

LSM1301

GENERAL BIOLOGY

Animal form and function

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Learning objectives

- To characterise the **key innovations** in major animal groups
- To describe the **functions** of different categories of vertebrate issues
- To define **homeostasis** and identify body functions maintained by negative and positive feedback systems
- To describe the organization and functions of selected **organ systems** involved in acquiring energy, and be able to compare and contrast these in different groups of animals
- To compare and contrast **modes of reproduction** in animals

Learning activities

- Pre-lecture
 - Watch videos on Comparative anatomy (7min) and the origin of tetrapods (17min)
(LumiNUS > Multimedia > Pre-lecture video assignments > “Animal:xxxxxxx”)
 - Take down notes and refer to lecture slides.
- Post-lecture
 - Take ungraded quiz to revise lecture material
(LumiNUS > Quiz > “Animal form and function”)

Outline

- Introduction to animals
- Animal evolution and diversity
 - Features of animals
 - Major animal groups
- Animal anatomy and physiology
 - Tissue types, organ systems, homeostasis
- Acquiring nutrition and energy
 - Digestive and circulatory systems
- Animal reproduction and development

Introduction to animals

Key features of animals

- Multicellular eukaryotes
- Cells without cell walls
- Heterotrophs: ingest food and digest it internally
- Generally mobile, able to respond rapidly to stimuli
- Most reproduce sexually



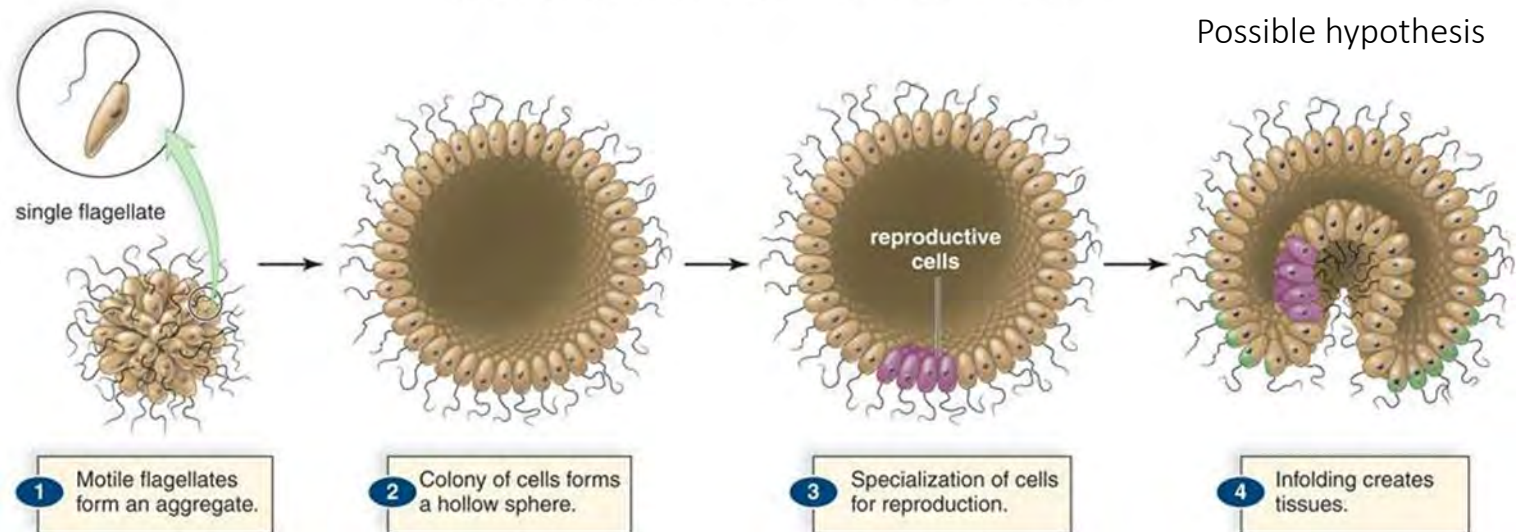
Animal evolution

First animals likely descended from a flagellated protist

- Evolution of **multicellularity** through colonial flagellate hypothesis: *infolding of cells into the center of the spherical colonies formed tissue layers*



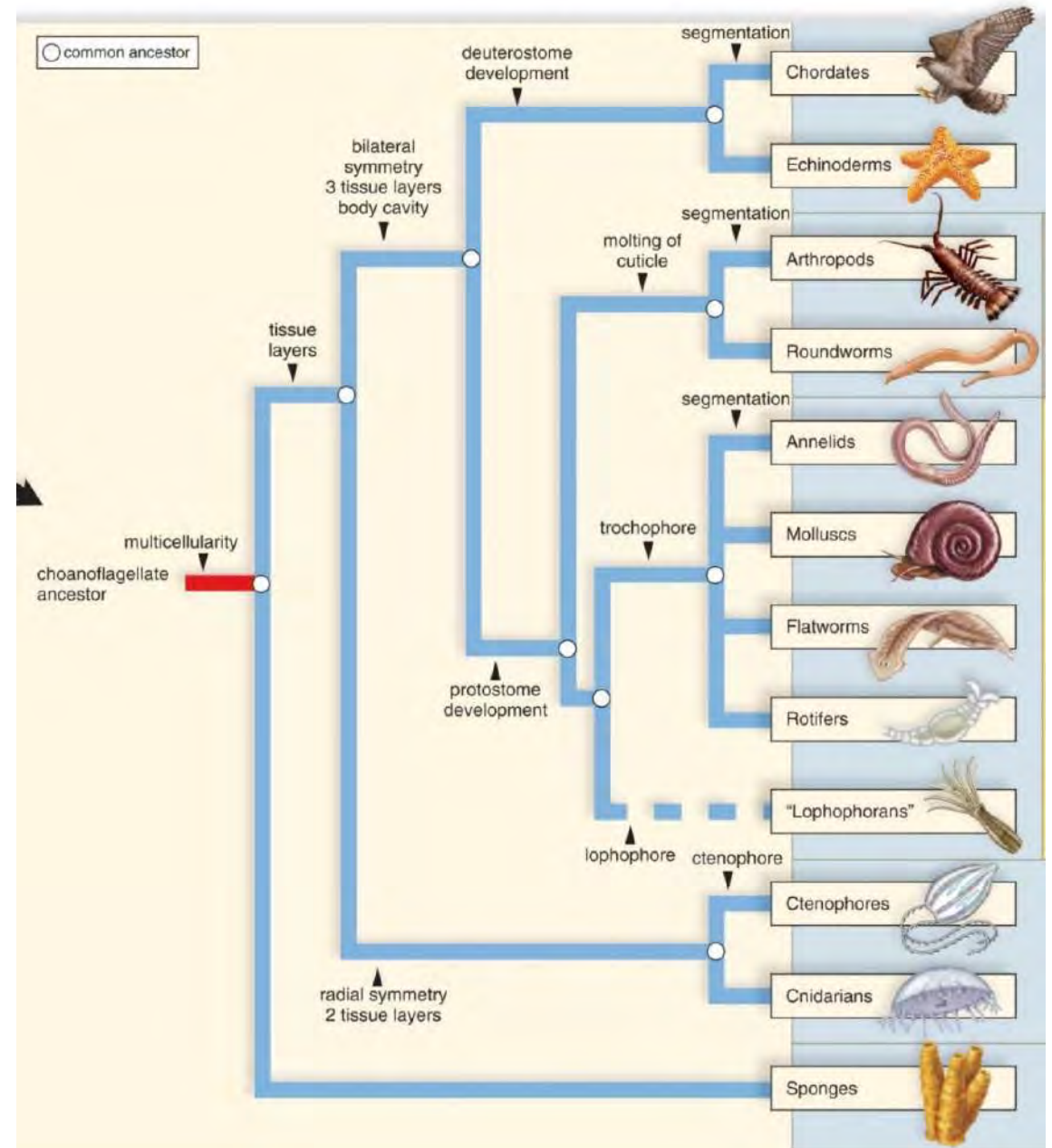
a. Solitary Colonial
Choanoflagellates are protists most closely related to animals



Animal evolution

Different animal groups characterized by:

- Number of tissue layers
- Type of body symmetry
- Presence of body cavity
- Presence of segmentation
- Developmental paths



Features of animals

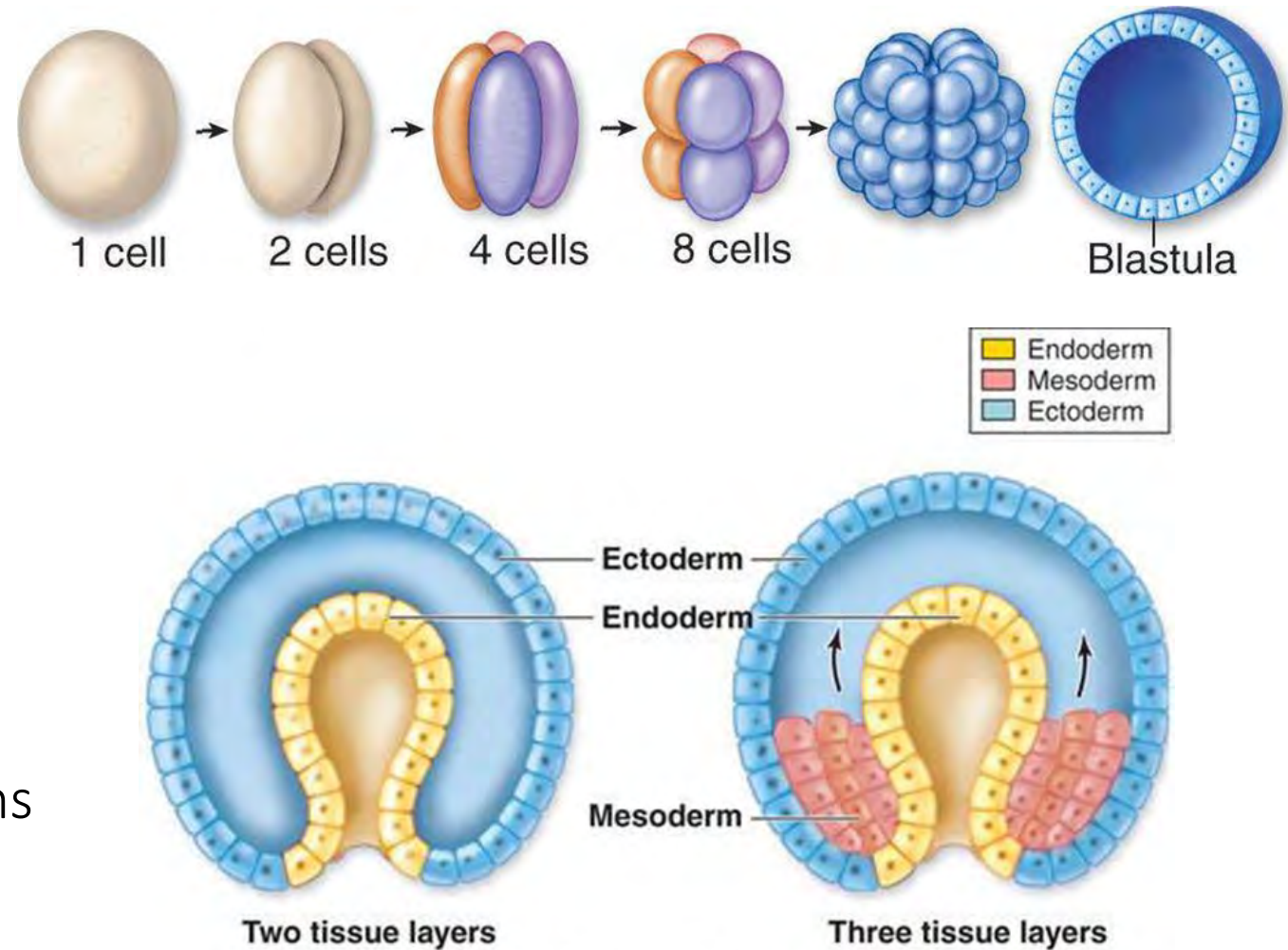
Tissue layers

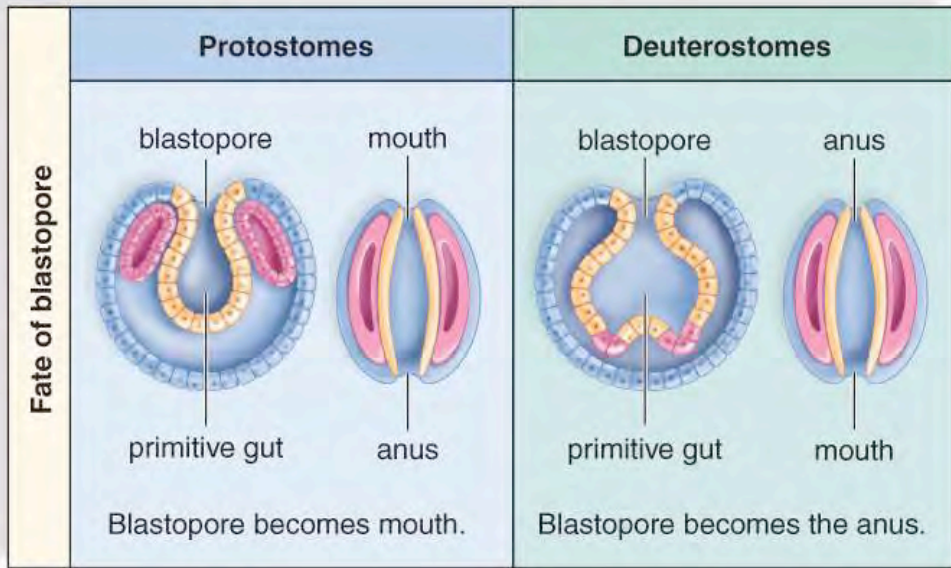
- Simplest animals do not have true specialized tissues
- Diploblastic animals have two layers of tissues but no specialized organs
- Triploblastic animals have 3 embryonic tissue layers
 - Ectoderm → skin and nervous system
 - Endoderm → digestive tract and derived organs
 - Mesoderm → muscles, reproductive system

Features of animals

Tissue layers

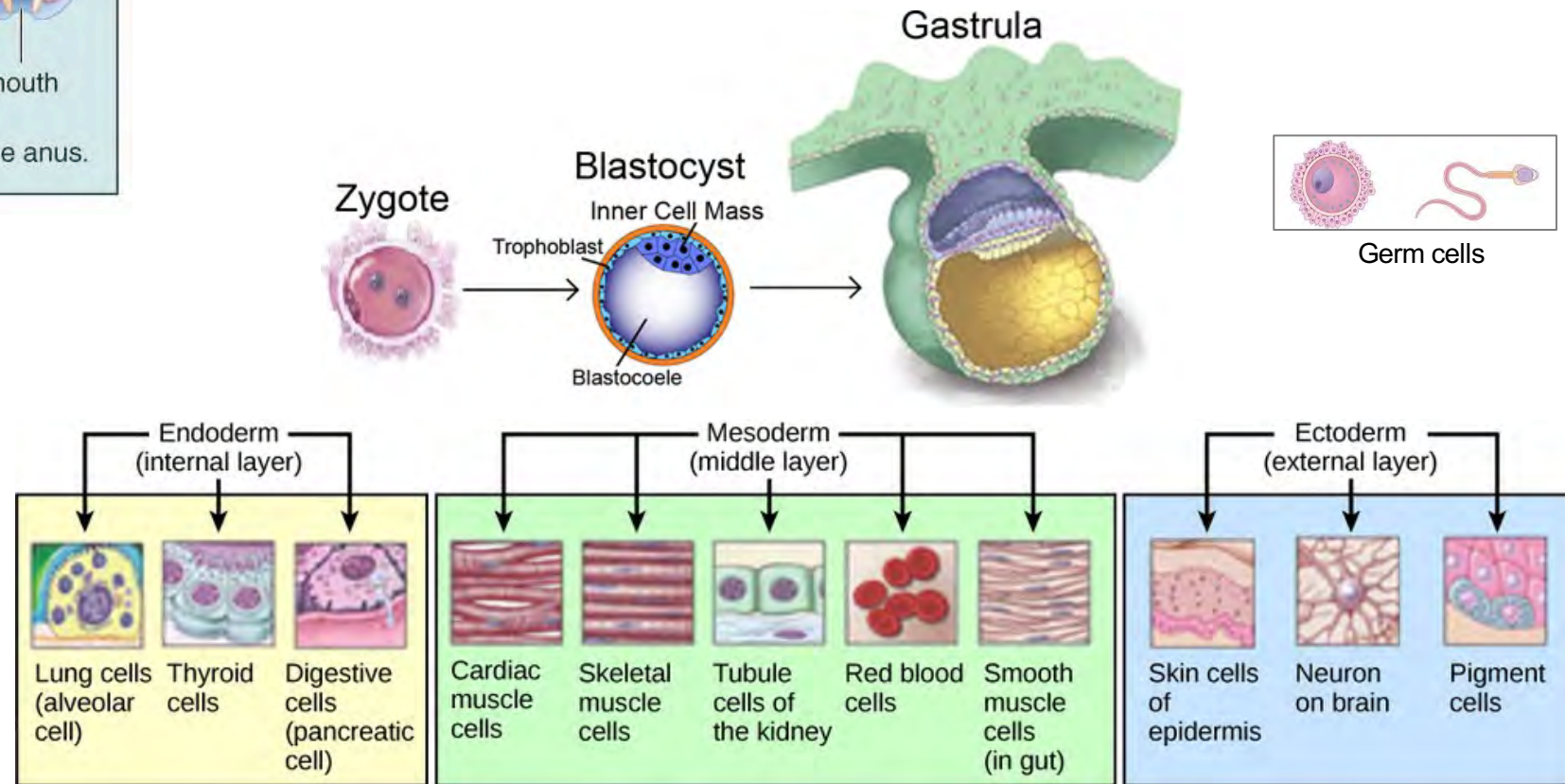
- Tissues are groups of cells that interact and perform specific functions
- Formation of tissue layers seen in animal embryos: ectoderm, endoderm and mesoderm
- Cells become **specialized** for different functions and form organs





Two developmental paths in triploblastic animals

During development, cells **differentiate** to produce specific cell types that make up tissues and organs



Humans have around 200 recognized cell types

Features of animals

Body symmetry

- Asymmetrical
 - No pattern to body plan
- Radial symmetry
 - Several planes divides into mirror images
 - Allows organism to extend in all directions from one central point
- Bilateral symmetry
 - Only 1 plane produces mirror image
 - Accompanied by cephalization

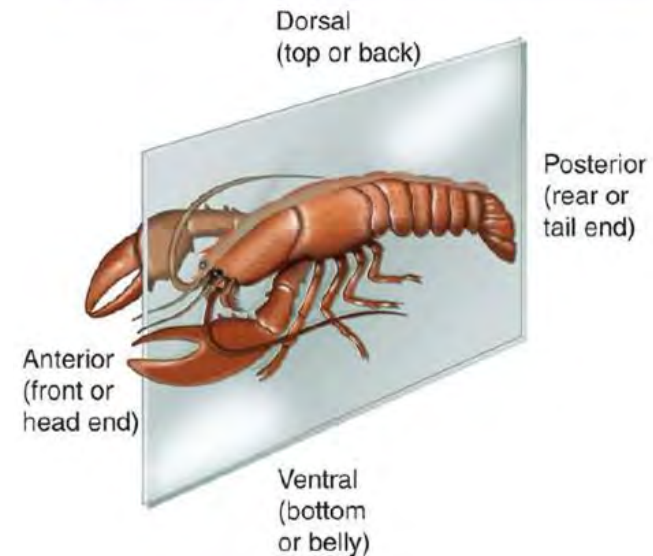
a. Sponge (asymmetry)



b. Hydra (radial symmetry)



