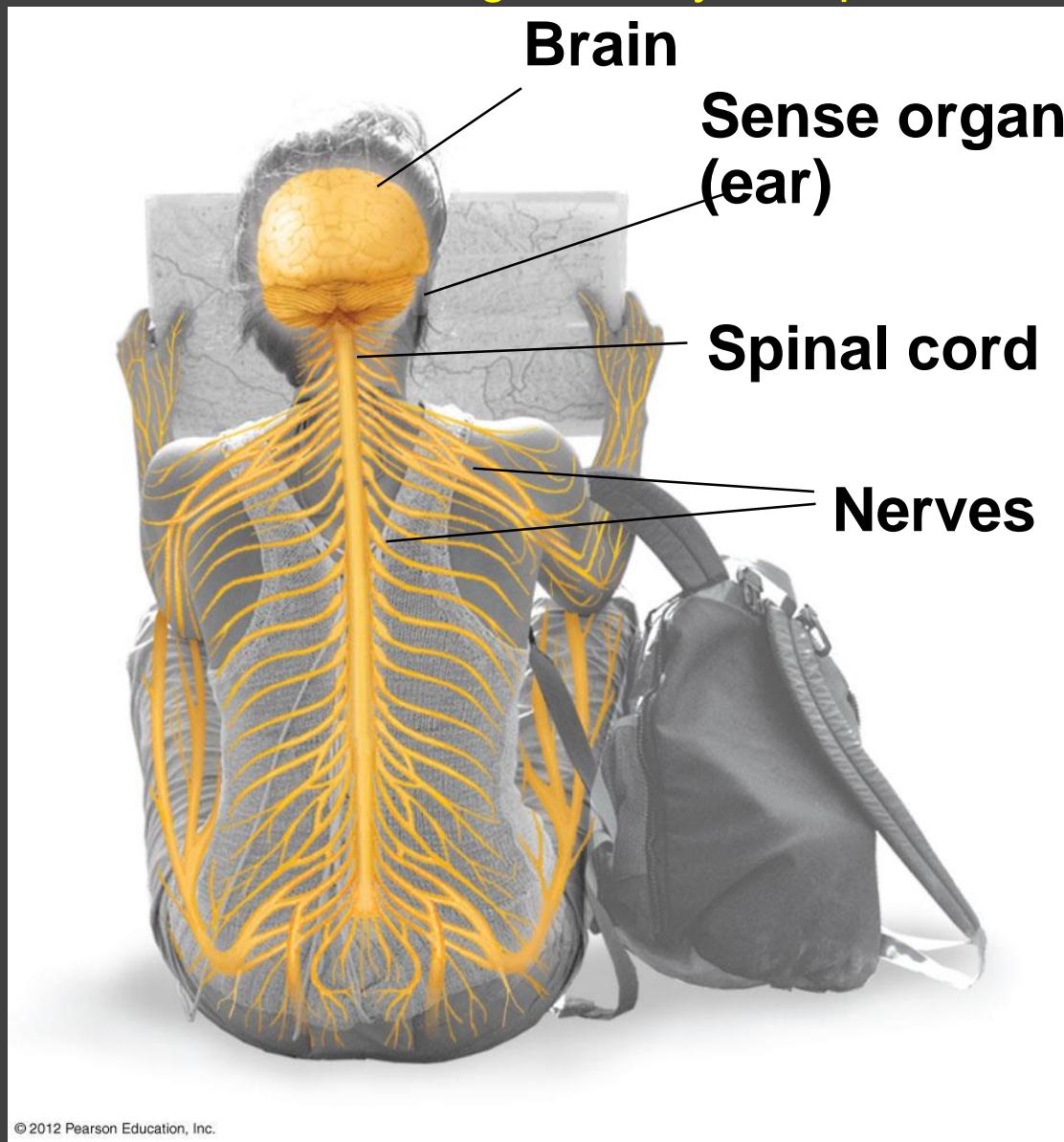


The **lymphatic system** returns excess body fluid to the circulatory system,
The **immune systems** defends your body against infections and cancer

