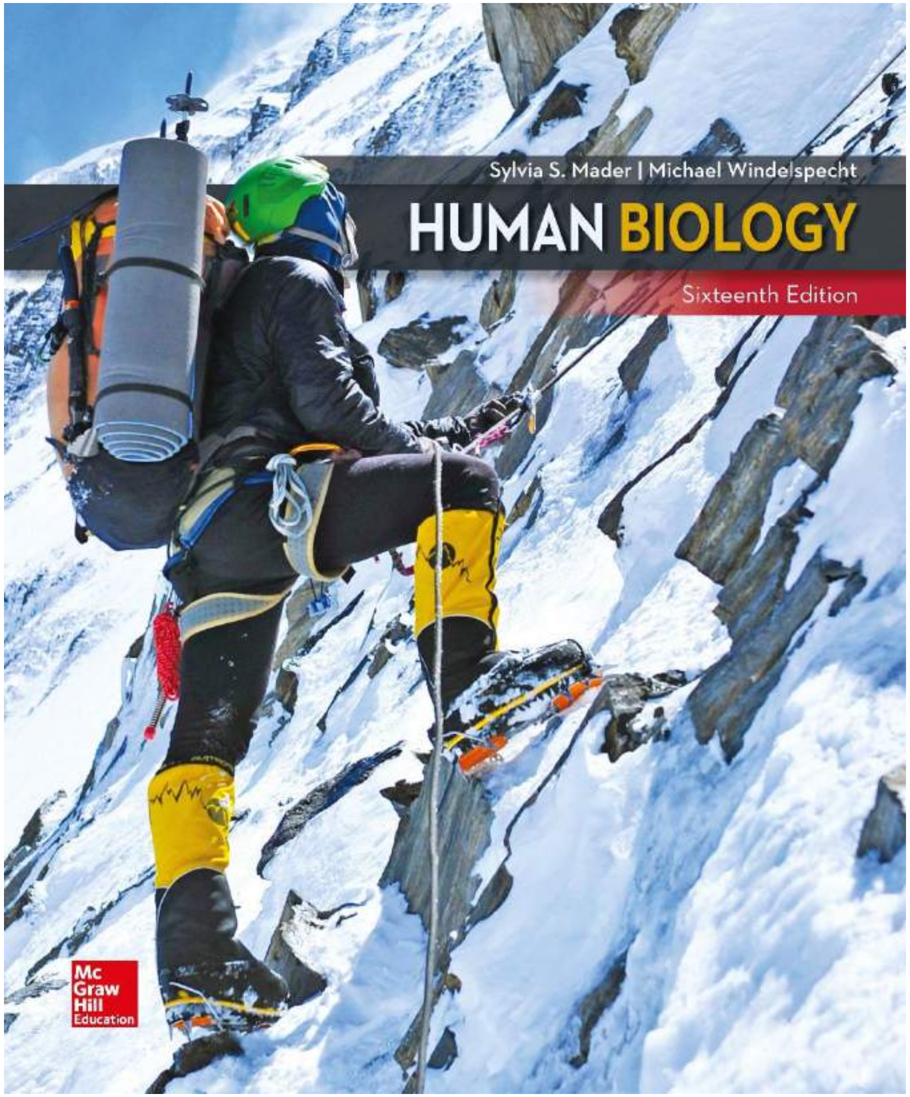
HUMAN BIOLOGY

Sixteenth Edition



Sylvia S. Mader

Michael Windelspecht

- **Laboratory 1**
  - Scientific Investigation Laboratory

Science as a Process 2

Science—a way of knowing about the natural world.

Scientists should be objective (factual), not subjective (involves judgment).

The scientific process uses the **scientific method.**

- A standard series of steps.

Start with an Observation

Observation is a formal way of watching the natural world.

Made with.

- the senses (sight, smell).
- the help of instruments like microscopes.
- through research.

Develop a Hypothesis

A **hypothesis** is a possible explanation for the observation of a natural event.

Inductive reasoning—when someone uses creative thinking to combine facts into a cohesive whole.

Scientists make a testable **prediction** based on a hypothesis.

Test a Hypothesis

Scientists use **deductive reasoning** to test the hypothesis ("if, then" logic).

Experiments are designed with **experimental variables** (independent) and responding (dependent) **variables.**

Test groups and a **control groups** are also used.

Model organisms (like mice) are also used.

Collecting and Analyzing the Data [1]

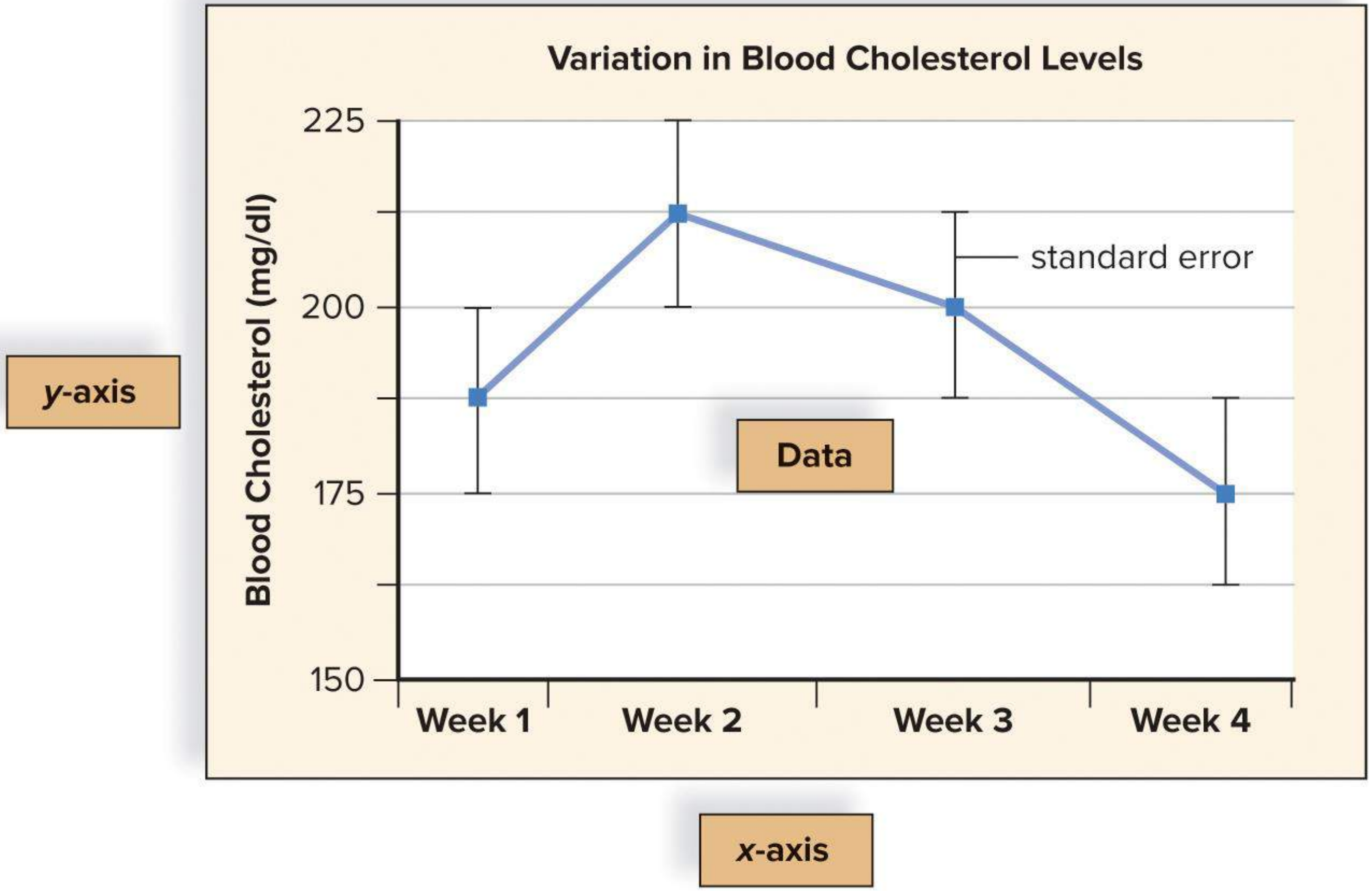
Results are derived from experiments.

Results, in the form of **data**, may be presented in a variety of formats.

Graphs are useful tools to summarize data.

- Line graphs, bar graphs.

The Presentation of Scientific Data (Figure 1.9)



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Collecting and Analyzing the Data 2

Statistics are used to interpret data.

Statistical data include a standard error (standard deviation) to show how uncertain a value is.

Statistical significance is determined to evaluate the probability that the results are due to chance or some other experimental variable.

Studies can be published in **Scientific publications**.

Develop a Conclusion

Scientists analyze the data in order to reach a **conclusion** about whether a hypothesis is supported or not.

The conclusion of one experiment can lead to the hypothesis for another experiment.

Scientific Theory

Scientific theory—accepted explanations for how the world works.

- That is, cell theory—all organisms are made of cells.

Law, or **principle**—accepted by an overwhelming majority of scientists.

- That is, evolution.

An Example of a Controlled Study

Hypothesis: antibiotic B is better than the currently used antibiotic A.

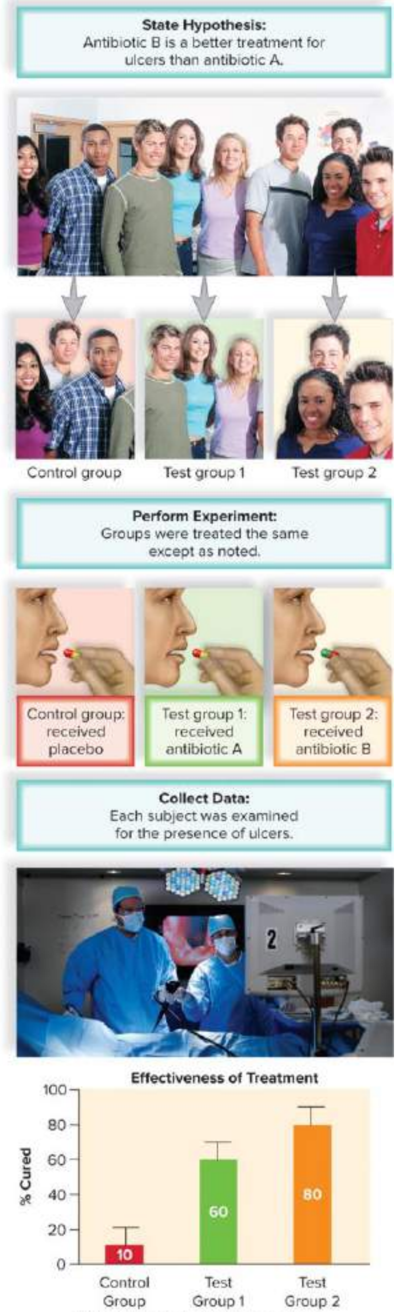
Control group: subjects with ulcers receive a **placebo** (a pill that contains no medication).

The two test groups each receive one of the antibiotics.

Double-blind study—neither the doctors nor the patients know which group they are in.

Conclusion—antibiotic B had better results.

A Controlled Laboratory Experiment to Test the Effectiveness of a Medication in Humans (Figure 1.10)



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Organ Systems, Body Cavities, and Body Membranes 1

Learning Outcomes:

- Summarize the function of each organ system in the human body.
- Identify the major cavities of the human body.
- Name the body membranes and provide a function for each.

Organ Systems, Body Cavities, and Body Membranes 2

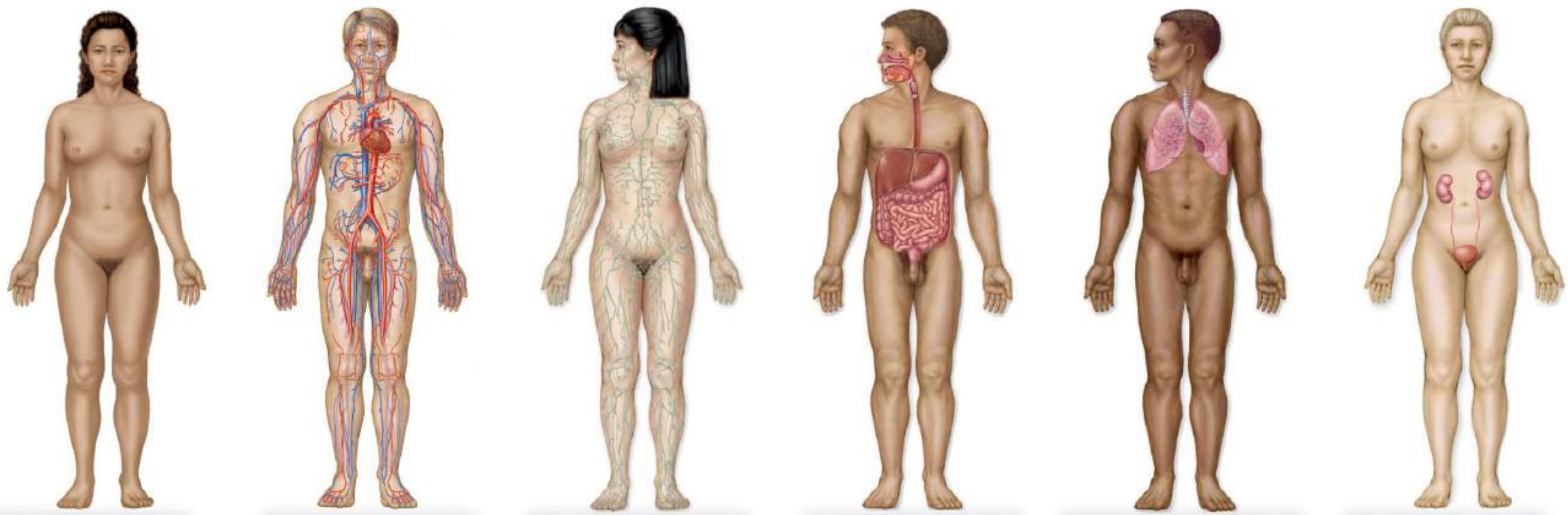
Organ—a group of tissues performing a common function.

Groups of organs with a similar function form an **organ system.**

- Some of these organ systems (for example, the respiratory system) occupy specific cavities; others, (for example, the muscular system) are found throughout the body.

Organs and cavities are lined with membranes, many of which secrete fluid.

Organ Systems of the Body (Figure 4.13) 1



Integumentary system
- protects body
- provides temperature homeostasis
- synthesizes vitamin D
- receives sensory input

Organ: Skin

Cardiovascular system
- transport system for nutrients, waste
- provides temperature, pH, and fluid homeostasis

Organ: Heart

Lymphatic and immune systems
- defends against infectious diseases
- provides fluid homeostasis
- assists in absorption and transport of fats

Organs: Lymphatic vessels, lymph nodes, spleen

Digestive system
- ingests, digests, and processes food
- absorbs nutrients and eliminates waste
- involved in fluid homeostasis

Organs: Oral cavity, esophagus, stomach, small intestine, large intestine, salivary glands, liver, gallbladder, pancreas

Respiratory system
- exchanges gases at both lungs and tissues
- assists in pH homeostasis

Organs: Lungs

Urinary system
- excretes metabolic wastes
- provides pH and fluids homeostasis

Organs: Kidneys, urinary bladder

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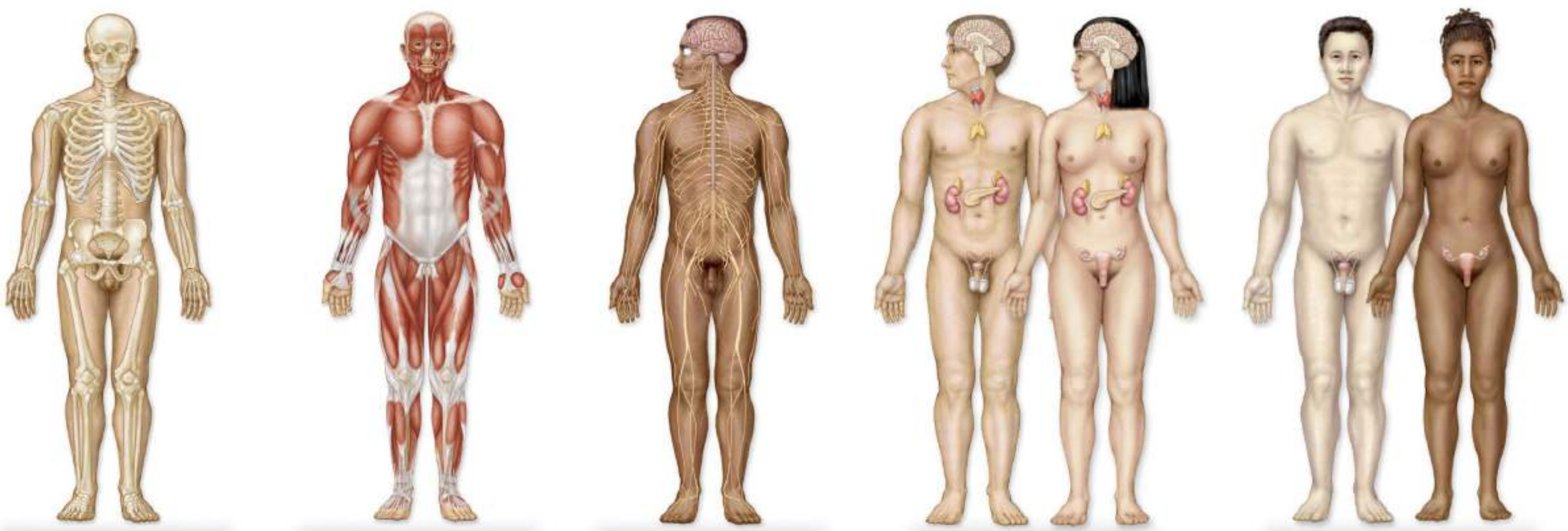
Organ Systems of the Body (Figure 4.13) 2



Skeletal system
- provides support and protection
- assists in movement
- stores minerals
- produces blood cells

Organ: Bones

Muscular system
- assists in movement and posture
- produces heat

Organ: Muscles

Nervous system
- receives, processes, and stores sensory input
- provides motor output
- coordinates organ systems

Organs: Brain, spinal cord

Endocrine system
- produces hormones
- coordinates organ systems
- regulates metabolism and stress responses
- involved in fluid and pH homeostasis

Organs: Testes, ovaries, adrenal glands, pancreas, thymus, thyroid, pineal gland

Reproductive system
- produces and transports gametes
- nurtures and gives birth to offspring in females

Organs: Testes, penis, ovaries, uterus, vagina

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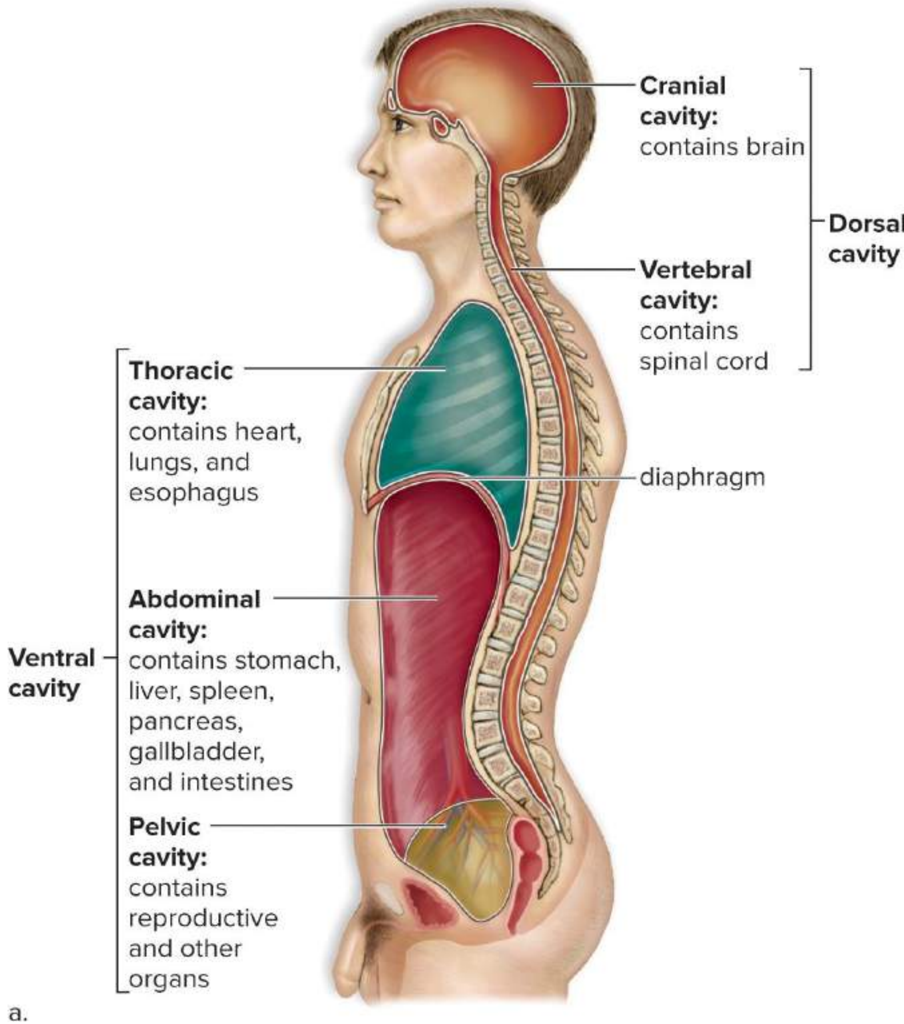
Body Cavities

Body cavities.

- Two main cavities: **ventral** and **dorsal.**
- **Ventral cavity.**
  - Contains the **thoracic, abdominal,** and **pelvic cavities.**
  - Thoracic and abdominal cavities are separated by the **diaphragm.**
- **Dorsal cavity.**
  - Contains the **cranial cavity** and **vertebral canal.**

Body Cavities of Humans (Figure 4.14a)



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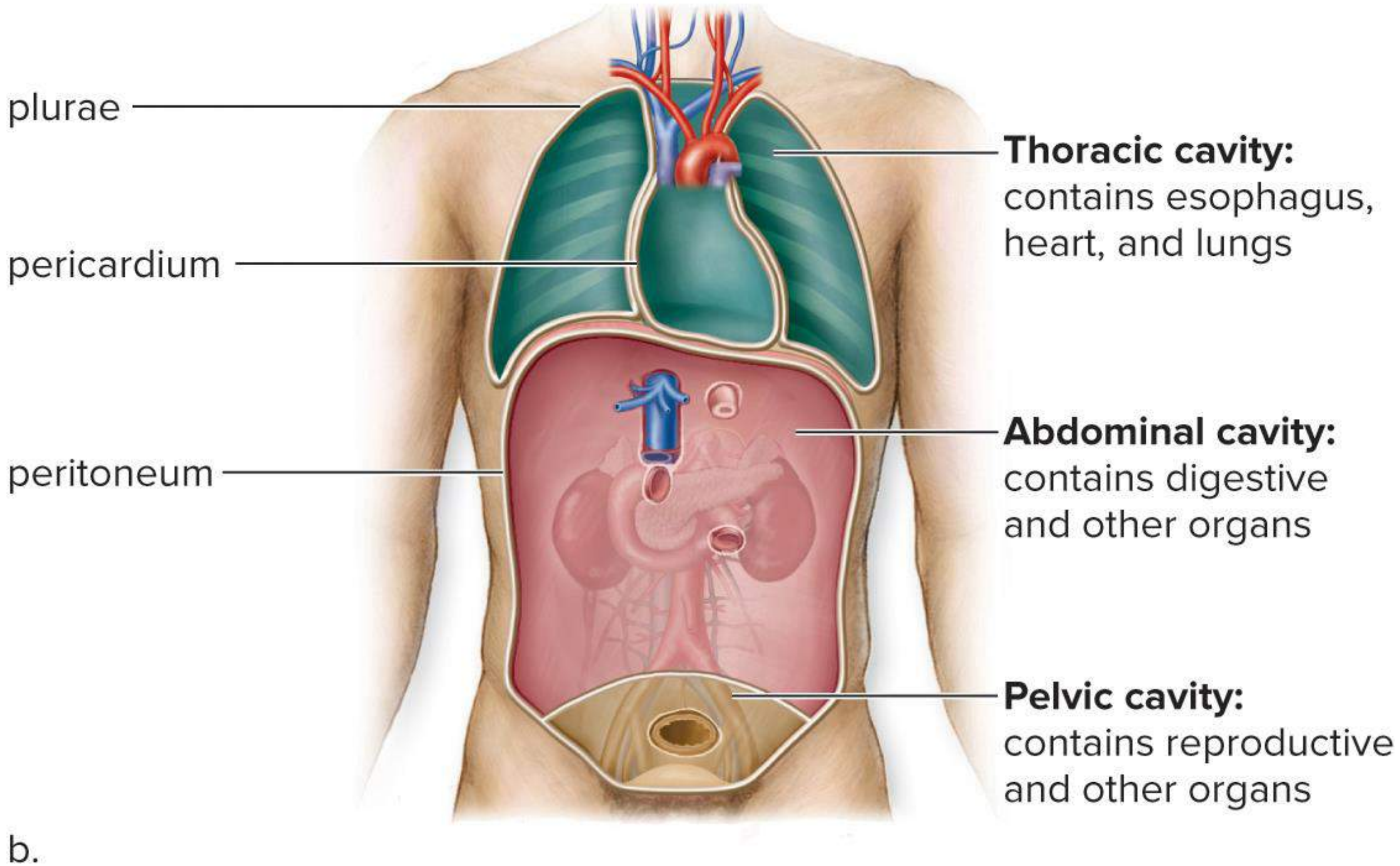
Body Cavities of Humans (Figure 4.14b)



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Homeostasis 2

Homeostasis.

- A relatively constant internal environment.
- There are various conditions in the body that are maintained within a relatively narrow range of normal values.
  - That is, blood glucose, pH, body temperature.
  - If conditions vary too much, illness results.

The Body Systems and Homeostasis

The nervous and endocrine systems coordinate the other organ systems.

- The nervous system is faster, but the effects of the endocrine system last longer.
- The endocrine system secretes **hormones**—chemical messengers that travel in blood.

Anatomical Position

The position with the body erect with the arms at the sides and the palms forward. The anatomical position is of importance in anatomy because it is the position of reference for anatomical nomenclature. Anatomic terms such as anterior and posterior, medial and lateral, abduction and adduction, and so on apply to the body when it is in the anatomical position.

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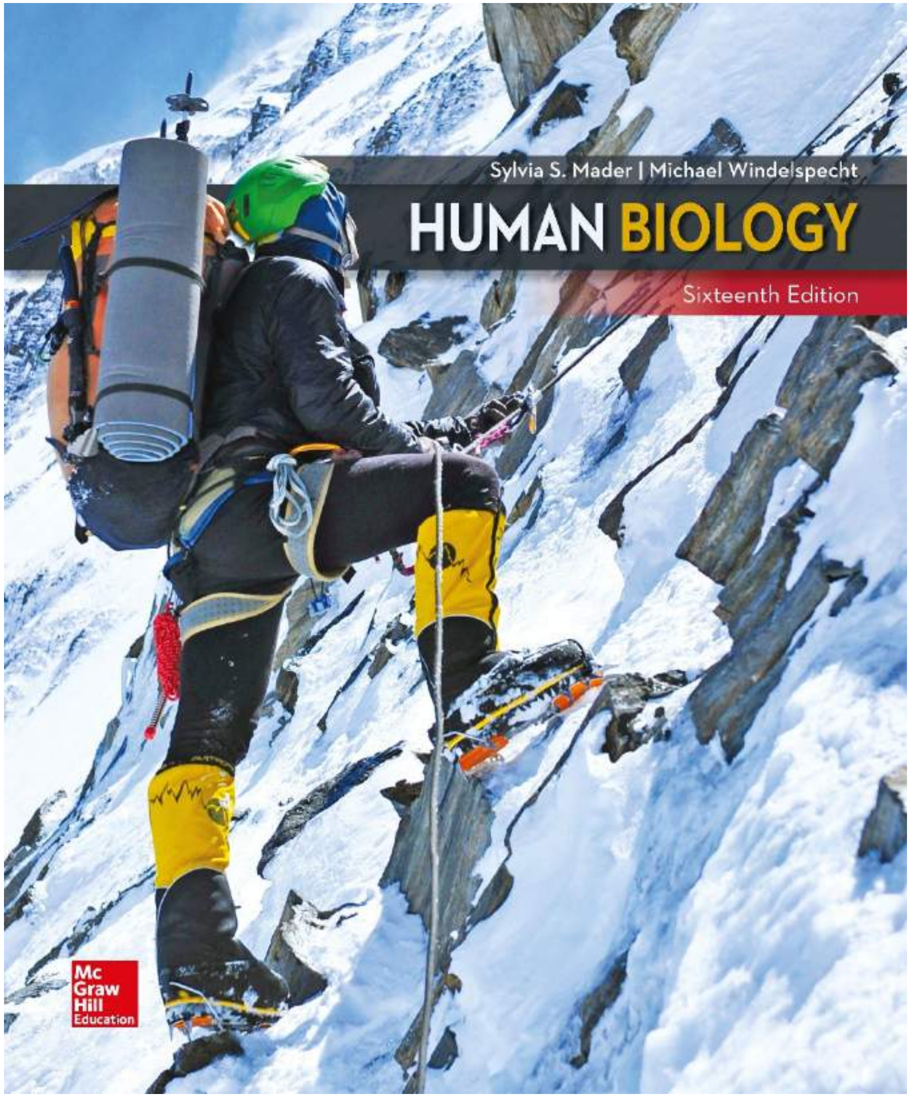


Sylvia S. Mader
Michael Windelspecht

Laboratory 2 Microscope and Cell Structure & Function

Cell Structure and Function: What Is a Cell

Learning Outcomes:

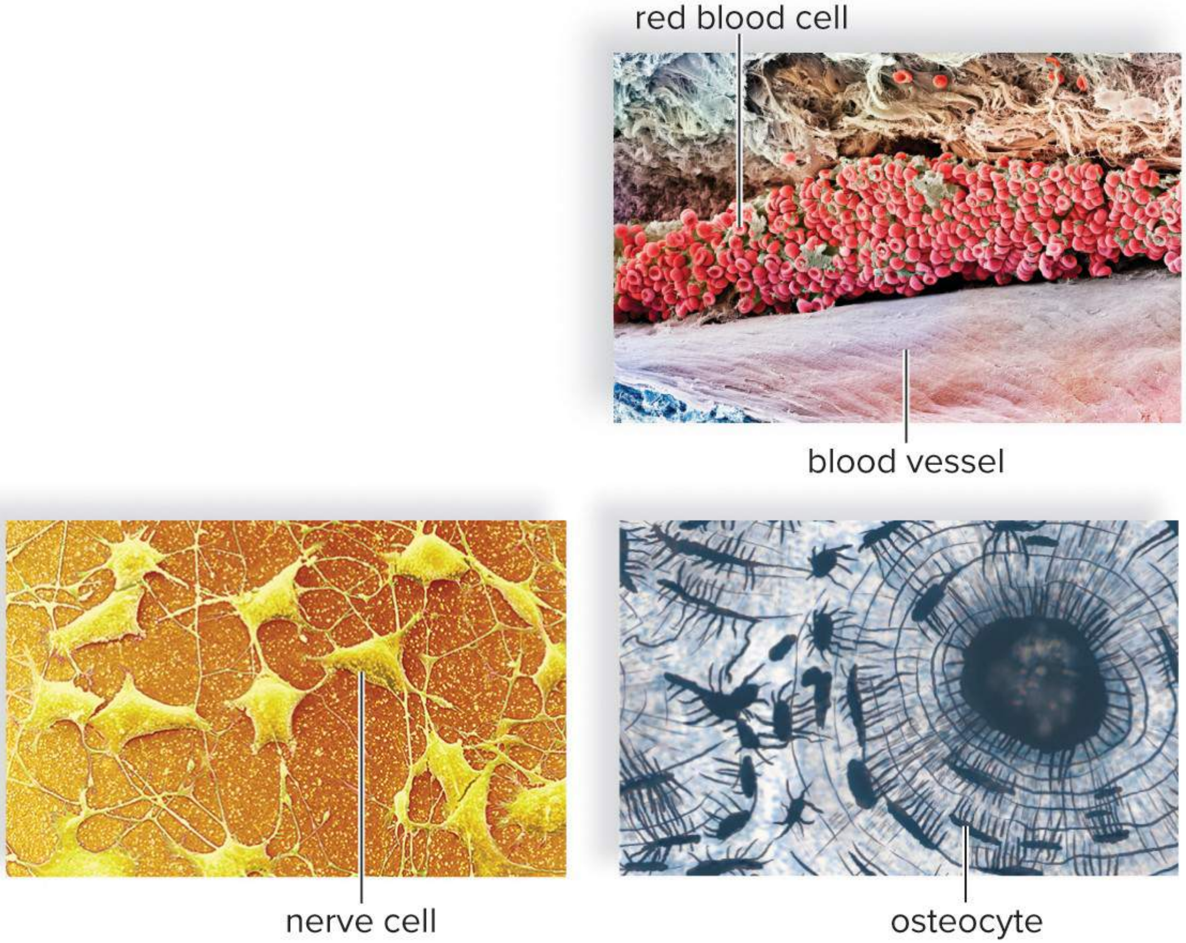
- State the basic principles of the cell theory.
- Explain how the surface-area-to-volume ratio limits cell size.
- Summarize the role of microscopy in the study of cells.