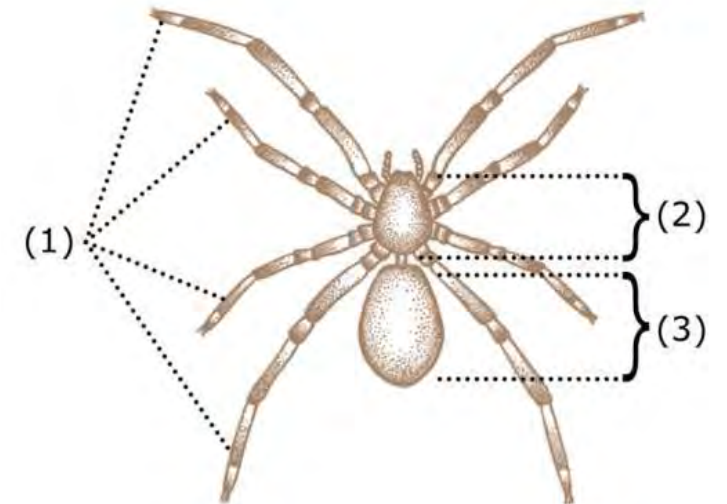
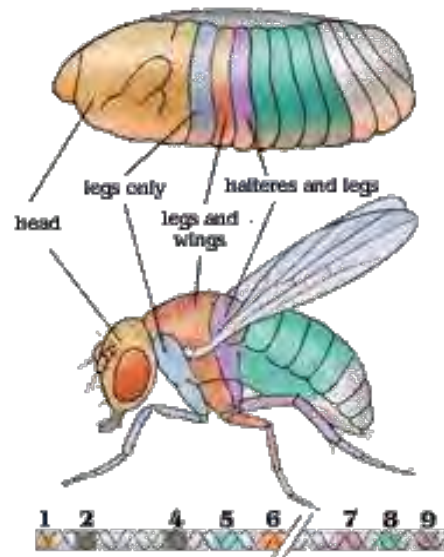
c. Crayfish (bilateral symmetry)



Features of animals

Segmentation

- Division of animal body into repeated sections, externally or internally
- Adds flexibility and potential for specialization
 - Segments may be fused and modified for special functions

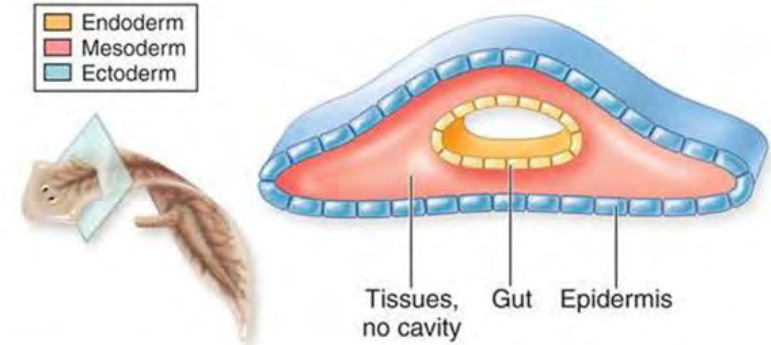


Features of animals

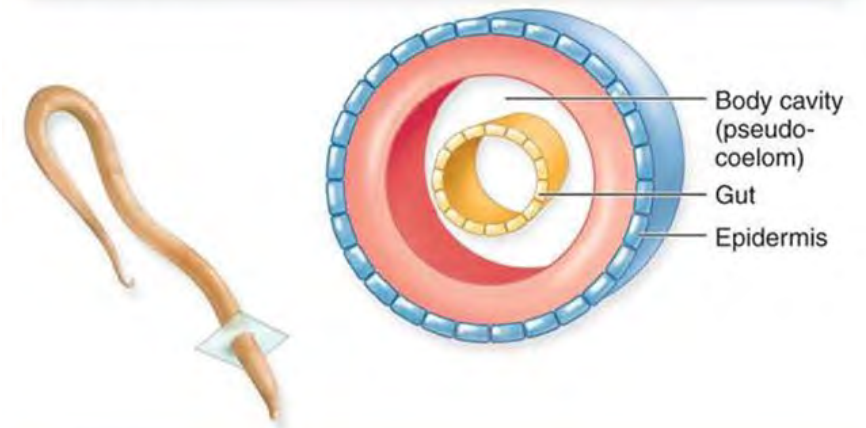
Presence of a body cavity

- The coelom is a fluid-filled cavity completely within the **mesoderm** that provides organs with flexibility and absorbs shock
- A bilaterally symmetrical animal may be:
 - Acoelomate – no body cavity
 - Pseudocoelomate – body cavity lined partly by mesoderm and endoderm
 - Coelomate – completely lined by mesoderm

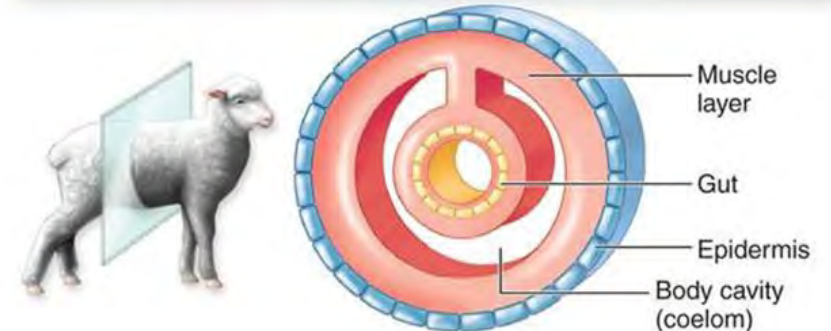
a. No coelom



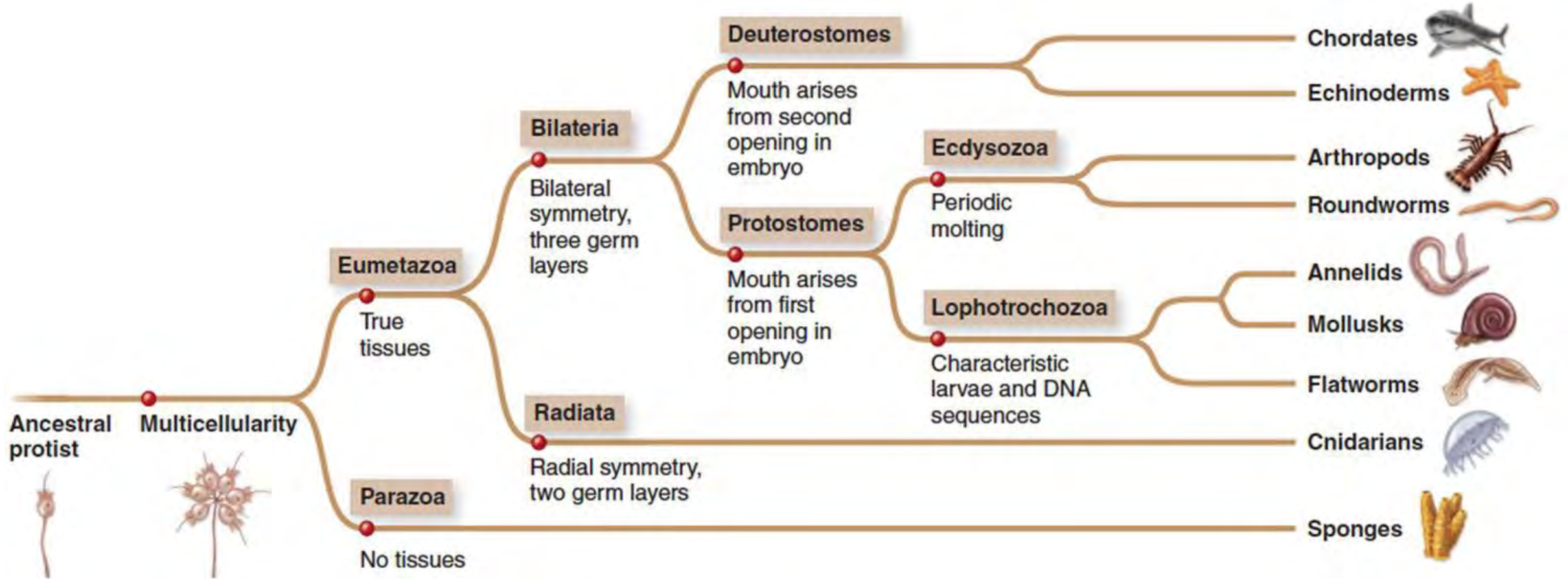
b. Pseudocoelom



c. Coelom



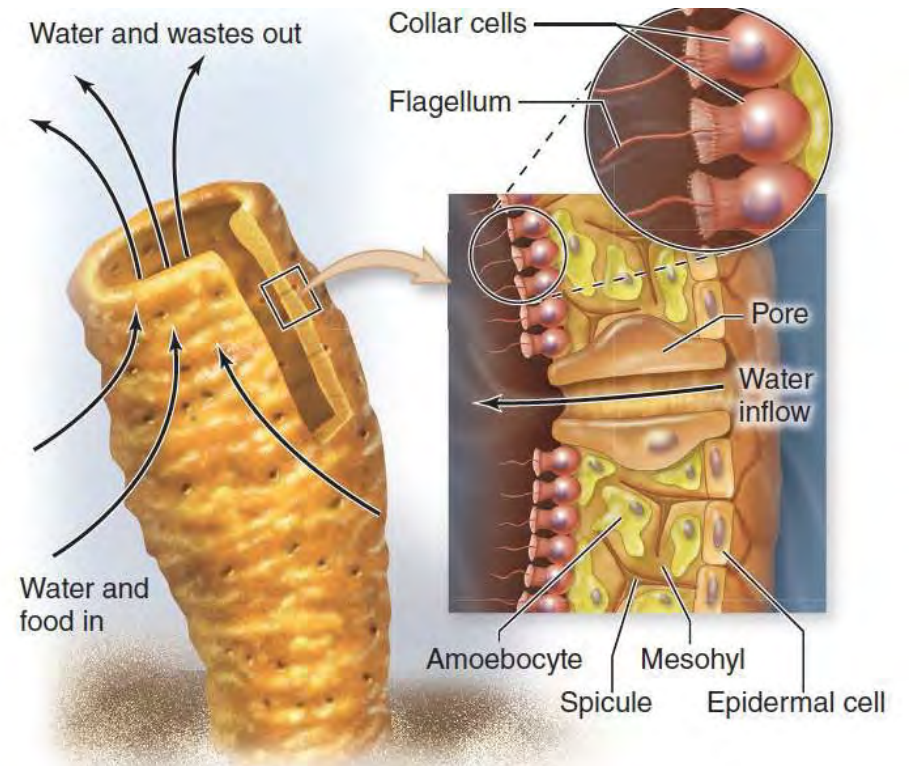
Major animal groups



Sponges

Porifera

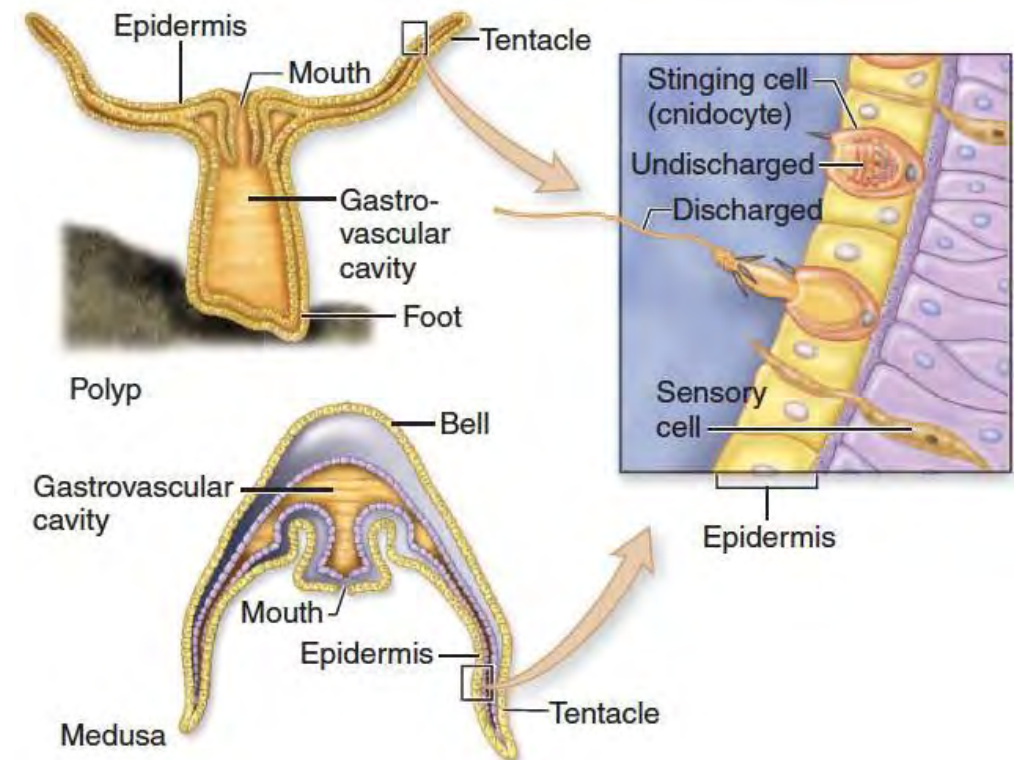
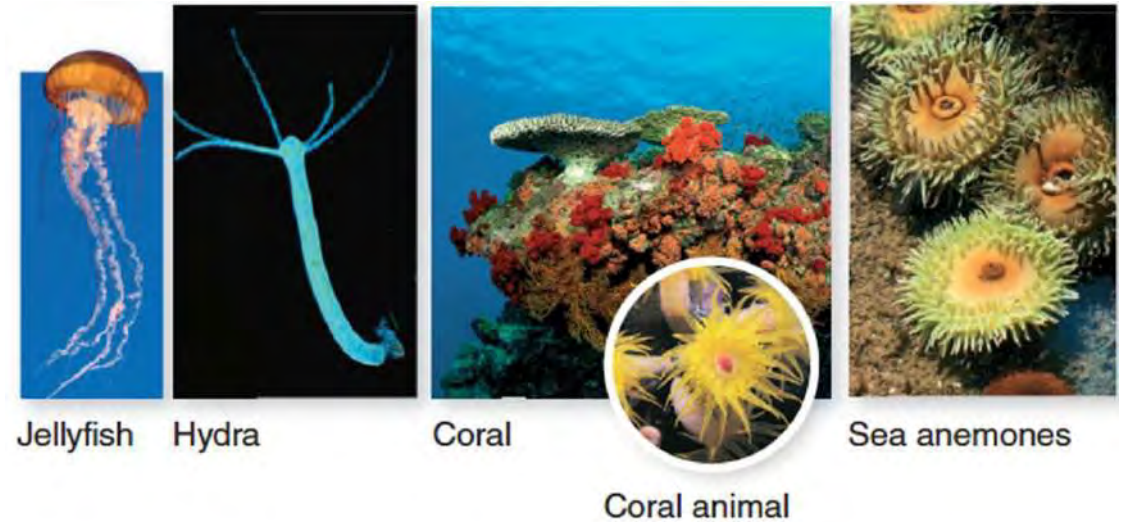
- Aquatic
- Asymmetrical or radially symmetrical
- Simple animals - no tissues or organs
- Overall shape usually stiffened by mineral spines
- Adults are sessile (fixed in one place)
- Filter-feeders
 - Depend on water flow
 - Cells digest food intracellularly



Cnidarians

Jellies, Corals, Anemones

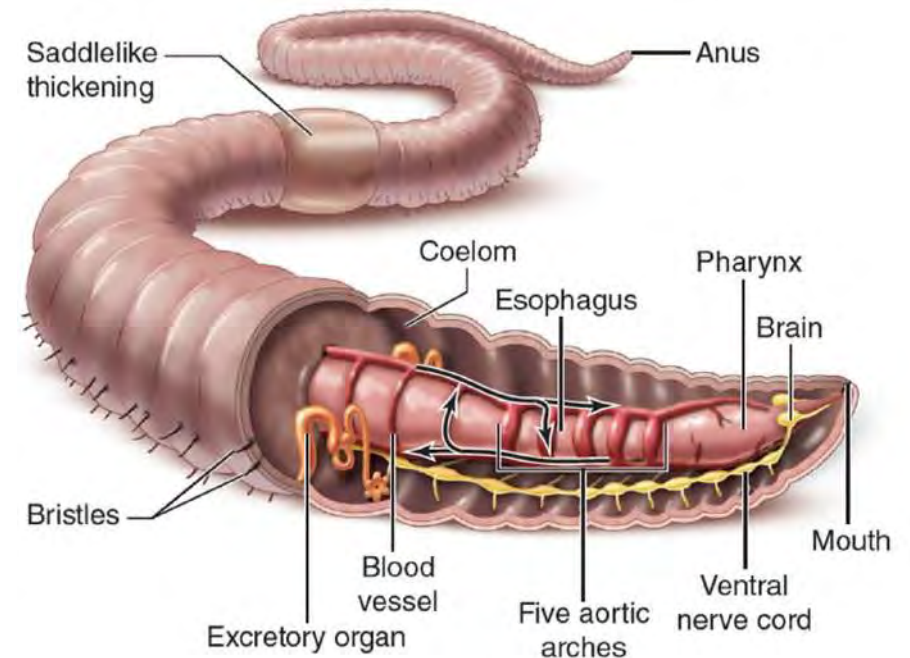
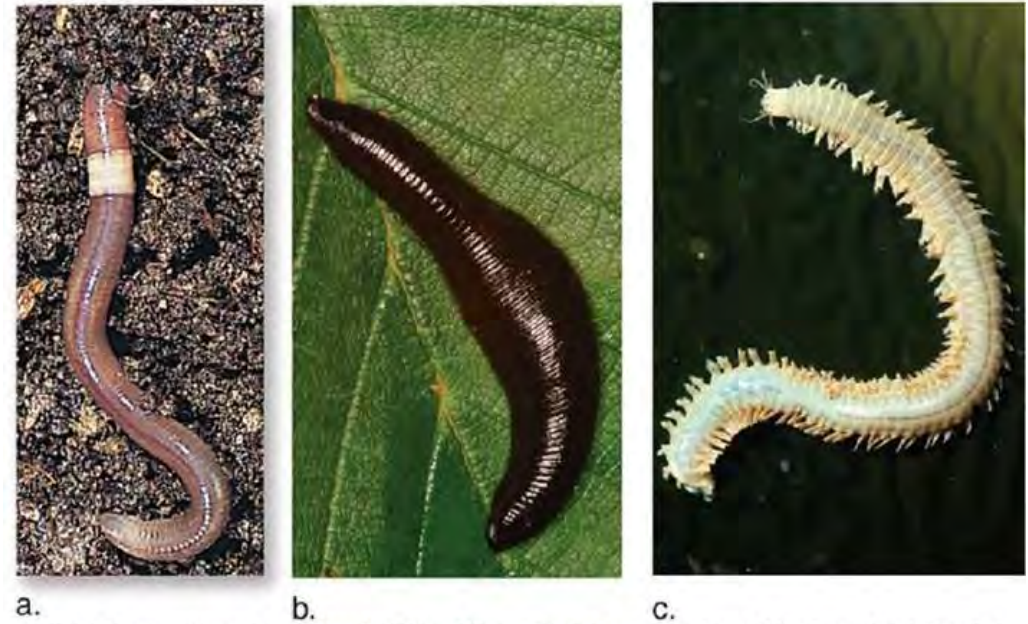
- Aquatic (predominantly marine)
- Radially symmetrical
- Adults have two forms:
 - Polyp – sessile with tentacles
 - Medusa – free-swimming
- Some species go through both as stages
- Two tissue layers enclose non-cellular jelly substance
- Incomplete digestive tract with tentacles around the mouth
- Predators: stinging cnidocytes help catch prey
- Hydrostatic skeletons (in some)