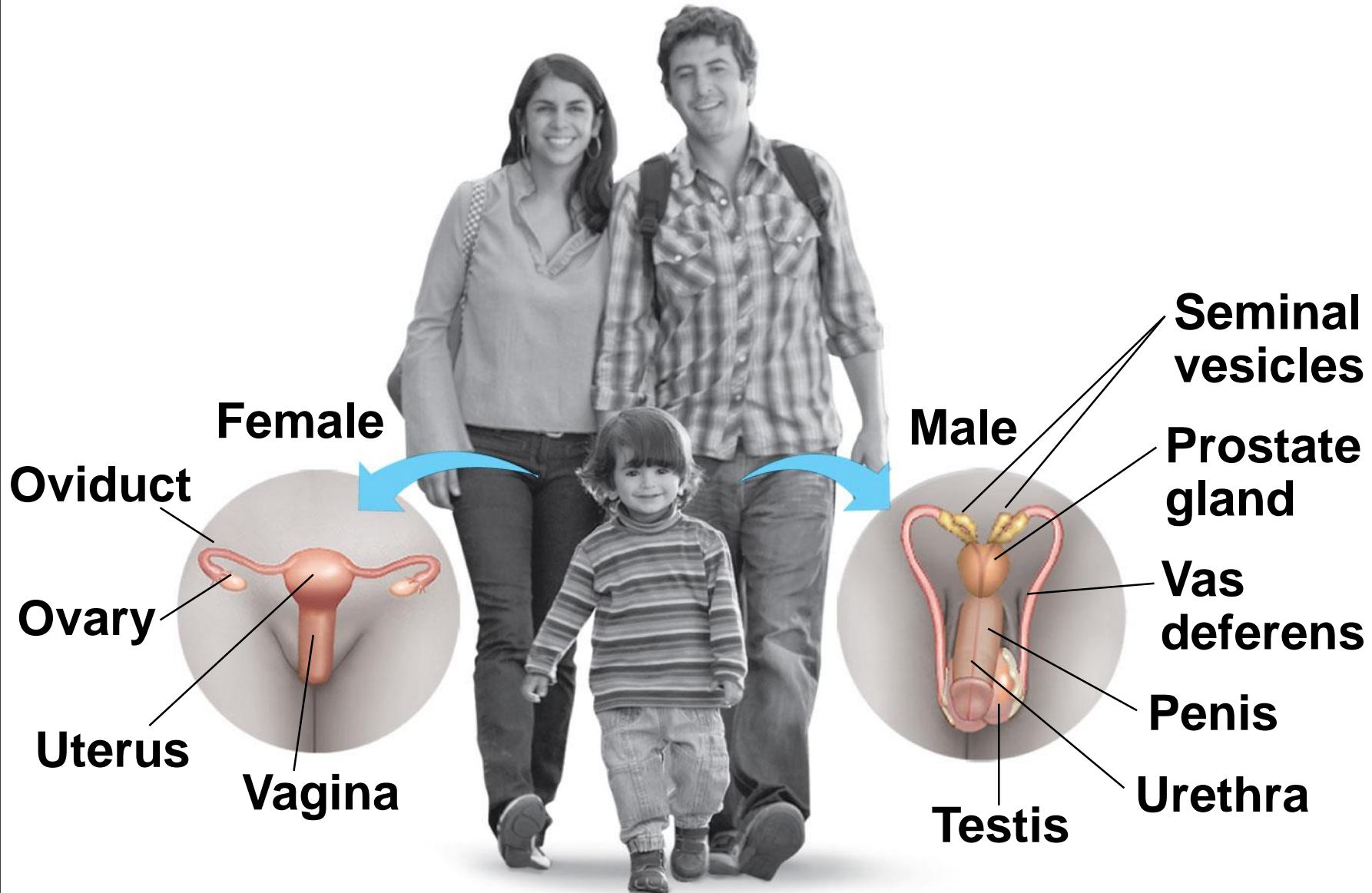


Nervous system

coordinates body's activates by detecting integrating information, and directing the body's responses



Reproductive system produces gametes and sex hormones.