The Cell Theory

The **cell theory.**

- **Cell**—the basic unit of life.
- All living things are made up of cells.
- New cells arise only from preexisting cells.

Cells Vary in Structure and Function (Figure 3.1)



(blood cells): ©Steve Gschmeissner/ Science Photo

Cell Size

Cells are small because of their **surface-area-to-volume ratio.**

- Smaller cells have a larger amount of surface area compared to the volume.
- An increase in surface area allows for more nutrients to pass into the cell and more wastes to exit the cell.
- There is a limit to how large a cell can be while remaining efficient and metabolically active.

Microscopy [1]

Resolution of the image varies among different types of microscopes.

Compound light microscope.

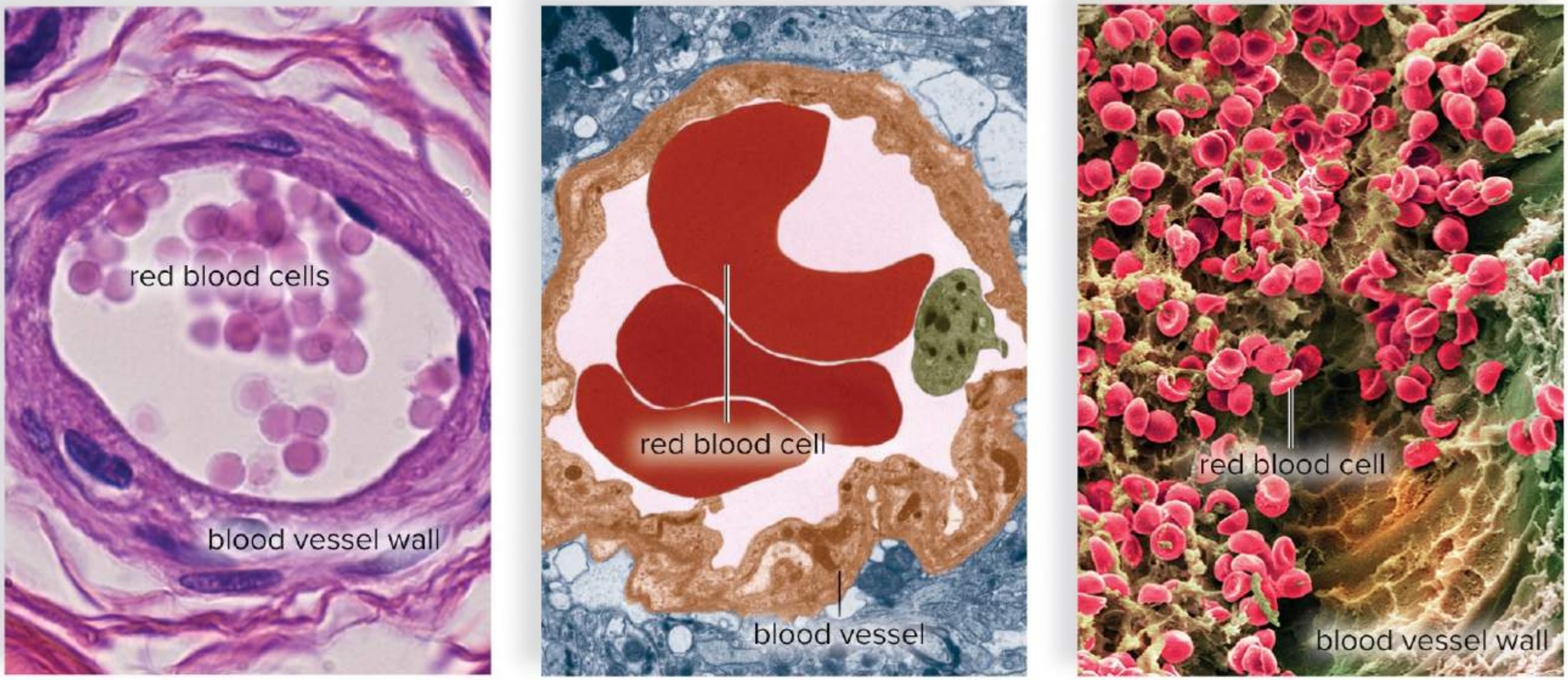
- Lower magnification than other microscopes.
- Uses glass lenses and light beams to view images.
- Can view live specimens.

Resolving Power of the Eye and Common Microscopes (Table 3.1)

Table 3.1 Resolving Power of the Eye and Common Microscopes

	Magnification	Resolving Power
Eye	N/A	0.1 mm (100 µm)
Light microscope	1.000×	0.0001 mm (0.1 µm)
Transmission electron microscope	100,000× (or greater)	0.000001 mm (0.01 µm)

Micrographs of Human Red Blood Cells (Figure 3.3)



a. Light micrograph 250×

b. Transmission electron micrograph 4,000×

c. Scanning electron micrograph

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Microscopy 2

Transmission electron microscope.

- 2-D image.
- Uses a stream of electrons to view magnified images.
- The human eye cannot see the image; it must be projected onto a screen.
- High magnification, no live specimens.

Microscopy 3

Scanning electron microscope.

- 3-D image.
- Uses a beam of electrons to view surface structures of specimens.
- High magnification, no live specimens.

Check Your Progress 3.1

Summarize the cell theory, and state its importance to the study of biology.

Explain how a cell’s size relates to its function.

Compare and contrast the information that may be obtained from a light microscope and an electron microscope.

How Cells Are Organized 1

Learning Outcomes:

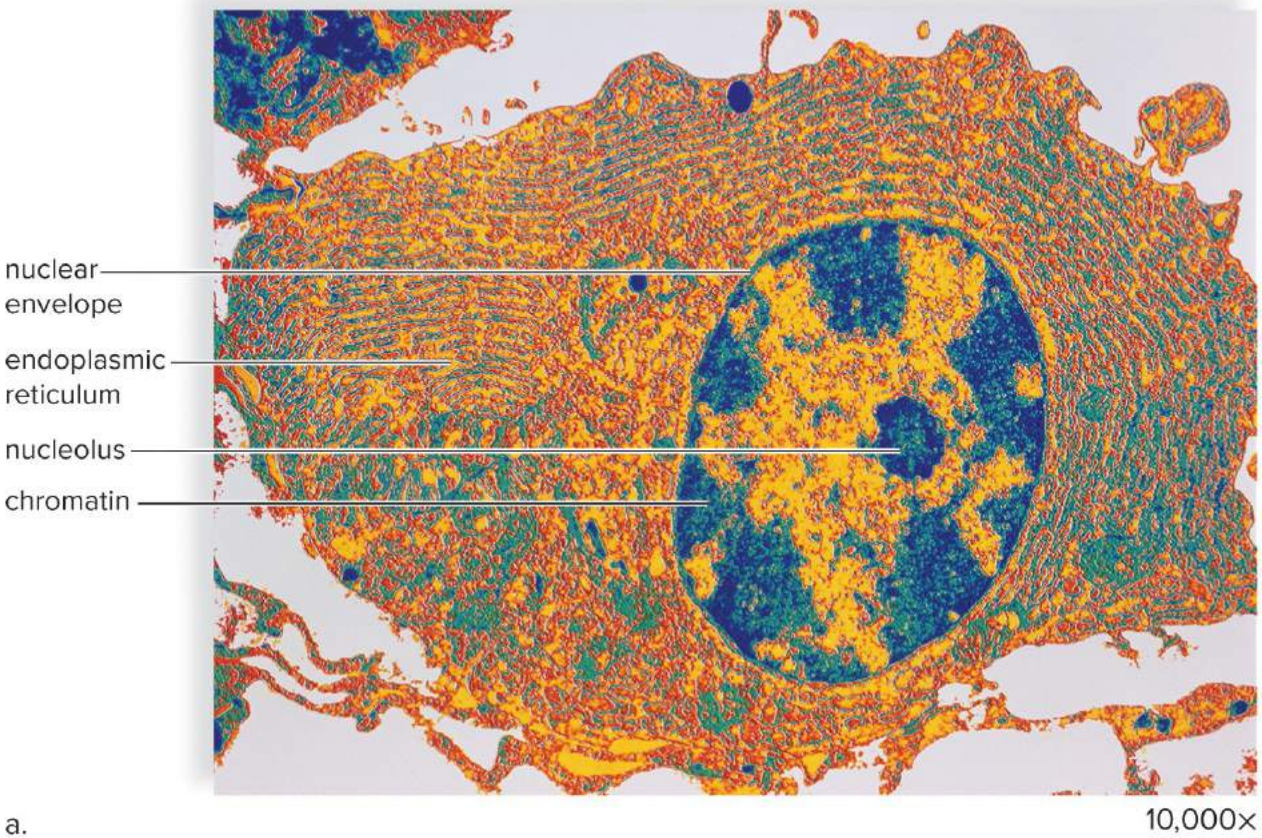
- Distinguish between the structure of a prokaryotic cell and that of a eukaryotic cell.
- Identify the roles of the plasma membrane and the organelles of a cell.
- Summarize how eukaryotic cells evolved from prokaryotic cells.

How Cells Are Organized 2

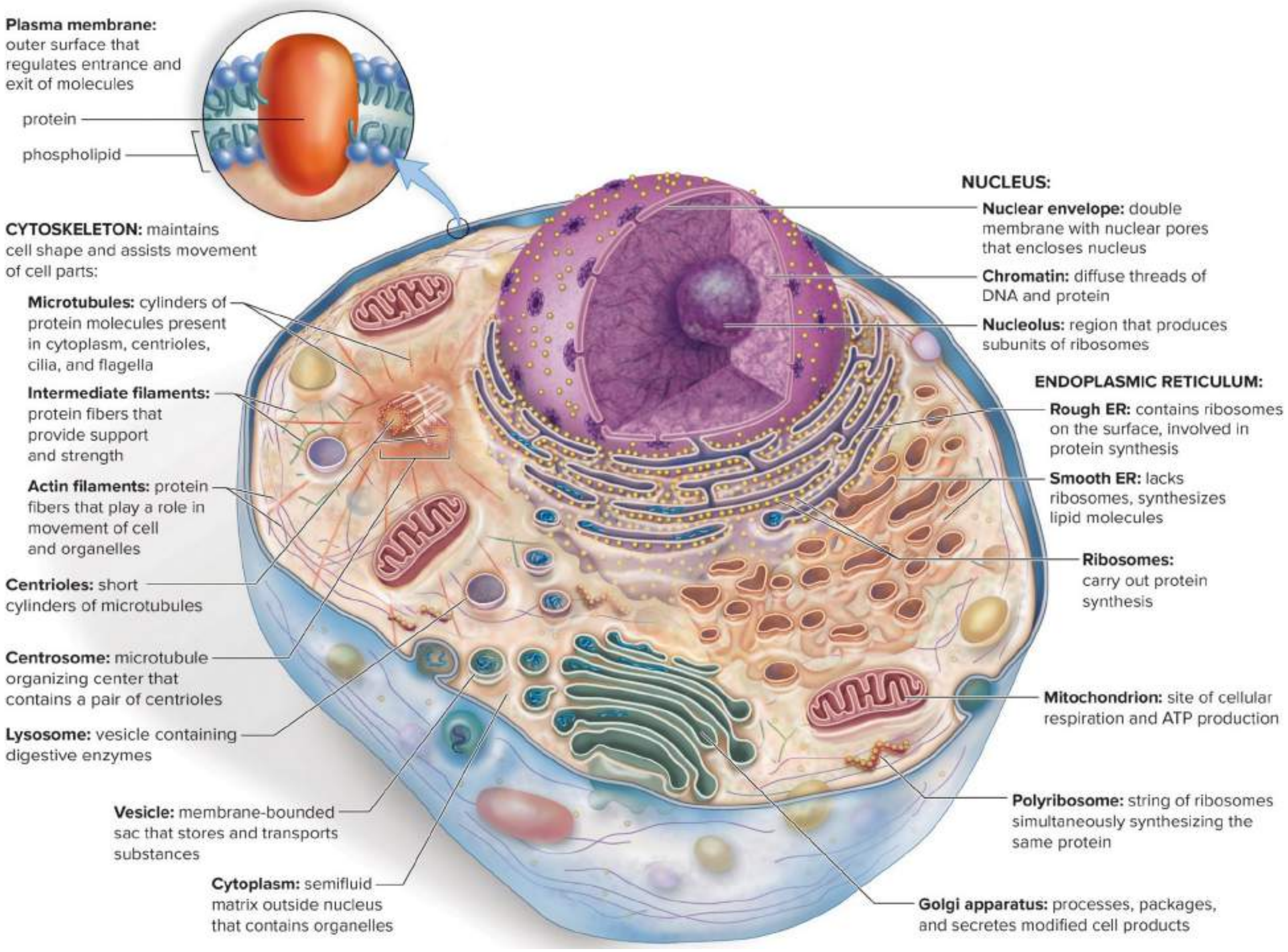
Cells are classified into two categories: prokaryotes and eukaryotes.

- **Prokaryotic cells (prokaryotes).**
  - Lack a nucleus.
  - Include two groups of bacteria: eubacteria and archaebacterial.
- **Eukaryotic cells (eukaryotes).**
  - Have a nucleus.
  - Include animals, plants, fungi, protists.

The Structure of a Typical Eukaryotic Cell (Figure 3.4a)



The Structure of a Typical Eukaryotic Cell (Figure 3.4b)



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How Cells are Organized 3

Both types of cells have:

- A **plasma membrane.**
  - Surrounds the cell.
  - Made of a phospholipid bilayer that is **selectively permeable** (regulates what enters and leaves the cell).
- A **cytoplasm**: the semifluid substance inside the cell.
  - Includes **organelles** (internal compartments with specialized functions).

Evolutionary History of the Eukaryotic Cell

The first cells on Earth were prokaryotes (archaeans).

- The atmosphere had no oxygen.
- Some archaeans still survive in very inhospitable conditions.
  - That is in thermal vents.
- Eukaryotic cells evolved from archaea.
  - **Endosymbiosis**—organelles may have developed from eukaryotes engulfing prokaryotic cells.

The Nucleus and Endomembrane System 1

Learning Outcomes:

- Describe the structure of the nucleus and explain its role as the storage place of genetic information.
- Summarize the functions of the organelles of the endomembrane system.
- Explain the role and location of the ribosomes.

The Nucleus and Endomembrane System 2

The **nucleus** contains the genetic instructions for manufacturing the proteins that are involved in most cellular functions.

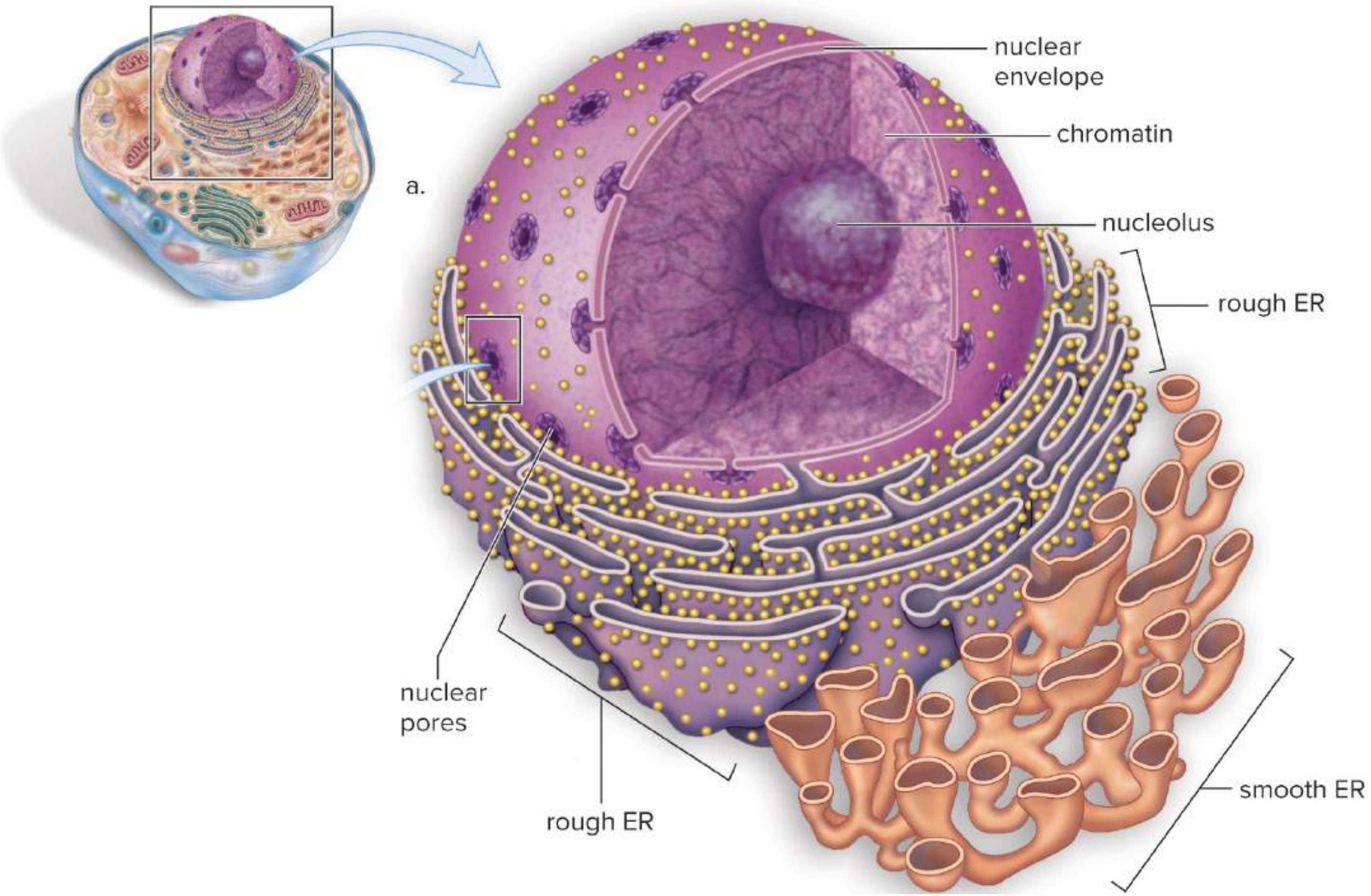
The **endomembrane system** is a series of membranous organelles that function to process materials for the cell.

The Nucleus [1]

The nucleus.

- Contains DNA in the form of **chromatin** most of the time, and **chromosomes** when the cell is dividing.
  - DNA is made up of **genes**, which contain instructions for the production of proteins.
- **Nucleoplasm**—the fluid inside the nucleus.
- **Nucleolus**—dark region inside the nucleus.
  - Produces ribosomes.

The Nucleus and Endoplasmic Reticulum (Figure 3.13a)



The Nucleus 2

The nucleus, continued.

- **Nuclear envelope**—a double membrane around the nucleus.
- **Nuclear pores**—holes in the nuclear envelope; allow passage of substances in and out of the nucleus.

Ribosomes

Ribosomes.

- Made of rRNA and protein.
- Sites of protein synthesis.
- Found attached to the endoplasmic reticulum or free-floating in the cytoplasm.
  - When free-floating, occur singly or in groups called **polyribosomes.**
  - Proteins synthesized at ribosomes attached to the endoplasmic reticulum have a different destination from those made at free-floating ribosomes.

The Endomembrane System 1

The **endomembrane system.**

- Consists of the **nuclear envelope, endoplasmic reticulum, Golgi apparatus, lysosomes,** and **vesicles.**
- Functions to compartmentalize the cell and transport substances throughout the cell.

The Endomembrane System 2

Rough endoplasmic reticulum (RER)—studded with ribosomes used to make proteins.

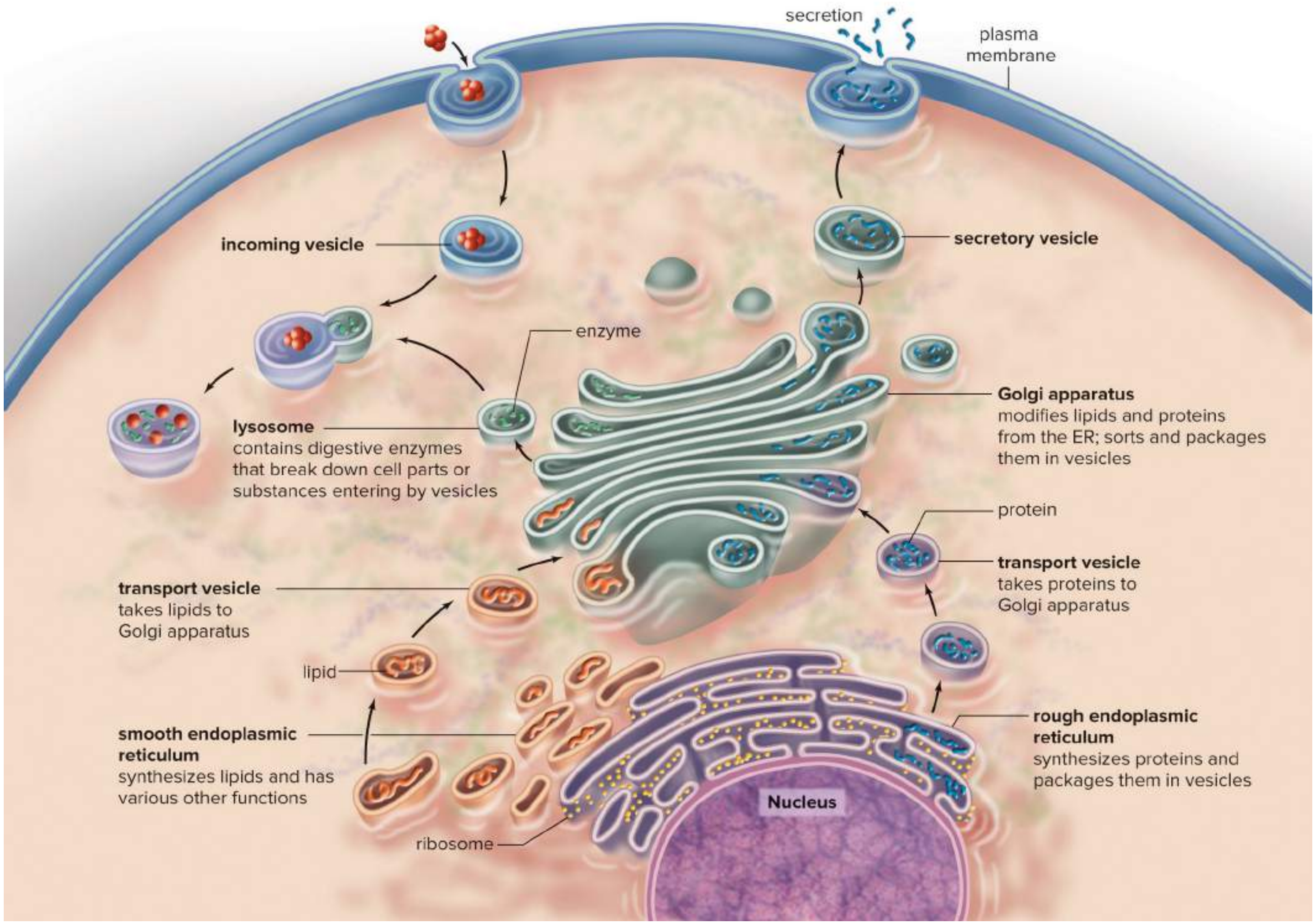
Smooth endoplasmic reticulum (SER)—lacks ribosomes; synthesizes lipids.

- Has different functions in various cell types.

Golgi apparatus—flattened sacs; modify proteins and lipids.

- Involved in processing, packaging, and secretion.

The Endomembrane System (Figure 3.14)



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The Endomembrane System 3

Vesicles—small membranous sacs used for transport.

Lysosomes—vesicles made by the Golgi that contain **hydrolytic enzymes**, which break down molecules into smaller parts.

- Prevalent in white blood cells that engulf disease-causing microbes.

Check Your Progress 3.4

Describe the functions of the following organelles: endoplasmic reticulum, Golgi apparatus, and lysosomes.

Explain how the nucleus, ribosomes, and rough endoplasmic reticulum contribute to protein synthesis.

Describe the organelles of the endomembrane system involved in the export of a protein from the cell.

The Cytoskeleton, Cell Movement, and Cell Junctions

Learning Outcomes:

- Explain the role of the cytoskeleton in the cell.
- Summarize the major protein fibers in the cytoskeleton.
- Describe the role of flagella and cilia in human cells.
- Compare the functions of adhesion junctions, gap junctions, and tight junctions in human cells.

The Cytoskeleton 1

The **cytoskeleton.**

- Protein fibers that maintain cell shape, anchor and/or move organelles in the cell.
- Made of 3 types of fibers: **microtubules**, which are the largest; middle-sized **intermediate filaments**; and thin **actin filaments**.

The Cytoskeleton 2

The **cytoskeleton**, continued.

- Microtubules.
  - Microtubule assembly is controlled by the **centrosome.**
  - Help maintain cell shape.
  - Act as tracks along which organelles move.
  - During cell division, form the spindle apparatus, which helps move chromosomes.

The Cytoskeleton 3

The **cytoskeleton**, concluded.

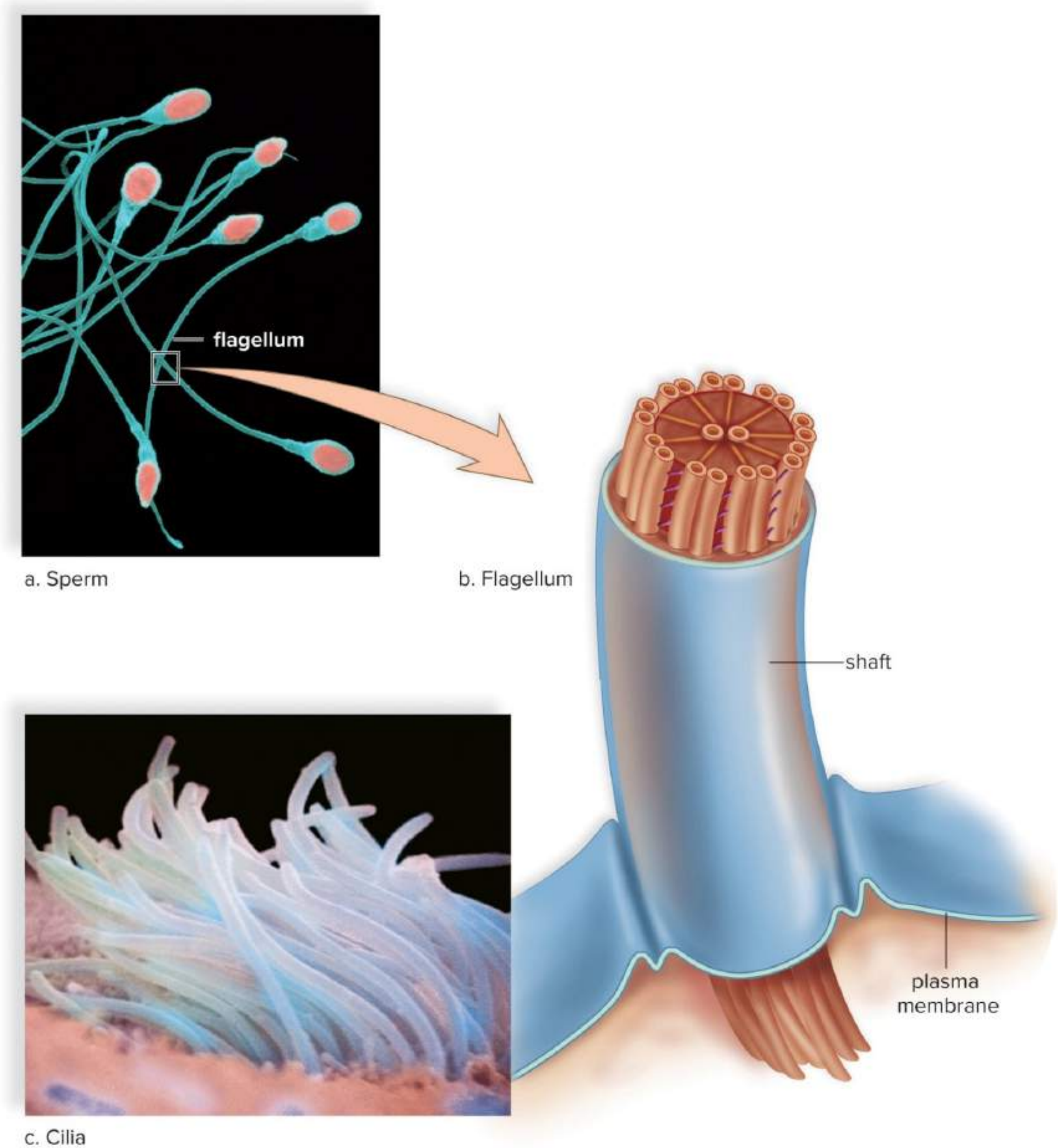
- Actin filaments.
  - Made of the protein **actin.**
  - Long and very thin.
  - Involved in movement.
- Intermediate filaments.
  - Sized in-between actin filaments and microtubules.
  - Functions vary.