Annelids

Earthworms, Leeches

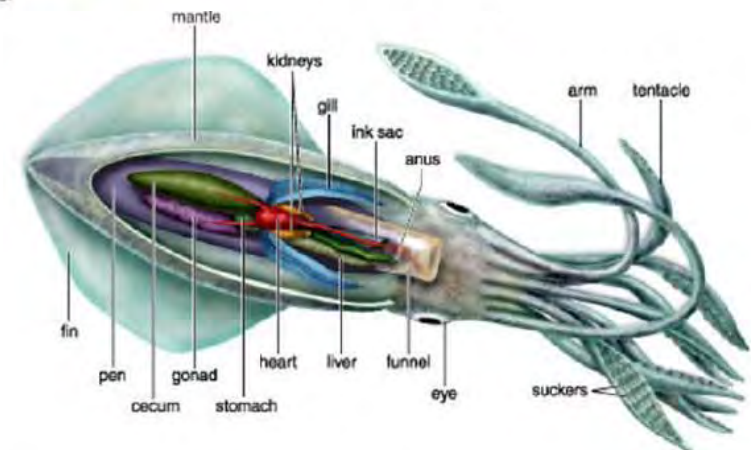
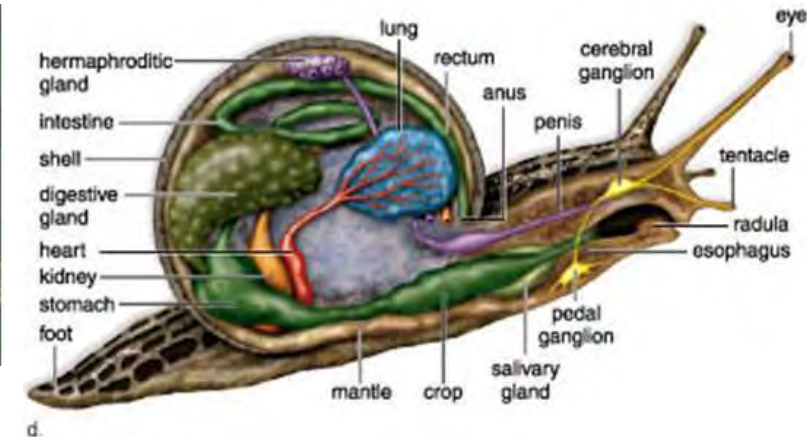
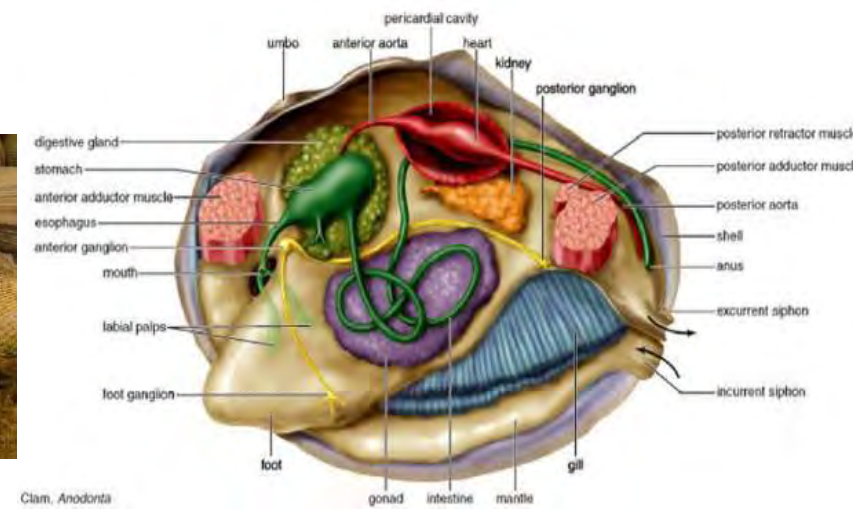
- Terrestrial and aquatic
- Bilateral symmetry
- Have repeated body segments
- Complete digestive tract; coelom
- Closed circulatory system, simple nervous and excretory system
- Detritivores, bloodsuckers, filter-feeders, predators
- Hydrostatic skeletons



Mollusks

Snails, Clams, Squid

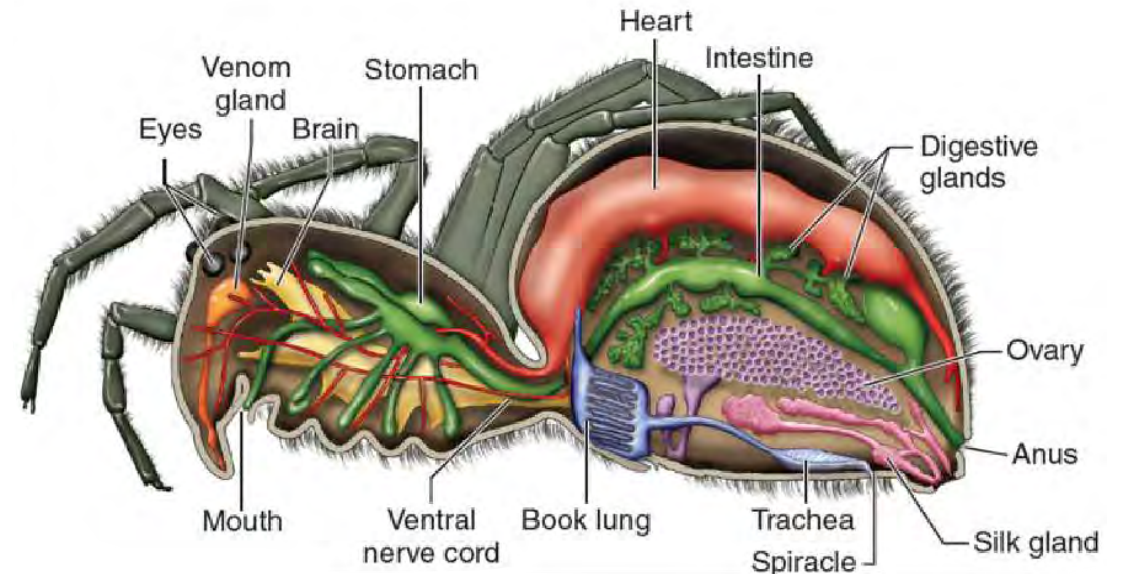
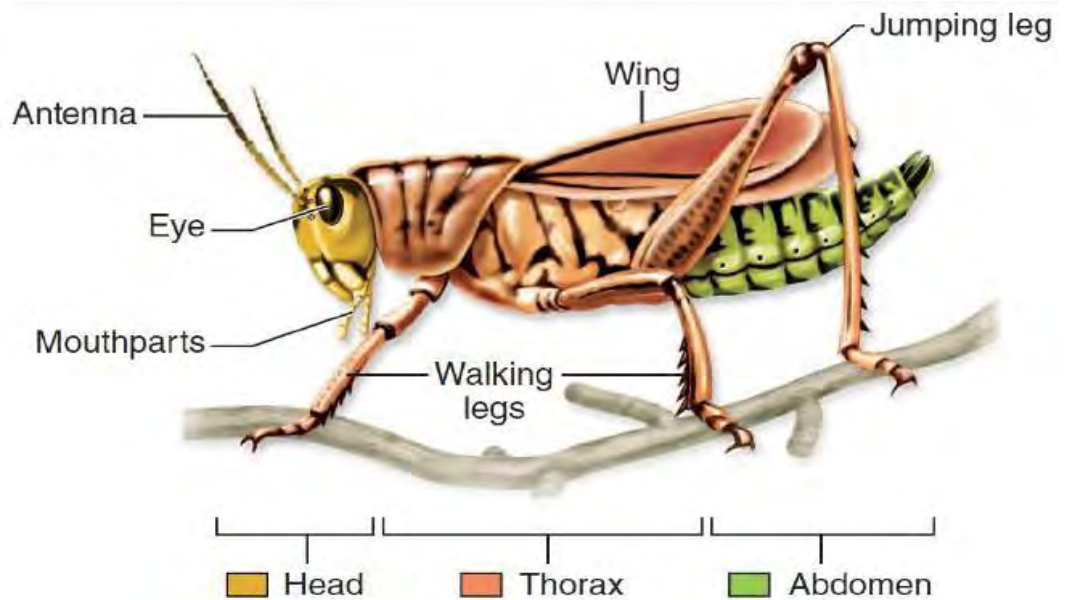
- Aquatic and terrestrial
- Unsegmented
- Bilaterally symmetrical and asymmetrical
- Hydrostatic skeleton, with supporting external or internal shell secreted by mantle tissue
- Complete digestive tract, coelom
- Muscular foot provides movement
- Filter-feeders, herbivores, and predators



Arthropods

Insects, Spiders, Crabs, Prawns

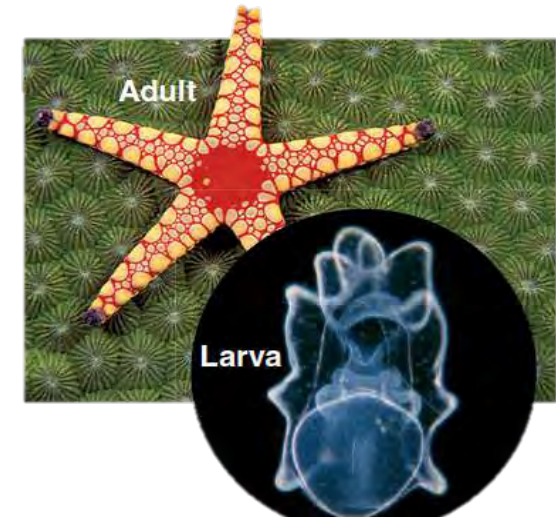
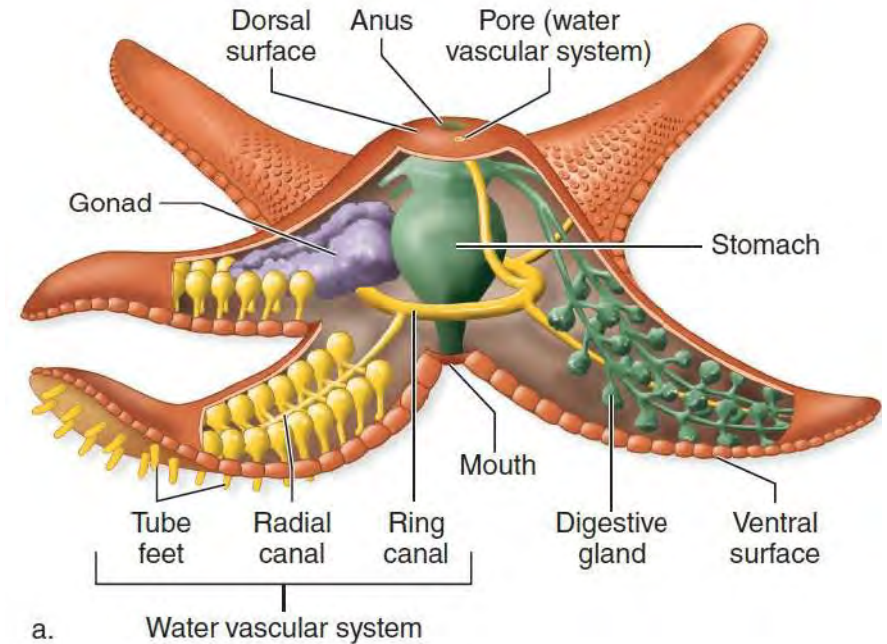
- Terrestrial, freshwater, marine
- Segmented body plan
 - Major body regions: head, thorax, abdomen
 - Jointed appendages
- Exoskeleton of chitin and protein
 - Must moult to grow
- Open circulatory system, extensive respiratory system of tubes open to outside
- Complete digestive tract, coelom
- Simple brain, well-developed nerves



Echinodermata

Starfish, Sea cucumbers, Sea urchins

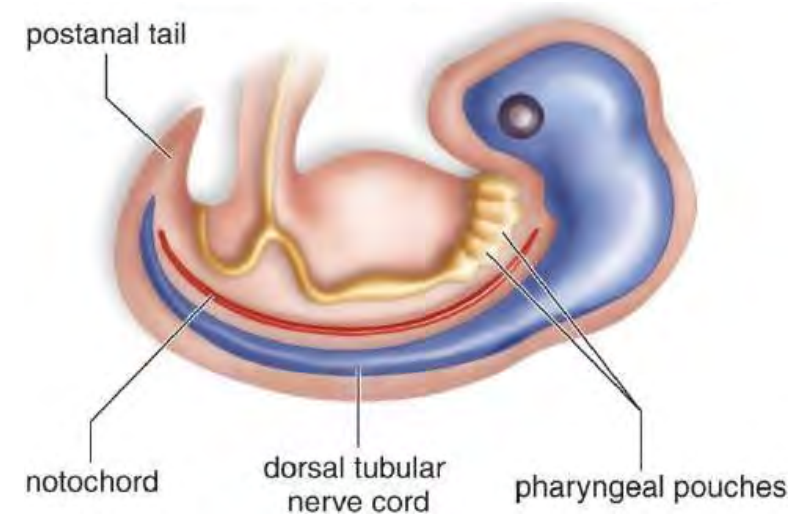
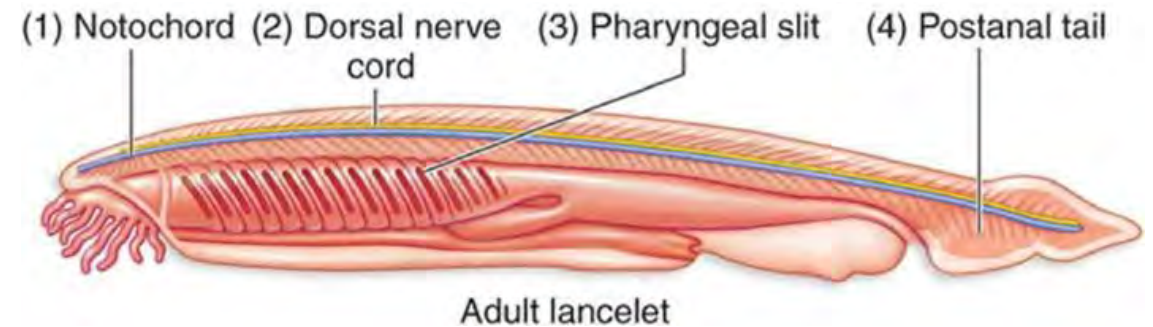
- Marine
- Five-part radial symmetry with bilaterally symmetrical larvae
- Complete digestive tract
- Water vascular system with tube feet act as gills, sense organs, perform circulatory and excretory functions
- Predators, detritivores



Chordates

Lancelets, Tunicates, Hagfish and Vertebrates

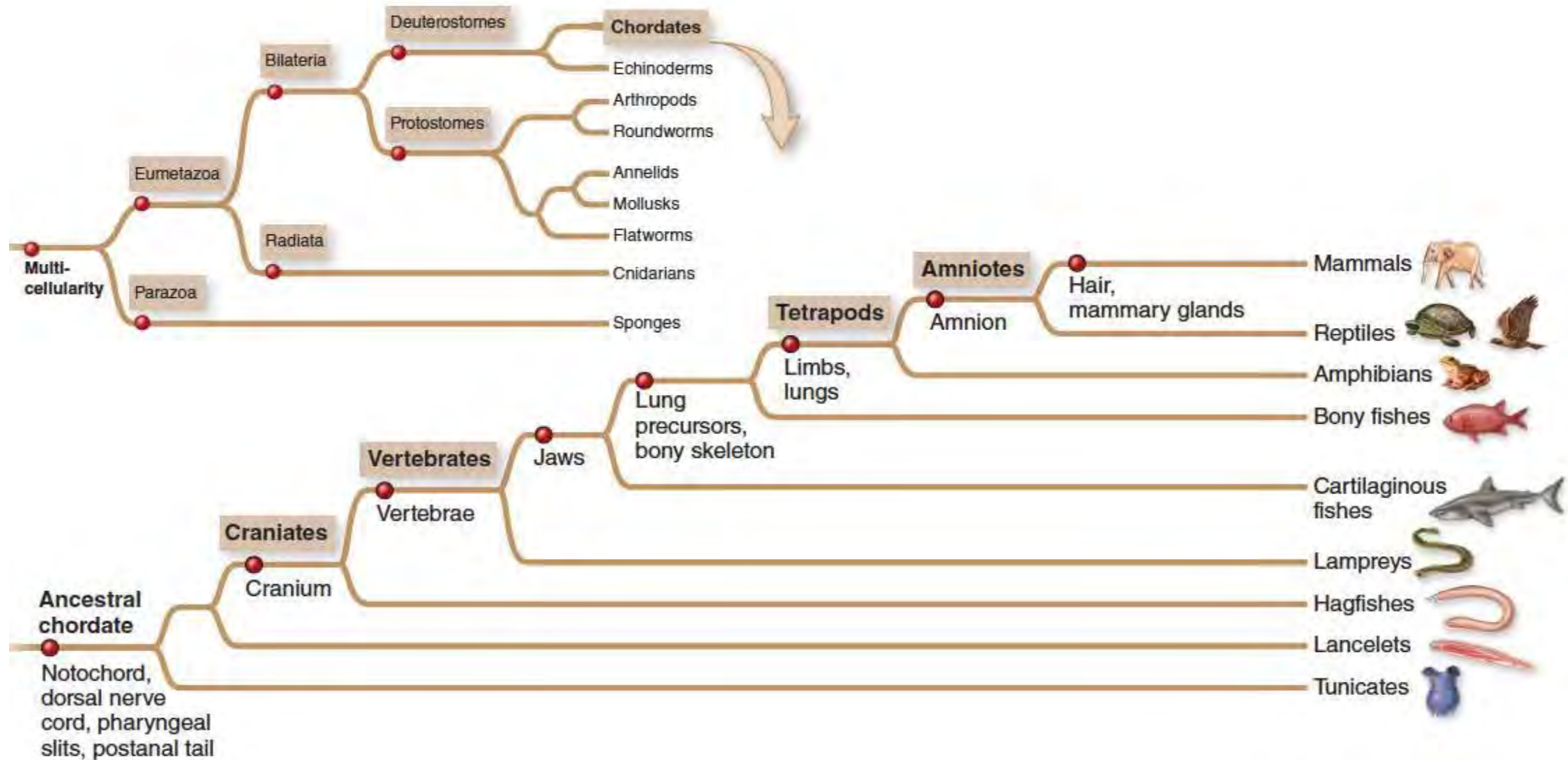
- Vertebrates share this clade with some invertebrates
- Four distinguishing features of chordates at some point of development:
 1. Notochord
 2. Dorsal, hollow nerve cord
 3. Pharyngeal pouches or slits
 4. Postanal tail



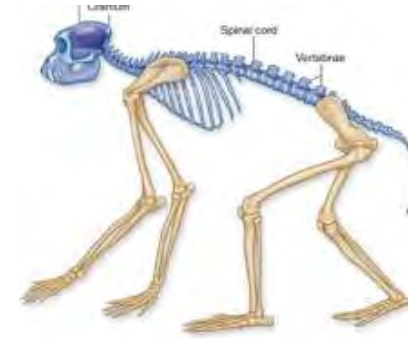
Major groups of chordates

Group	Examples	Features	Number of existing species
Tunicates	Sea squirts	Invertebrate filter feeders with protective tunic and two siphons	3,000
Lancelets	Amphioxus	Invertebrate filter feeders with all four chordate features in adults	25
Hagfishes	Slime hags	Wormlike bodies with cranium but not vertebrae	60
Fishes	Lampreys, sharks, salmon, lungfishes, coelacanth	Scale-covered bodies with fins and external gills	29,000
Amphibians	Frogs, salamanders, caecilians	Naked (scaleless) tetrapods that breathe through their moist skin and spend time both on land and in water	6,000
Reptiles	Turtles, lizards, snakes, tuataras, crocodilians	Tetrapods with amniote eggs and dry body scales composed of keratin	8,000
Birds	Ostriches, penguins, hummingbirds, eagles	Two-legged tetrapods in which the forelimbs are modified as wings; produce amniote eggs; feathers composed of keratin cover the body	9,000 to 10,000
Mammals	Platypus, kangaroo, dog, whale, human	Milk-producing tetrapods with hair composed of keratin; amnion surrounds developing embryo	5,500