Reflex control pathway

To maintain homeostasis, animal must detect external condition and if necessary initiate compensatory responses that keep vital areas buffered against unfavorable changes.

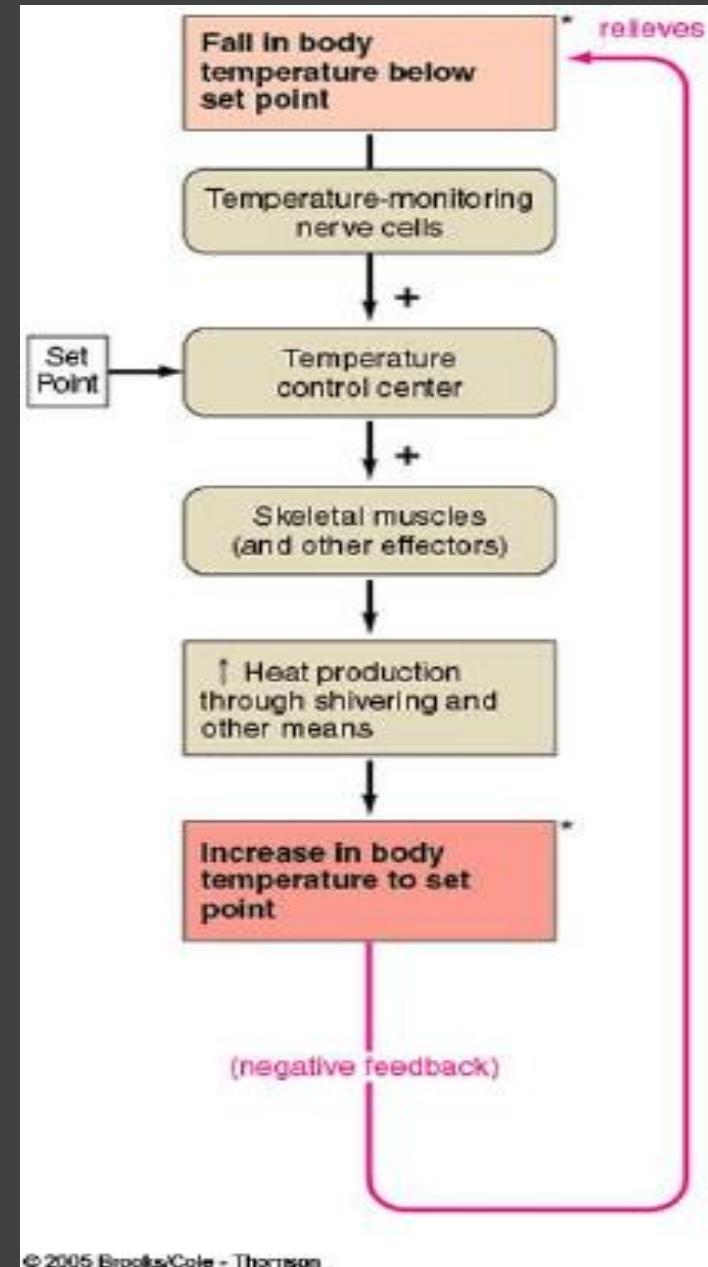
Negative feedback systems

Antagonistic control

Opposes change in the variable to maintain Homeostasis

- It must first suffer a disturbance before it can act
- Delayed response
- Overshoots the set point