Cilia and Flagella

Cilia (*singular*, cilium) and **flagella** (*singular*, flagellum).

- Both are made of microtubules.
- Both are used in movement.
  - That is, cilia in the respiratory tract move mucus toward the throat.
  - That is, flagella on sperm propel them toward the egg.

Structure and Function of the Flagella and Cilia (Figure 3.15)



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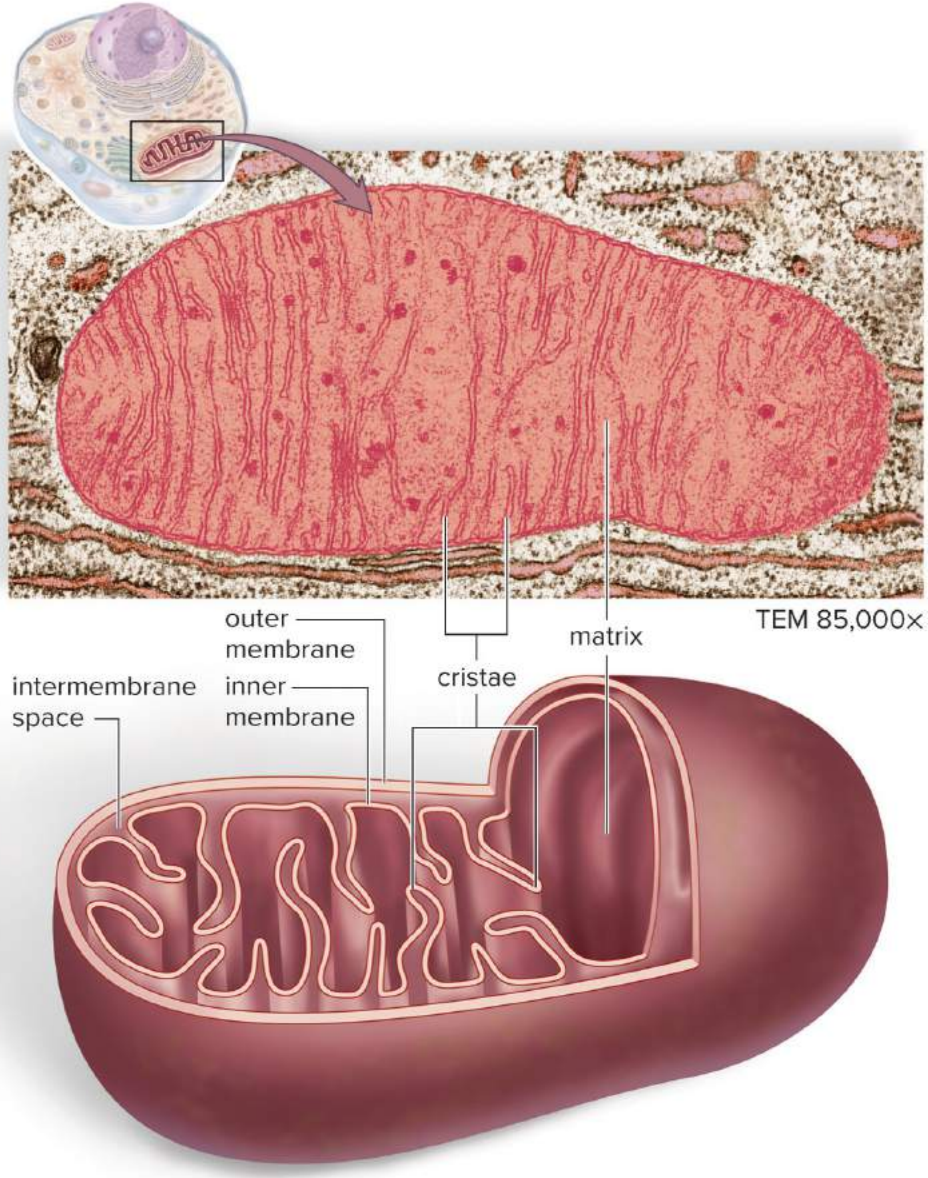
Extracellular Matrix

Extracellular matrix.

- A protective mesh of proteins and polysaccharides.
- Surrounds the cell that produces it.
- Contains **collagen**, which resists stretching, and **elastin**, which provides resilience.
- **Fibronectin**—an adhesive protein that binds to **integrin**, an integral membrane protein that is connected to the cytoskeleton.
    - Plays a role in cell signaling.

The Structure of a Mitochondrion (Figure 3.20)



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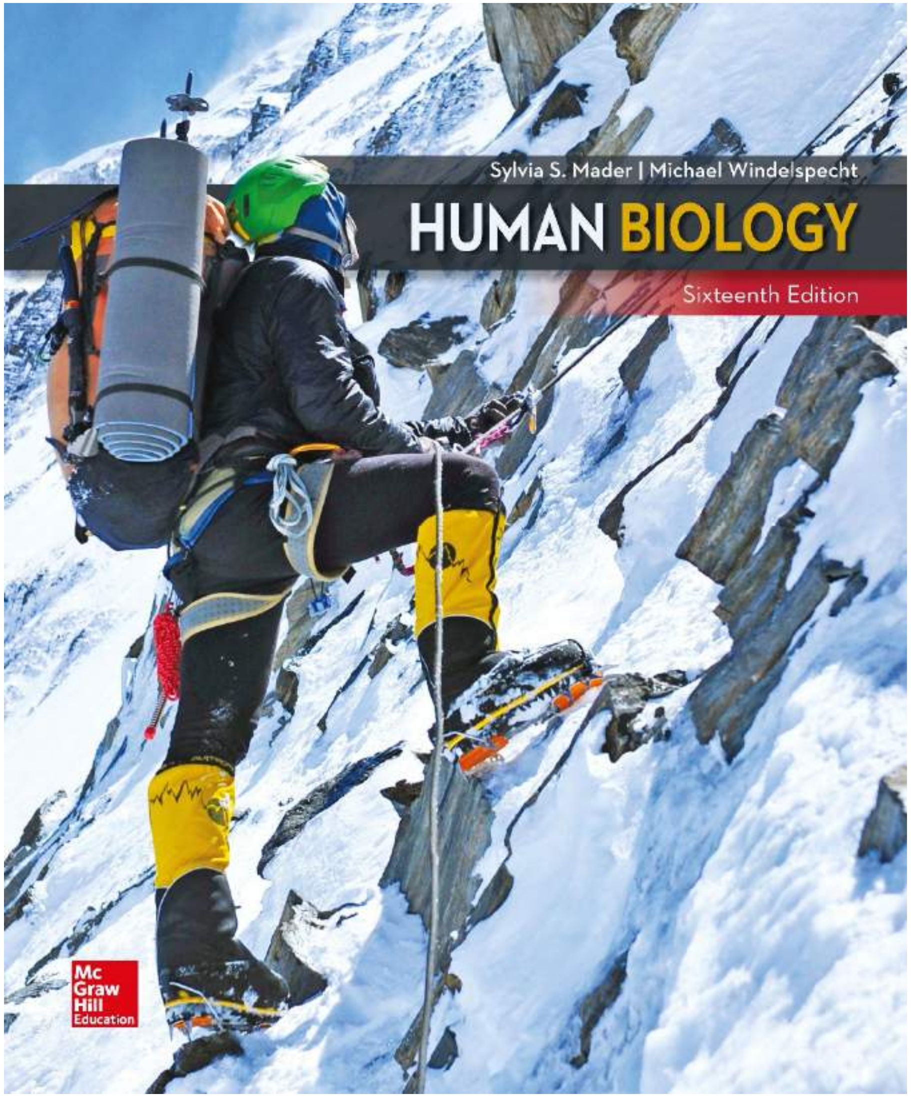

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Laboratory 3

Molecular Movement, Cell Membrane & Transport

The Plasma Membrane and How Substances Cross It

Learning Outcomes:

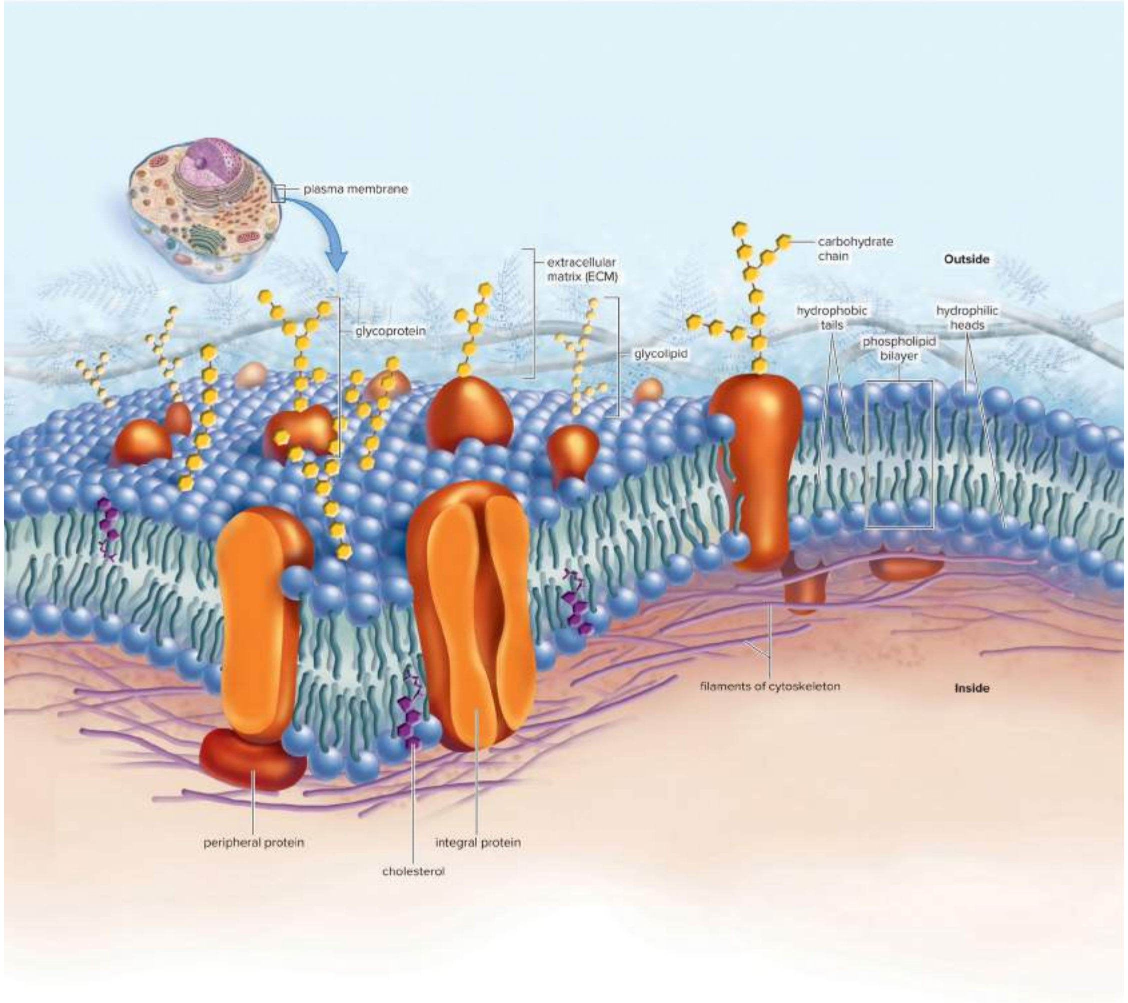
- Describe the structure of the plasma membrane and list the type of molecules found in the membrane.
- Distinguish between the processes of diffusion, osmosis, and facilitated transport.
- Explain how tonicity relates to the direction of water movement across a membrane.
- Compare passive-transport and active-transport mechanisms.
- Summarize how eukaryotic cells move large molecules across membranes.

The Plasma Membrane 1

Plasma membrane.

- Phospholipid bilayer with proteins that are attached and embedded.
  - When phospholipids are placed in water, they naturally form a spherical bilayer.
  - Hydrophilic heads face the cytoplasm and extracellular fluid.
  - Hydrophobic tails face inward.

Organization of the Plasma Membrane (Figure 3.6)



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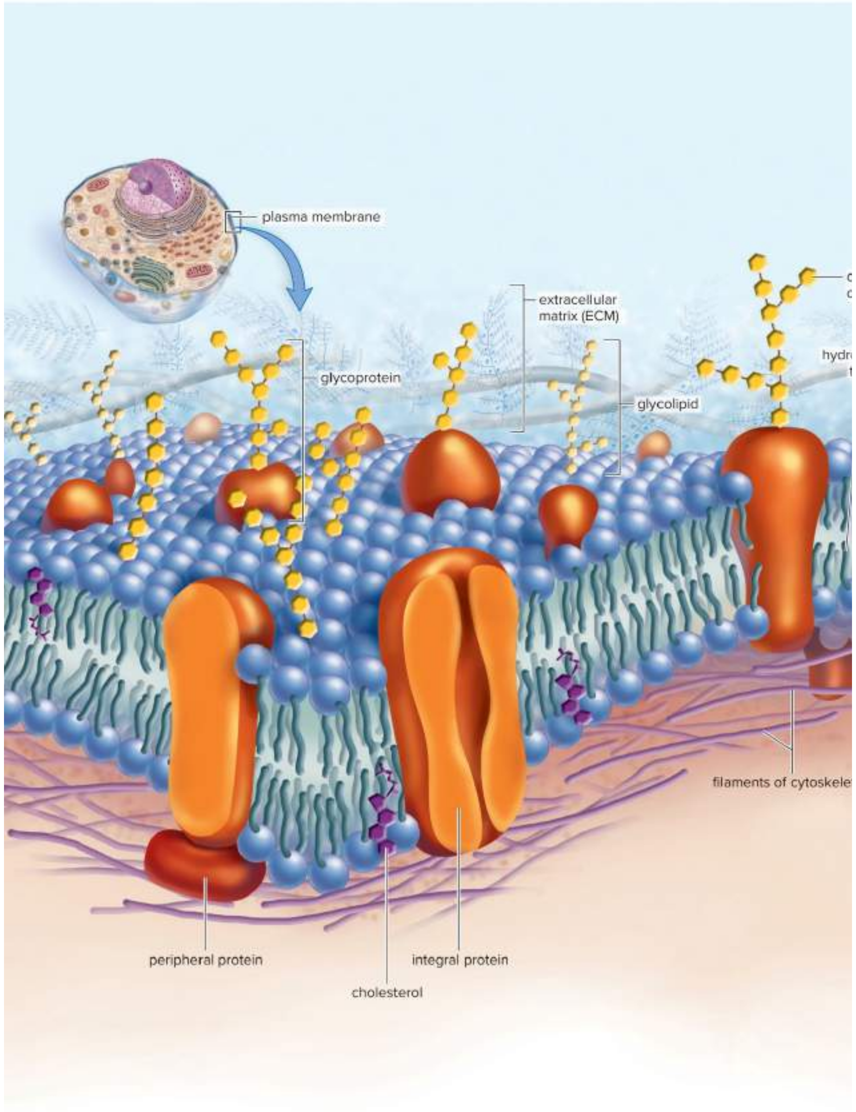
The Plasma Membrane



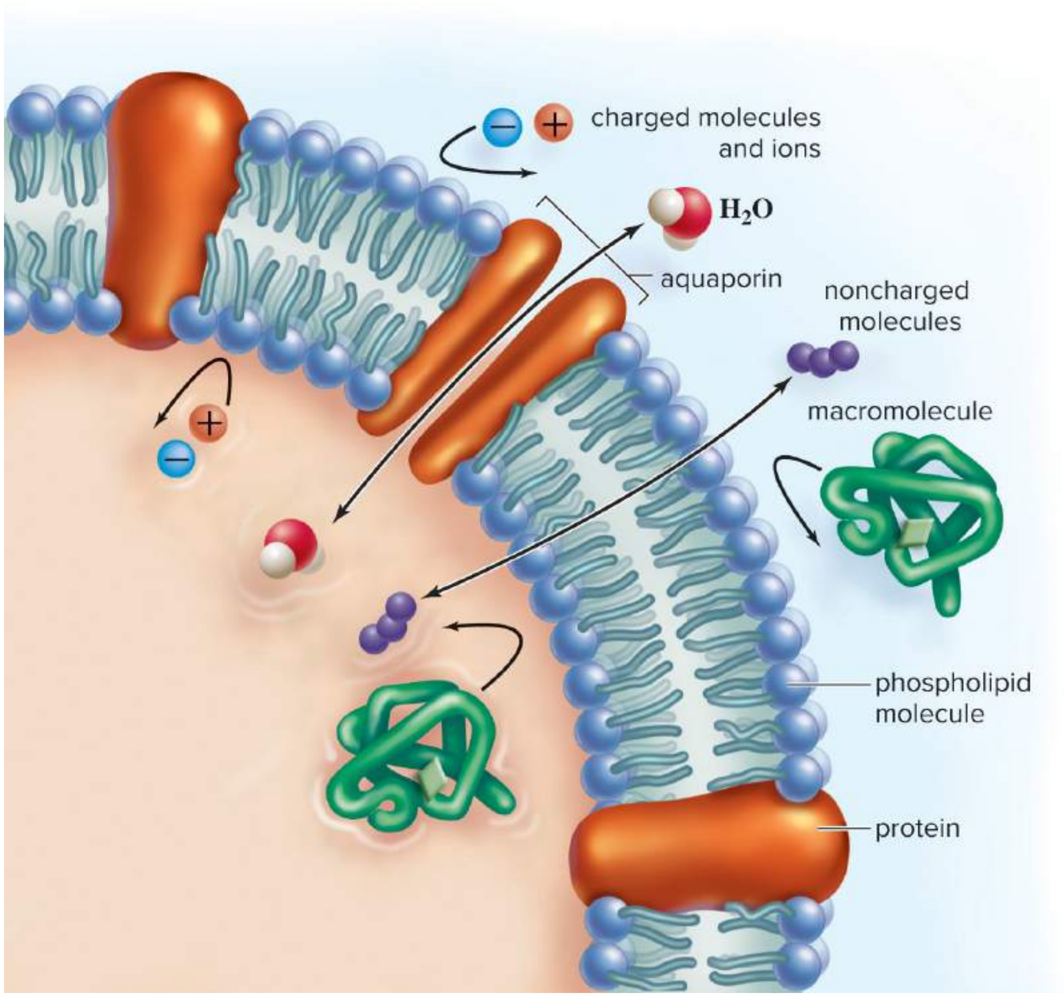
- **Fluid-mosaic model.**
  - Proteins move like "ships" through phospholipid "sea"
- Contains cholesterol for support.
- **Glyco**proteins & **Glyco**lipids

The Plasma Membrane 3

Plasma membrane, concluded.

- Some membrane proteins act as channels.
  - selective
- Small, hydrophobic substances pass freely through the phospholipid bilayer.
  - Ex: oxygen and carbon dioxide.
- Ions and large molecules need help passing through.
  - Ex: Water can cross the membrane by passing through channels called **aquaporins.**

Selective Permeability of the Plasma Membrane (Figure 3.7)



Ways Substances Cross the Plasma Membrane [1]

Diffusion.

Osmosis.

Facilitated diffusion.

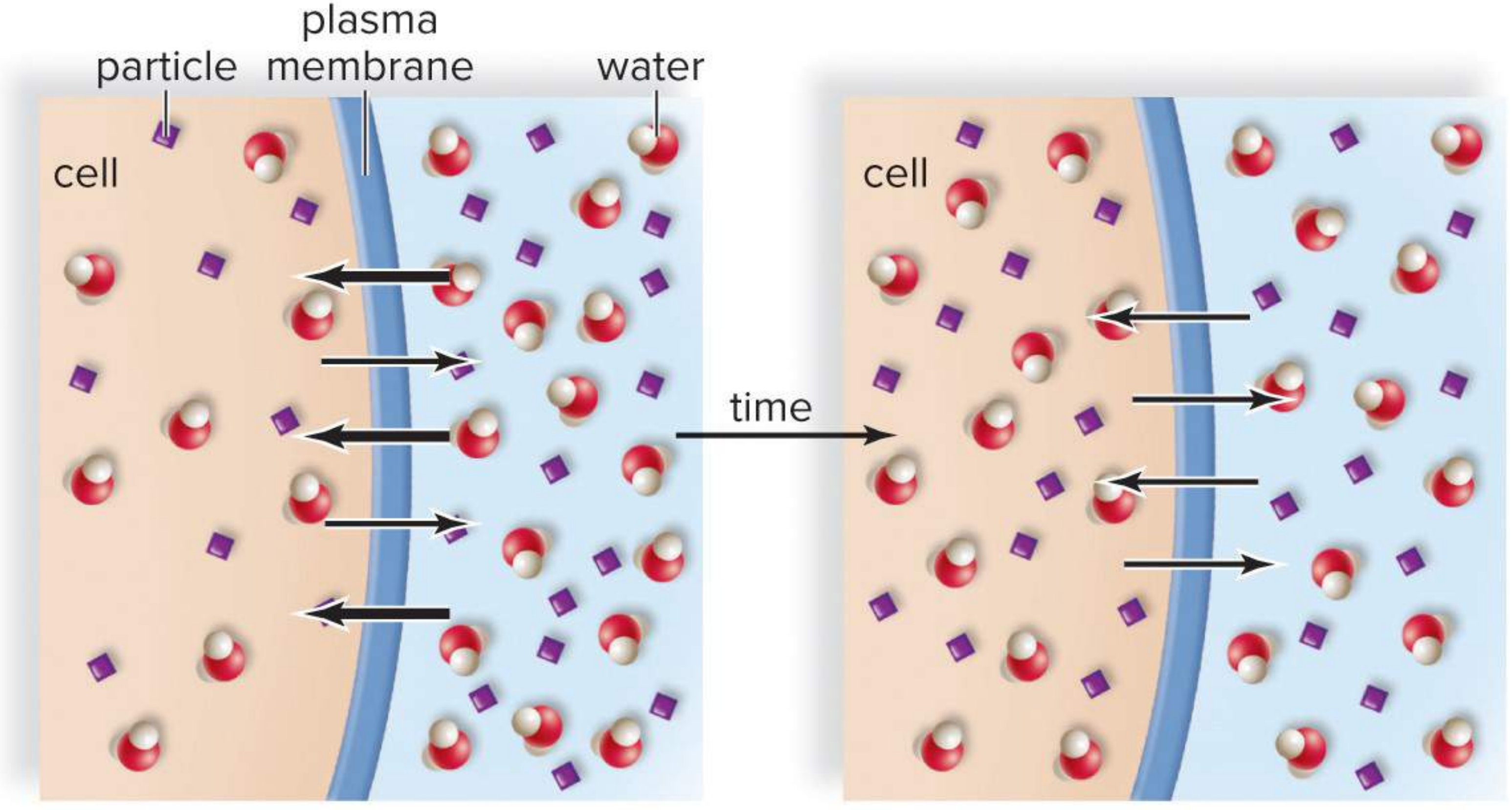
Active transport.

Endocytosis and exocytosis.

Diffusion—the random movement of molecules from a higher concentration to a lower concentration.

- Until they are equally distributed.
- **Passive movement**; no energy is required.
- Molecules move in both directions, but the **net movement** is from high to low concentration.
    - At **equilibrium**, the same number of molecules move in and out of the cell.

Diffusion Across the Plasma Membrane (Figure 3.8)



a. Initial conditions

b. Equilibrium conditions

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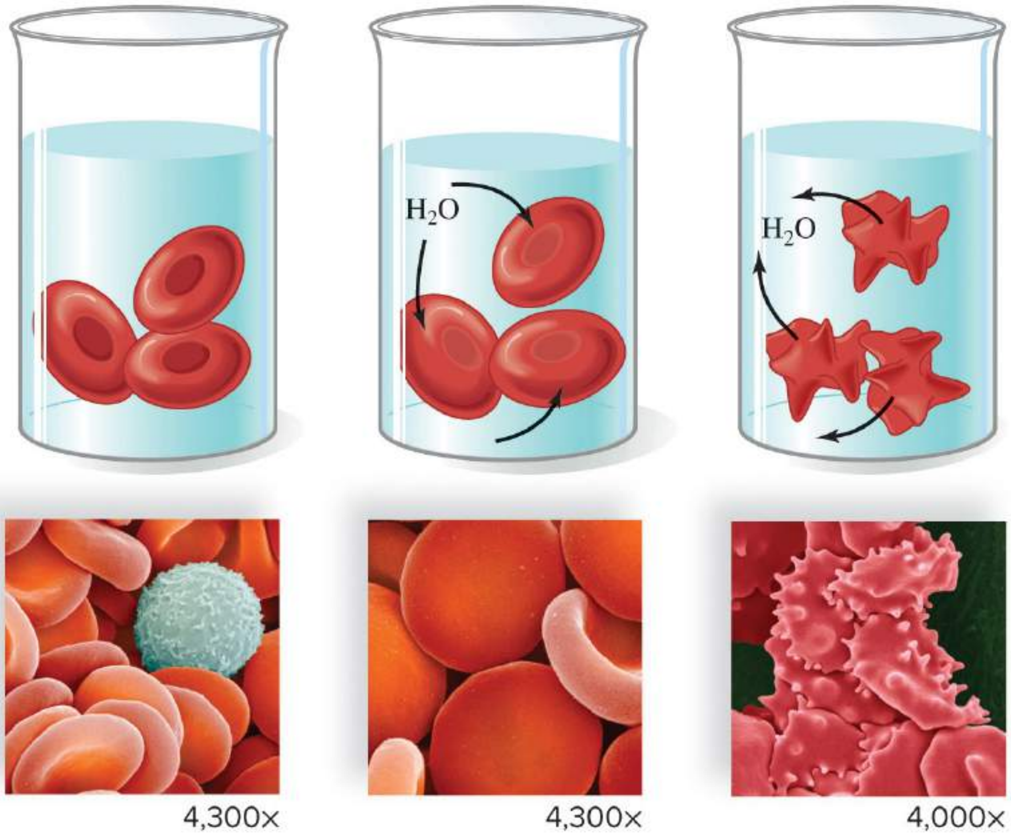
Osmosis

Osmosis—the diffusion of water molecules; from high to low *water* concentration.

- Normally body fluids are **isotonic** to cells.
  - The same concentration of impermeable solutes.
  - Cells do not change in size.
- **Hypotonic** solutions have fewer solutes.
  - Cells swell and can burst (**lysis**).
- **Hypertonic** solutions have more solutes.
  - Cells shrink (**crenation**).
- **Osmotic pressure** drives osmosis.

Effects of Changes in Tonicity on Red Blood Cells (Figure 3.9)



a. Isotonic solution (same solute concentration as in cell)

b. Hypotonic solution (lower solute concentration than in cell)

c. Hypertonic solution (higher solute concentration than in cell)

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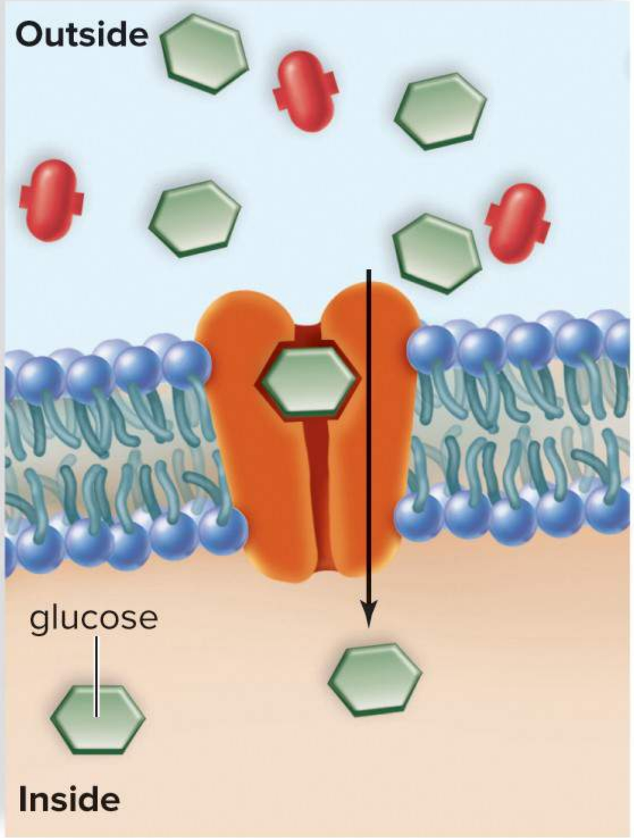
Facilitated Transport

Facilitated transport.

- The transport of molecules across the plasma membrane from higher concentration to lower concentration via a protein carrier.
- **Passive transport** (no energy required).
- Protein transporters are very specific and only move certain molecules.