Vertebrate evolution



Vertebrate characteristics



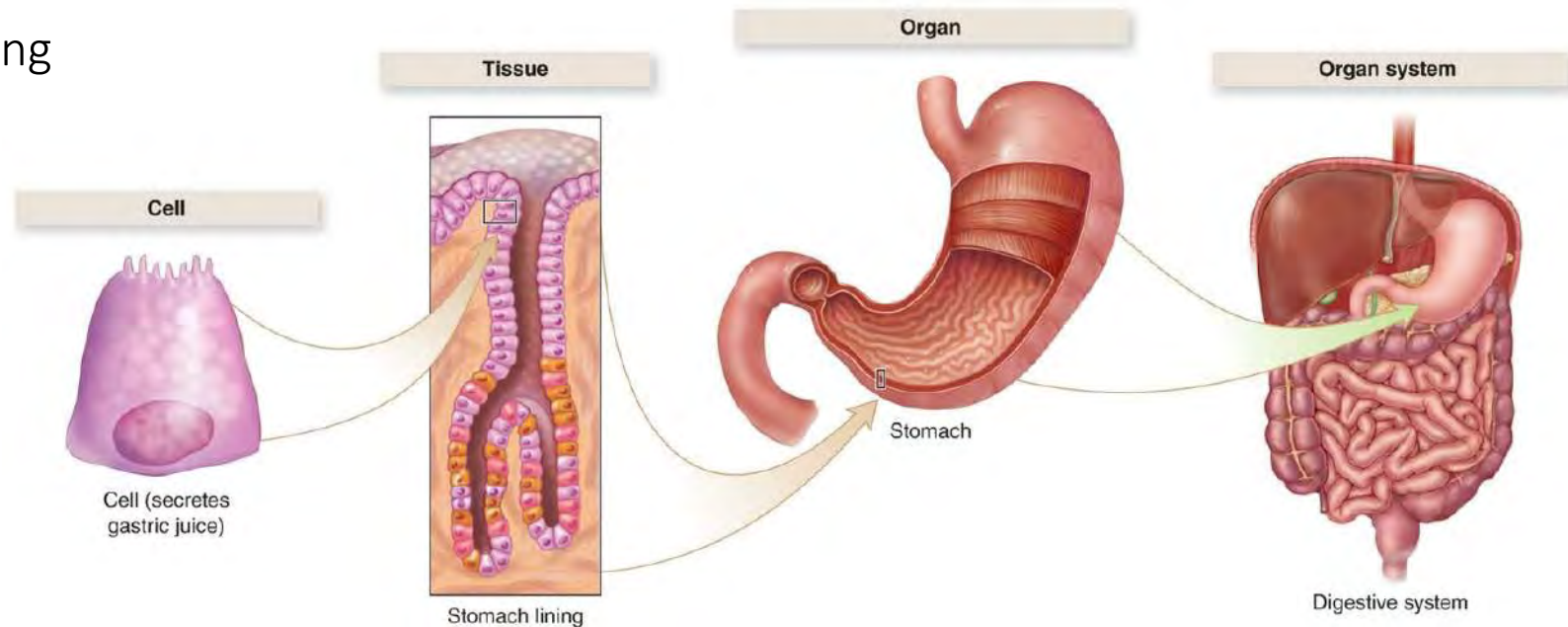
Feature	Advantage
Internal skeleton	Support, movement, protect internal organs
Jaws	Efficiency in capturing prey
Four limbs with skeleton	Promote locomotion
Lungs	Exchange of gases with air instead of water
Amniotic egg and internal fertilization	Reproduction away from water
Body coverings	Better insulation



Animal anatomy and physiology

Organizational hierarchy in the body

- Cells - basic building blocks of the body
- Tissues - cells that interact and provide specific functions
- Organs - two or more interacting tissues
- Organ systems - two or more organs joined physically or functionally



Animal tissues

Four main types of animal tissues:

- Epithelial
- Connective
- Nervous
- Muscle



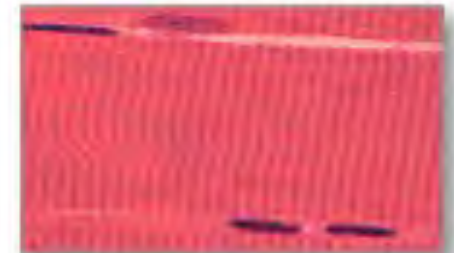
Epithelial tissue



Connective tissue



Nervous tissue

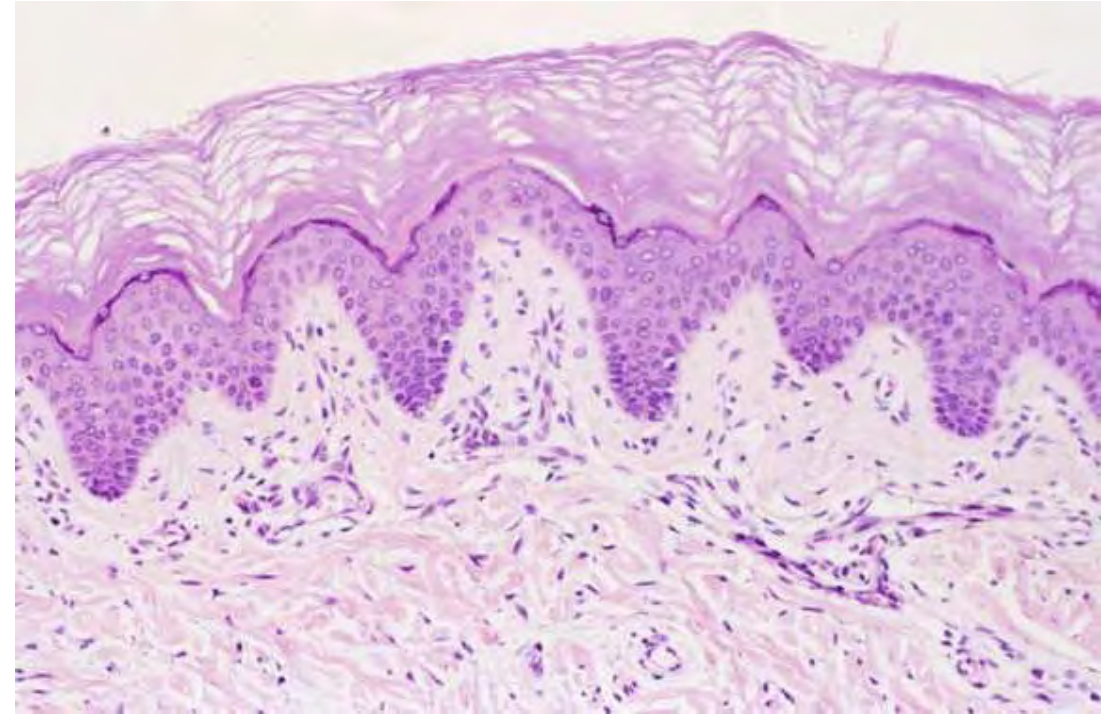


Muscle tissue

Animal tissues

Epithelial Tissue

- Cover body's internal and external surfaces with one or more layers of tightly packed cells
 - One surface exposed either to the outside or to a space within the body
 - Opposite surface anchored to other tissues by a basement membrane
- Functions: protection, nutrient absorption, gas diffusion, secretion



Some epithelia forms glands that secrete substances such as milk or sweat

Animal tissues

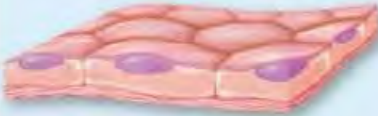

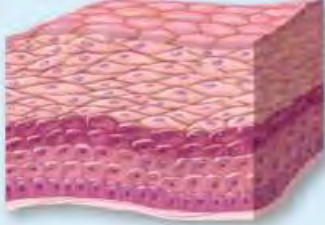
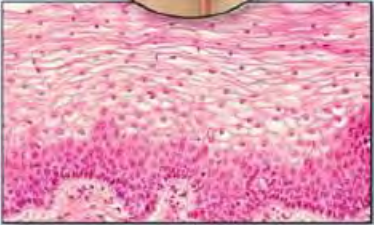






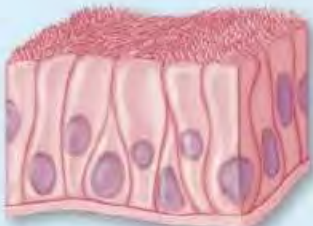
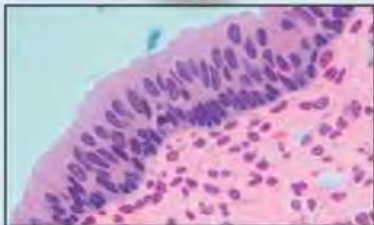
Types of epithelial tissue based on combination of

➤ Layers

- Simple
- Stratified
- Pseudostratified

➤ Shape

- Squamous
- Cuboidal
- Columnar

Epithelial tissues			
Simple squamous		Stratified squamous	
Functions: filtration, diffusion Examples: lining of heart and blood vessels, alveoli of lungs, glomeruli of kidneys		Functions: protection in areas subject to abrasion Examples: outer layer of skin, lining of body openings	
			
Simple cuboidal		Stratified cuboidal	
Functions: secretion, absorption Examples: glands, lining of kidney tubules		Function: secretion Examples: lining of sweat ducts, secretory ducts of salivary glands	
			
Simple columnar		Pseudostratified columnar	
Functions: secretion, absorption Examples: lining of digestive tract, bronchi (ciliated), and uterine tubes (ciliated)		Function: secretion of mucus Example: upper respiratory tract	
			

Animal tissues

Connective tissue

- Most **variable** tissue type
- Cells embedded in extracellular matrix of non-living substances:

Extracellular matrix

Substances: Solid (bone); liquid (blood); semisolid (cartilage)

Protein fibers: Collagen; elastin

Cells

Fibroblasts: Cells that secrete protein ingredients of extracellular matrix

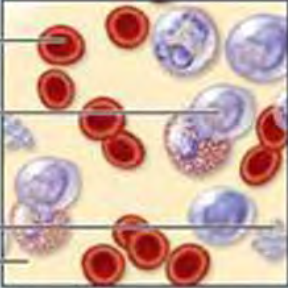
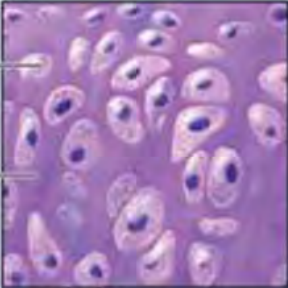

Macrophages: Cells that engulfing dead cells via phagocytosis

- Functions: fill spaces, attach epithelium to other tissues, protect and cushion organs, provide mechanical support

Animal tissues

Types of connective tissue

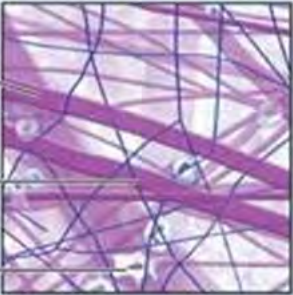
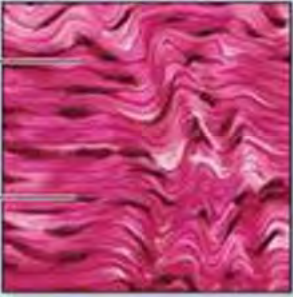
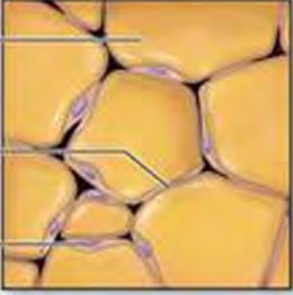
- Blood
- Cartilage
- Bone

	Type of connective tissue	Cells	Matrix composition	Proportion of cells to matrix	Site
 <p>Red blood cell</p> <p>White blood cell</p> <p>Platelet</p> <p>Plasma</p>	Blood	Red and white blood cells, platelets	Plasma	Low	In vessels throughout the body
 <p>Cartilage cell (chondrocyte)</p> <p>Ground substance</p>	Cartilage	Chondrocytes	Fine fibers of collagen	Low	Ears, joints, bone ends, respiratory passages, embryonic skeleton
 <p>Compact bone tissue</p> <p>Space that contained blood vessel</p> <p>Osteocyte</p>	Bone	Osteoclasts, osteoblasts, osteocytes	Collagen, minerals	Low	Skeleton

Animal tissues

Types of connective tissue

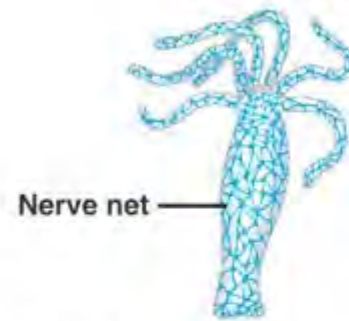
- Blood
- Cartilage
- Bone
- Loose
- Dense
- Adipose (Fat)

	Type of connective tissue	Cells	Matrix composition	Proportion of cells to matrix	Site
 <p>Collagen fiber</p> <p>Elastic fiber</p> <p>Fibroblast</p>	Loose connective tissue	Fibroblasts, fat cells (adipocytes), white blood cells	Loose elastin and collagen networks	Low	Under skin
 <p>Collagen fiber</p> <p>Fibroblast</p>	Dense connective tissue	Fibroblasts	Dense elastin and collagen networks	Low	Ligaments and tendons
 <p>Lipid droplet</p> <p>Cell membrane</p> <p>Nucleus</p>	Adipose tissue	Fat cells (adipocytes)	Minimal	High	Beneath skin, between muscles, around heart and joints

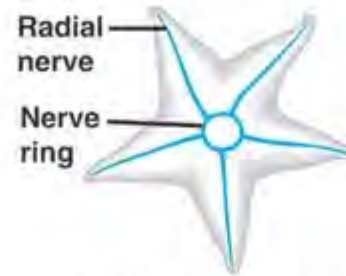
Animal tissues

Nervous systems

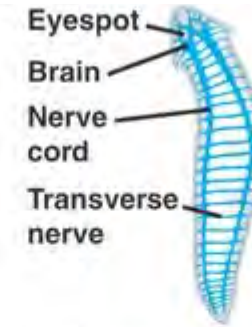
Primitive brains



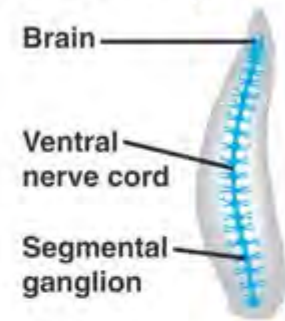
(a) Hydra (cnidarian)



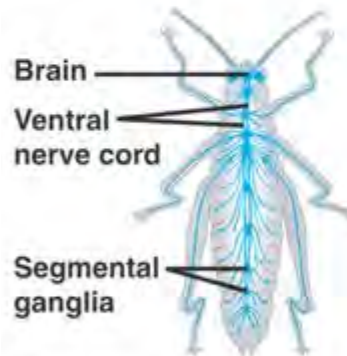
(b) Sea star (echinoderm)



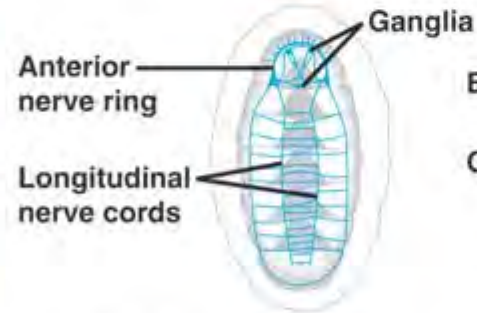
(c) Planarian (flatworm)



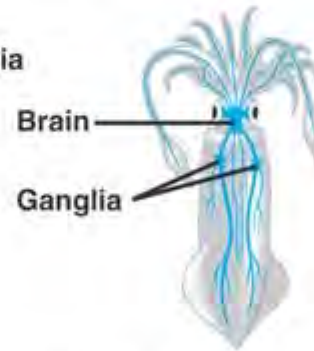
(d) Leech (annelid)



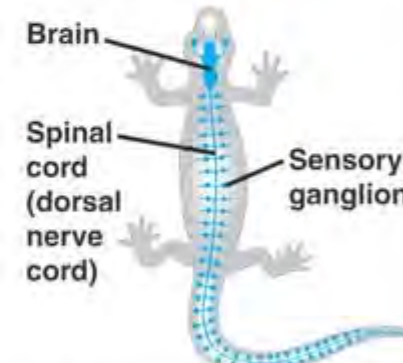
(e) Insect (arthropod)



(f) Chiton (mollusc)



(g) Squid (mollusc)

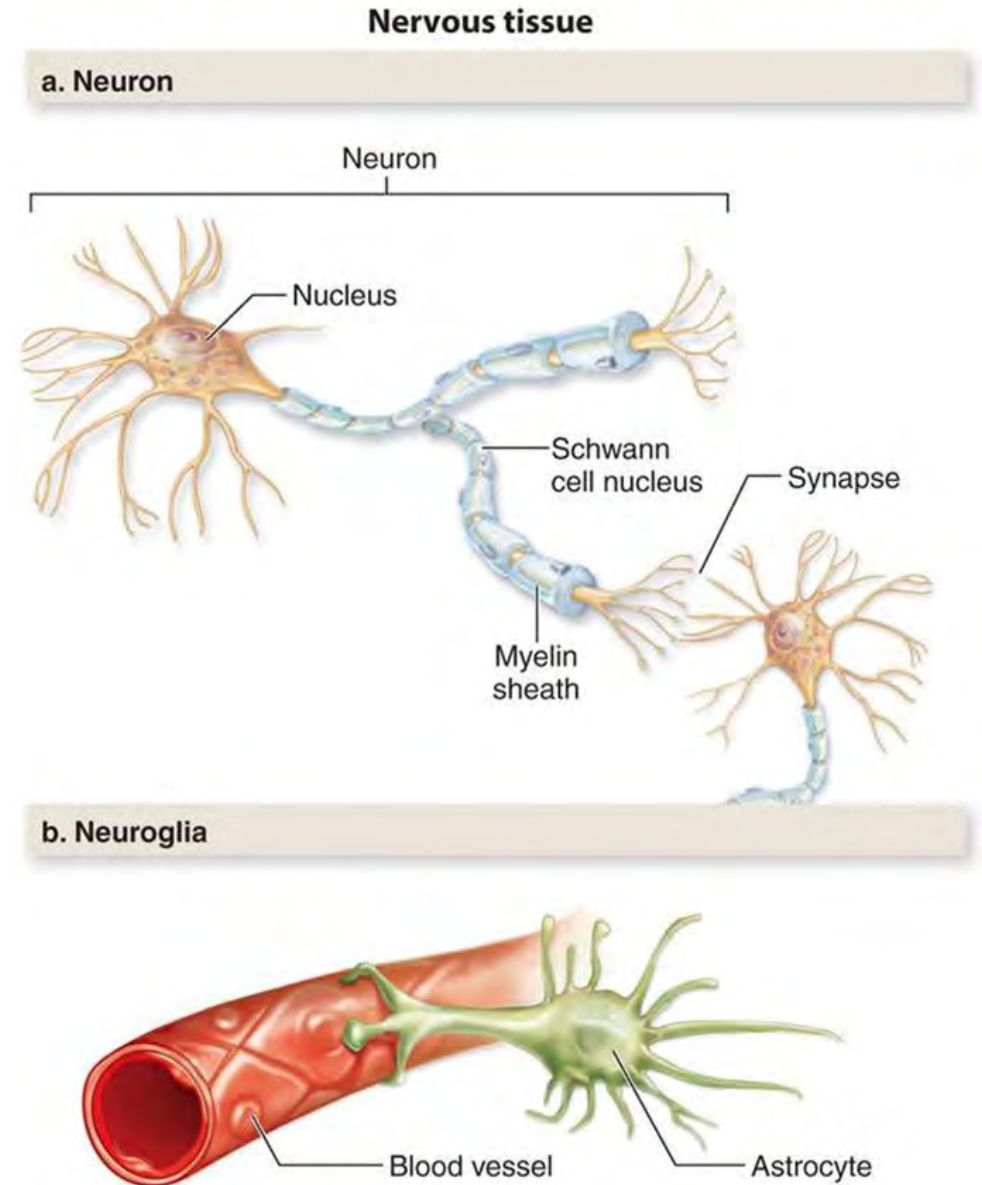


(h) Salamander (chordate)