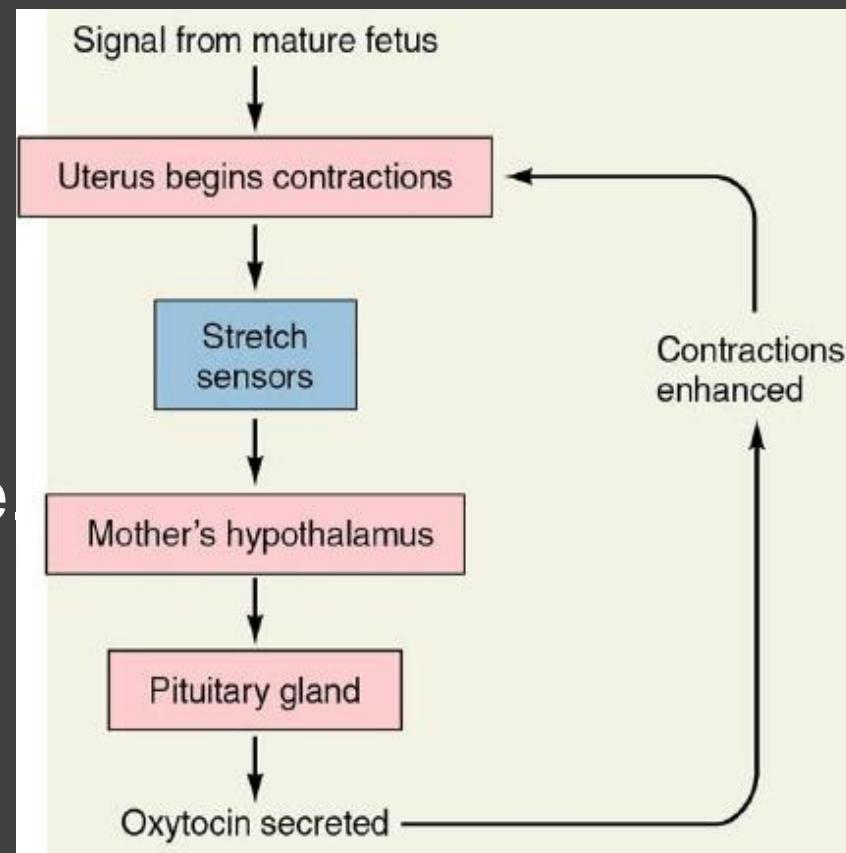
Temperature falls — effectors produce change to increase temperature (thermostatic effect)



Positive feedback system

Feed-forward system generate an explosive response