Facilitated Transport Across a Plasma Membrane (Figure 3.10)



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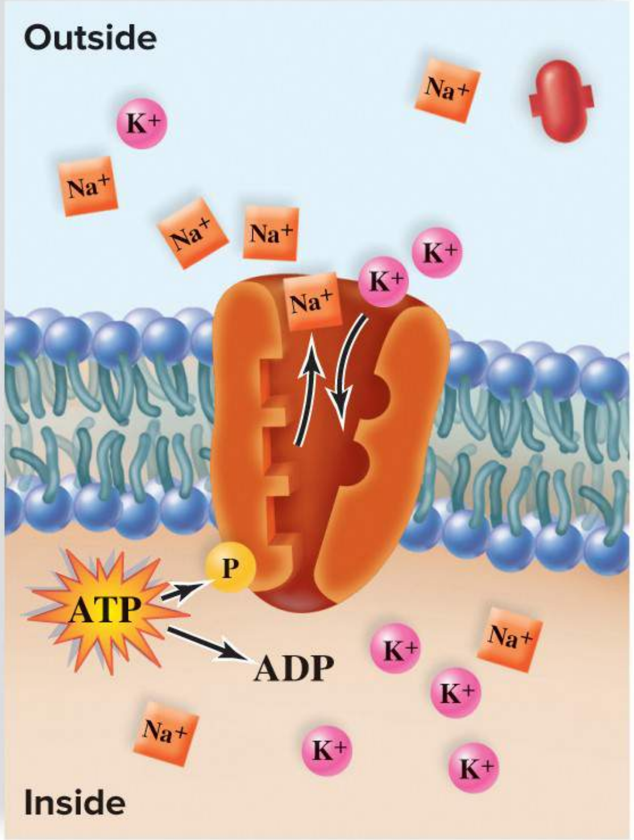
Active Transport

Active transport—the movement of molecules from a *lower* to *higher* concentration.

- Uses ATP as energy.
- Requires a protein carrier, which is often called a **pump.**

Active Transport and the Sodium-Potassium Pump (Figure 3.11)



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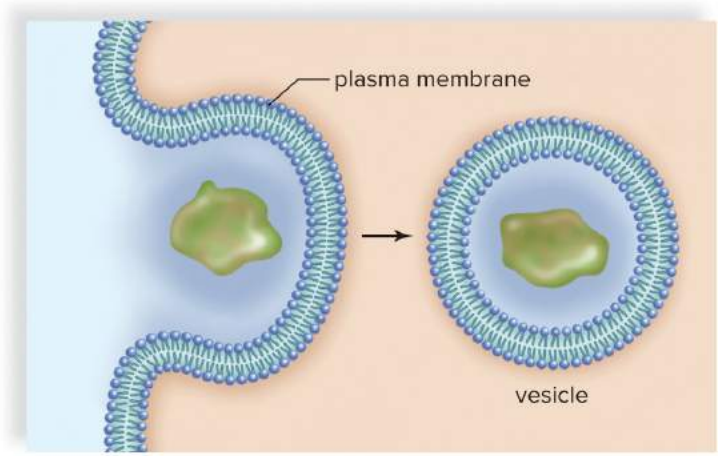
Bulk Transport [1]

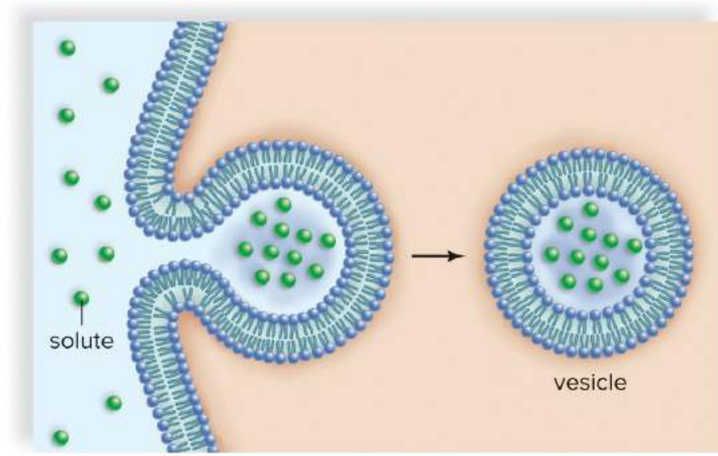
Cells use bulk transport to move large molecules across the membrane.

- **Endocytosis** transports molecules or cells into the cell via invagination of the plasma membrane to form a vesicle.
  - **Phagocytosis**—endocytosis of pathogens (that is, bacteria) by white blood cells.
  - **Pinocytosis**—endocytosis of fluid with small particles.

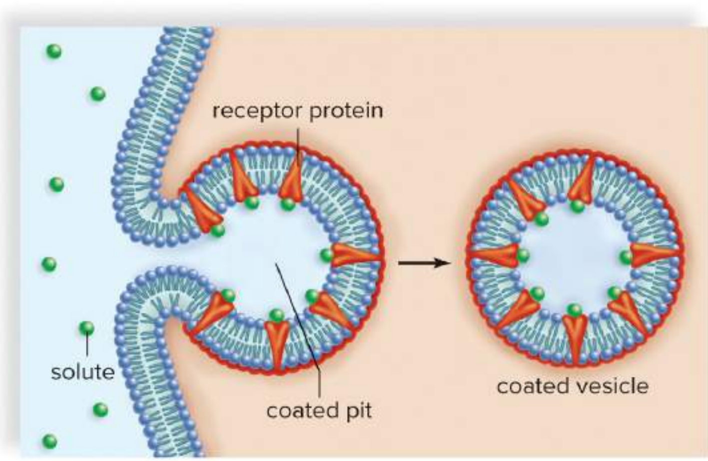
Examples of Bulk Transport (Figure 3.12)



a. Phagocytosis



b. Pinocytosis



c. Receptor-mediated endocytosis

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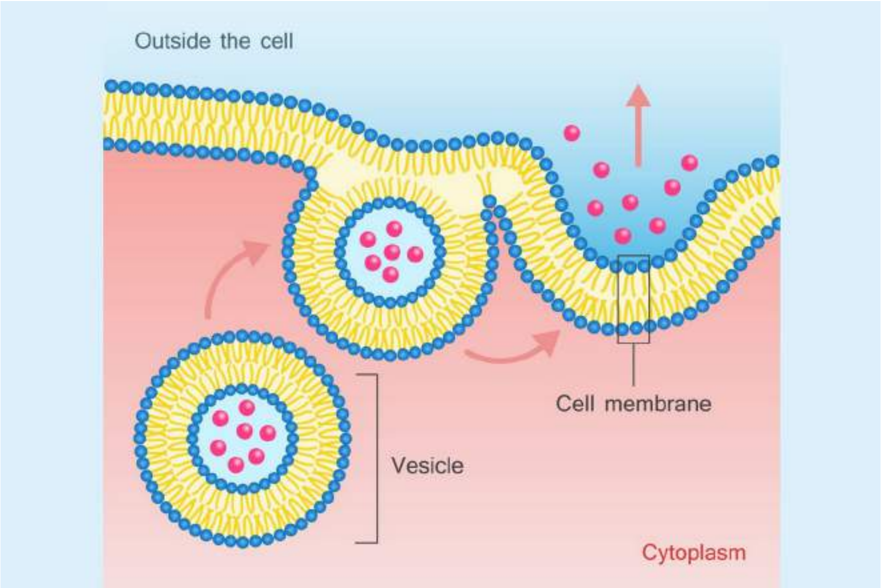
Bulk Transport 2

Bulk transport, continued.

- **Exocytosis** transports molecules outside the cell via the fusion of a vesicle with the plasma membrane.
  - Sort of like reverse endocytosis.



The Nucleus and Endomembrane System 1

Learning Outcomes:

- Describe the structure of the nucleus and explain its role as the storage place of genetic information.
- Summarize the functions of the organelles of the endomembrane system.
- Explain the role and location of the ribosomes.

The Nucleus and Endomembrane System 2

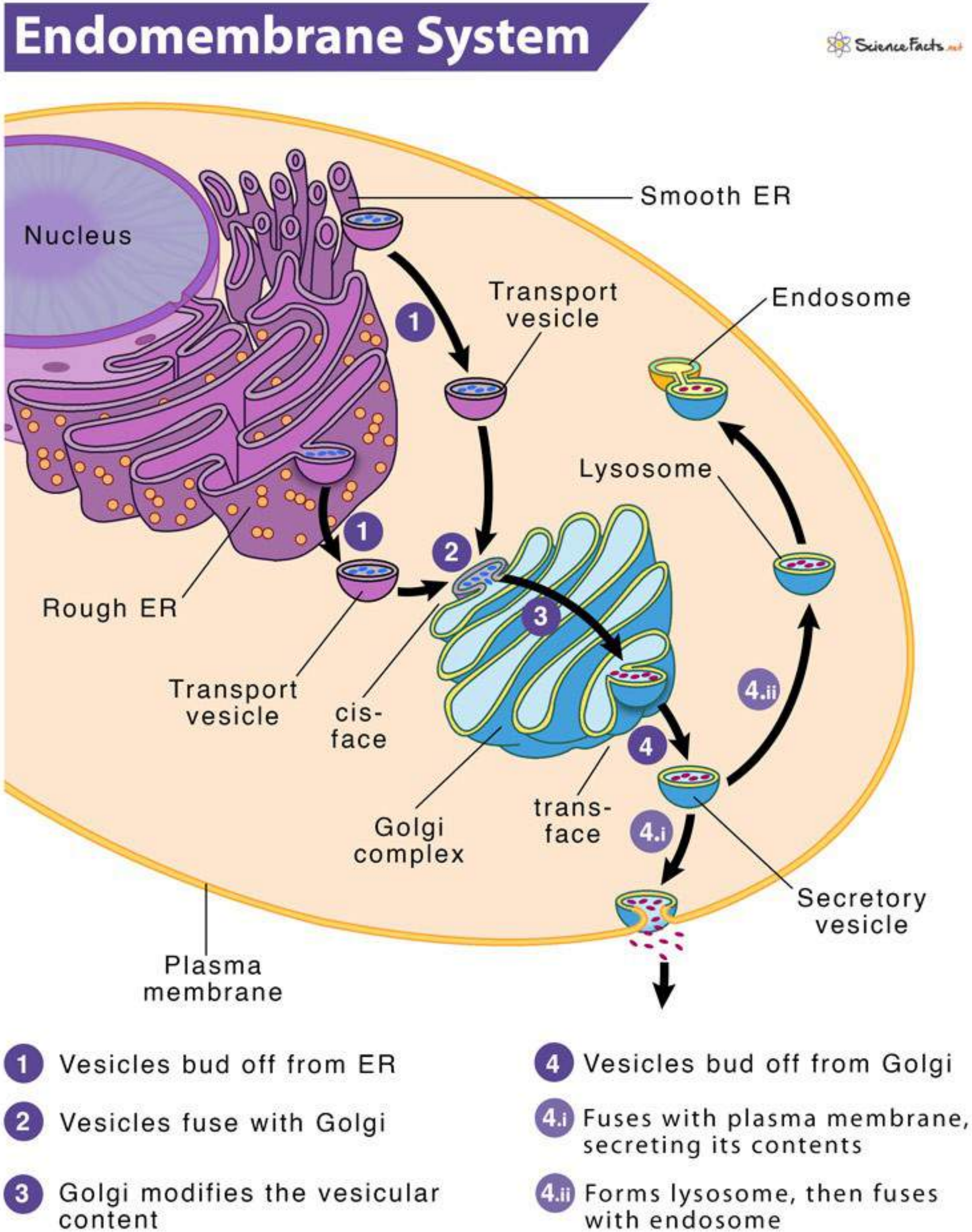
The **nucleus** contains the genetic instructions for manufacturing the proteins that are involved in most cellular functions.

The **endomembrane system** is a series of membranous organelles that function to process materials for the cell.

The Nucleus 1

The nucleus.

- Contains DNA in the form of **chromatin** most of the time, and **chromosomes** when the cell is dividing.
  - DNA is made up of **genes**, which contain instructions for the production of proteins.
- **Nucleoplasm**—the fluid inside the nucleus.
- **Nucleolus**—dark region inside the nucleus.
  - Produces ribosomes.


Endomembrane System
ScienceFacts.net
Smooth ER
Nucleus
Transport vesicle
Endosome
Lysosome
Rough ER
Transport vesicle
cis-face
Golgi complex
trans-face
Secretory vesicle
Plasma membrane
1 Vesicles bud off from ER
2 Vesicles fuse with Golgi
3 Golgi modifies the vesicular content
4 Vesicles bud off from Golgi
4.i Fuses with plasma membrane, secreting its contents
4.ii Forms lysosome, then fuses with endosome

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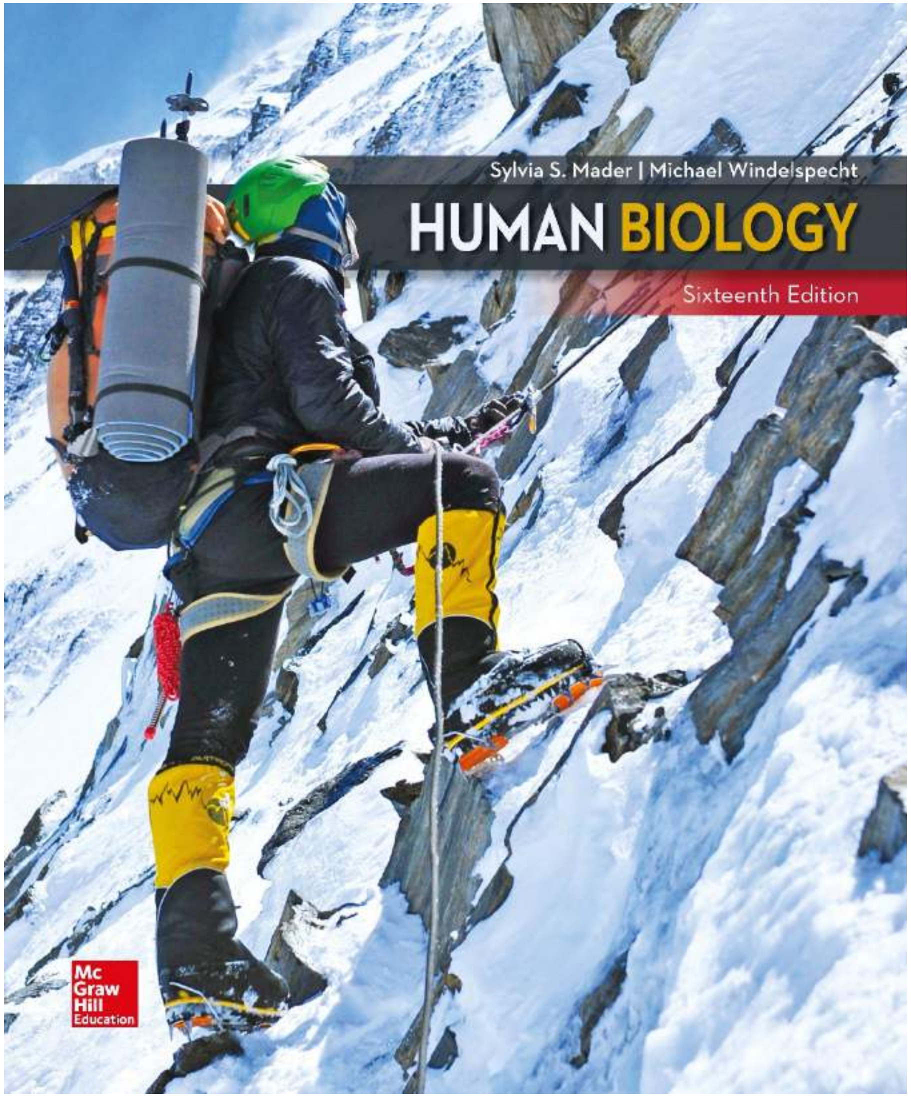


Sylvia S. Mader

Michael Windelspecht

Laboratory 4
Enzymes

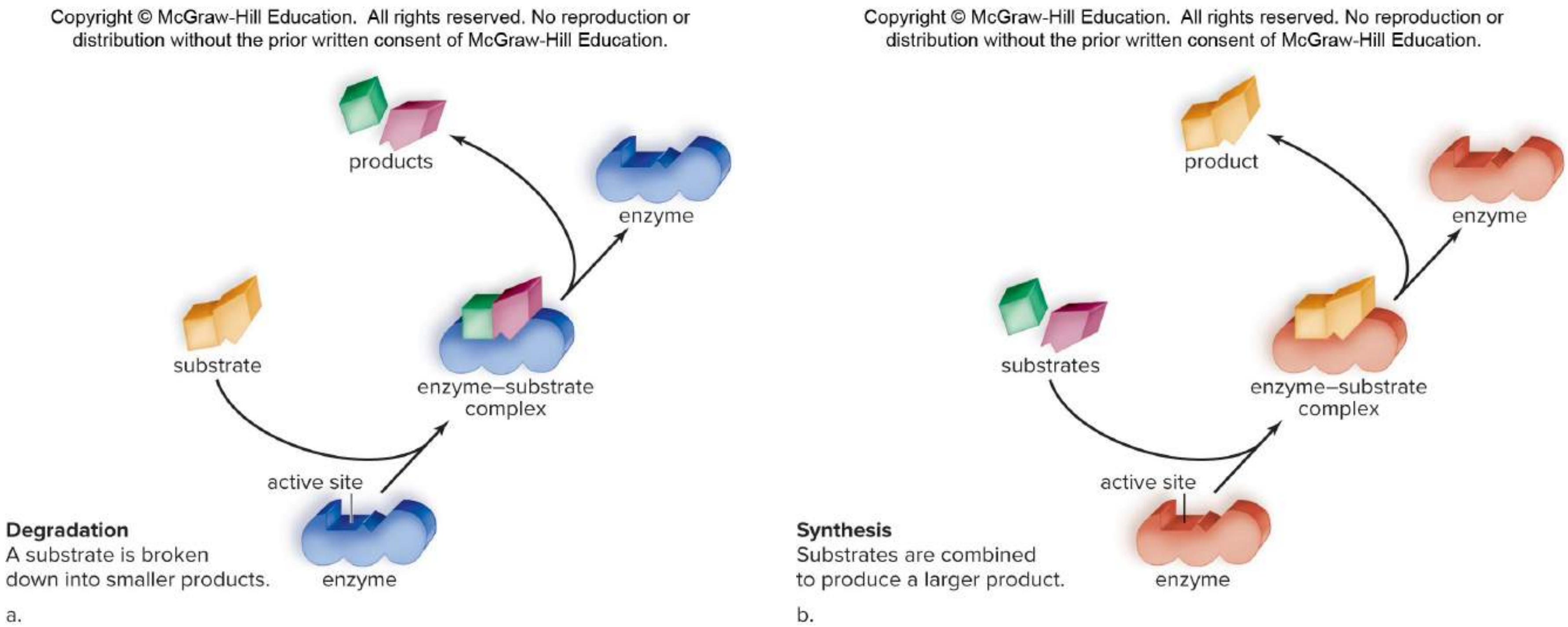
Because learning changes everything.™

Enzymes[1]

Enzymes.

- Speed up the rate of a chemical reaction.
- Often named for the molecules that they work on (called **substrates**).
  - That is, lipids are broken down by lipase.
- **Active site**—area of the enzyme where the substrate binds.
  - Impart specificity to the enzyme.
- Are not used up in a reaction; are reused.

Action of an Enzyme (Figure 3.18)



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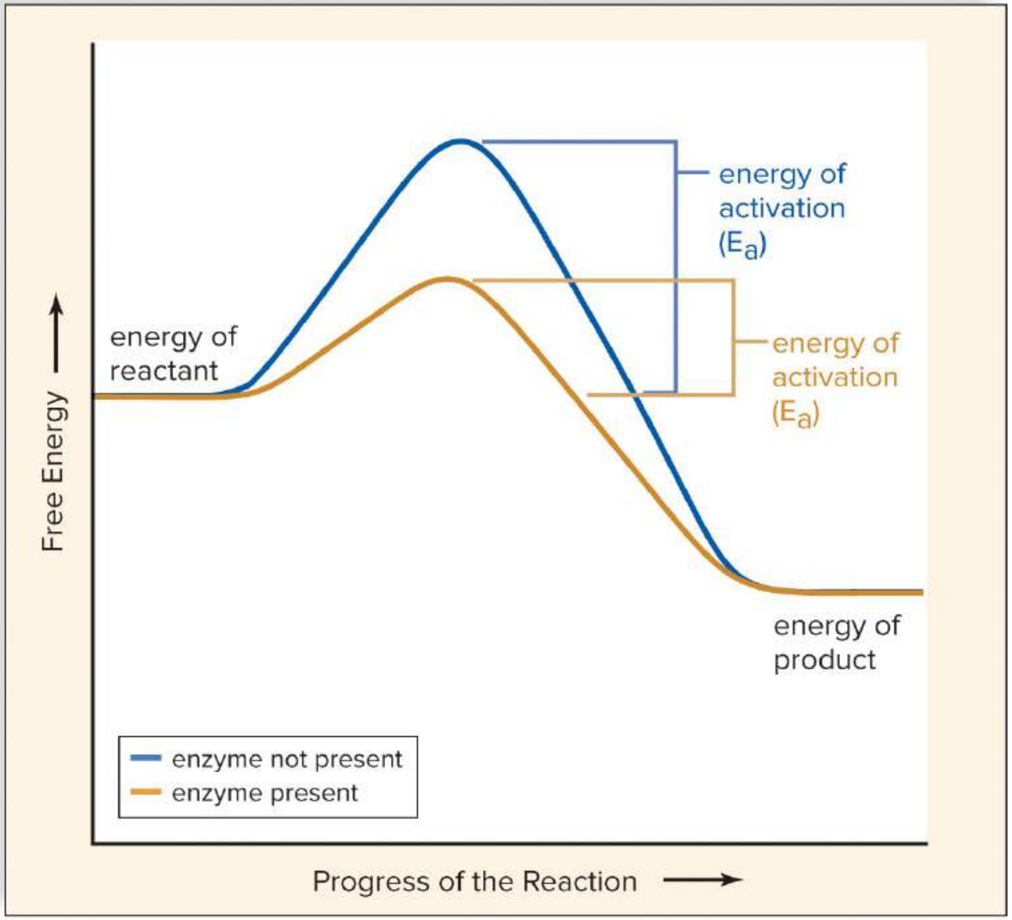
Enzymes 2

Enzymes, continued.

- Lower the **energy of activation**—the energy needed to start a chemical reaction.
- Some enzymes are aided by nonprotein molecules called **coenzymes.**
  - Vitamins are often components of coenzymes.

Energy of Activation (Figure 3.19)



Proteins

Learning Outcomes.

- Describe the structure of an amino acid.
- Explain how amino acids are combined to form proteins.
- Summarize the four levels of protein structure.

Protein Functions 1

Protein functions:

- **Support**—that is, keratin forms hair and nails, collagen lends support to ligaments and skin.
- **Enzymes**—speed chemical reactions.
- **Transport.**
  - That is, channel and carrier proteins in cell membranes allow substances to leave and enter the cell.
  - That is, transport molecules in the blood.

Protein Functions 2

Protein functions, continued:

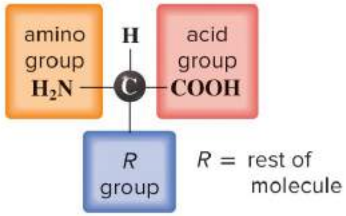
- **Defense**—antibodies are proteins that bind to foreign substances called antigens and disable them.
- **Hormones**—chemical messengers.
- **Motion**—contractile proteins allow parts of cells to move and muscles to contract.

Amino Acids: Subunits of Proteins

Amino acids—the subunits of proteins.

- Components: an amino group, a carboxyl group and an *R* group.
  - Each amino acid differs in its *R* group.

The Structure of Amino Acids (Figure 2.21)



Amino acid

a. Structure of an amino acid

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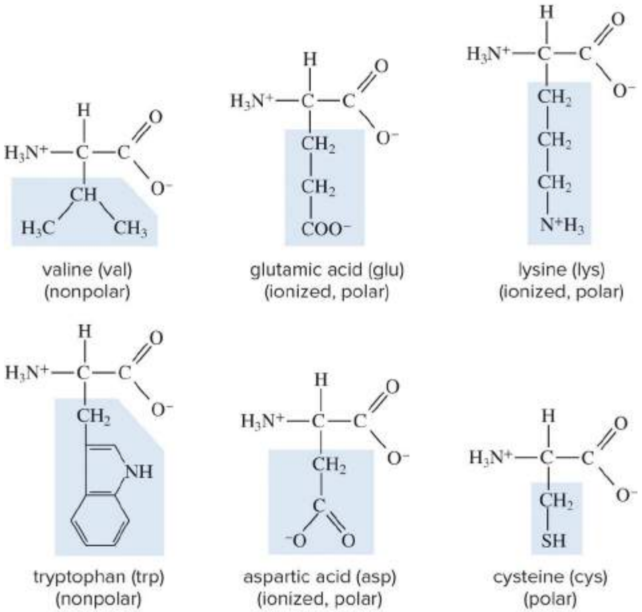

b. Examples of amino acids

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Peptides

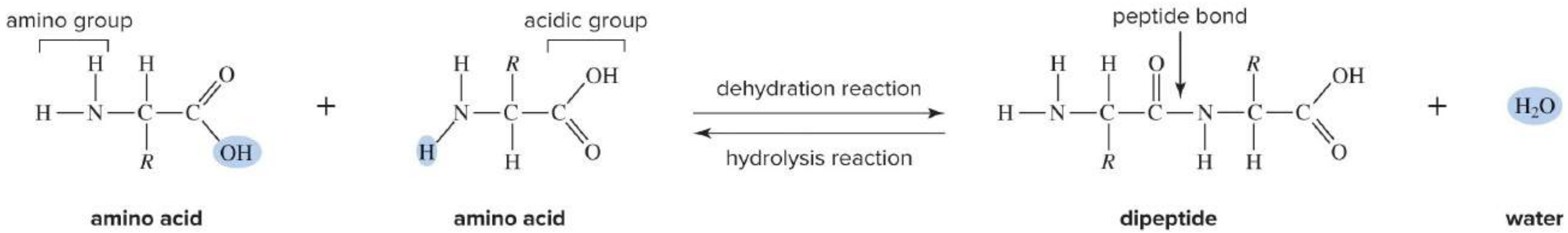
Peptide bond

- The polar covalent bond between two amino acids.

Polypeptide

- Three or more amino acids linked together.

Synthesis and Breakdown of a Protein (Figure 2.22)



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Shape of Proteins

A protein's 3-dimensional shape is closely linked to its function.

Denaturation—the change in the shape of a protein; caused by extreme heat or pH.

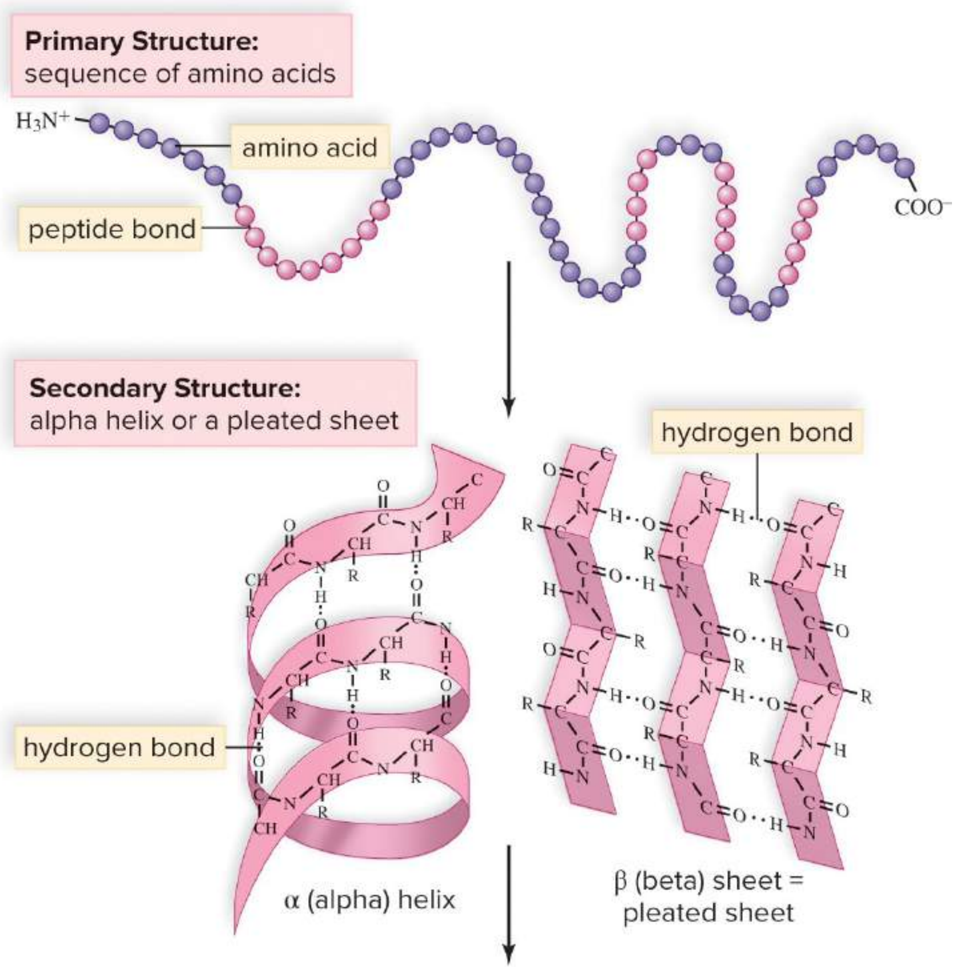
- Disrupts the protein's function.

Levels of Protein Organization 1

All proteins have primary, secondary, and tertiary levels of structure; only a few have quaternary structure.