Animal tissues

Nervous tissue

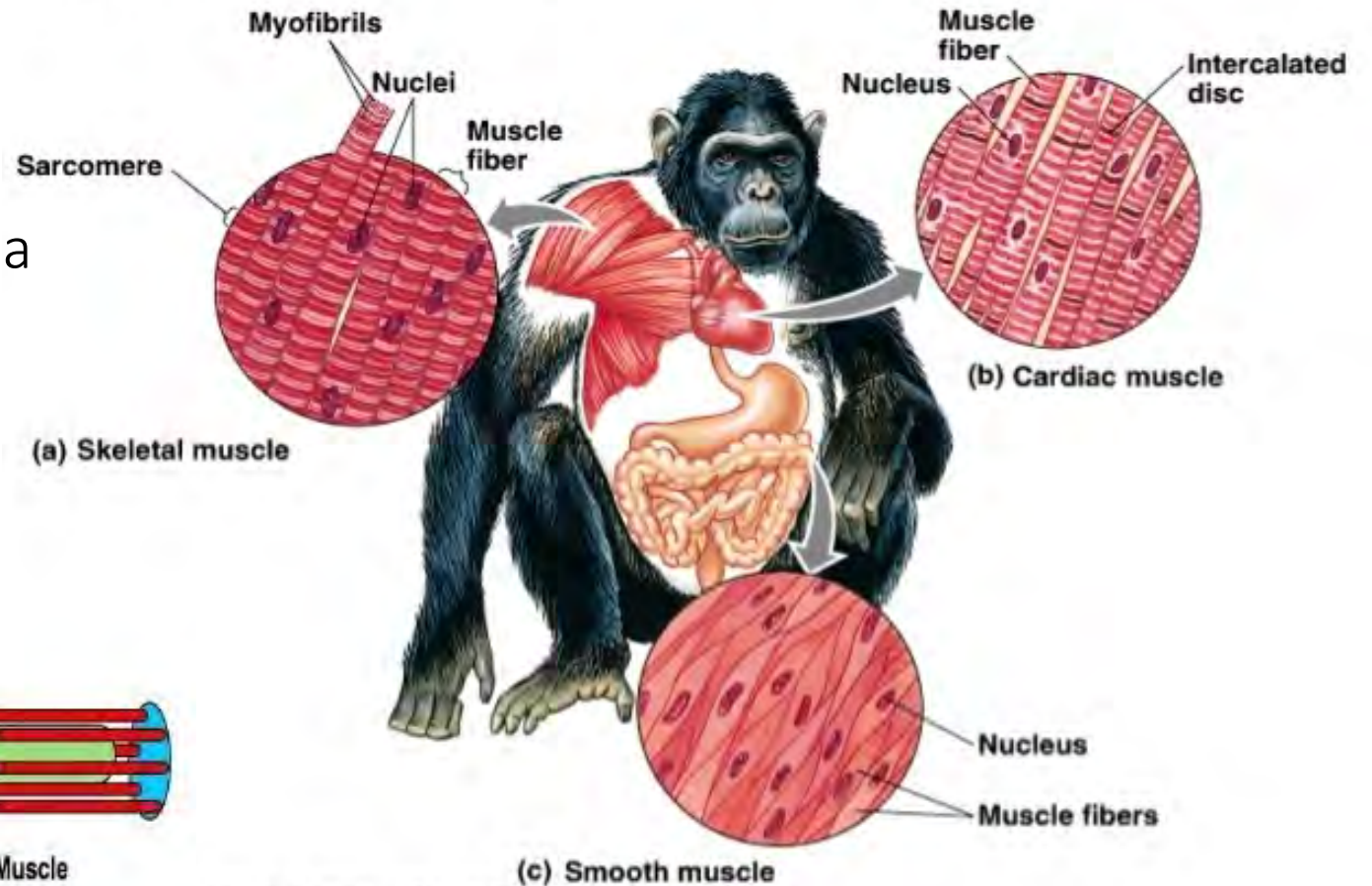
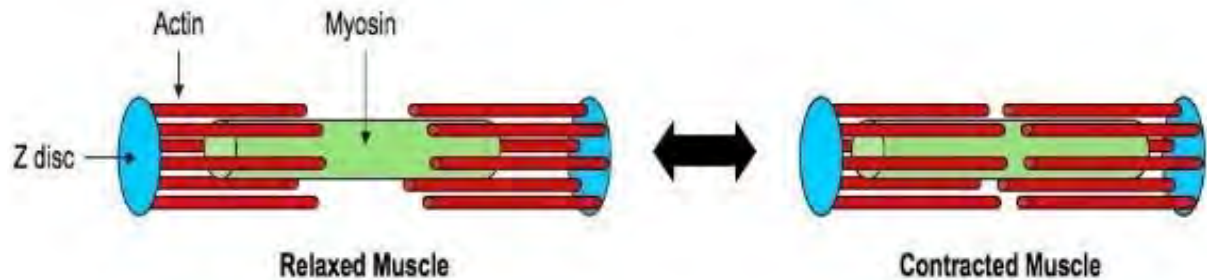
- Transmit information rapidly within an animal's body by electrical and chemical signals
- Two cell types:
 - Neurons = form communication networks that receive, process, and transmit information
 - Neuroglia = support cells that assist neurons in functioning



Animal tissues

Muscle tissue

- Cells with abundant mitochondria that contract when protein filaments slide past one another

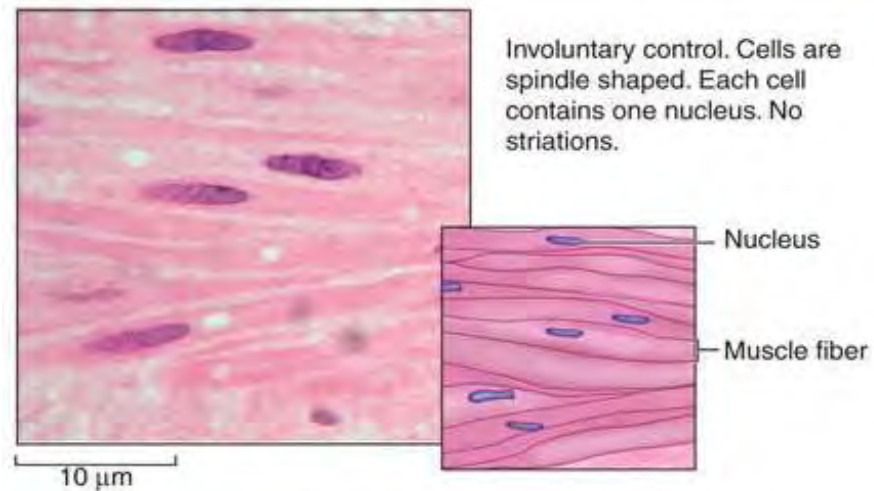


Animal tissues

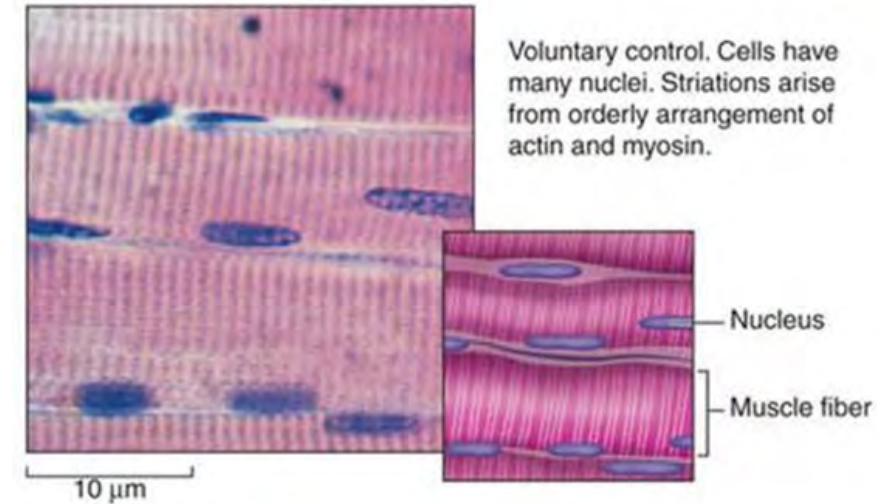
Muscle tissue

- Three types in vertebrates:
 - Skeletal → striated, attaches to bone, voluntary control
 - Cardiac → only in heart, striated, involuntary control
 - Smooth → not striated, involuntary control

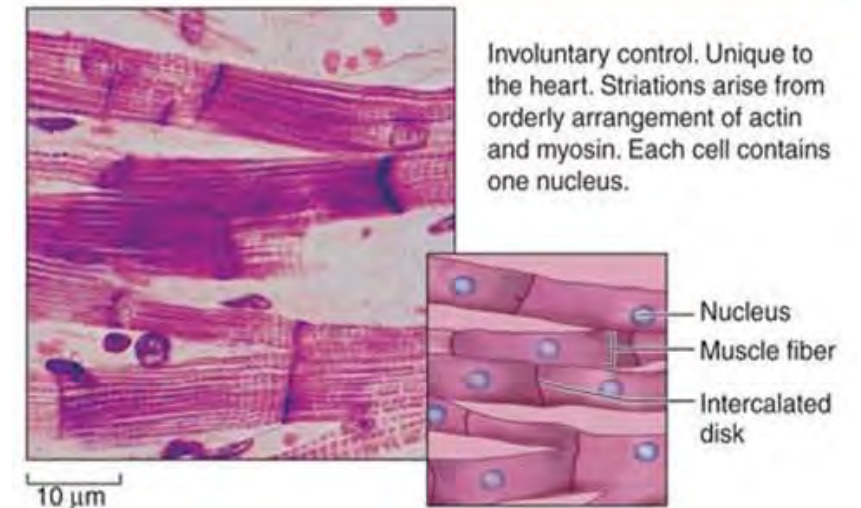
c. Smooth muscle



a. Skeletal muscle



b. Cardiac muscle

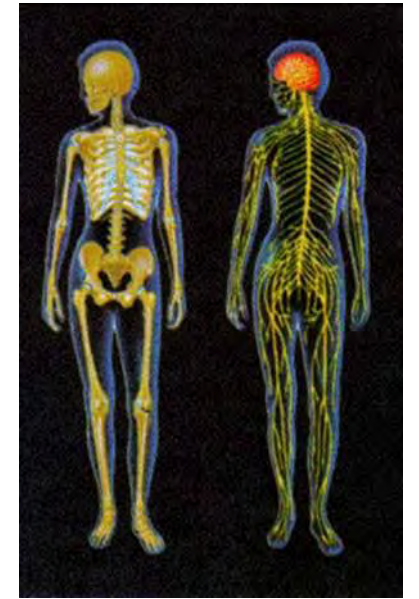


Organ systems



- Acquiring energy
 - Digestive system
 - Circulatory system
 - Respiratory system
- Protection
 - Integumentary system
 - Urinary system
 - Immune system
 - Lymphatic system

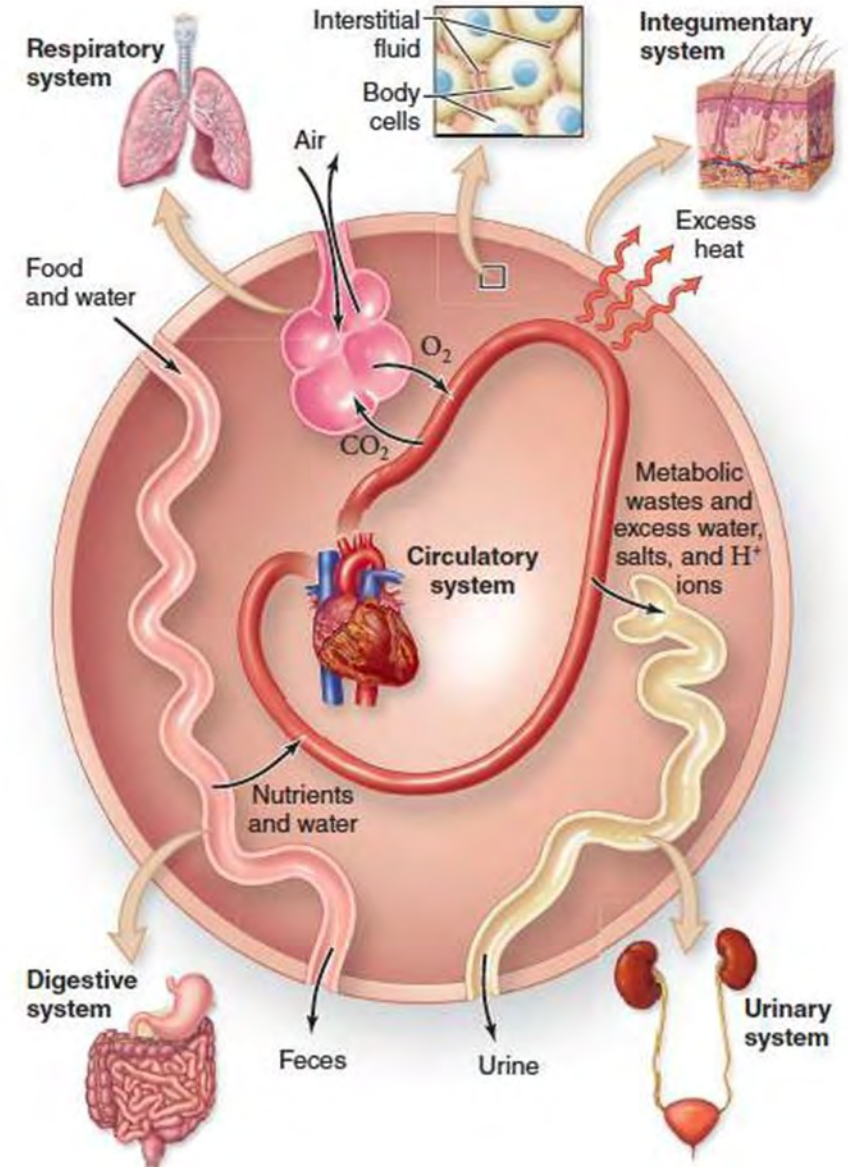
- Communication
 - Nervous system
 - Endocrine system
- Support and movement
 - Skeletal system
 - Muscular system
- Reproduction
 - Reproductive system



Homeostasis

Organ systems work together to maintain homeostasis

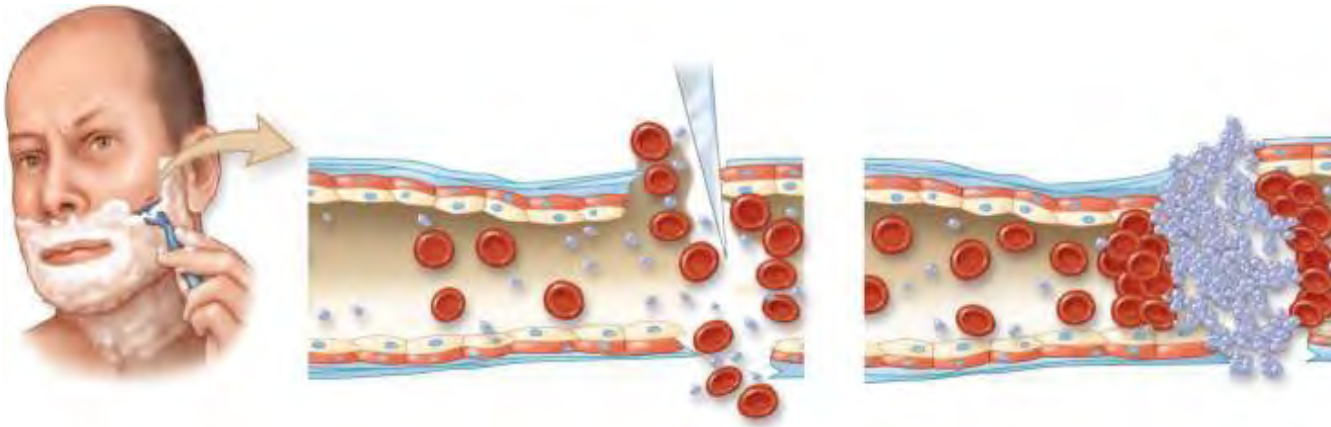
- Maintaining a **stable internal environment** in the face of external changes
- Many systems in the body use negative feedback to maintain homeostasis
- When a change from the optimal internal conditions is detected, the body responds by counteracting the change
 - Examples: body temperature, blood pressure, fluid composition in the body



Homeostasis

Organ systems work together to maintain homeostasis

- A few biological functions demonstrate **positive feedback**, in which the body reacts to a change by amplifying it
 - Examples: breastfeeding, clotting



Negative feedback:
Mechanism that reduces or counteracts the original action of a stimulus on the body

Digestive systems

- All animals are **heterotrophs**, and need to consume food to obtain carbon and energy
- Different diets select for differences in animal digestive tracts
- But all share the four-step process of obtaining and using food



a.



b.



c.



d.