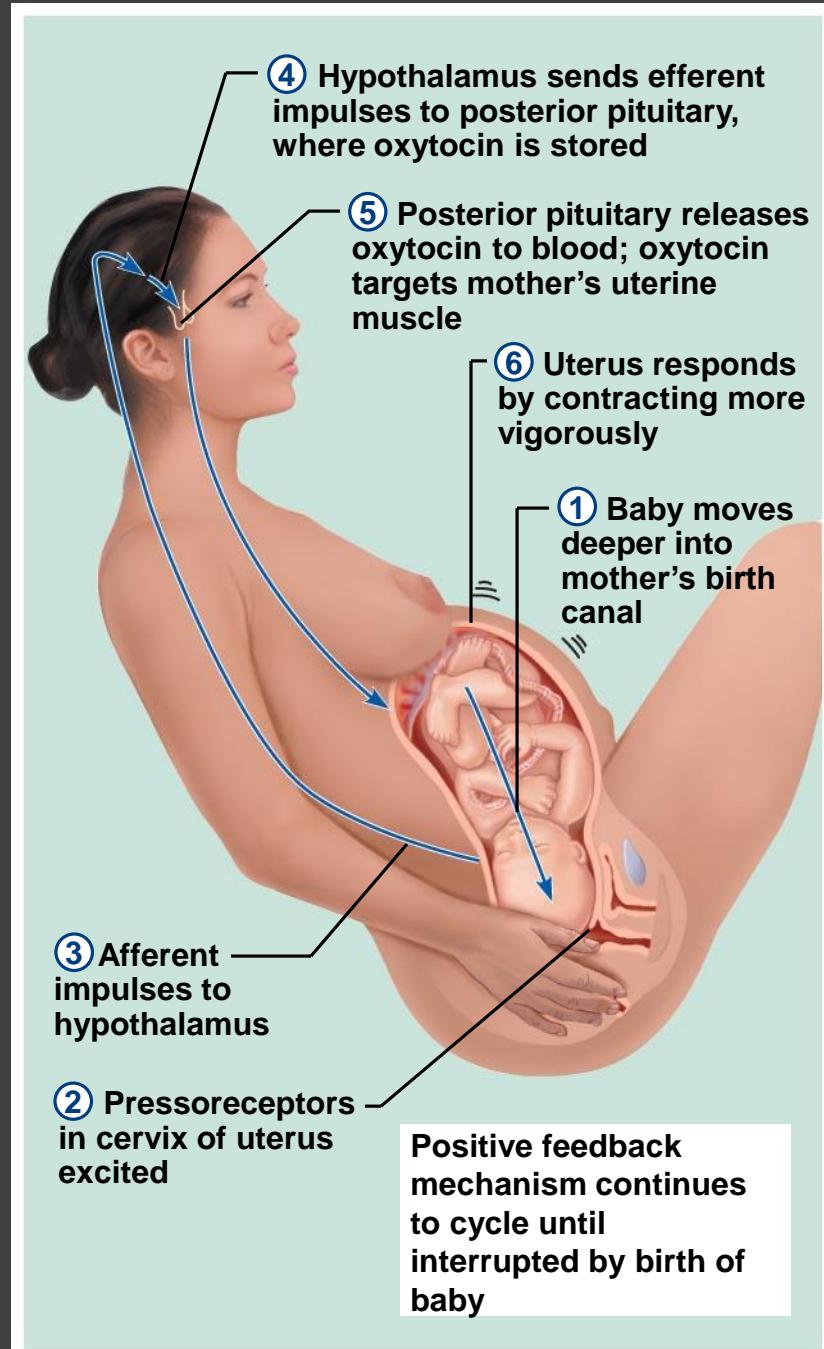
- Creates rapid change, which amplify the signal lead to a **rapid departure from the set point** of the controlled variable.
- Reinforces the change in the same direction.
e.g. birth of a mammal