- Shapes are created by hydrogen bonding between amino acids.
- **Primary structure**—the linear order of amino acids.
- **Secondary structure**—localized folding.
  - Results in an **alpha (α) helix** or **beta (β) pleated sheet.**

Levels of Protein Structure (Figure 2.23 a-b)

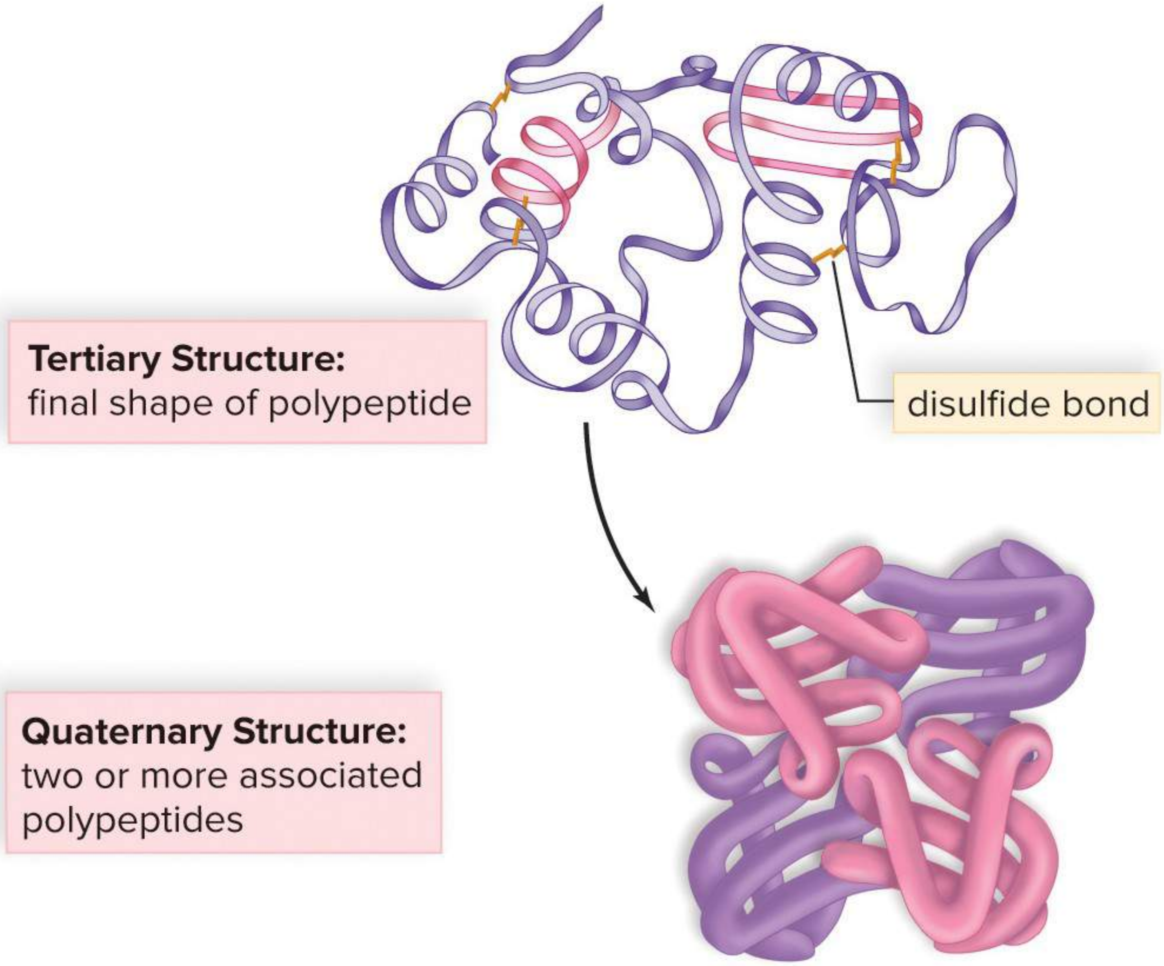


Levels of Protein Organization 2

Protein structure, continued.

- **Tertiary structure.**
  - The 3-D shape of the entire protein.
  - Determined by all three bond types (ionic, covalent, hydrogen).
- **Quaternary structure**—a combination of more than one polypeptide, each with its own primary, secondary, and tertiary structure.

Levels of Protein Structure (Figure 2.23 c-d)



Check Your Progress 2.6

Describe the major functions of proteins.

Explain the structure of an amino acid.

List the four levels of protein structure and briefly explain the factors that contribute to each level.

Lab 5: Organic Molecule Laboratory

What do biologists mean when they use the term “organic”?

- Molecules that contain both Carbon & Hydrogen

What are the 4 groups of Organic Molecules

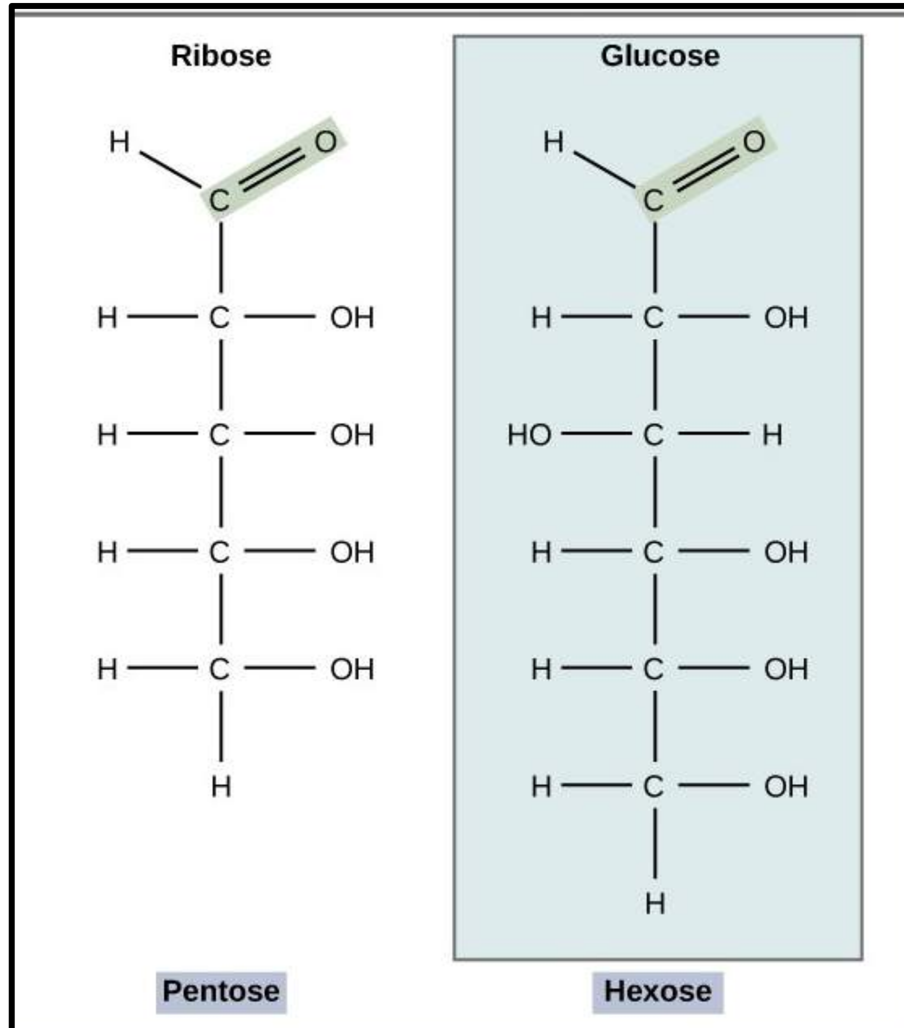
- Carbohydrates
- Proteins
- Lipids
- Nucleic Acids

Carbohydrates

- All contain C, H & O
- Basic Structural Unit is 1:2:1
- Glucose is the most common simple sugar (monosaccharide)
- What do you call it when you combine 2 monosaccharide ______________________?
- What reaction do you use to do this?
- Long chains of monosaccharide's are called?
- Polysaccharide Cellulose is found in plant walls and is an insoluble fiber.
- Glycogen is another form of glucose found in animals and is often referred to as "animal starch" (short term energy storage) Where is it stored in the human body?
- Functions of Carbohydrates
  - Immediate energy and short-term energy storage
  - Structural/Support – Cell walls

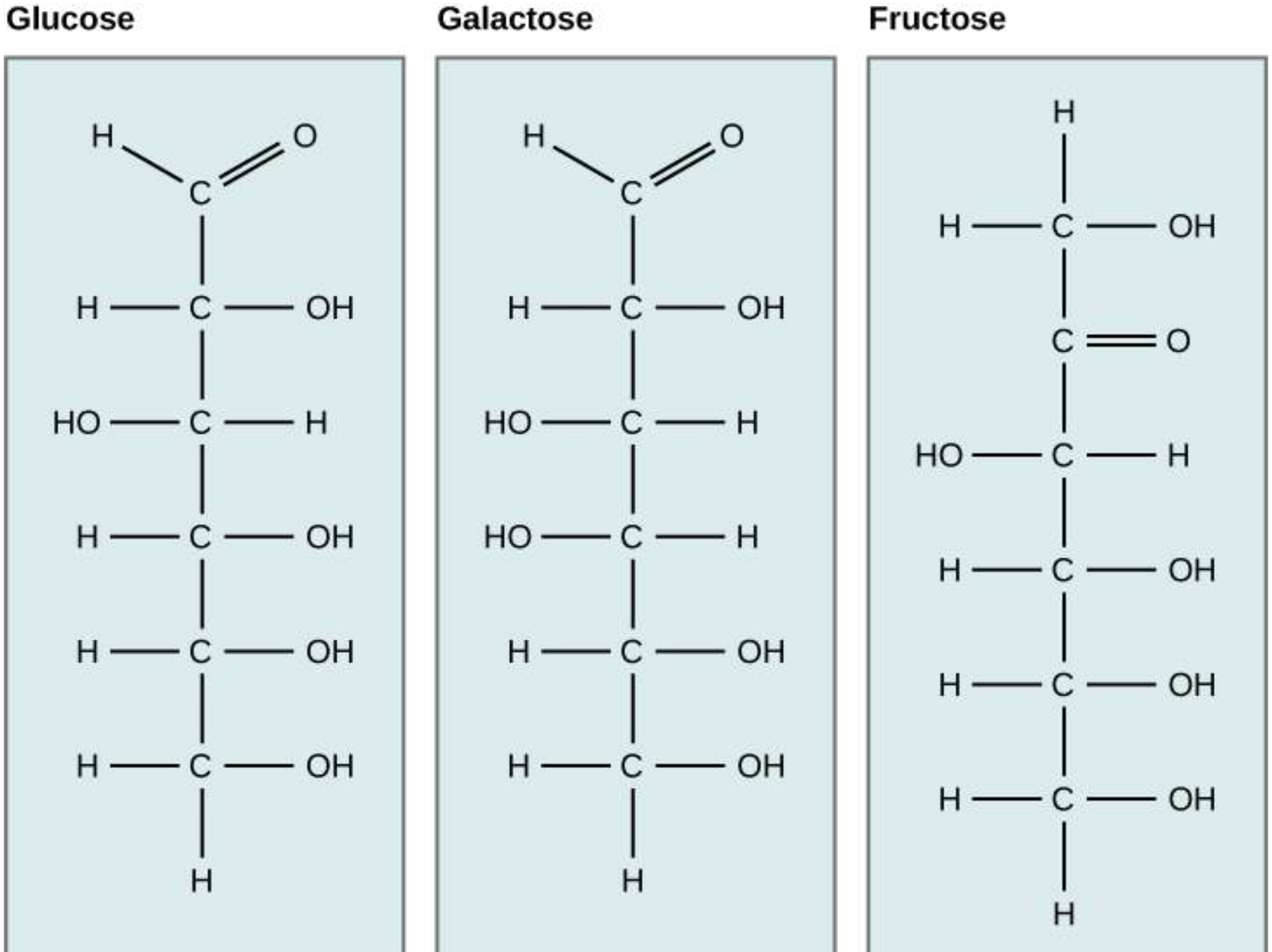
Monosaccharides

- Are simple sugars with 3-7 carbon atoms
- Pentose is the generic term for a 5-carbon sugar
- Hexose is the generic term for a 6-carbon sugar

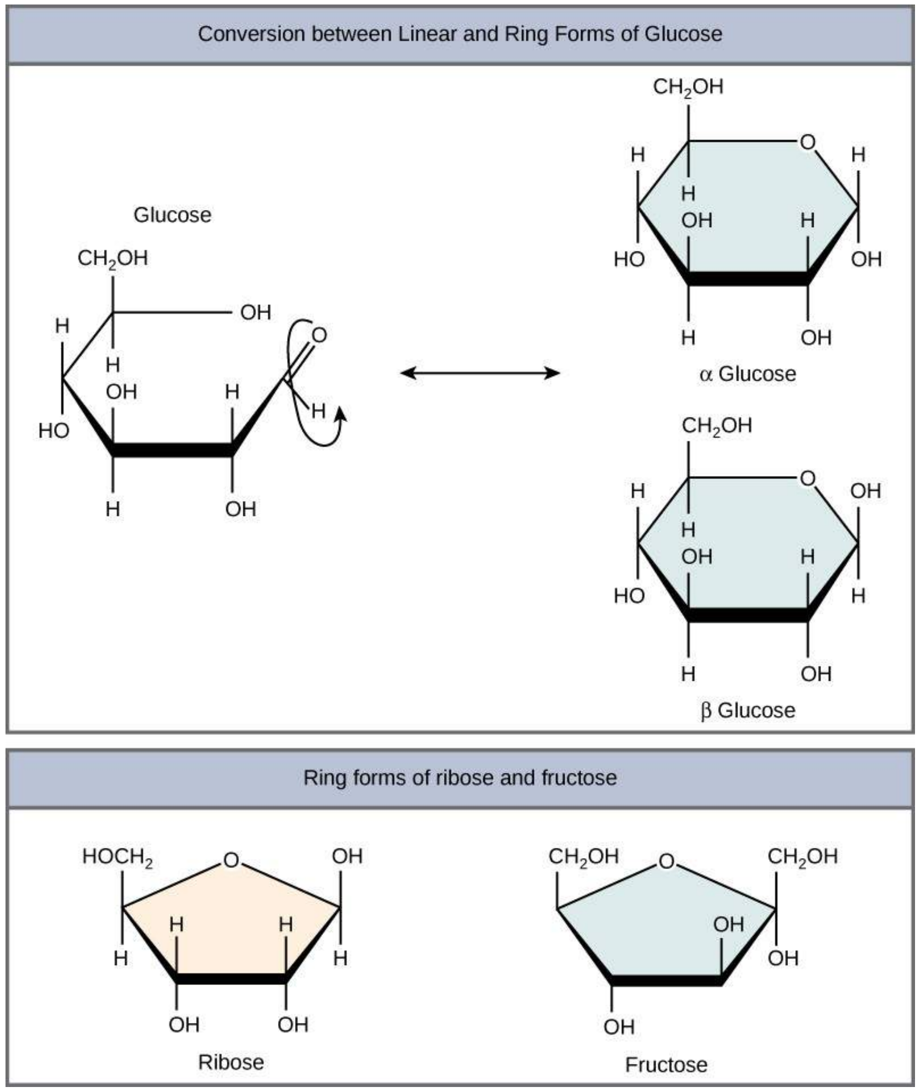


Monosaccharides cont.

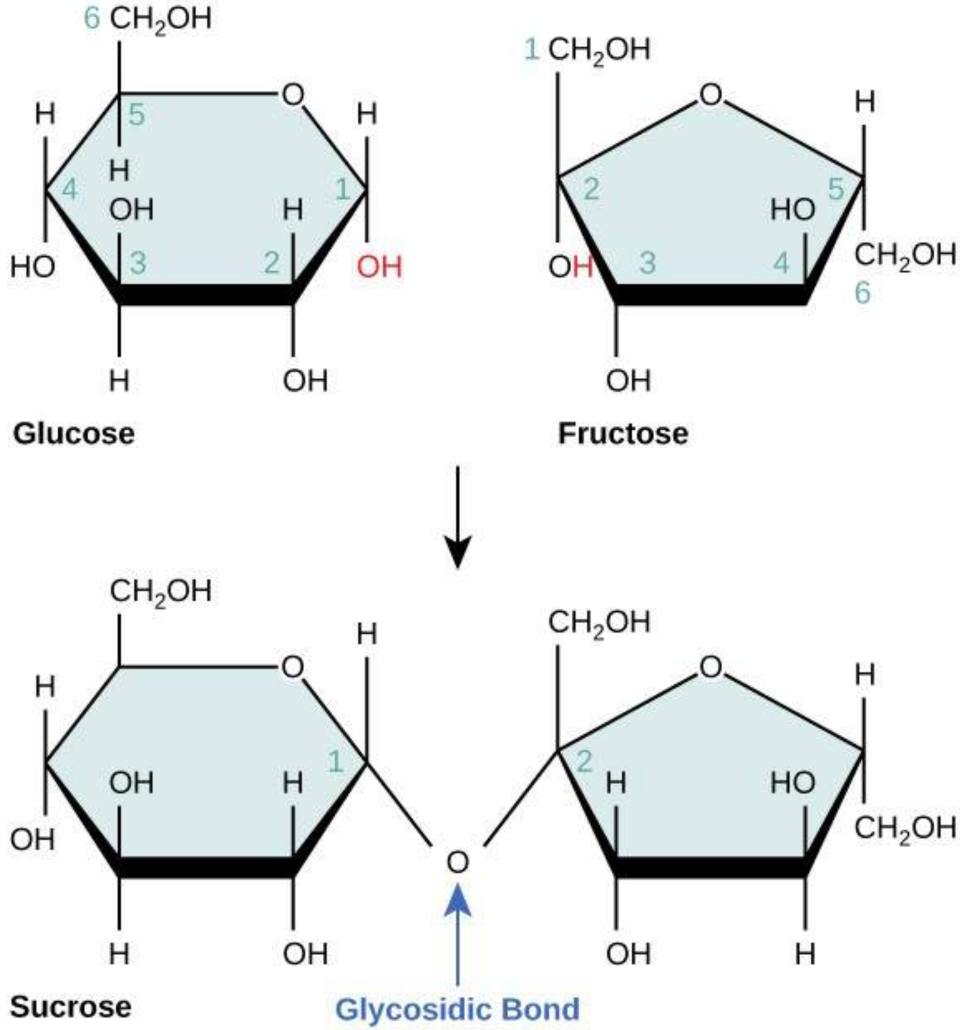
- What is a structural isomer?



Monosaccharides form ring structures in aqueous solutions



What is the name of the bond formed when Dehydration Synthesis occurs with Simple Sugars

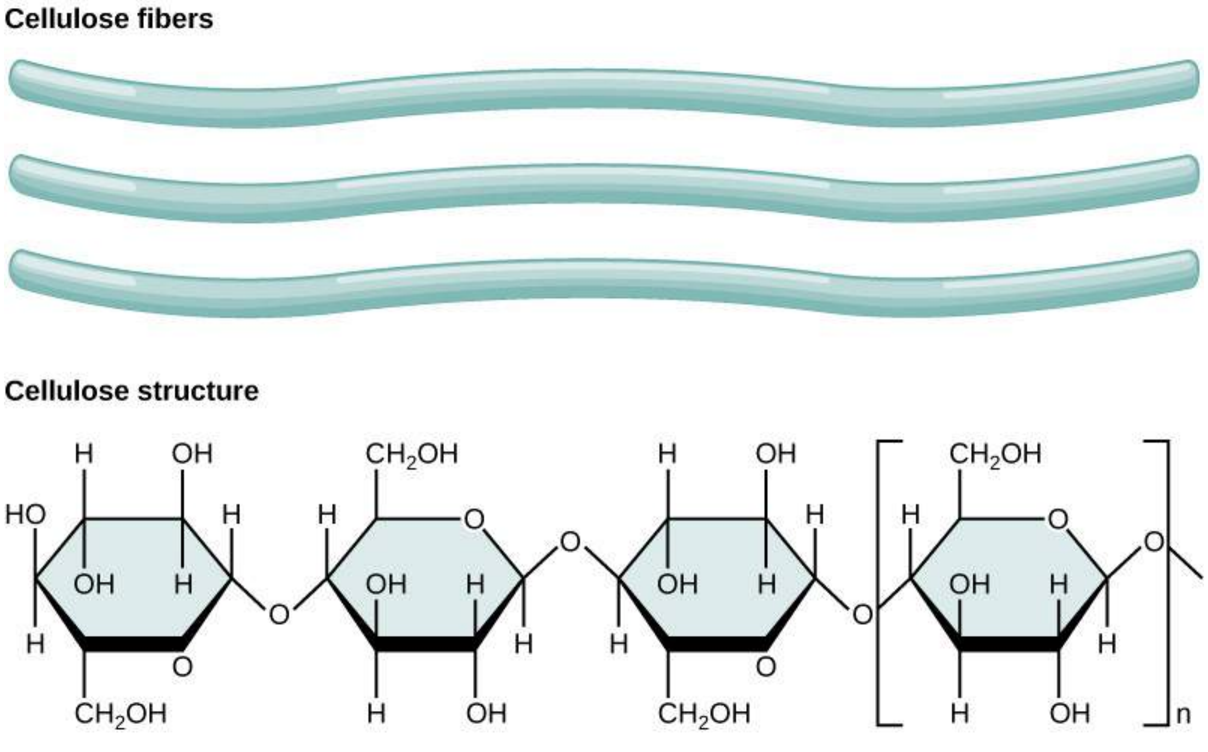


**Other disaccharides include maltose and galactose

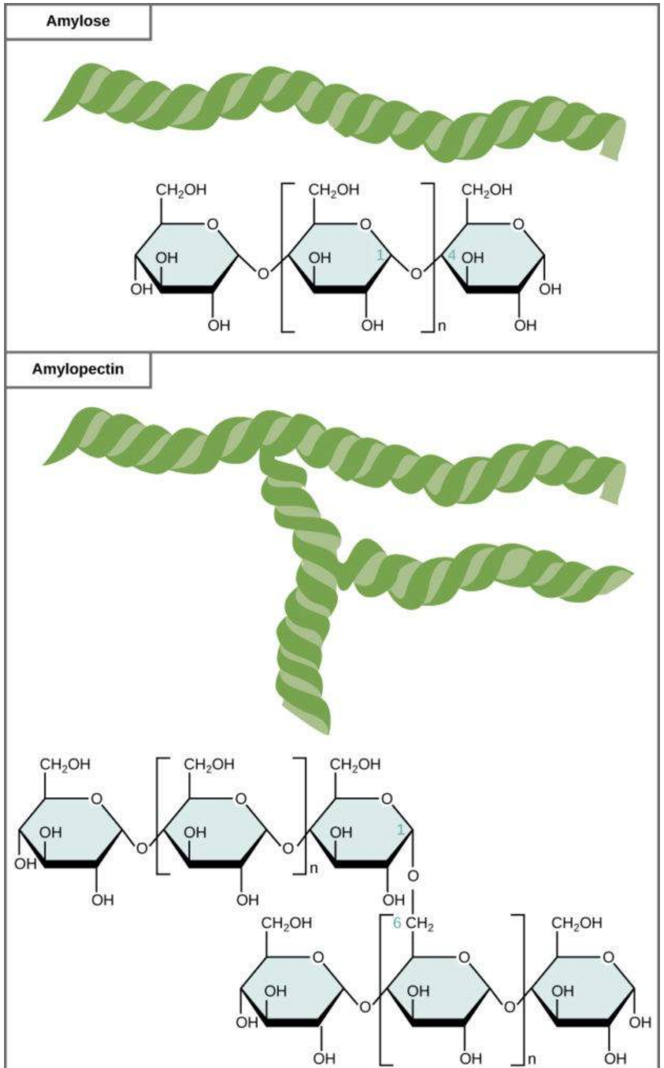
Polysaccharides
Who Produces them?
What do they do?

- Cellulose: Plants (found in plant walls)
  - Why do we as humans need “insoluble fiber”
- Starch: Storage form of Glucose in Plants
- Glycogen: Storage form of Glucose in Animals

Cellulose



Starch- storage of glucose in plant



What is used to store glucose in animals (including humans)?

Proteins

- What protein did we look at last week?
- Basic structural unit is an amino acid (H_2N + COOH)
- 6 functions of proteins
  - Structure/Support & Movement
  - Communication (hormones & receptors)
  - Transport
  - Catalysis
  - Recognition and protection (markers, antibodies, clotting factors)
  - Cell adhesion

What type of bond holds amino acids together?

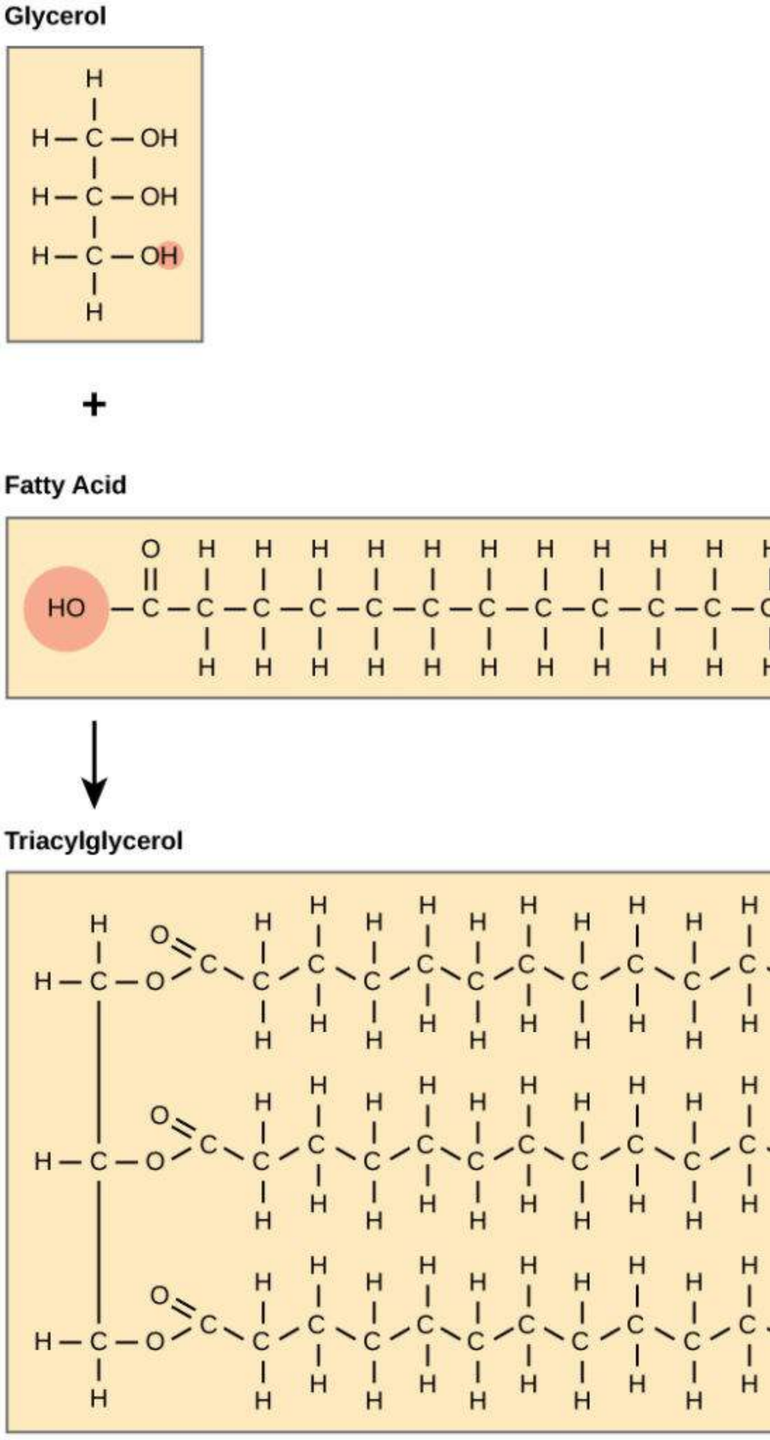
- Peptide Bond
  - Is this a covalent, ionic or hydrogen bond?
  - Does this bond break when an enzyme becomes denatured?

Lipids

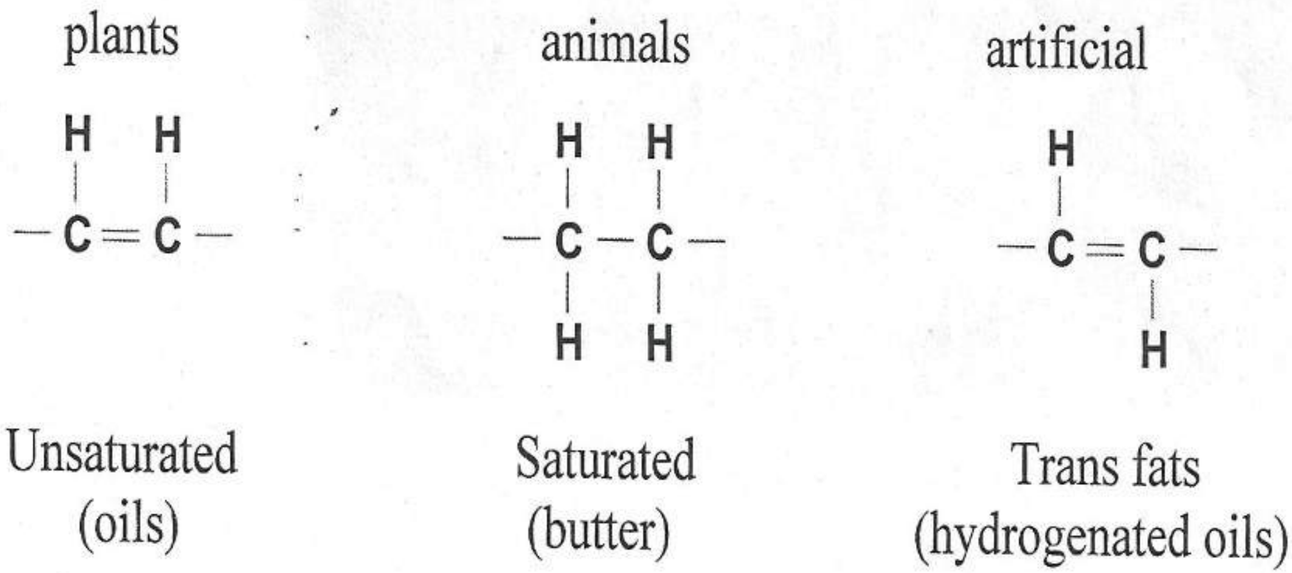
- All contain C, H & O (what does this sound like?)
- What is different? Hydrogen to Oxygen ratio is greater than 2 to 1
- Lipids are non-polar (this makes them hydrophobic)
- Functions of Lipids
  - Long term energy storage
  - Insulation
  - Shock absorption
  - Membrane structure (Phospholipid Bilayer)
  - Steroids (covered in lecture)
  - Waxes (covered in lecture

Lipid Structure

triglycerides are the polymers of lipids (used for long-term energy storage)



Fat types



Which one should you limit in your diet?
Which one should you NOT have at all in your diet?

What about Nucleic Acids?