Digestive systems

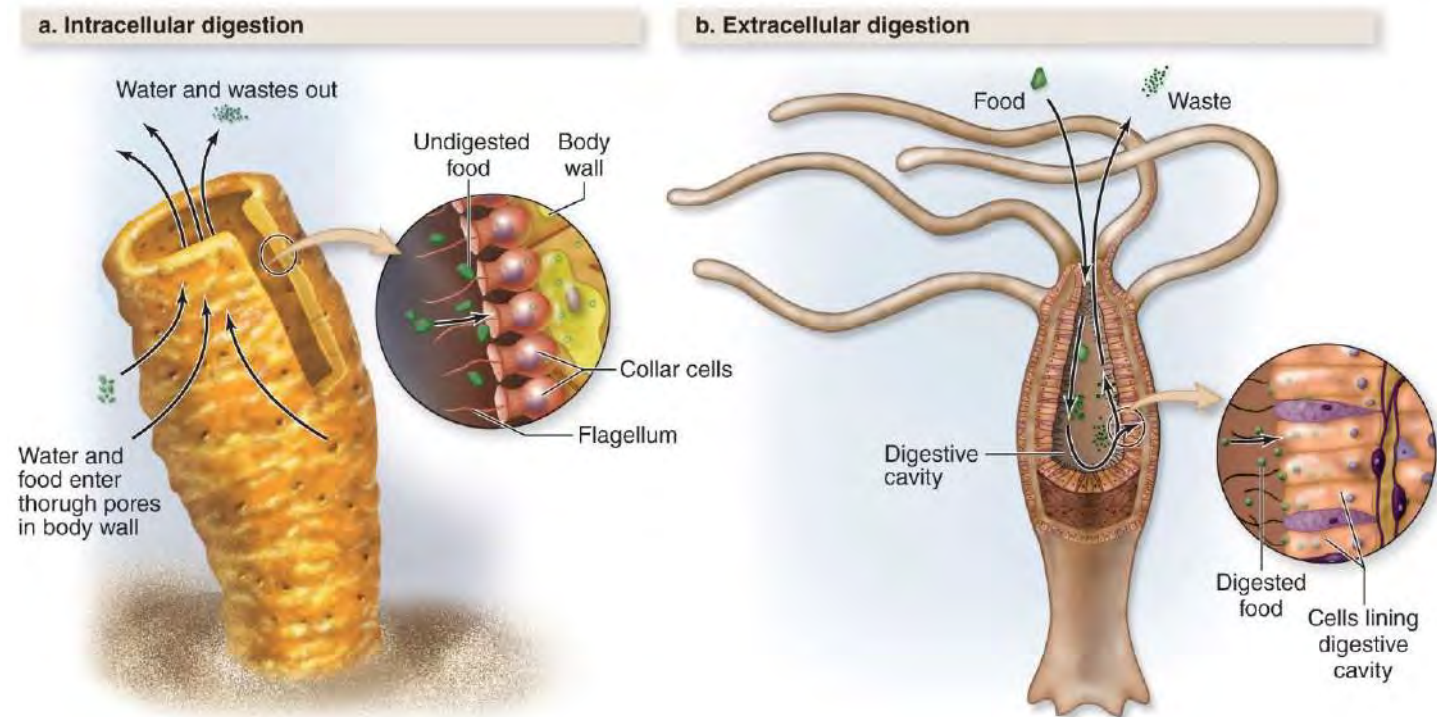
Four steps in obtaining and using food

1. Ingestion – assimilation of food into the digestive tract
2. Digestion – physical and chemical breakdown of food
3. Absorption – nutrient cross cells lining the digestive system and enter the blood
4. Elimination – undigested food egested



Digestive systems

- Sponges have no special compartment for digestion
 - Particles captured by collar cells which utilize intracellular digestion
- Most animals use extracellular digestion within a digestive tract

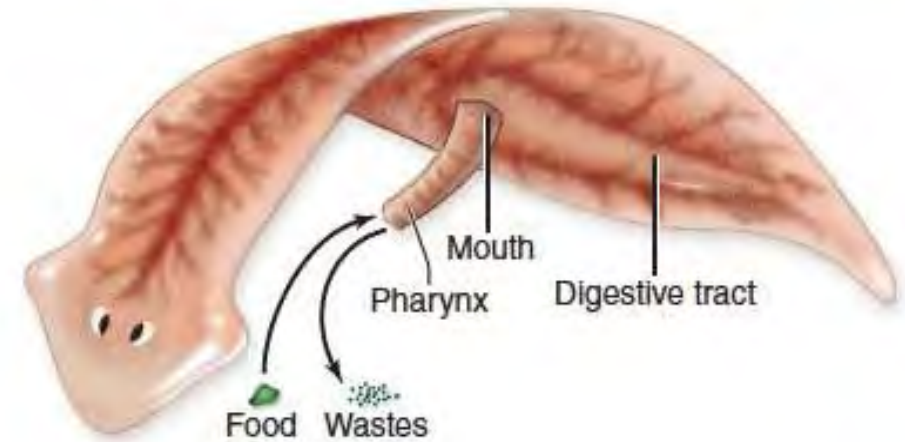


Digestive systems

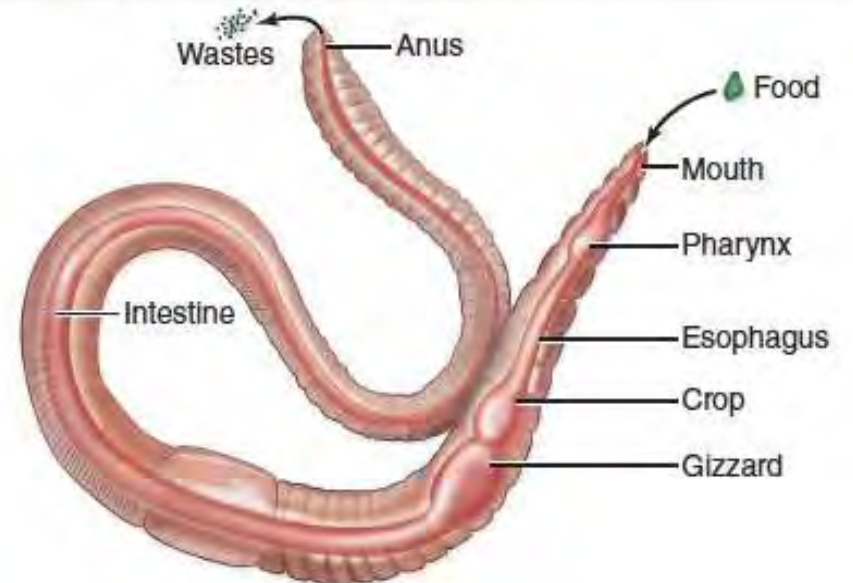
Types of digestive tracts

- Incomplete digestive tracts
 - Have only one opening for ingestion and elimination
- Complete digestive tracts
 - Have two openings (mouth and anus)

a. Incomplete digestive tract: one opening



b. Complete digestive tract: two openings

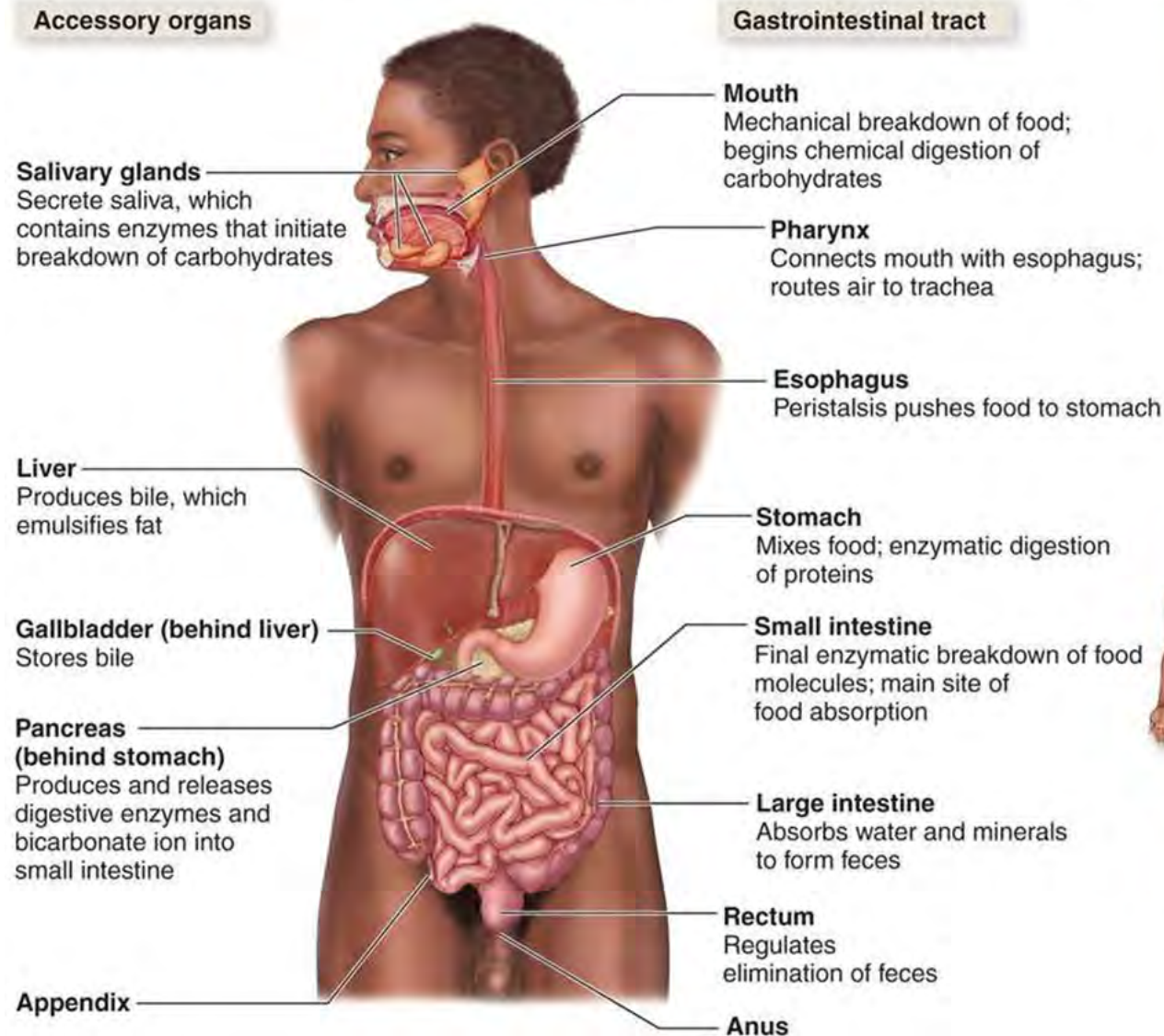


Human digestive tract

- Complete digestive tract
 - Two openings
 - One way travel
- Extracellular digestion
 - Secrete hydrolytic enzymes to digest food
 - Food remains outside the body cells until it is absorbed
- Accessory structures
 - Salivary glands, teeth, tongue, pancreas, liver, gall bladder
 - Help to physically and chemically break down food



Human digestive tract



Digestive System	
Main tissue types	Examples of Locations/Functions
Epithelial	Secretes hormones, enzymes, and mucus into digestive tract; absorbs products of digestion; protects mouth, esophagus, and anal canal from pathogens and abrasion
Connective	Blood (a connective tissue) transports nutrients from the digestive system to all parts of the body; supports esophagus, liver, and digestive lining
Muscle	Smooth muscle moves food along digestive tract and aids in mechanical digestion; skeletal and smooth muscle controls mouth, tongue, esophagus, and anal canal
Nervous	Stretch receptors signal presence of food in stomach; nerves regulate activity of digestive organs

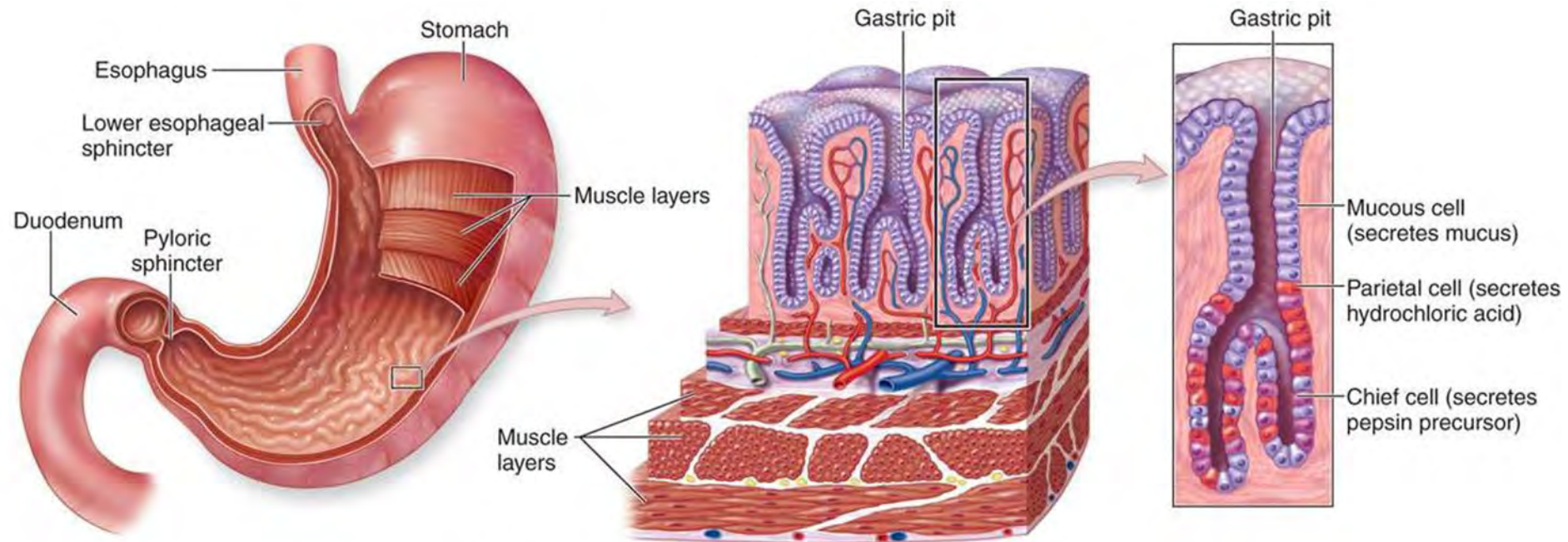


Human digestive tract

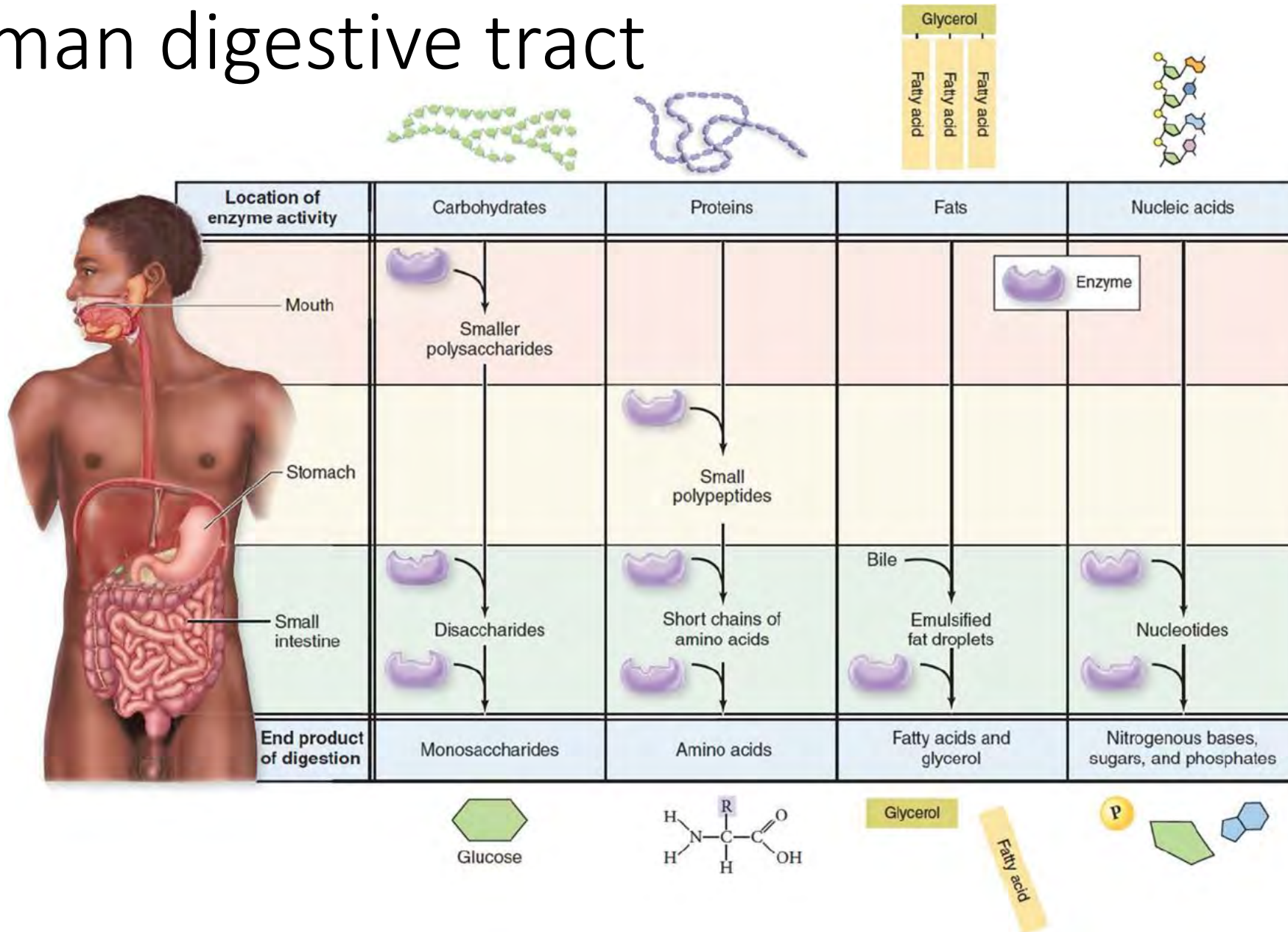
Primarily for
protein digestion

➤ Stomach

- Can expand to 3-4 litres
- Mechanical and chemical digestion (hydrochloric acid and enzymes)

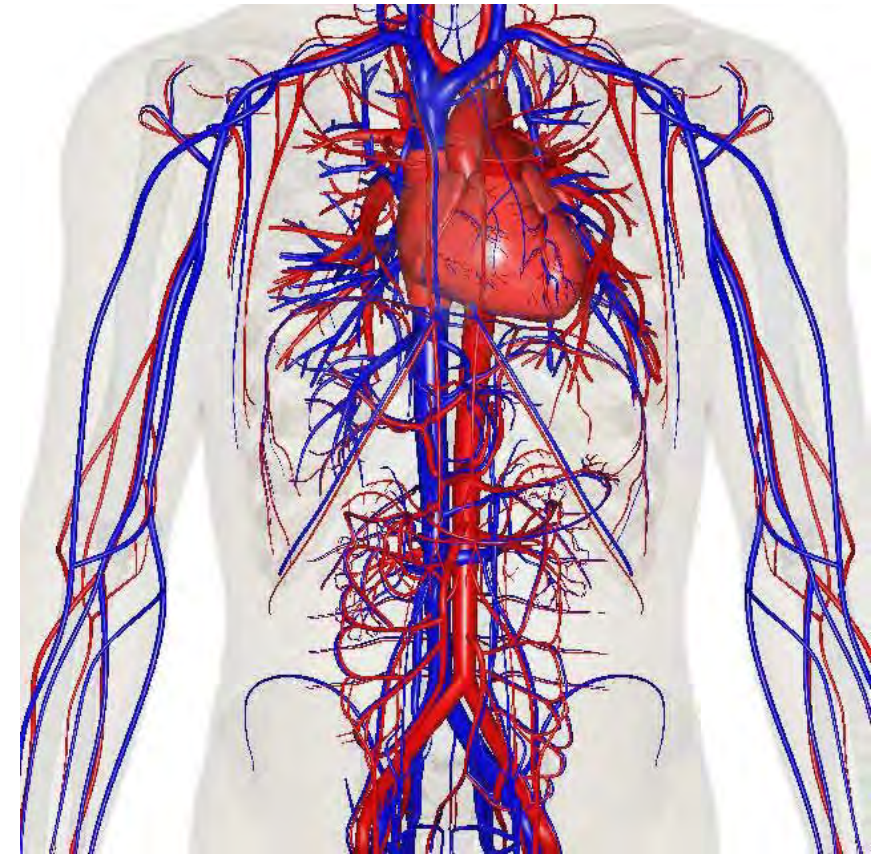


Human digestive tract



Circulatory systems

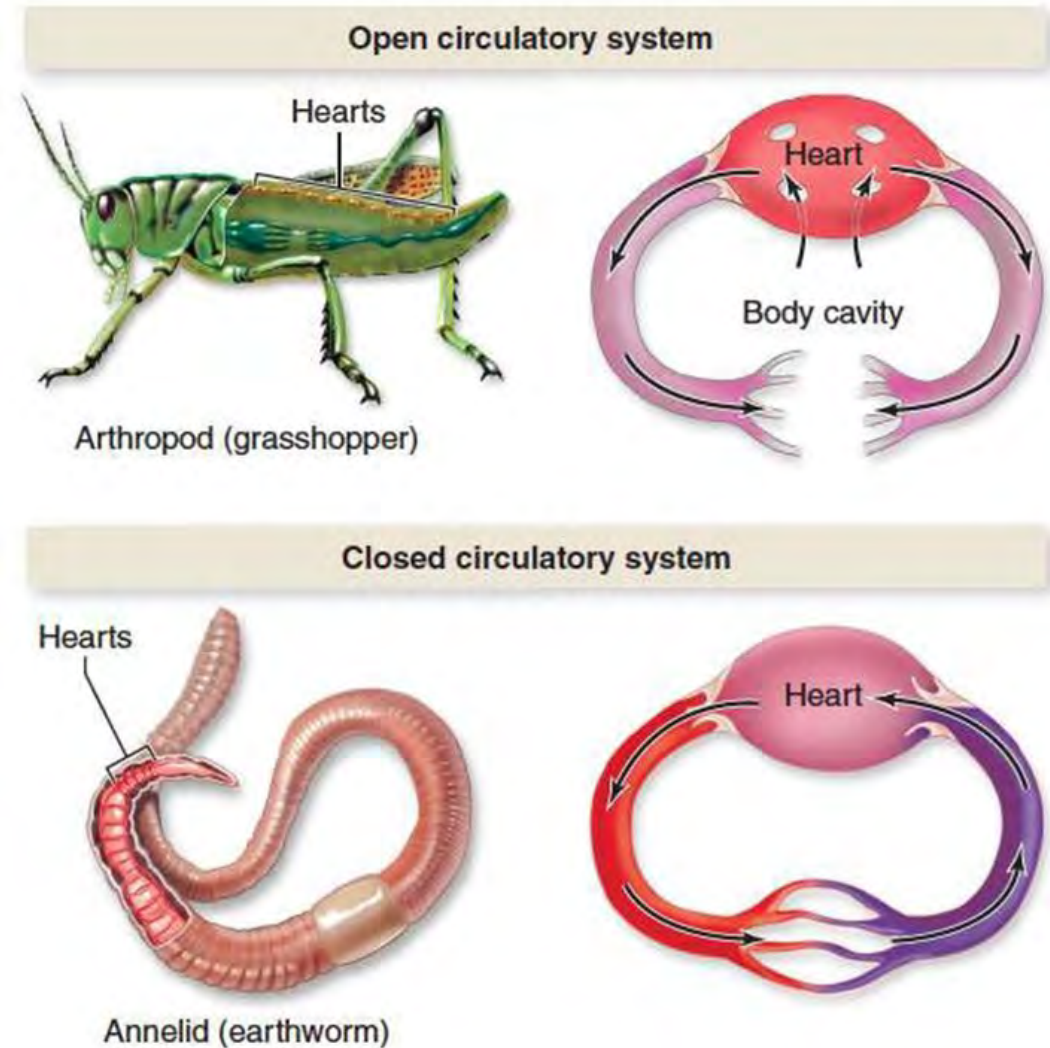
- Circulatory system functions to **transport gases, nutrients, hormones, etc.** to and from cells in the body via blood through a system of blood vessels (arteries and veins)
- In vertebrates, it also functions to fight diseases, stabilize temperature and carry nitrogenous waste to the excretory system
- Contractions of the heart create pressure and continuous flow of blood through vessels