(c) Example of positive feedback: birth of a mammal

Childbirth (Parturition)

- Initiation of labor
 - Estrogen levels rise
 - Uterine contractions begin
 - The placenta releases prostaglandins
 - Oxytocin is released by the pituitary
 - Combination of these hormones oxytocin and prostaglandins produces contractions



Coronary Artery Disease



Transverse section

Atherosclerotic plaque

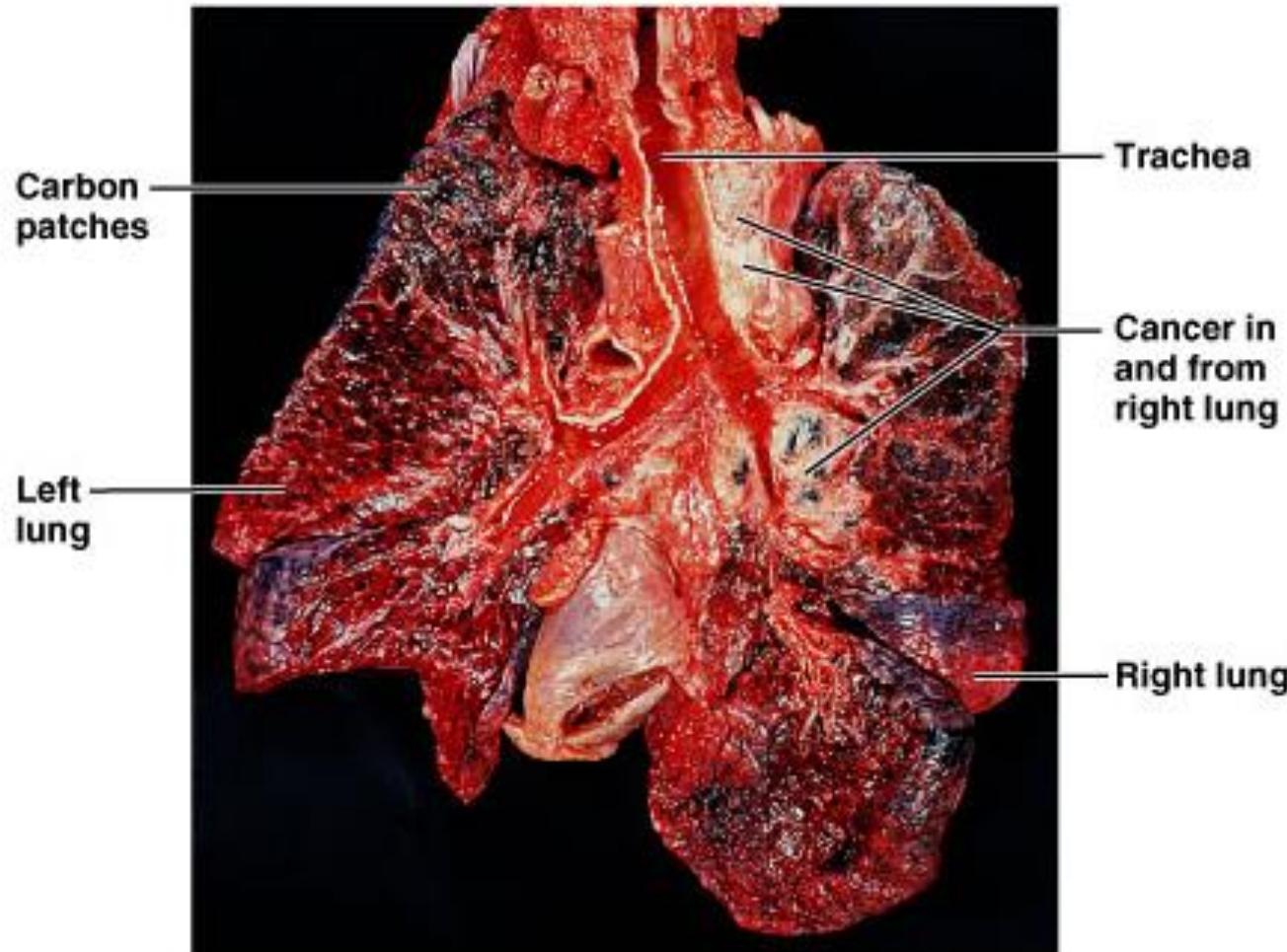
Partially obstructed lumen (space through which blood flows)

- Heart muscle receiving insufficient blood supply
 - narrowing of vessels--atherosclerosis, artery spasm or clot
 - atherosclerosis--smooth muscle & fatty deposits in walls of arteries
- Treatment
 - drugs, bypass graft, angioplasty, stent