- Nucleic Acid – 2 types
  - DNA
  - RNA

  - To be continued…………

Tissues

- Connective tissue
  - Binds and supports parts of the body
  - Composed of cells surrounded by a matrix that contains fibers
  - Four general classes
    - Connective tissue proper
      - Loose fibrous or areolar
      - Dense fibrous
      - adipose
    - Bone
    - Cartilage
    - blood

Connective Tissue

- Composition of non fluid matrix
  - Fibers:
    - **Collagen**: protein that gives flexibility and strength
    - **Elastic**: protein that is not as strong as collagen, but more elastic
    - **Reticular**: thin, highly branched fibers that form supporting network

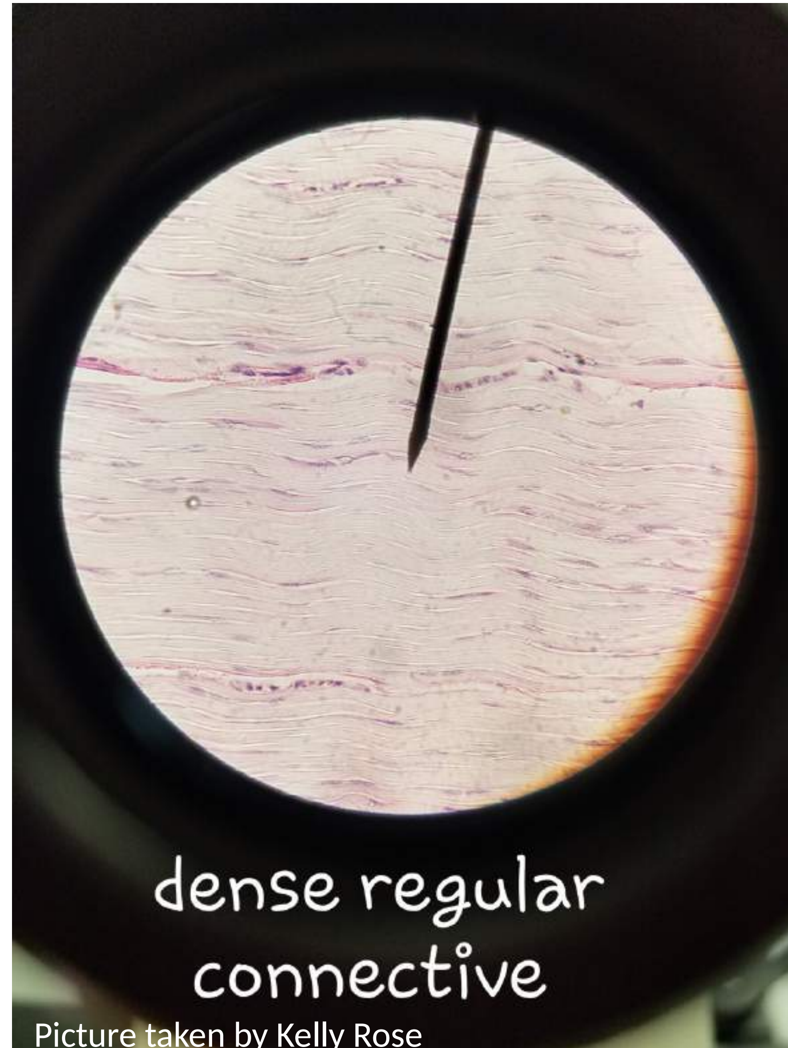
Loose Fibrous Connective Tissues

- **Loose fibrous connective tissue**
- aka loose Areolar connective tissue
  - Supports epithelium and many internal organs while allowing them to expand

Picture taken by Kelly Rose

Dense fibrous Connective Tissues

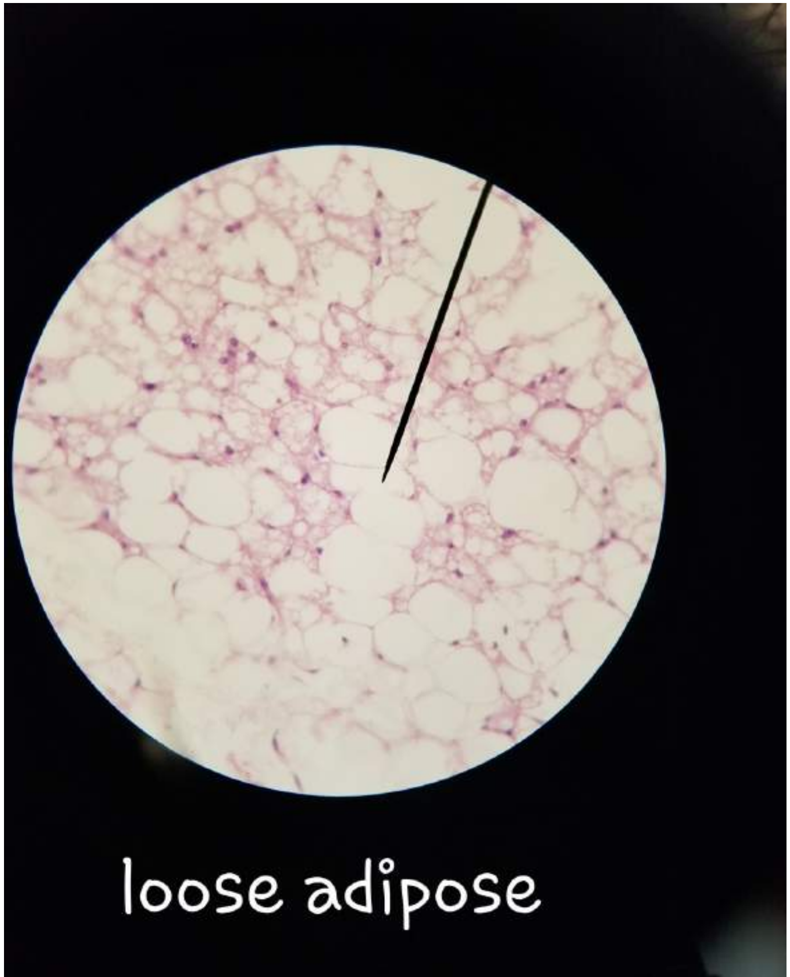
- **Dense fibrous connective tissue**
  - Contains many collagen fibers packed together
  - Found in structures such as
    - Tendons – connect muscles to bones
    - Ligaments – connect bones to other bones
- Both loose and dense connective tissue have cells called **fibroblasts**
  - Separated by a jelly-like matrix with collagen and elastic fibers



Picture taken by Kelly Rose

Adipose Tissue and Reticular Connective Tissue

- **Adipose Tissue**
  - Fibroblasts enlarge and store fat and become adipocytes
  - Used for:
    - Energy storage
    - Insulation against heat loss or gain
    - Organ protection
      - Found beneath the skin, around the kidneys and surface of the heart



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Don’t forget to study your assigned Anatomical Terms

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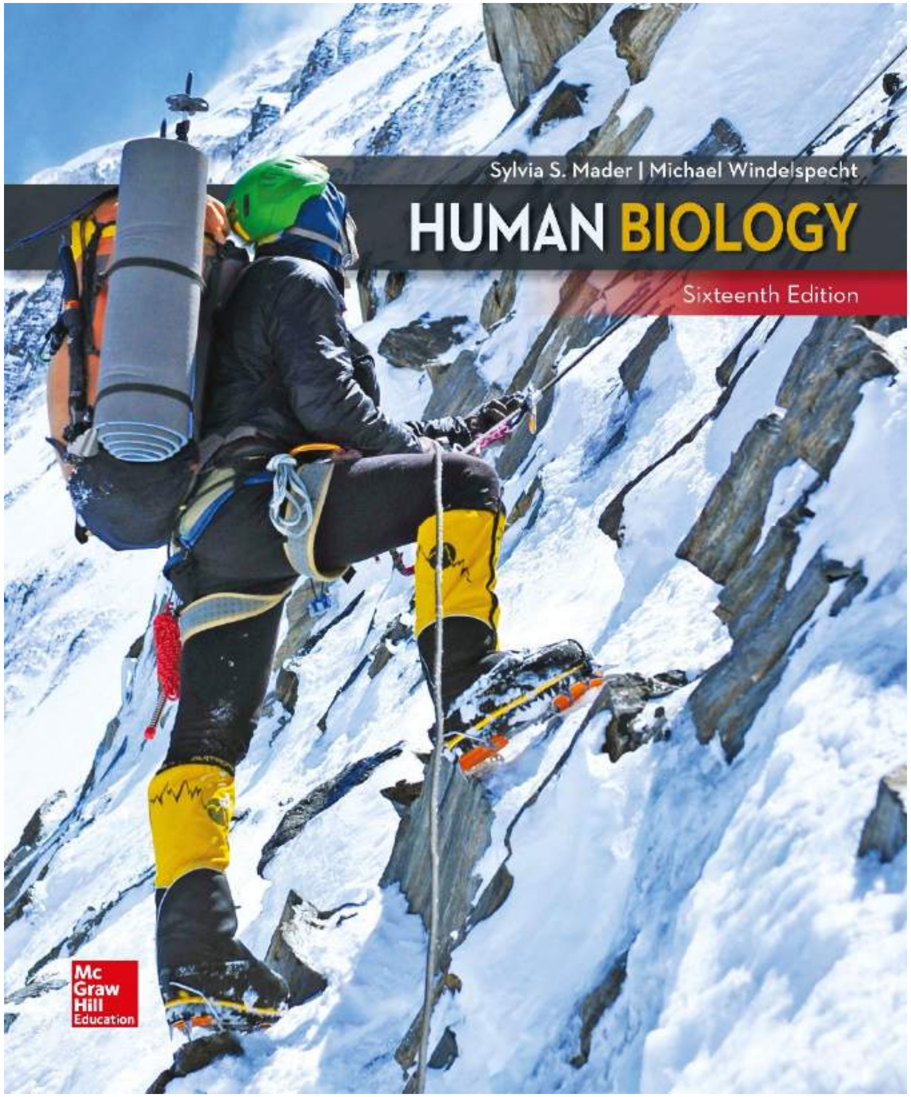


Sylvia S. Mader

Michael Windelspecht

Lab 6
Skeletal System

Functions of the Skeleton

Functions of the skeleton:

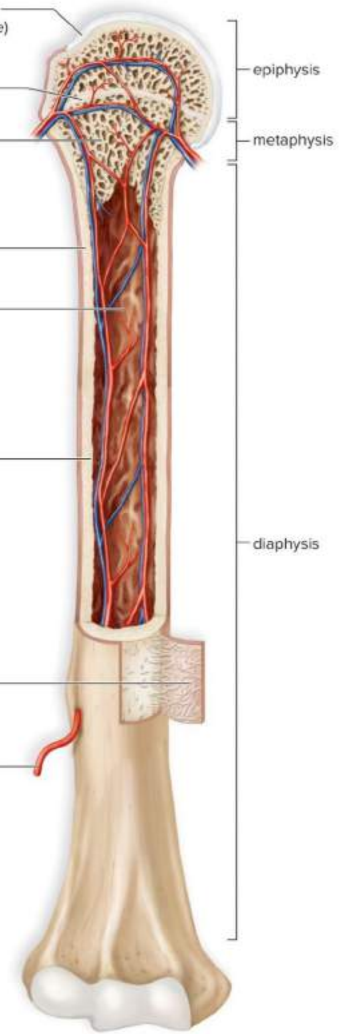
- Supports the body.
- Working with the muscular system, moves the body
- Protection.
  - Skull protects the brain, rib cage protects the heart and lungs, the vertebrae protect the spinal cord.
- Produces blood cells.
- Stores minerals (calcium and phosphate) and fat.

Anatomy of a Long Bone [1]

Anatomy of a long bone.

- **Diaphysis**—shaft of the bone.
  - **Medullary cavity**—inside the diaphysis; its walls are made of **compact bone.**
  - The medullary cavity is lined with the **endosteum** and is filled with **yellow bone marrow**, which stores fat.
- **Epiphysis** (*plural*, epiphyses)—expanded end of a long bone.
  - Composed of spongy bone that contains **red bone marrow**, where blood cells are made.

The Anatomy of a Long Bone (Figure 12.1)



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Anatomy of a Long Bone 2

Anatomy of a long bone, continued.

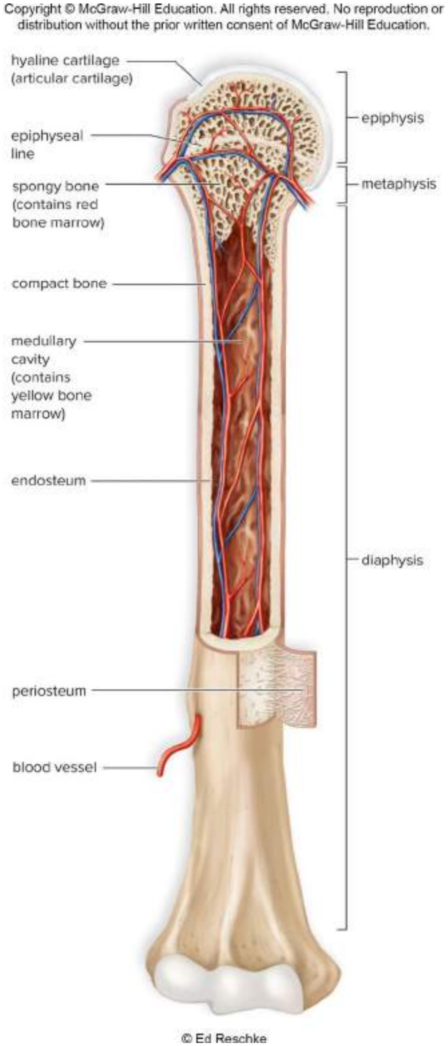
- The epiphyses are coated with a thin layer of hyaline cartilage, which is also called **articular cartilage**, because it occurs at a **joint.**
- **Metaphysis**—between the epiphysis and diaphysis.
  - Contains the **epiphyseal plate**, a region of cartilage that allows for bone growth.
- **Periosteum**—connective tissue covering all bones; continuous with ligaments and tendons.

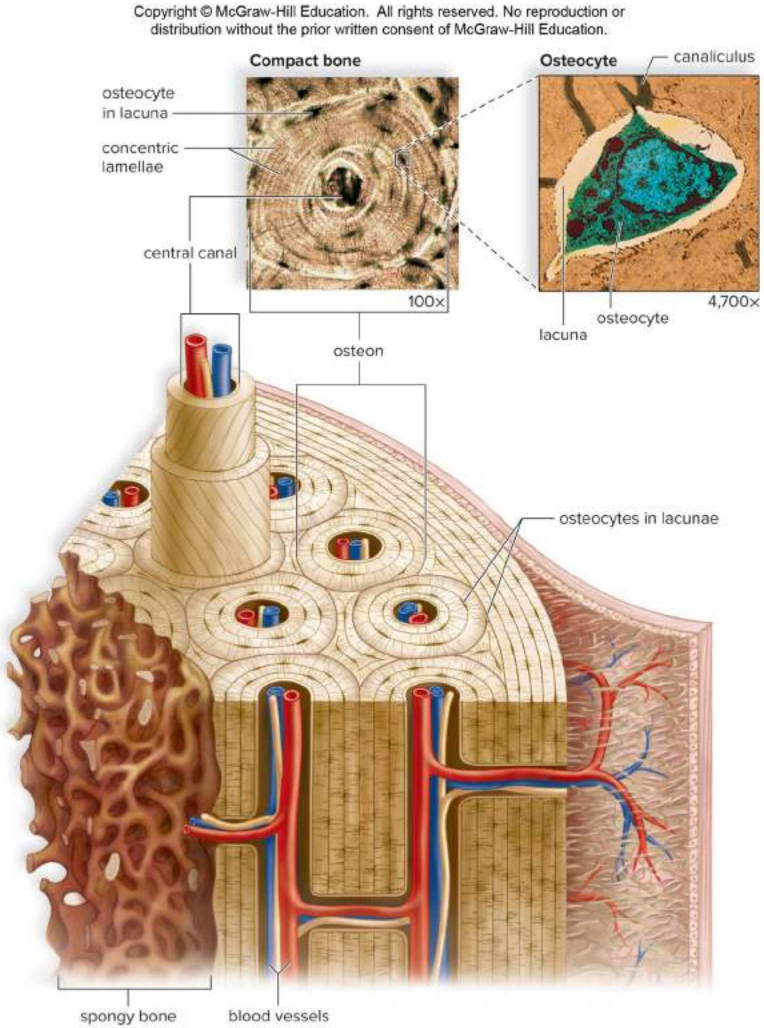
Bone [1]

Bone.

- There are two types of bone tissue: **compact** and **spongy.**
  - **Compact bone** is highly organized and composed of tubular units called **osteons.**
  - **Osteocytes** are bone cells; they lie in **lacunae** (*singular*, lacuna), tiny chambers arranged in concentric circles around a **central canal.**
  - Matrix fills the space between the rows of lacunae.

The Anatomy of a Long Bone (Figure 12.1, 12.2)





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(photos) (compact bone): ©Ed Reschke; (osteocyte):

Bone 2

Bone, continued.

- Tiny canals called **canaliculi** (*singular*, canaliculus) connect the lacunae with one another and with the central canal.
- Osteocytes stay in contact with each other in the canaliculi.
  - They exchange nutrients and wastes through gap junctions that connect adjacent osteocytes.

Bone 3

Bone, concluded.

- **Spongy bone** contains numerous thin plates called **trabeculae.**
  - Although lighter than compact bone, spongy bone is still designed for strength.
  - **Red bone marrow**—in the spaces of spongy bone.
    - Produces all types of blood cells.
  - Osteocytes of spongy bone are irregularly placed within the trabeculae.

Cartilage 1

Cartilage—not as strong as bone, but is more flexible.

- Matrix contains collagen and elastic fibers.
- **Chondrocytes**—cartilage cells; lie within lacunae.
- Has no nerves or blood vessels; relies on neighboring tissues for nutrient and waste exchange.
  - This makes it slow to heal.
- There are three types of cartilage: **hyaline, fibrocartilage,** and **elastic cartilage.**

Cartilage 2

Locations of cartilage.

- **Hyaline cartilage**: ends of long bones, nose, ends of ribs, larynx, and trachea.
- **Fibrocartilage**: disks between vertebrae and in the knee.
- **Elastic cartilage**: ear flaps and epiglottis.

Fibrous Connective Tissue

Fibrous connective tissue.

- Made of rows of **fibroblasts** separated by bundles of collagenous fibers.
- Makes up ligaments and tendons.
  - Ligaments connect bone to bone.
  - Tendons connect muscle to bone at a joint (also called an **articulation**).

Bones of the Axial Skeleton 1

Learning Outcomes:

- Identify the bones of the skull, hyoid, vertebral column, and rib cage.
- Identify the regions of the vertebral column.
- Explain the function of the sinuses and intervertebral disks.

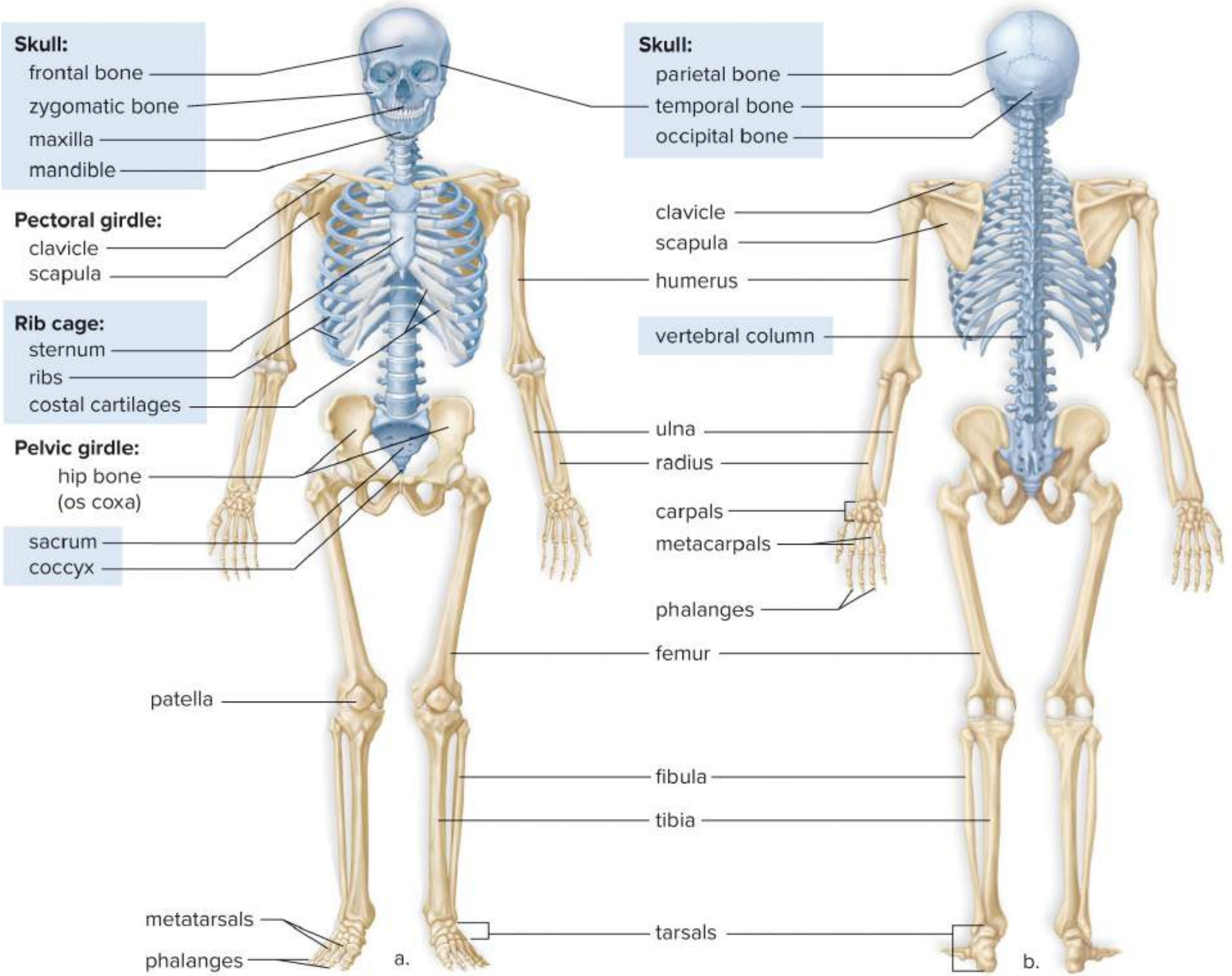
Bones of the Axial Skeleton 2

The 206 bones of the skeleton are classified as the axial or appendicular skeleton.

Axial skeleton—midline of the body.

- Consists of the skull, hyoid bone, vertebral column, and the rib cage.

The Axial and Appendicular Skeletons (Figure 12.3)



The Skull [1]

The **skull.**

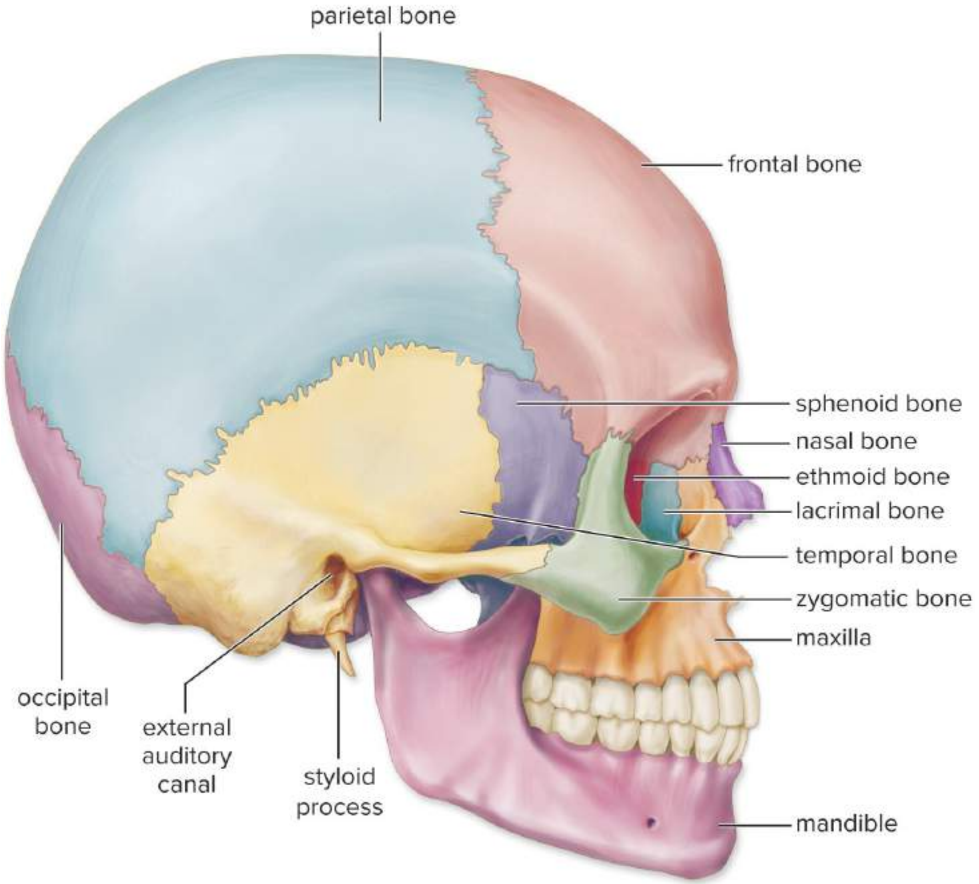
- Formed by the cranium and the facial bones.
- **Cranium.**
  - Contains and protects the brain.
  - In adults, made of eight bones.
  - In newborns, cranial bones are joined by membranous **fontanels.**
    - Usually close by the age of 16 months.

The Skull [2]

The **cranium**, continued.

- Bones: **frontal, parietal, occipital, temporal, sphenoid, ethmoid.**
  - **Foramen magnum**—a hole in the occipital bone through which the spinal cord passes.
  - **External auditory canal**—in each temporal bone; leads to the middle ear.
  - The sphenoid completes the sides of the skull and contributes to forming the **orbits** (eye sockets).
  - The ethmoid bone also helps form the orbits and the nasal septum.

The Bones of the Skull (Figure 12.4a)



a.

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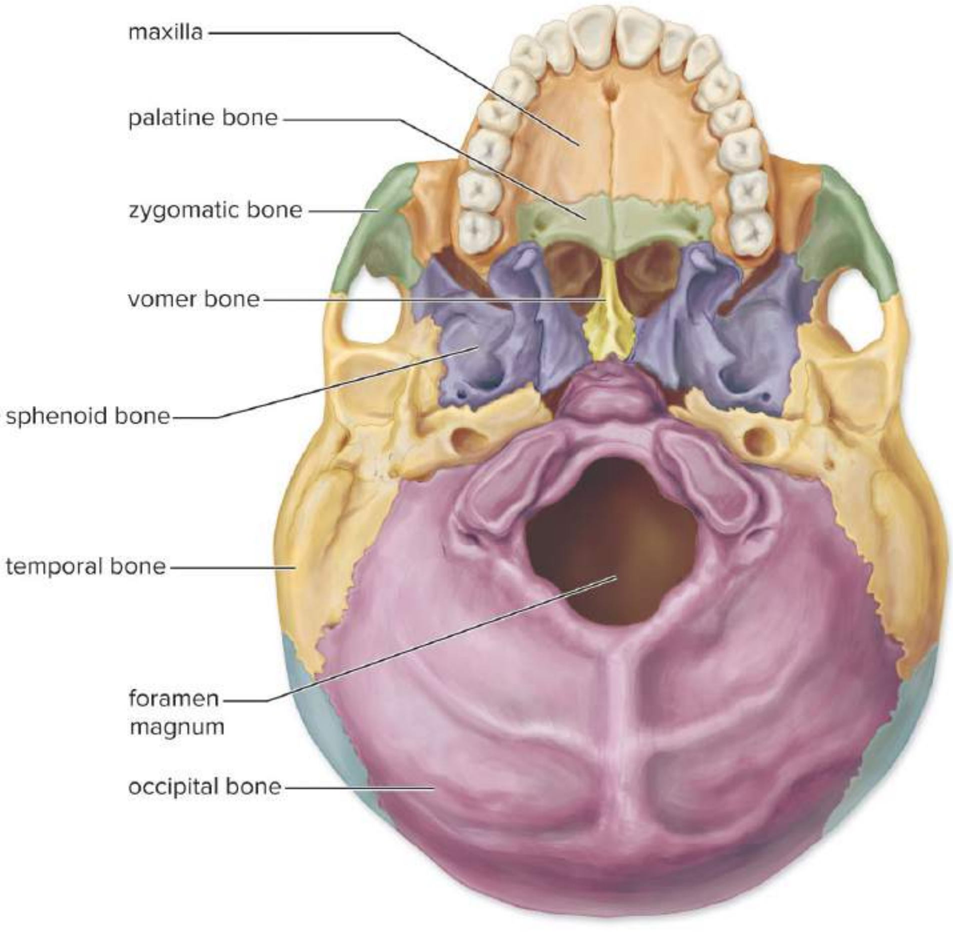
The Bones of the Skull (Figure 12.4b)



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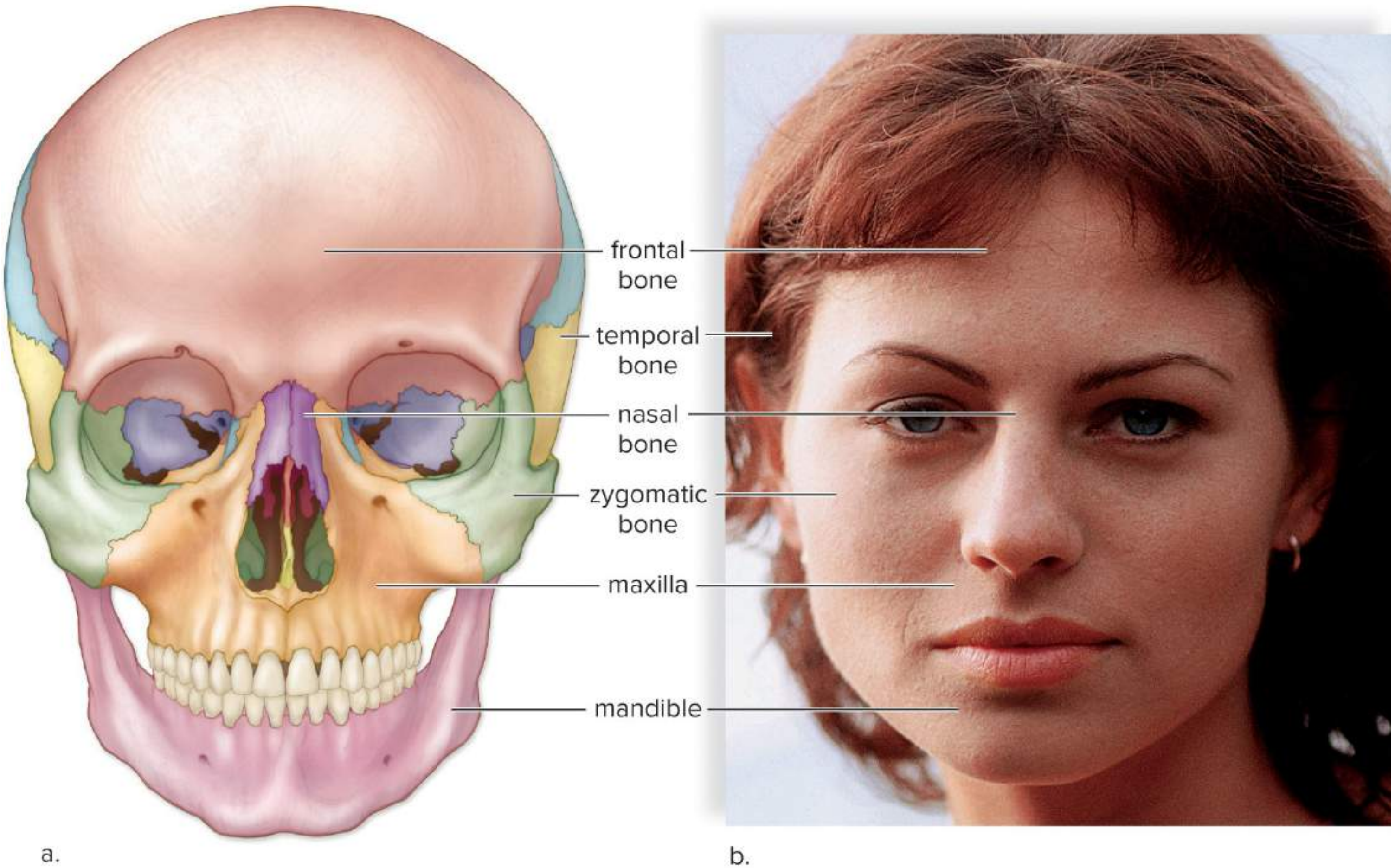
The Bones of the Face (Figure 12.5a-b)



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The Facial Bones [1]

Facial bones.