Circulatory systems

Types of circulatory systems

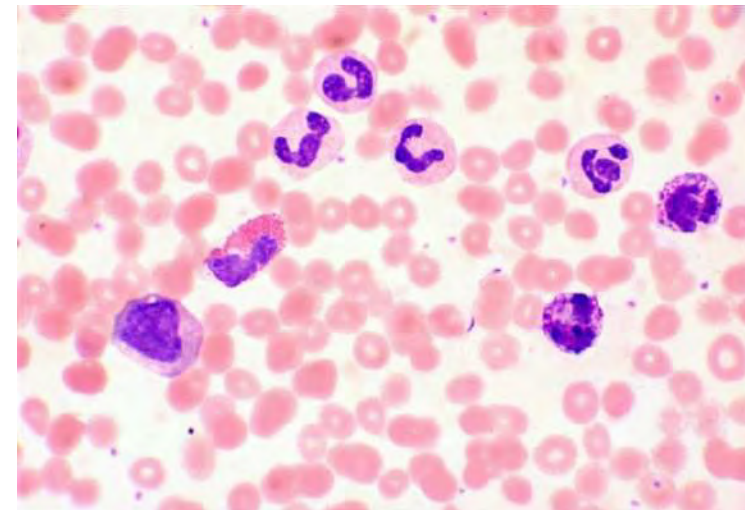
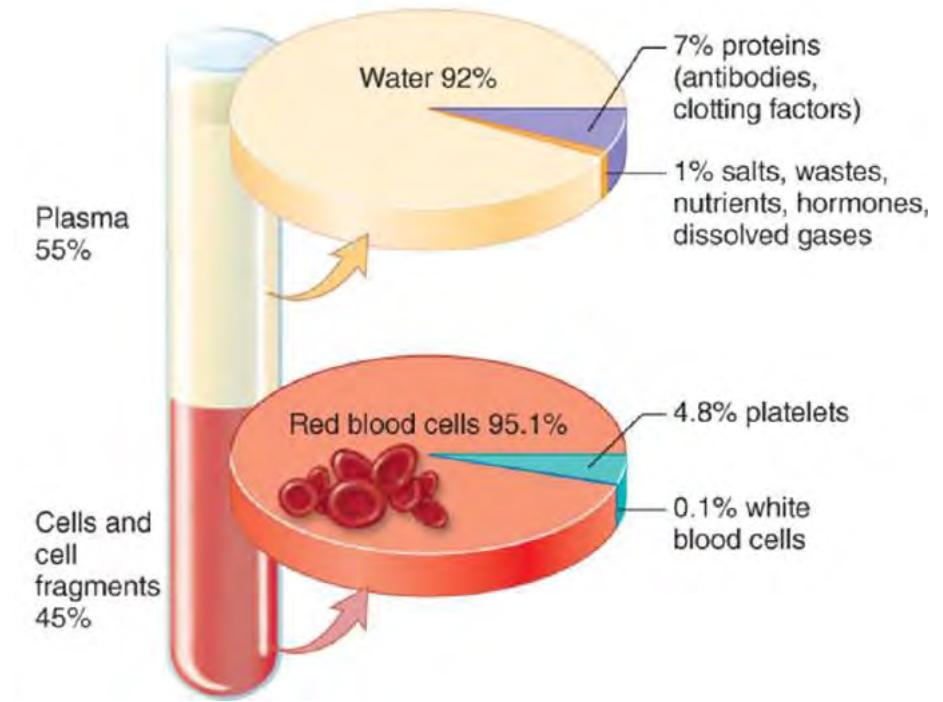
- **Open** circulatory system has short, open-ended vessels
 - No distinction between blood and the interstitial fluid
 - Combined fluid is called hemolymph
- **Closed** circulatory system is where blood remains in vessels
 - Vertebrates, annelids and cephalopods only



Circulatory systems

➤ Blood

- Fluid of vertebrate circulatory system
- Plasma is the medium of exchange of many substances in the body
- Red blood cells have haemoglobin for oxygen transport
- White blood cells fight infection
- Platelets initiate clotting



Circulatory systems

Vertebrates have two circulatory circuits

1. **Pulmonary** circuit - vessels lead to respiratory surfaces, where blood exchanges gases with the environment
 2. **Systemic** circuit – vessels lead to body tissues, where blood exchanges gases and nutrients with tissues
- Diffusion occurs in smallest vessels called capillaries

To and from rest of body

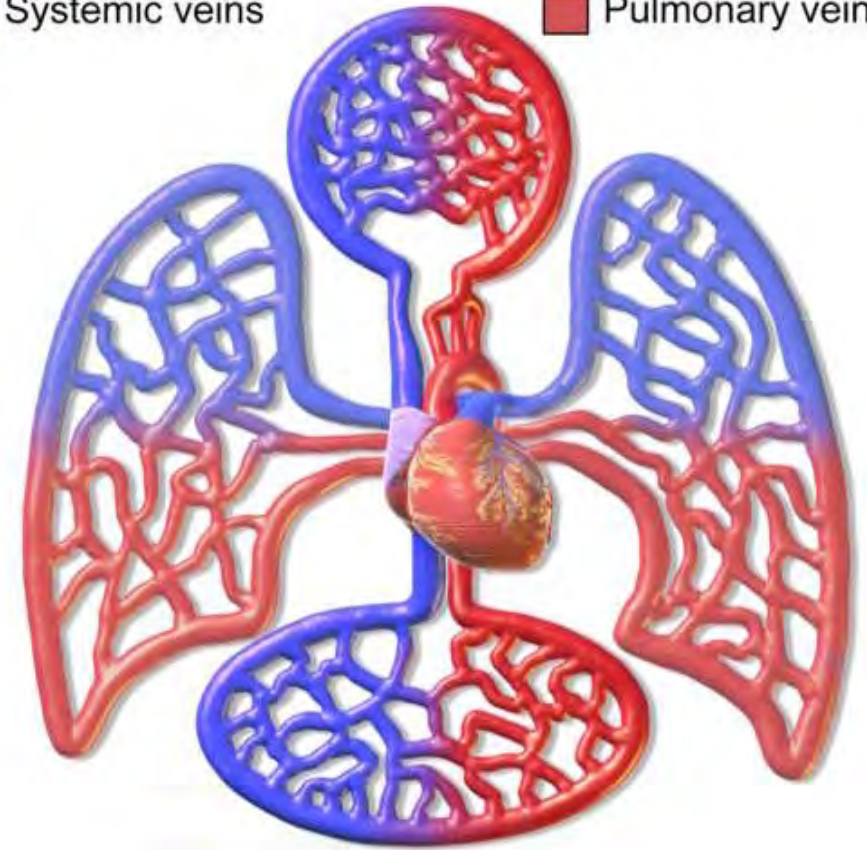
Systemic Circuit

- Systemic arteries
- Systemic veins

To and from lungs

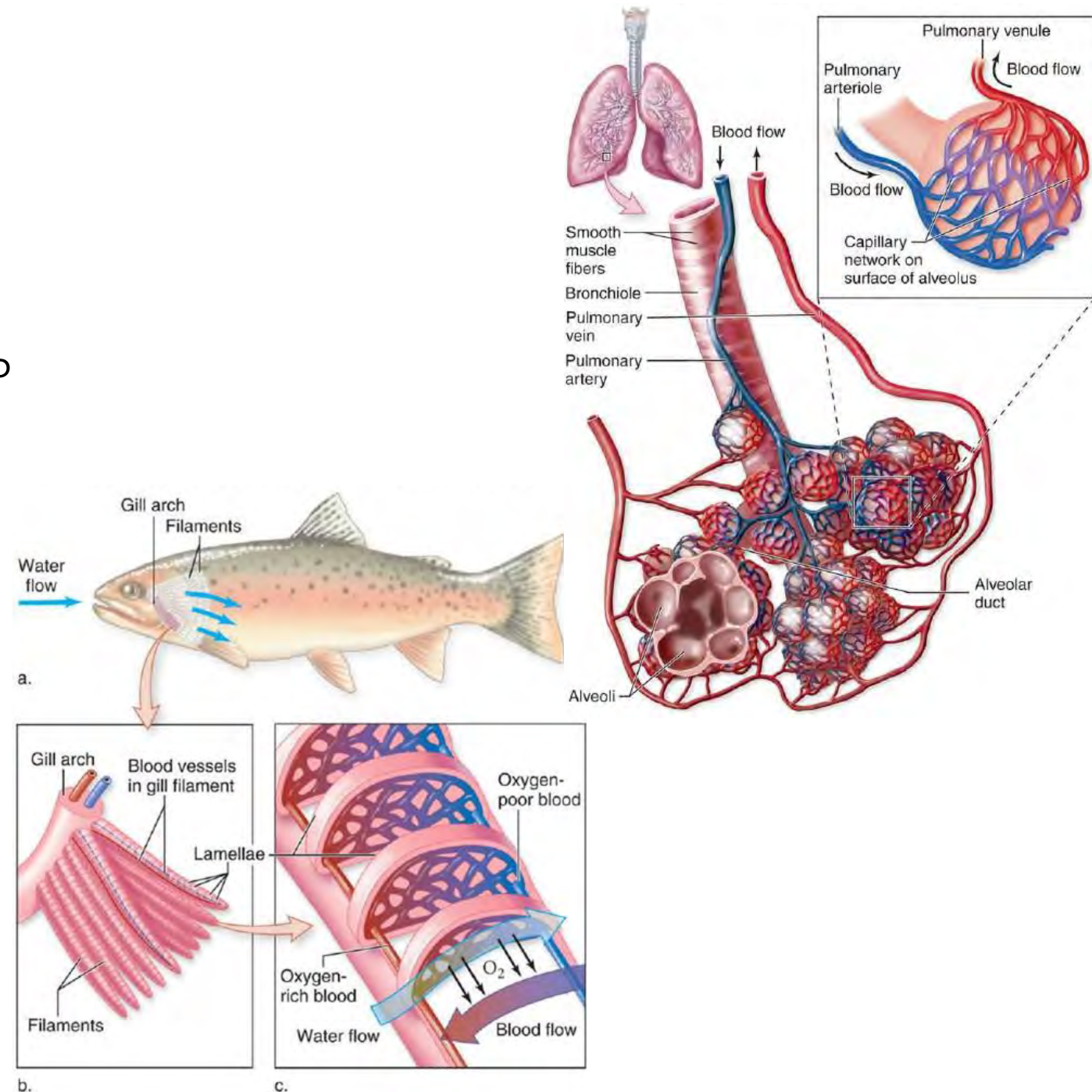
Pulmonary Circuit

- Pulmonary arteries
- Pulmonary veins



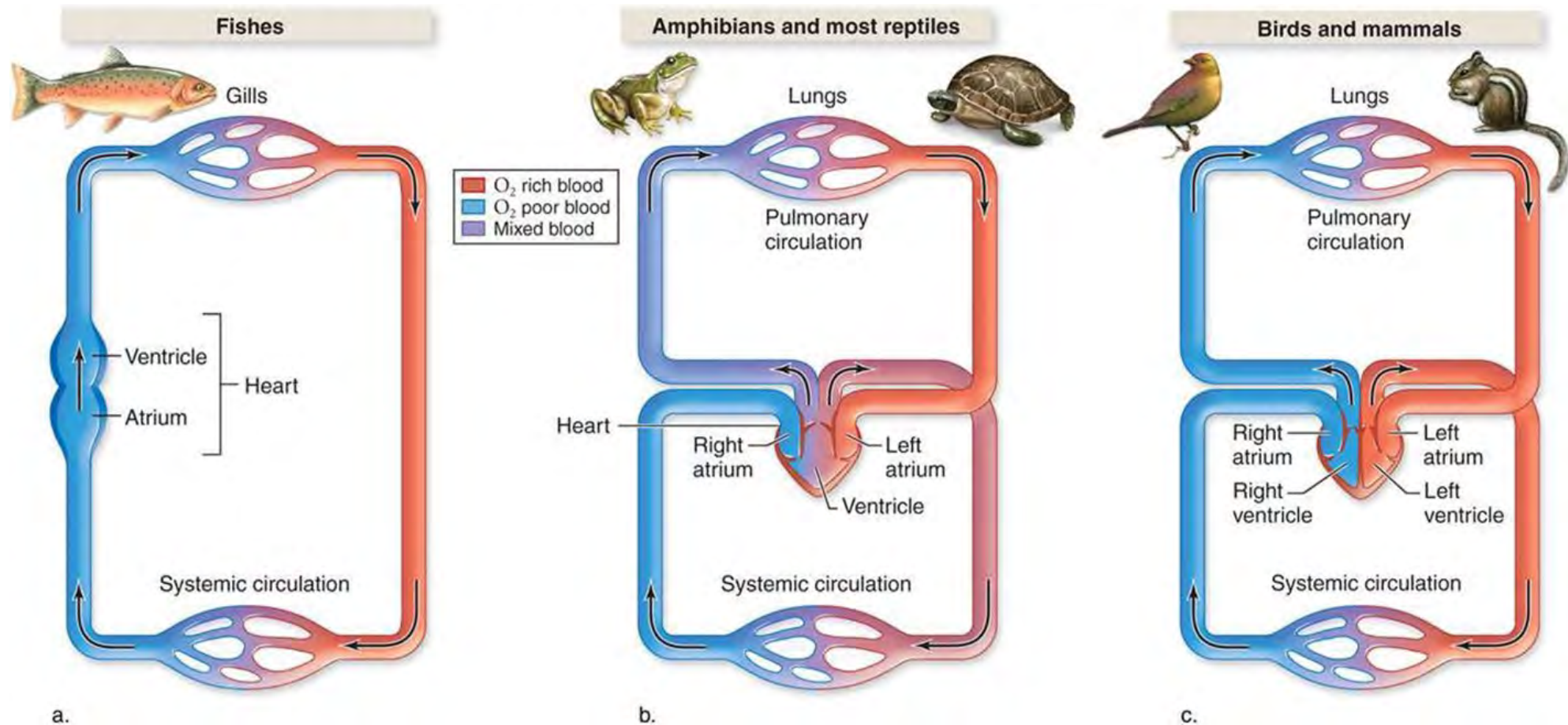
Circulatory systems

- Cells require oxygen as part of aerobic respiration to generate ATP
- Respiratory system works with circulatory system to acquire and deliver oxygen and to pick up and eliminate carbon dioxide
- Respiratory surfaces are varied
 - All must be **moist** for gas diffusion
 - All must have **sufficient surface area**

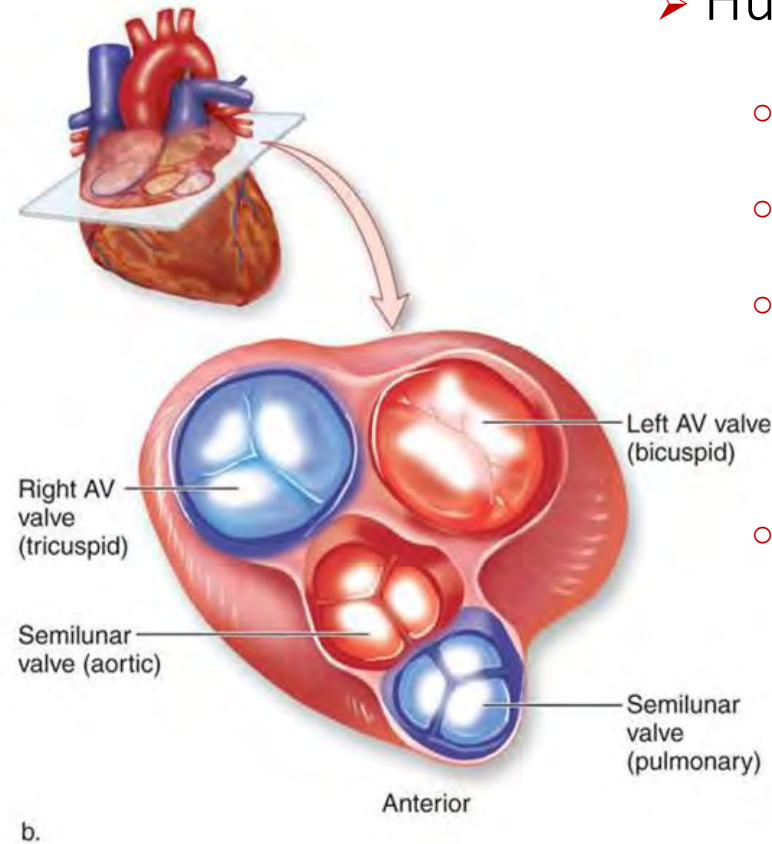
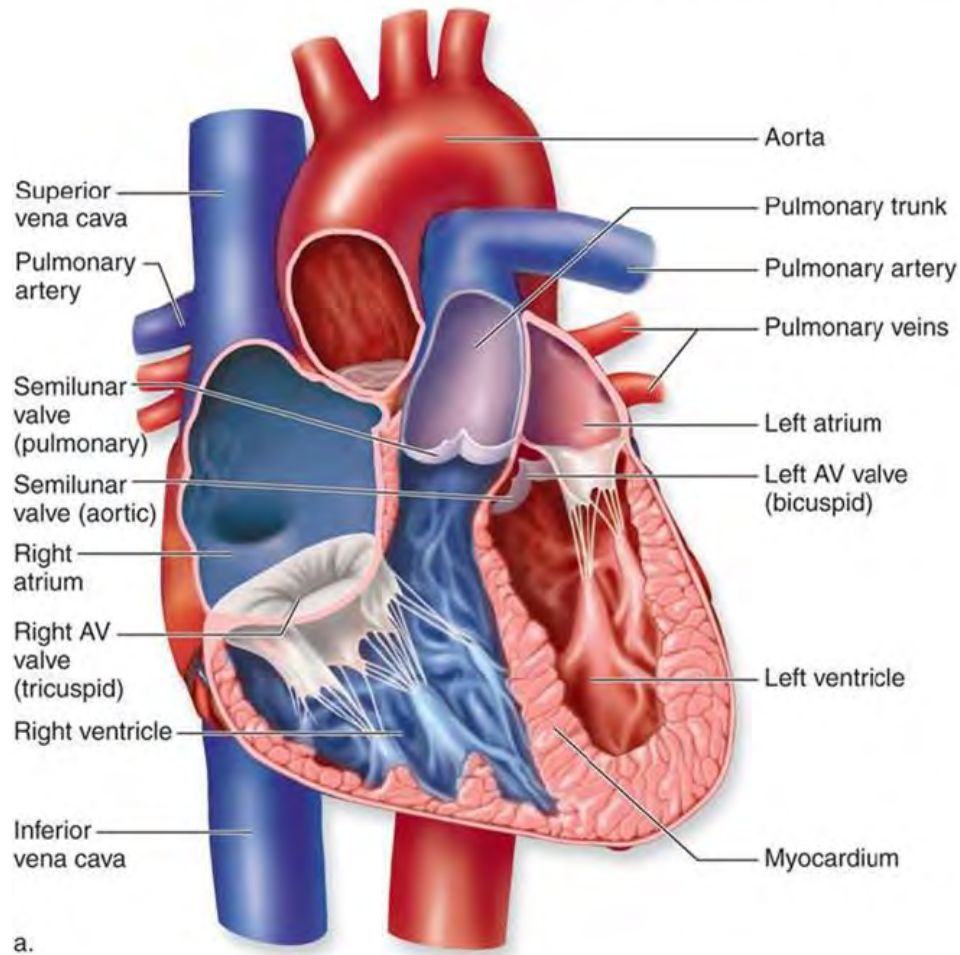