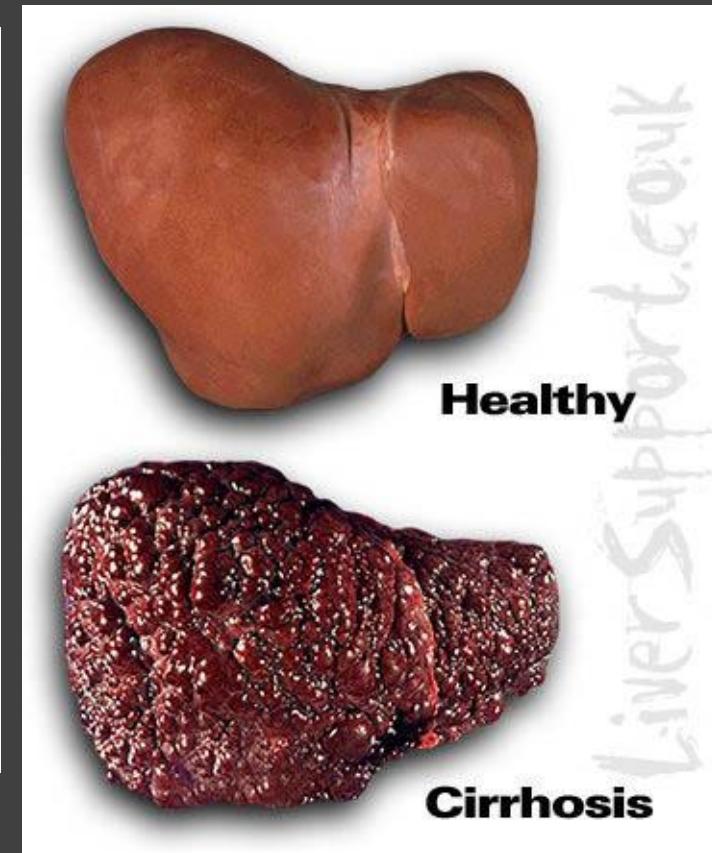
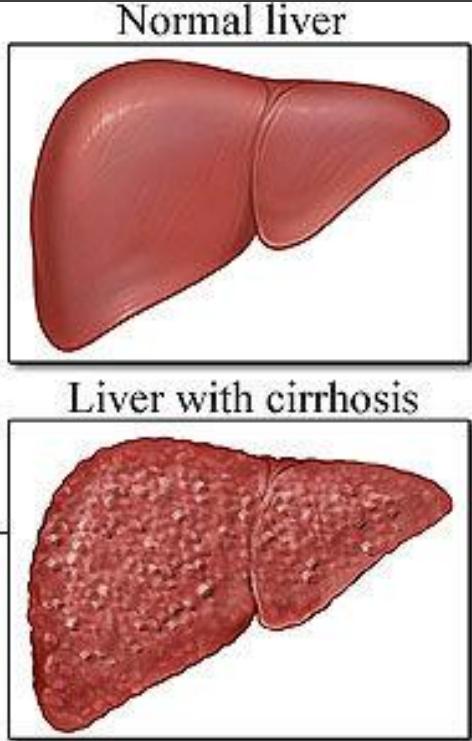
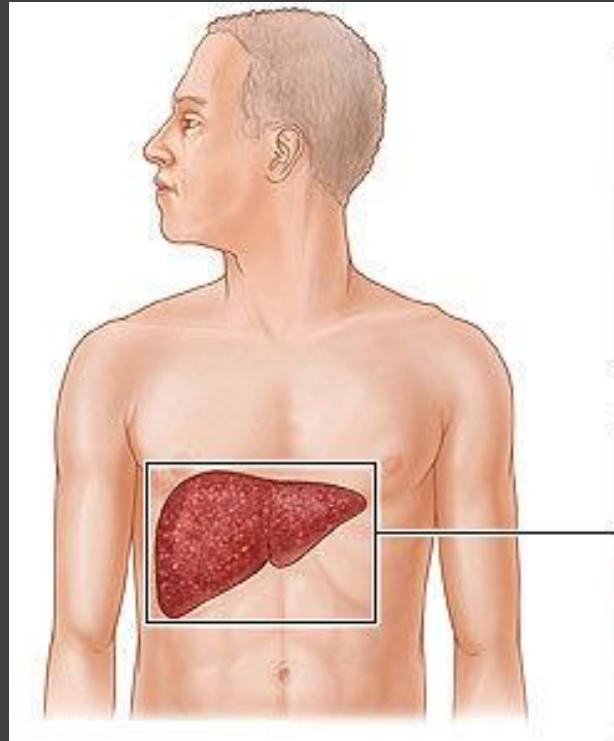
Normal lung versus cancerous lung



You might want to think twice about smoking....



Liver cirrhosis 肝硬变



The adhesive relationship is an example of the correlation between structure and function



How can geckos (壁虎) climb walls and stick to the ceiling?

The surfaces of gecko toes are covered by millions of microscopic hairs. Each hair has a slight molecular attraction that helps it stick to the surface.

Use of Animals in Research

Animal rights and animal welfare

Animal Welfare have changed drastically over the years. Physiologists accept certain moral responsibilities.

- Animals are used only for worthwhile experiments.**
- All necessary steps are taken to minimize pain and distress.**
- All possible alternatives to the use of animals are considered.**

Institutional Animal Care and Use Committee
Animals rights -Animals have the same legal and moral rights as humans do.

The Hypothetic deductive Method

Science is a way of thinking.

- Science is a logical way to investigate the universe.
- Observation and ask questions
- Hypothesis
- Experimentation
- Control and testing
- Data analysis
- Replication