- **Mandible**, **maxillae** (*singular*, maxilla), **zygomatic** bones, and **nasal** bones.
  - The mandible is the only movable bone in the skull.
  - The maxillae form the upper jaw and a portion of the orbits.
  - The hard palate and the floor of the nose are formed by the maxillae joined to the **palatine** bones.
  - The zygomatic bones form the cheekbones.

The Facial Bones 2

Facial bones, continued.

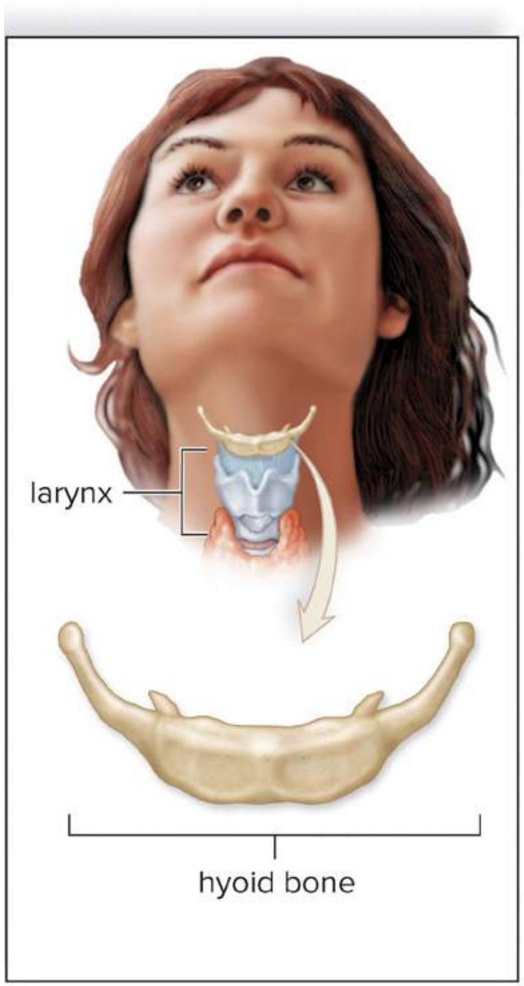
- **Mandible**, **maxillae** (*singular*, maxilla), **zygomatic** bones, and **nasal** bones, continued.
  - The nasal bones form the bridge of the nose.
  - Other bones (that is, **ethmoid** and **vomer**) are a part of the nasal septum, which divides the interior of the nose into two nasal cavities.
  - The **lacrimal** bone contains the opening for the **nasolacrimal canal**, which drains tears from the eyes to the nose.

The Hyoid Bone

Hyoid bone.

- Not part of the skull, but is part of the axial skeleton.
- The only bone in the body that does not articulate with another bone.
- The hyoid bone anchors the tongue and serves as the site for the attachment of muscles associated with swallowing.
- In cases of suspicious death, a fractured hyoid is a strong indication of manual strangulation.

The Location of the Hyoid Bone (Figure 12.5c)



c.

The Vertebral Column 1

Vertebral column—consists of 33 vertebrae.

- There are four curvatures that provide more strength for an upright posture than a straight column.
- **Scoliosis**—abnormal sideways curvature of the spine.
- **Kyphosis**—abnormal posterior curvature; “hunchback.”
- **Lordosis**—abnormal anterior curvature; “swayback.”

The Vertebral Column 2

Vertebral column, continued.

- **Vertebral canal**—in the center of the column; the spinal cord passes through.
- **Intervertebral foramina** (*singular*, foramen, “a hole”) on each side of the column; **spinal nerves** travel through.
  - Spinal nerves control skeletal muscle contraction, among other things.
  - If the spinal cord and/or spinal nerves are injured, there can be paralysis or even death.

The Vertebral Column 3

Vertebral column, concluded.

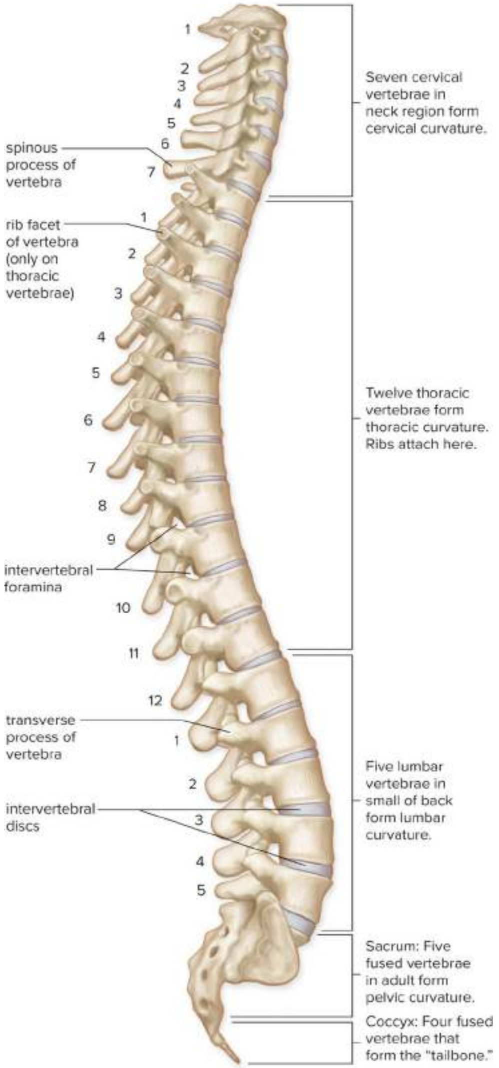
- **Spinous processes** of the vertebrae—bony projections along the midline of the back.
- **Transverse processes** extend laterally.
- Both spinous and transverse processes serve as attachment sites for muscles.

Types of Vertebrae

Types of vertebrae.

- **Cervical vertebrae**—in the neck.
  - **Atlas**—first cervical vertebra; holds up the head.
    - Movement permits the “yes” motion of the head.
  - **Axis**—second cervical vertebra.
    - Named because it rotates around the long axis of the body when we shake the head “no.”

The Vertebral Column (Figure 12.6)



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Intervertebral Disks [1]

Intervertebral disks.

- Composed of fibrocartilage.
- Prevent the vertebrae from grinding.
- Absorb shock caused by movements such as running, jumping, and even walking.
- Allows the vertebrae to move as we bend forward, backward, and from side to side.

Intervertebral Disks 2

Intervertebral disks, continued.

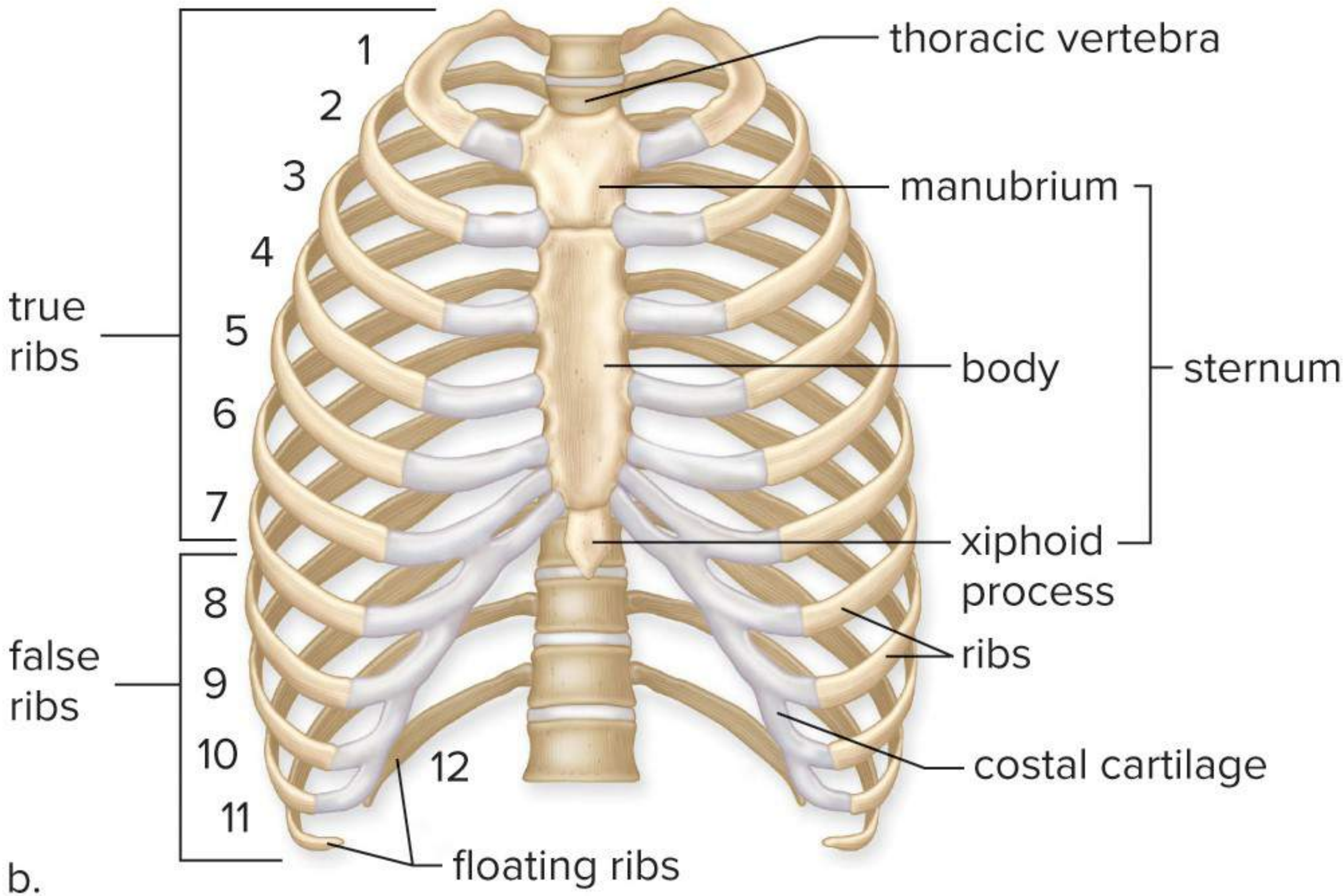
- Become weakened with age and can herniate and rupture.
  - Pain results if a disk presses against the spinal cord and/or spinal nerves.

The Rib Cage

Rib cage (thoracic cage)—composed of the thoracic vertebrae, the ribs and their associated cartilages, and the sternum.

- Part of the axial skeleton.
- Protects the heart and lungs.
- Swings outward and upward upon inspiration and then downward and inward upon expiration.

The Thoracic Vertebrae, Ribs, and Sternum (Figure 12.7b)



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The Ribs 1

The ribs.

- There are 12 pairs; all connect directly to the thoracic vertebrae in the back.
- Each rib articulates with the body and transverse process of its corresponding thoracic vertebra.
- Curve outward and then forward and downward.
- **True ribs**—ribs 1 to 7; connect directly to the sternum by means of a long strip of hyaline cartilage called **costal cartilage.**

The Ribs 2

The ribs, continued.

- **False ribs**—ribs 8 to 12; their costal cartilage does not connect directly to the sternum.
  - **Floating** ribs—ribs 11 and 12; they have no connection with the sternum.

The Sternum [1]

Sternum (breastbone)

- Along with the ribs, it helps protect the heart and lungs.
- Composed of three bones: **manubrium, body,** and **xiphoid process.**
  - The manubrium articulates with the clavicles.
  - The manubrium joins with the body of the sternum at an angle.

The Sternum 2

Sternum, continued.

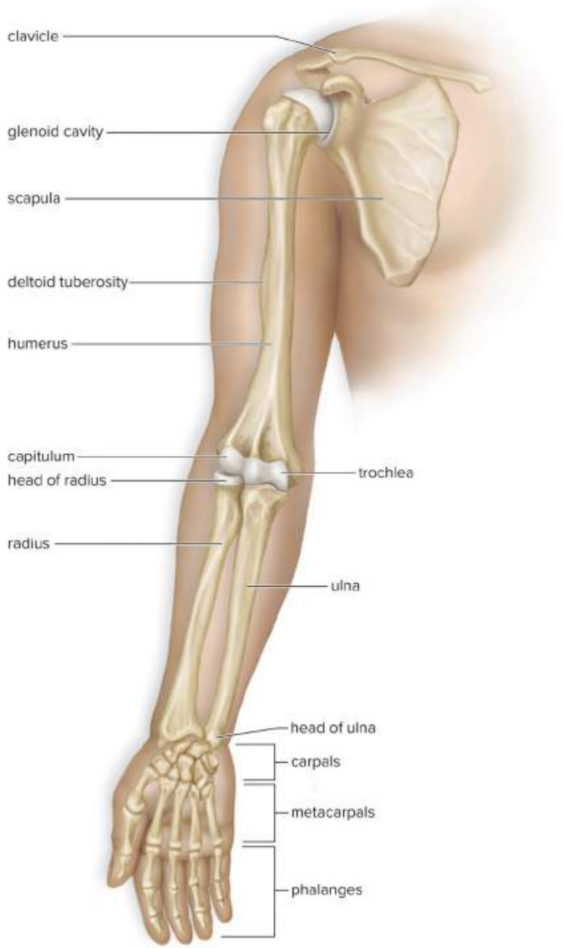
- Counting the ribs is sometimes done to determine where the apex of the heart is located—usually between the fifth and sixth ribs.
- The xiphoid process serves as an attachment site for the diaphragm, which separates the thoracic cavity from the abdominal cavity.

The Pectoral Girdle and Upper Limb [1]

Pectoral girdle—consists of a **scapula** (shoulder blade) and a **clavicle** (collarbone).

- The clavicle joins with the sternum and the **acromion process** of the scapula.
- The muscles of the arm and chest attach to the **coracoid process** of the scapula.
- The **glenoid cavity** of the scapula articulates with the head of the humerus, the upper arm bone.

The Bones of the Pectoral Girdle and Upper Limb (Figure 12.8)



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The Pectoral Girdle and Upper Limb 2

Pectoral girdle, continued.

- This joint is very mobile, but also unstable.
  - It can dislocate.
- Ligaments and tendons stabilize it.
  - **Rotator cuff**—tendons that extend to the humerus from four small muscles originating on the scapula.
    - Vigorous circular movements of the arm can lead to rotator cuff injuries.

The Upper Limb [1]

The upper limb—**humerus** in the arm and the **radius** and **ulna** in the forearm.

- The humerus, the single long bone in the arm, has a smoothly rounded head that fits into the glenoid cavity of the scapula.

The Upper Limb 3

The upper limb, concluded.

- **Carpal** bones—eight bones in the wrist.
- **Metacarpal** bones—five bones in the palm.
  - The metacarpal that leads to the thumb is opposable to the fingers.
    - An opposable thumb can touch each finger separately.
  - The knuckles are the enlarged ends of the metacarpals.
- **Phalanges**—the bones of the fingers and the thumb.

The Pelvic Girdle and Lower Limb 1

Pelvic girdle (hip girdle)—consists of two **coxal bones** (hip bones).

Pelvis—composed of the pelvic girdle, sacrum, and coccyx.

- Bears the weight of the body, protects the organs within the pelvic cavity, and is the place of attachment for the legs.

The Bones of the Pelvis and Lower Limb (Figure 12.9)

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The Pelvic Girdle and Lower Limb 3

Pelvic girdle, concluded.

- The male pelvis is different from the female pelvis.
- In the female, the iliac bones are more flared and the pelvic cavity is more shallow, but the outlet is wider.
  - These adaptations facilitate the birthing process.

The Lower Limb 1

The lower limb—the **femur** in the thigh, the **tibia** and **fibula** in the lower leg.

- Femur—longest, strongest bone in the body.
  - The **head** of the femur articulates with the coxal bones at the acetabulum; the **neck** better positions the legs for walking.
- **Patella** (kneecap)—held in place by the quadriceps tendon, which continues as a ligament that attaches to the **tibial tuberosity.**
- **Tibia**—leg bone on the medial side of the leg.
- **Fibula**—the more slender bone in the leg.

The Lower Limb 3

The lower limb, concluded.

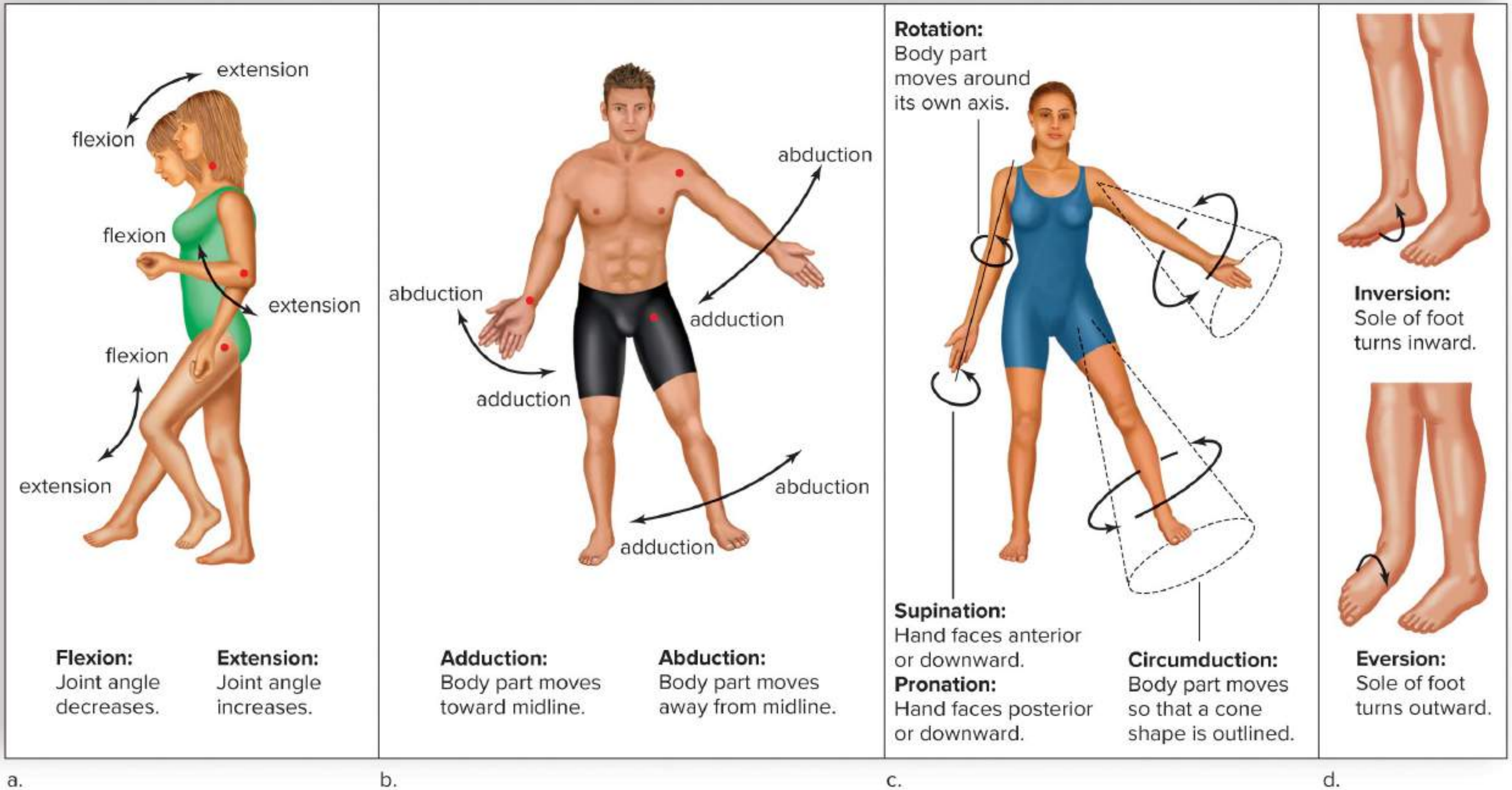
- **Tarsal** bones—seven bones in the ankle.
  - **Talus**—joins the tibia and fibula.
  - **Calcaneus**—heel bone.
  - The talus and calcaneus support the body weight.
- **Metatarsal** bones—five bones in the instep.
- **Phalanges**—the bones of the toes.

Articulations [2]

Articulations (joints).

- Where bones come together.
- Are classified as **fibrous, cartilaginous**, or **synovial.**
  - Most fibrous joints are immovable.
    - That is, **sutures** between the cranial bones.
  - Cartilaginous joints are connected by hyaline cartilage, (that is, costal cartilages) or fibrocartilage (that is, intervertebral disks).
    - Slightly movable.
  - **Synovial joints** are freely movable.

Synovial Joints Allow for a Variety of Movement (Figure 12.11)



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Biology Today: Science 2

Osteoarthritis and joint replacement surgery.

- **Osteoarthritis**—degeneration of articular cartilage.
- **Rheumatoid arthritis**—an autoimmune disease that causes inflammation in joints.

Bone Growth and Homeostasis 2

Cells involved in bone growth, remodeling, and repair:

- **Osteoblasts**—bone-forming cells.
  - Secrete the organic matrix of bone and promote the deposition of calcium salts into the matrix.
- **Osteocytes**—mature bone cells.
  - When osteoblasts surround themselves with calcified matrix, they become osteocytes within lacunae.
- **Osteoclasts**—bone-absorbing cells.
  - Break down bone; return calcium and phosphate to the blood.
  - Throughout life, osteoclasts remove the matrix of bone and osteoblasts build it up.

Bone Development and Growth

Ossification—the formation of bone.

- Bones form during embryonic development in two distinctive ways: **intramembranous ossification** and **endochondral ossification.**

Intramembranous Ossification

Intramembranous ossification—forms flat bones (that is, bones of the skull).

- Bones develop between sheets of fibrous connective tissue.

Endochondral ossification—forms most bones (that is, long bones like the tibia).

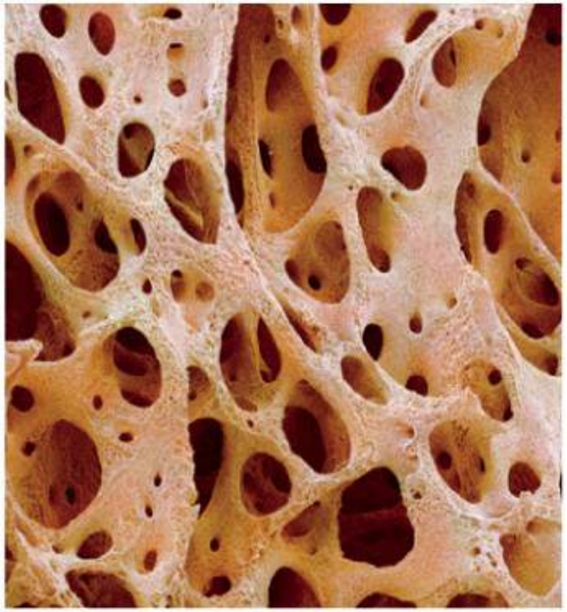
- Calcified bone matrix replaces the hyaline cartilage models of the bones.
- Bone formation spreads from the center of the bone to the ends.

Biology Today: Health

Osteoporosis.

- Bones are weakened due to decreased bone mass.
- Skeletal mass increases until age 30.
  - After that, there is an equal rate of formation and breakdown of bone mass until age 50.
  - Then, reabsorption begins to exceed formation, and the total bone mass slowly decreases.
- Risk factors include: women, white or Asian, thin, family history, early menopause, smoking, diet low in calcium, excessive caffeine or alcohol consumption, and a sedentary lifestyle.

Preventing Osteoporosis (Figure 12C)



a. Normal bone

b. Osteoporosis

(a): ©Susumu Nishinaga/Science Source; (b): ©Ed

Blood Cells Are Produced in Bones

There are two types of marrow: **yellow** and **red.**

- Fat is stored in yellow bone marrow.
- Red bone marrow is the site of blood cell production.

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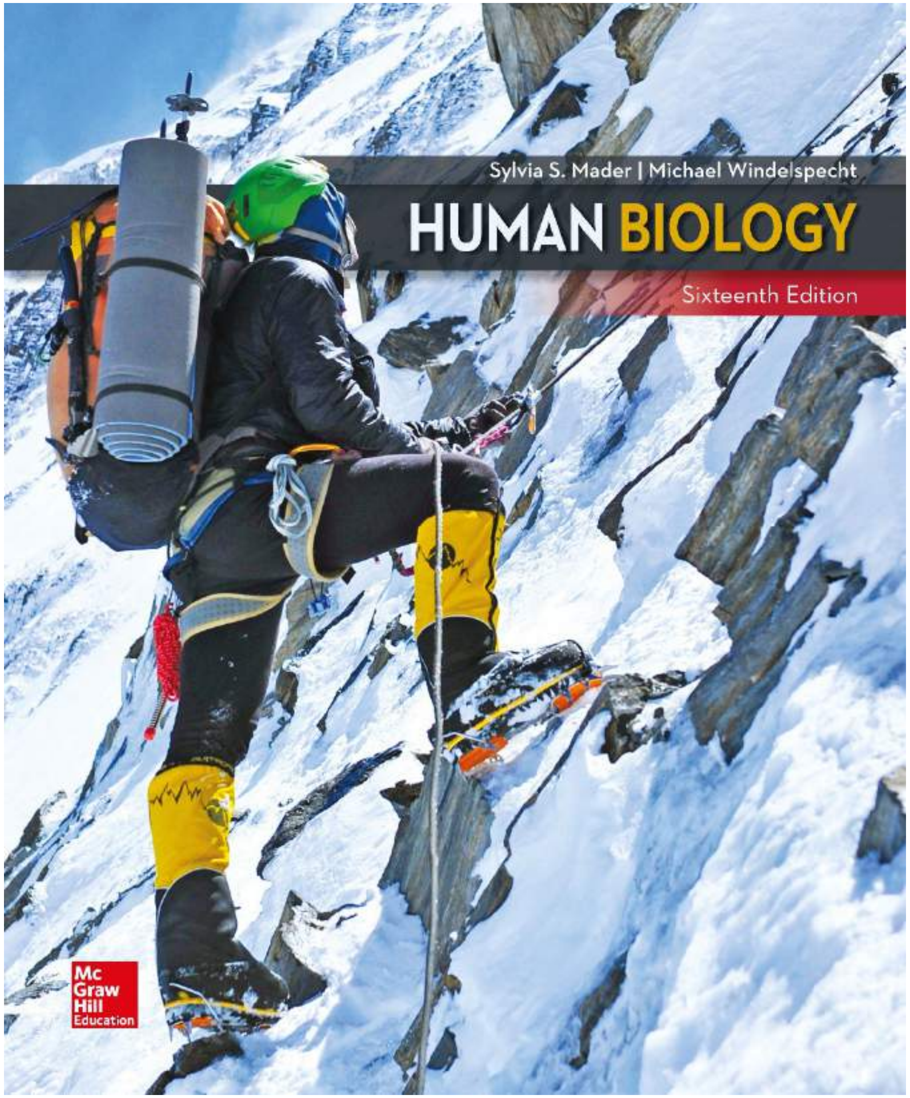


Sylvia S. Mader

Michael Windelspecht

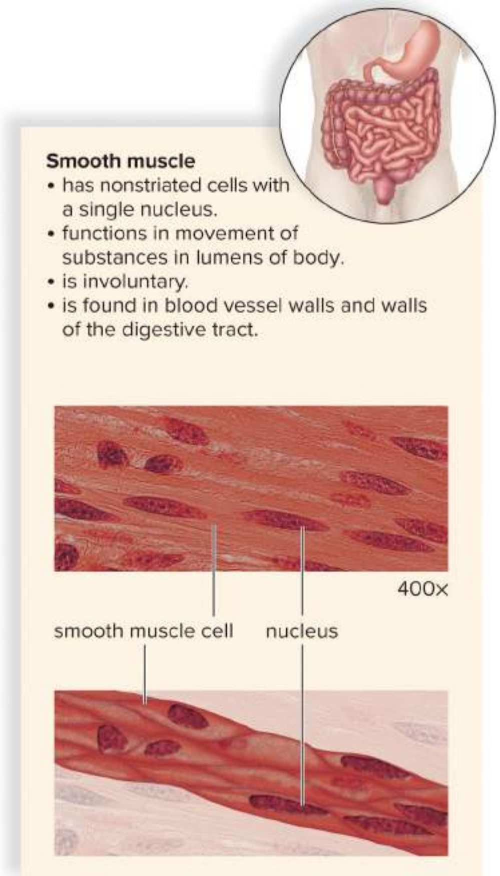
Lab 7
Muscles

Because learning changes everything.™

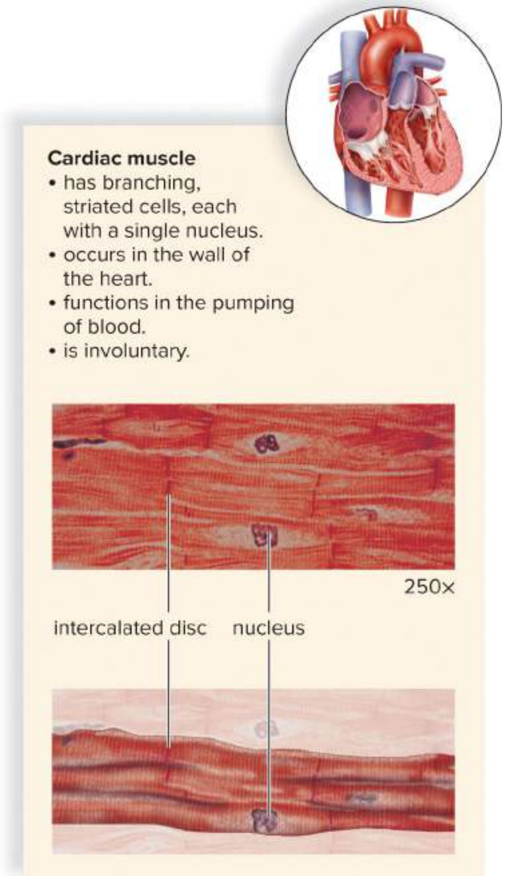
Types of Muscles

Three types of muscle tissue: **smooth, cardiac,** and **skeletal.**

- The cells are called **muscle fibers.**



b.