Circulatory systems

Closed circulatory systems are distinguished based on the number of heart chambers



Human circulatory system



➤ Human heart

- 2 upper atria
- 2 lower ventricles
- Atrioventricular (AV) valves
 - Allow 1-way flow from atria to ventricle
- Semilunar valves
 - Block blood from re-entering ventricles

Animal reproduction and development

Animals may reproduce **sexually** or asexually

- Animals have complex behaviours associated with reproduction
 - Courtship may function for species identification, stimulation of hormonal changes in participants or mate quality assessment



Animal reproduction and development

Mating systems and parental care

Amount of care given at various stages of development differs among species

- Males and females typically both provide care in **monogamous** species
- In **polygamous** mating systems, males are not likely to care for young, in part because they cannot be confident which young are theirs
- In **polyandrous** mating systems, males might care for young instead of females



Animal reproduction and development

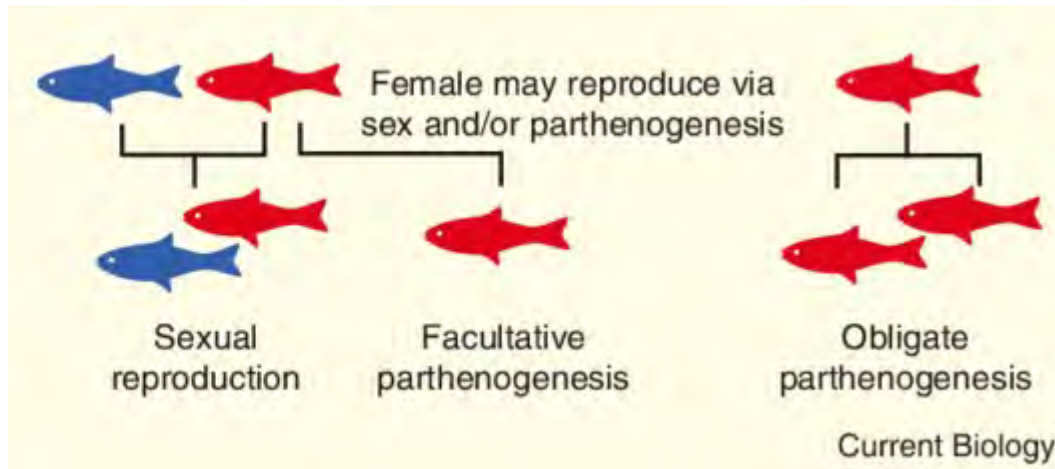
Animals may reproduce sexually or **asexually**

➤ Parthenogenesis

- Development of an embryo from an unfertilized egg cell.



Reptiles



Fishes

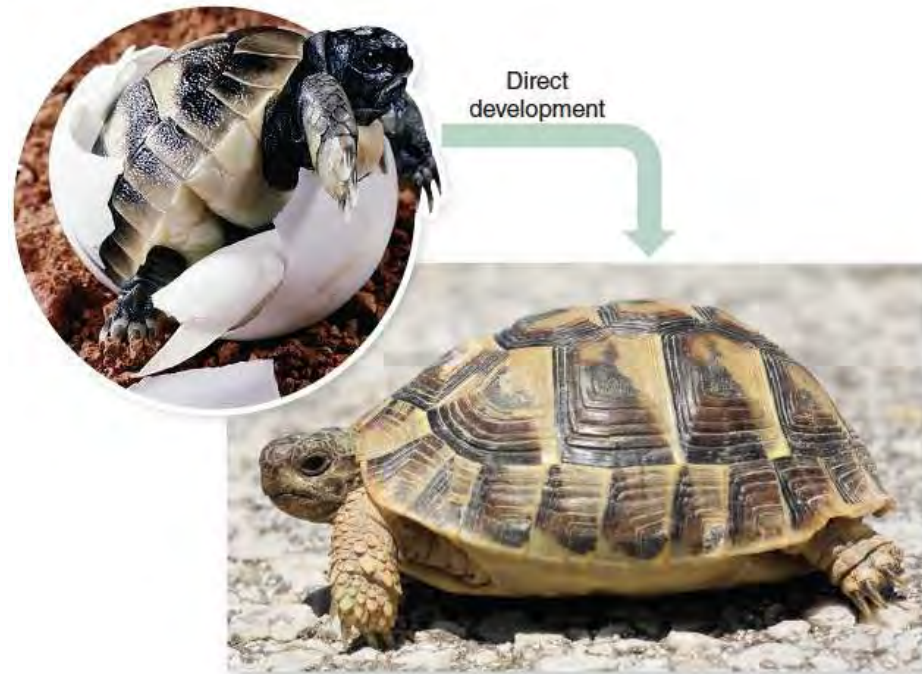


Insects

Animal reproduction and development

Development in animals can be indirect or direct

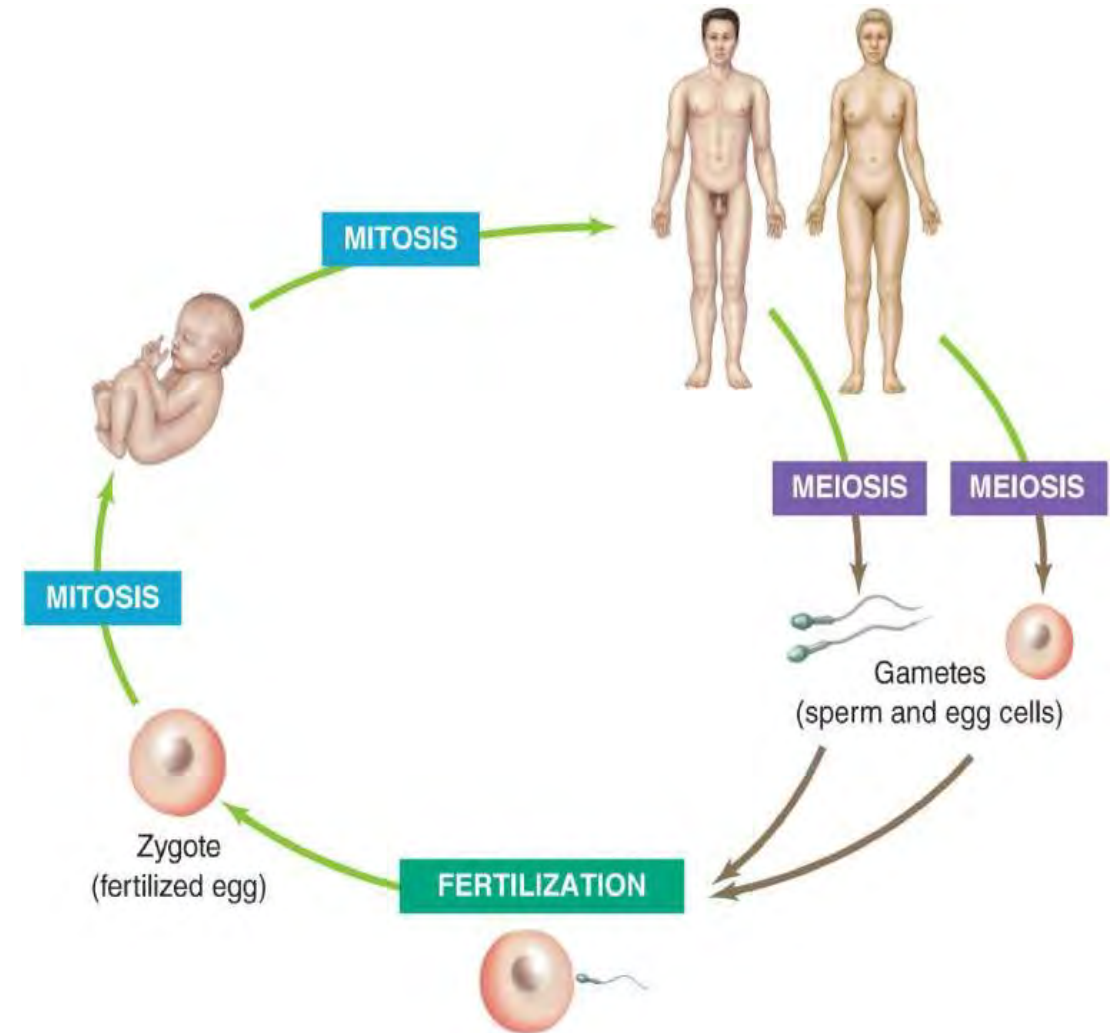
- **Indirect** development – immature stage looks different from the adult
- **Direct** development – immature stage looks like a small adult



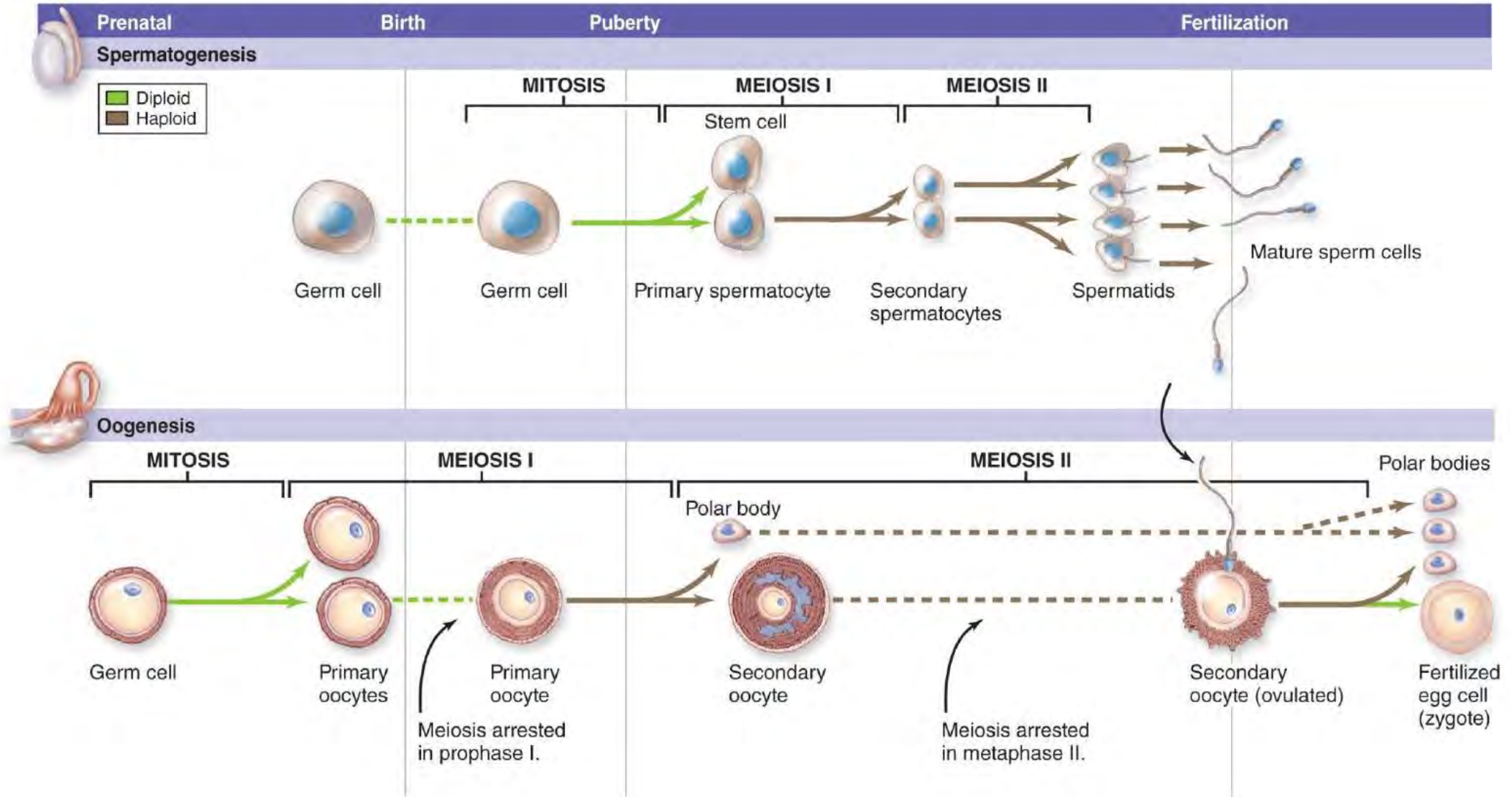
Animal reproduction and development

The gonads of sexually reproducing individuals produce haploid gametes by meiosis

- Human male and female gametogenesis occur at different life stages
- Gametes unite at fertilization, forming a diploid zygote



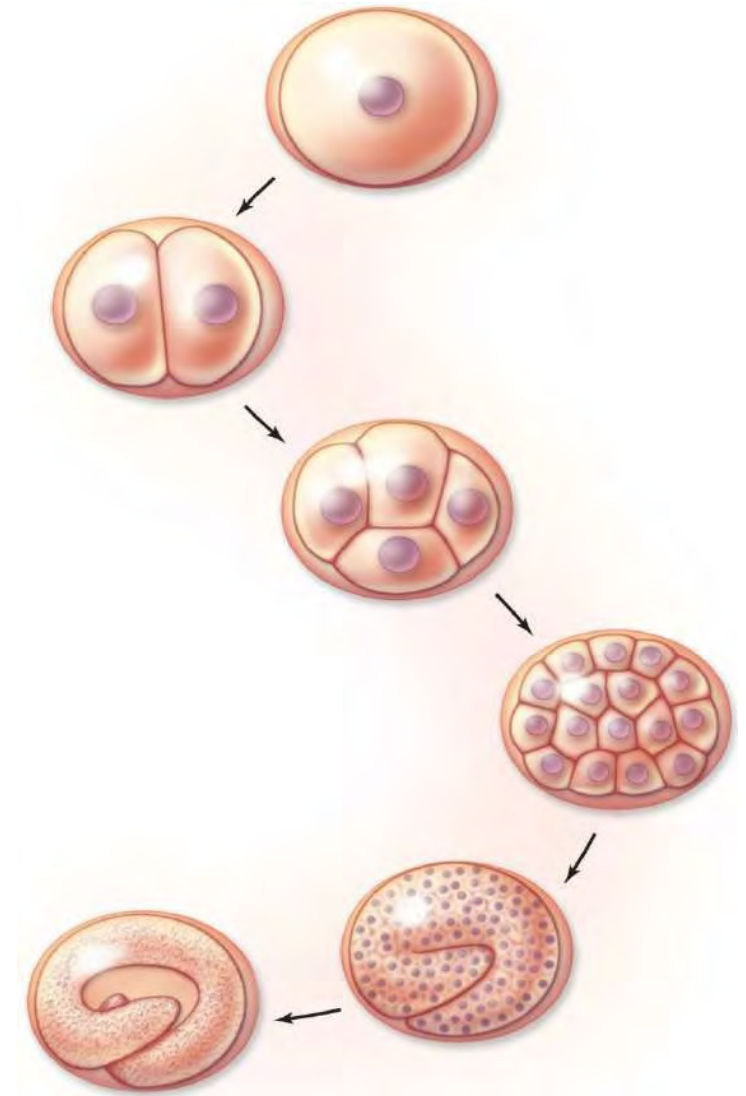
Animal reproduction and development



Animal reproduction and development

Embryogenesis

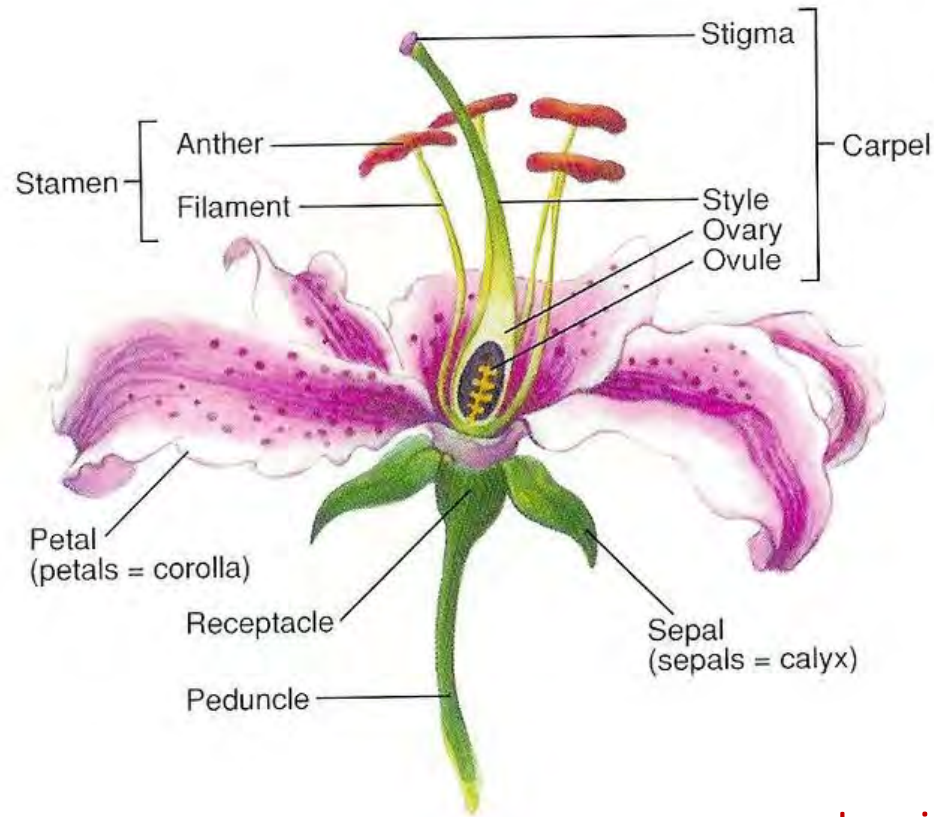
- The zygote begins to divide soon after fertilization is complete
- Cells begin to differentiate, or acquire specialized functions
- Genes then determine the overall shape and structure of the animal's body



Summary

- Animals are heterotrophs that use chemical energy in food to sustain form and function.
- Specialized cells are organized into tissues which are combined into functional units known as organs and groups of organs work together to form organ systems.
- Many animals regulate their internal environment via homeostasis (e.g. thermoregulation).
- Animal reproduction and development can vary according to mating systems.
- Take home questions:
 - What are examples of alternative reproductive strategies in animals?
 - Why do some animals have hundreds of offspring whilst others less than five?

This Thursday: Lab on flowering plants



Prepare for practical by reading instructions beforehand

- Working in groups
- Individual lab reports

****Watch video on use of a compound microscope prior to coming for the lab session.**

LumiNUS > Multimedia > Laboratory > The Compound Microscope.mp4

Next week: Museum Scavenger Hunt



Prepare for scavenger hunt by reading instructions carefully

- Individual answer sheets
- Use OWN words and paraphrase