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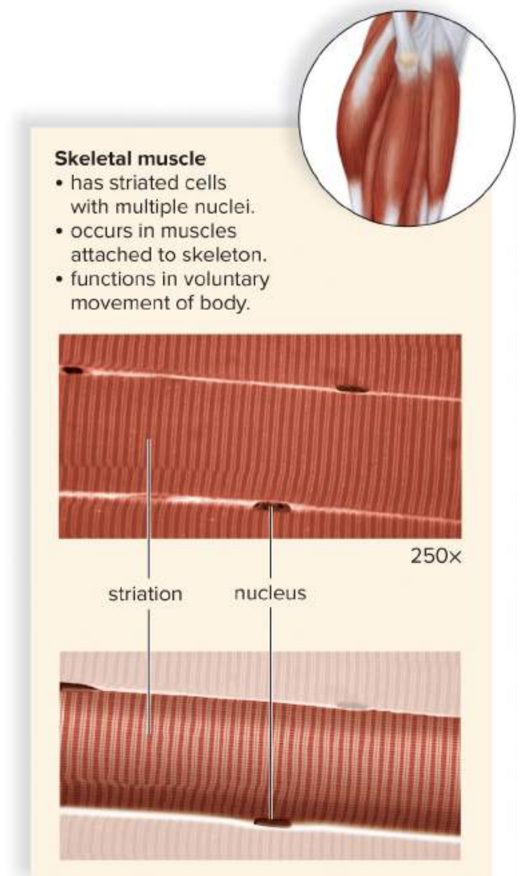


a.

Skeletal Muscle

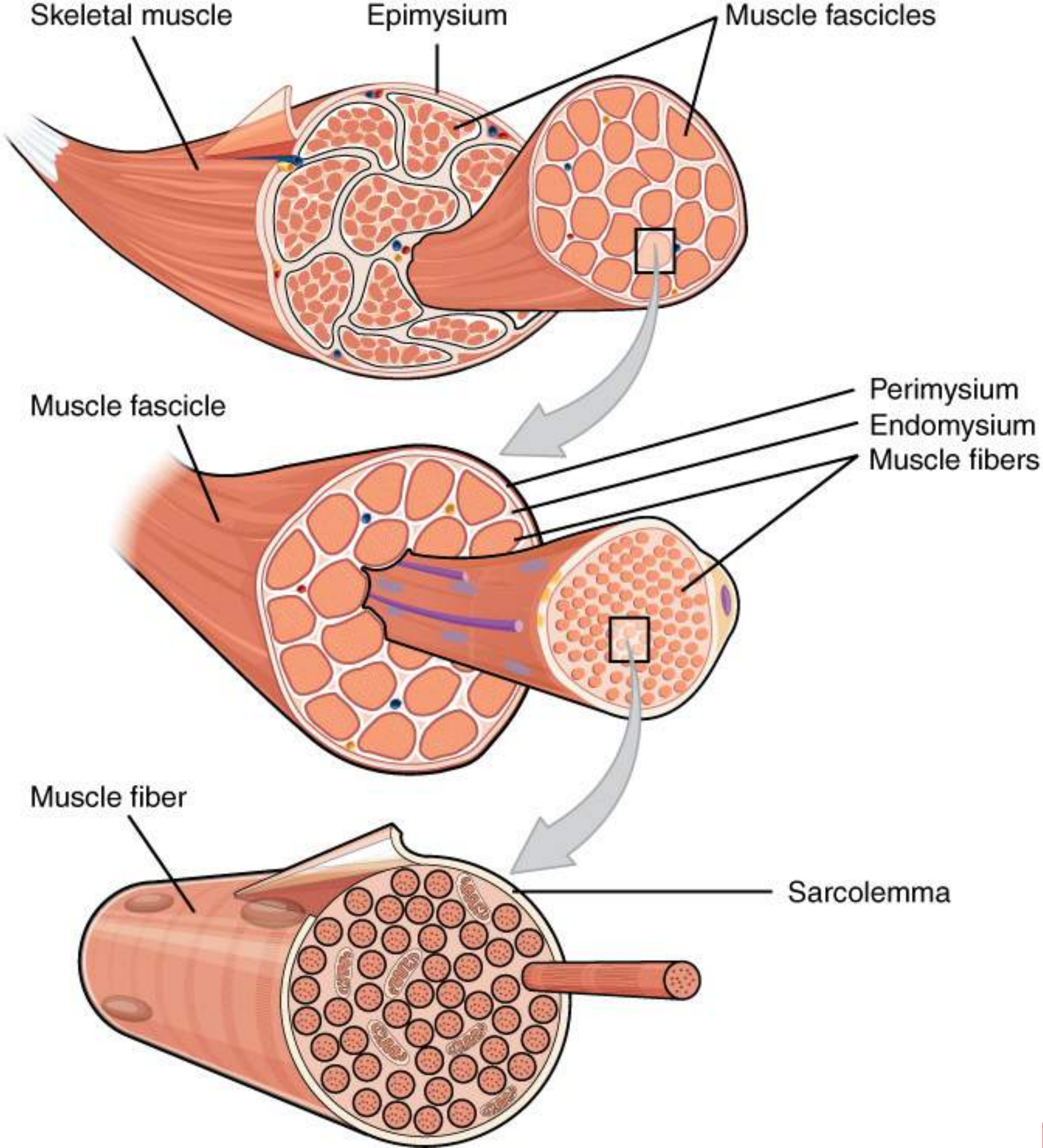
Skeletal muscle.

- Fibers are:
  - Tubular, multinucleated, and striated.
  - Make up skeletal muscles, which are attached to the skeleton.
  - Very long; run the length of the muscle.
- Is voluntarily controlled.

Functions of Skeletal Muscles [1]

Functions of skeletal muscles:

- **Support**—muscle contraction opposes gravity and allows us to remain upright.
- **Movements of bones and other body structures.**
  - Arms, legs, eyes, facial expressions, and breathing.
- **Maintenance of a constant body temperature.**
  - Contraction causes ATP to break down, releasing heat, which is distributed throughout the body.
- **Movement of fluids in the cardiovascular and lymphatic systems.**
  - Keeps blood moving in cardiovascular veins and lymph moving in lymphatic vessels.
- **Protection of the internal organs and the stabilization of joints.**
  - Muscles pad the bones, and the muscular wall of the abdomen protects internal organs.
  - Muscle tendons hold bones together at joints.


Skeletal muscle
Epimysium
Muscle fascicles
Muscle fascicle
Perimysium
Endomysium
Muscle fibers
Muscle fiber
Sarcolemma

Basic Structure of Skeletal Muscles

Fascicle—bundle of skeletal muscle fibers (cells).

- Within a fascicle, each fiber is surrounded by connective tissue; the fascicle is also surrounded by connective tissue.
- **Fascia**—connective tissue that covers muscles and extends to become its **tendon.**
- Small, fluid-filled sacs called **bursae** (*singular*, bursa) can often be found between tendons and bones.
  - The bursae act as cushions, lubrication.

Skeletal Muscles Work in Pairs [1]

The **origin** of a muscle is the attachment site to the stationary bone

The **insertion** is the attachment on the bone that moves.

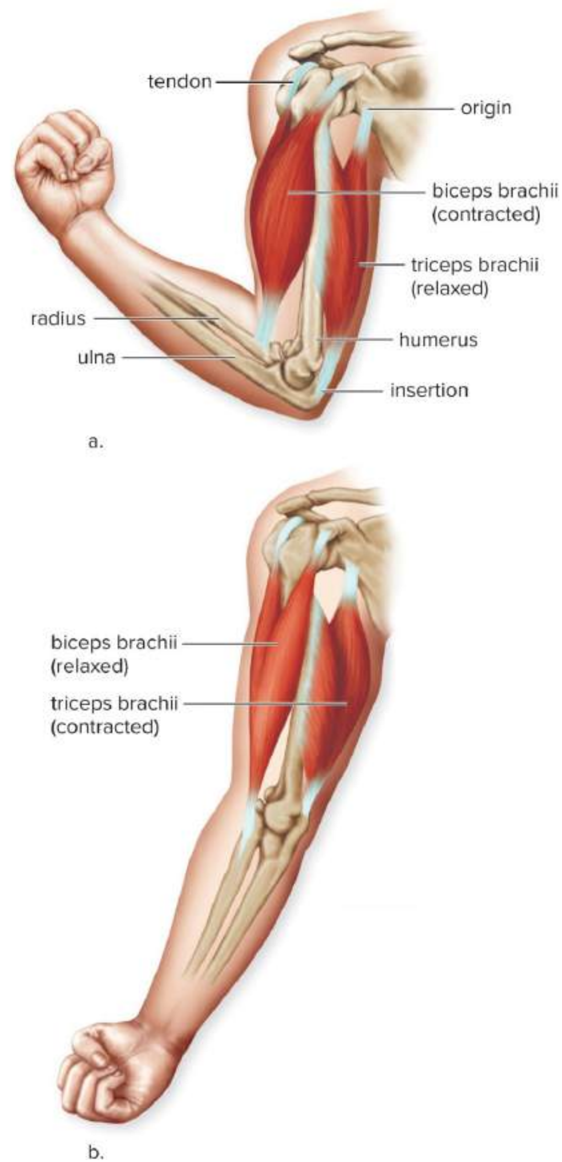
- When a muscle contracts, it pulls on the tendons at its insertion and the bone moves.
  - ie, when the biceps brachii contracts, it raises the forearm.

Skeletal Muscles Work in Pairs 2

Skeletal muscles usually function in groups.

- **Agonist (prime mover)**—the muscle that does most of the work.
- **Synergist**—assists the agonist.
- **Antagonist**—the muscle that acts opposite to a prime mover.
  - That is, the biceps brachii and the triceps brachii are antagonists; biceps flexes the forearm, and the triceps extends the forearm.
    - If both contract at once, there would be no movement.

Skeletal Muscles Often Work in Pairs (Figure 13.3)



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Names and Actions of Skeletal Muscles 1

The names of skeletal muscles often use the following terms to characterize them:

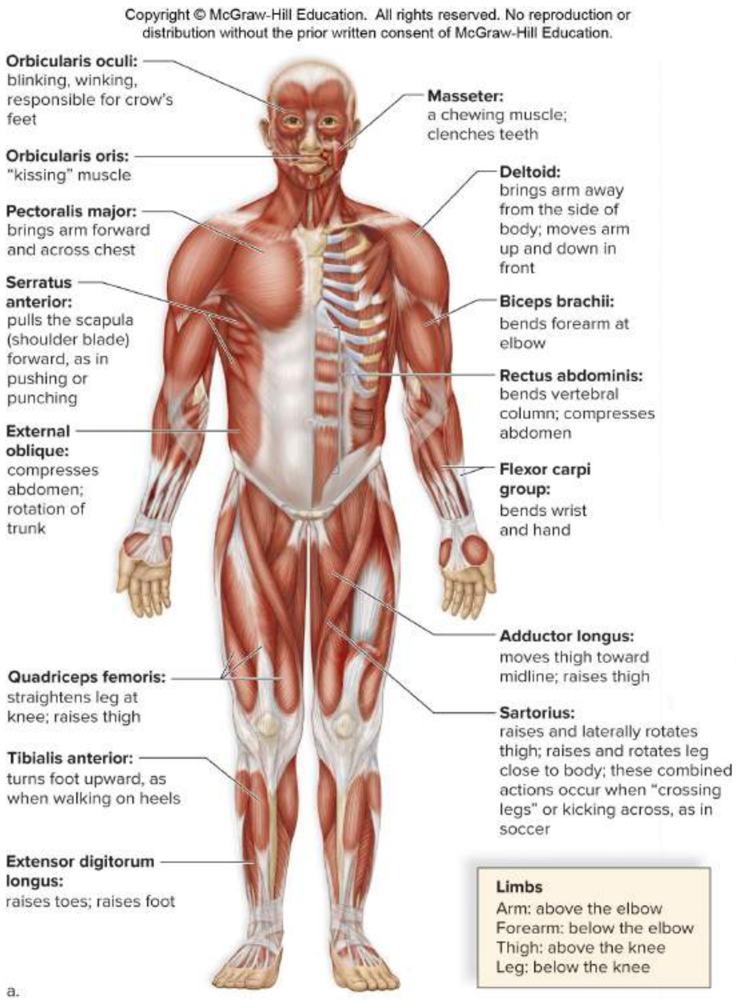
- **Size**: gluteus **maximus,** gluteus **minimus.**
  - Other terms used to indicate size: **vastus** (huge), **longus** (long), and **brevis** (short).
- **Shape**: **deltoid** (shaped like the Greek letter delta).
  - **Trapezius** is shaped like a trapezoid.
  - Other terms used to indicate shape are **latissimus** (wide) and **teres** (round).
- **Location: external** obliques, **internal** obliques.
  - **Frontalis** muscle overlies the frontal bone.
  - Other terms used to indicate location are **pectoralis** (chest), **gluteus** (buttock), **brachii** (arm), and **sub** (beneath).
- **Direction of muscle fibers: rectus** abdominis (**rectus** = "straight").
  - **Orbicularis** oculi—circular muscle around the eye.
  - Other terms used to indicate direction are **transverse** (across) and **oblique** (diagonal).

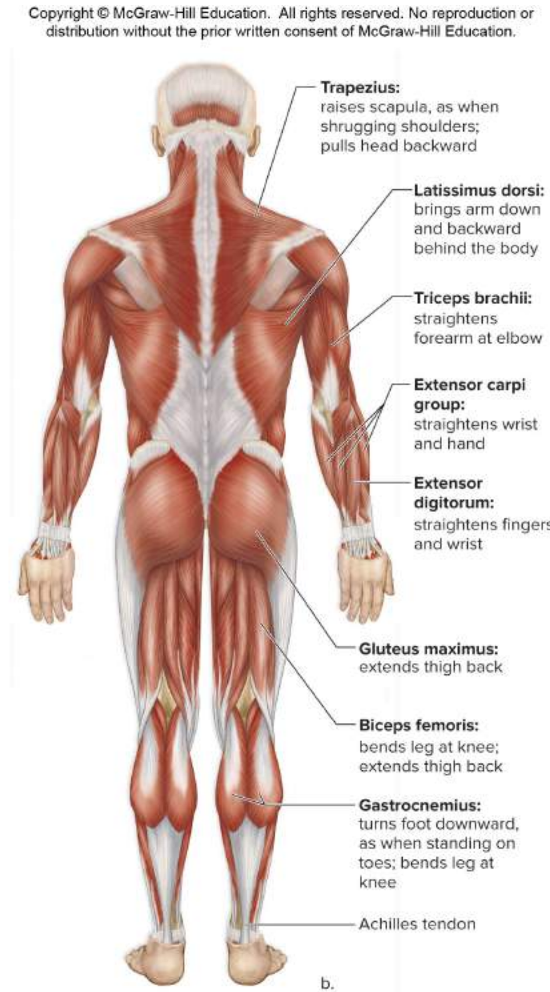
Names and Actions of Skeletal Muscles 3

The names of skeletal muscles, continued:

- **Attachment**: **sternocleidomastoid** is attached to the sternum, clavicle, and mastoid process.
  - **Brachioradialis**—attached to the brachium (arm) and the radius (forearm).
- **Number of attachments: biceps** brachii has two attachments.
  - **Quadriceps** femoris has four origins.
- **Action: extensor** digitorum extends the fingers (digits).
  - **Adductor** longus adducts the thigh.
  - Other terms used to indicate action are **flexor** (to bend), **masseter** (to chew), and **levator** (to lift).

The Major Skeletal Muscles of the Human Body (Figure 13.5)





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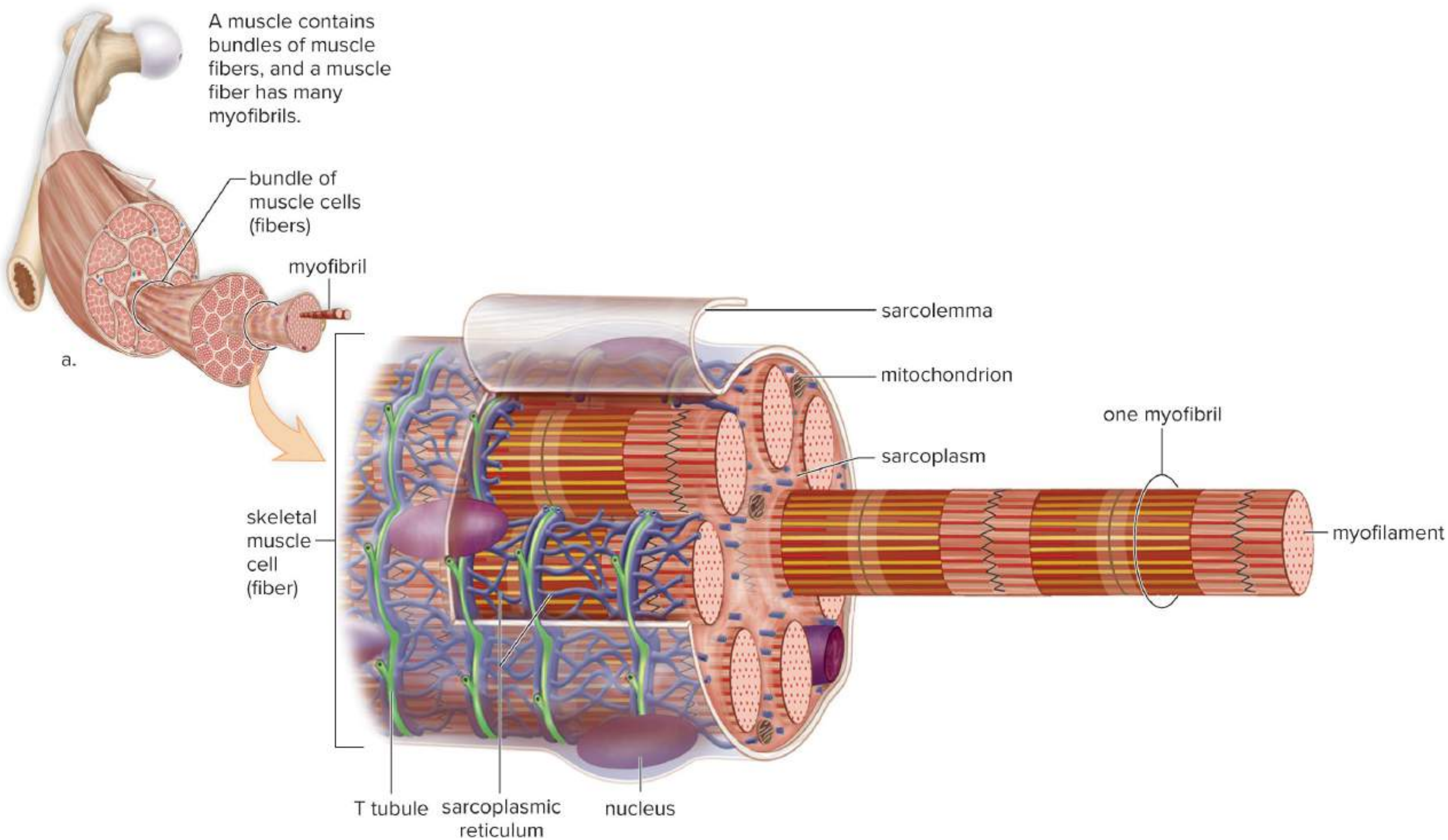
Anatomy of a Muscle Fiber (Table 13.1)

Table 13.1 Anatomy of a Muscle Fiber.

Name	Function
Sarcolemma	The plasma membrane of a muscle fiber that forms T tubules
Sarcoplasm	The cytoplasm of a muscle fiber that contains the organelles, including myofibrils
Myoglobin	A red pigment that stores oxygen for muscle contraction
T tubule	An extension of the sarcolemma that extends into the muscle fiber and conveys impulses that cause Ca^{2+} to be released from the sarcoplasmic reticulum
Sarcoplasmic reticulum	The smooth endoplasmic reticulum (ER) of a muscle fiber that stores Ca^{2+}
Myofibril	A bundle of myofilaments that contracts
Myofilament	An actin or a myosin filament, whose structure and functions account for muscle striations and contractions

The Structure of a Skeletal Muscle Fiber (Figure 13.6)



Muscle Fibers and How They Slide 2

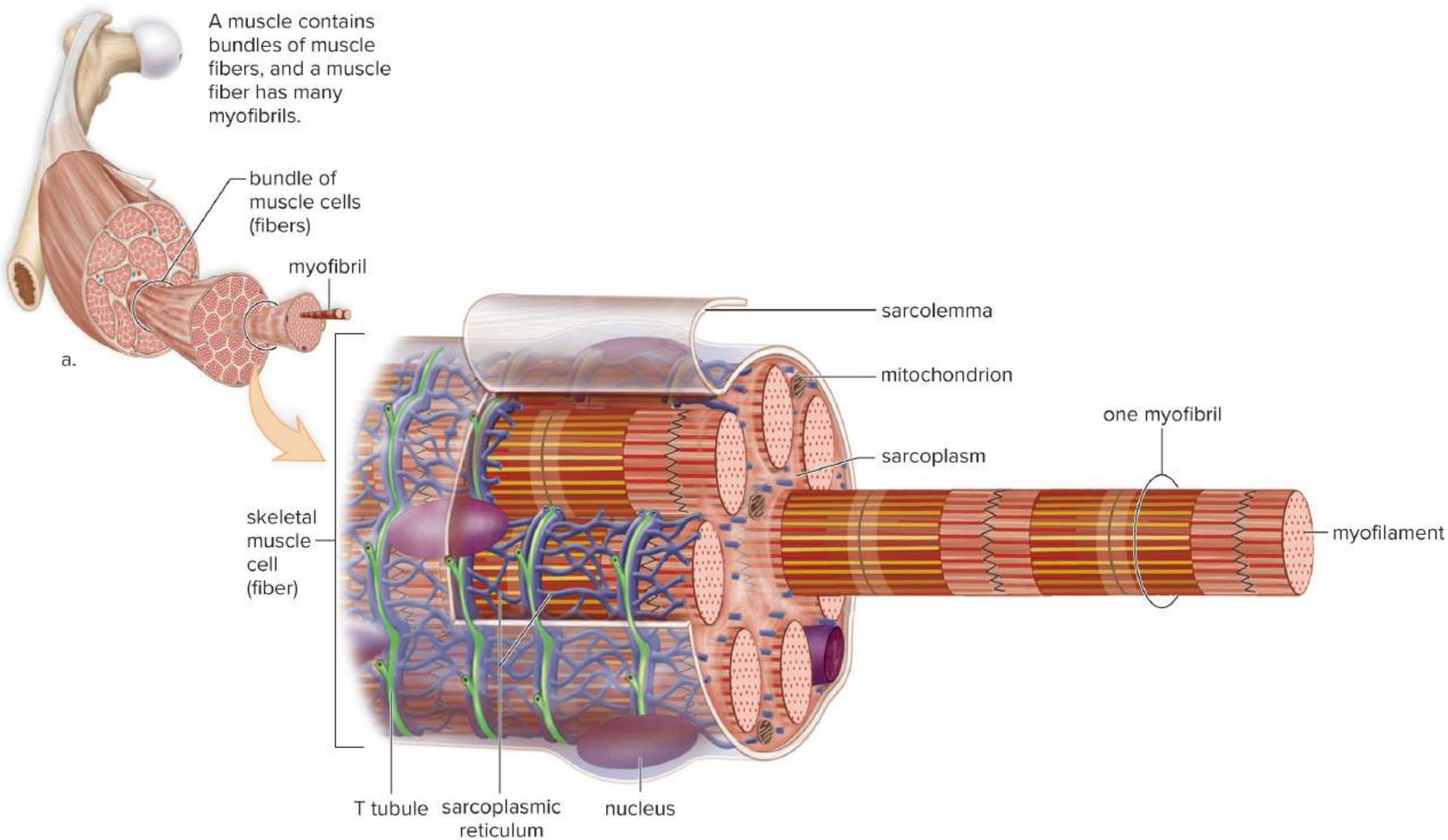
Cellular components of a muscle fiber, continued:

- The sarcolemma contains many **myofibrils**, the contractile parts of muscle fibers.
- The sarcoplasm also contains many mitochondria and glycogen, which provides energy for muscle contraction.
- The sarcoplasm includes the red pigment **myoglobin**, which binds oxygen.

Muscle fibers

- Cylindrical in shape.
- Grouped inside this larger cylinder are smaller cylinders called **myofibrils.**
  - Myofibrils run the entire length of the muscle fiber.
  - Made of smaller cylinders called **myofilaments.**
- **Striations**—stripes formed by the placement of myofilaments within myofibrils.
- Two types of myofilaments:
  - Thick myofilaments are **myosin.**
  - Thin myofilaments are **actin.**

The Structure of a Skeletal Muscle Fiber (Figure 13.6)



Myofibrils and Sarcomeres 3

Muscle fiber, concluded.

- Myofibrils are further divided into **sarcomeres.**
  - Sarcomeres extend between two dark vertical lines called **Z lines.**
  - **I band**—light colored; made of only thin myofilaments.
  - **A band**—made of overlapping thin and thick myofilaments.
    - Centered within the A band is a vertical **H band**, which contains only thick myofilaments.

Myofilaments

Thick filaments.

- Composed of the protein **myosin.**
  - Each myosin molecule is shaped like a golf club, with the straight portion of the molecule ending in a globular head, or **cross-bridge**.

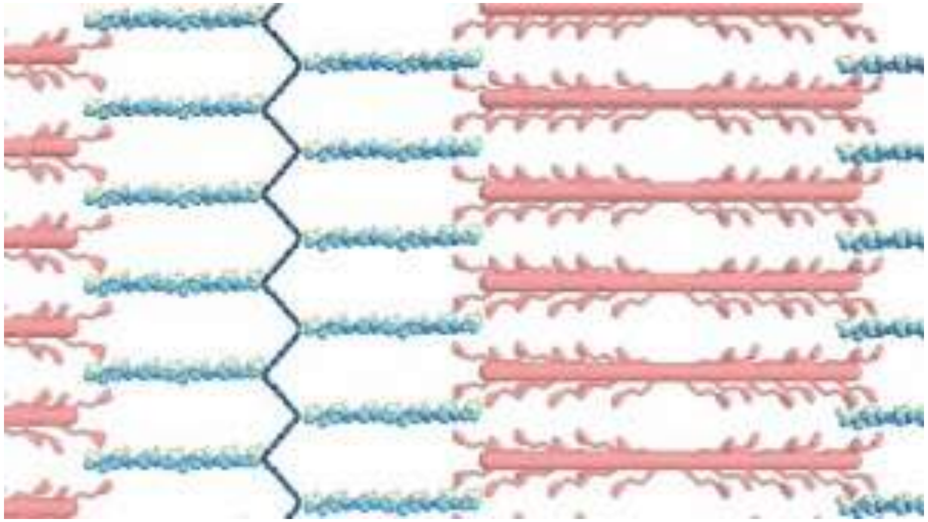
Thin filaments.

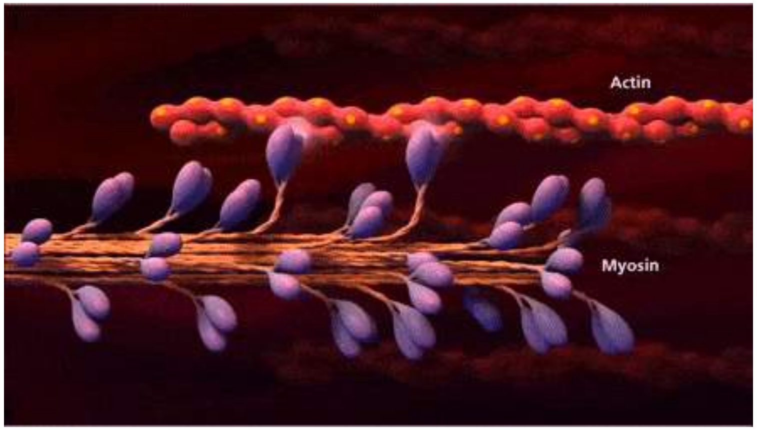
- Made of two intertwining strands of the protein **actin**, with **tropomyosin,** and **troponin.**

Sliding Filament Model 1

Sliding filament model: the muscle fiber contracts as the sarcomeres shorten.

- The thin filaments slide past the thick filaments.
- The I band shortens, the Z lines move inward, and the H band almost disappears.



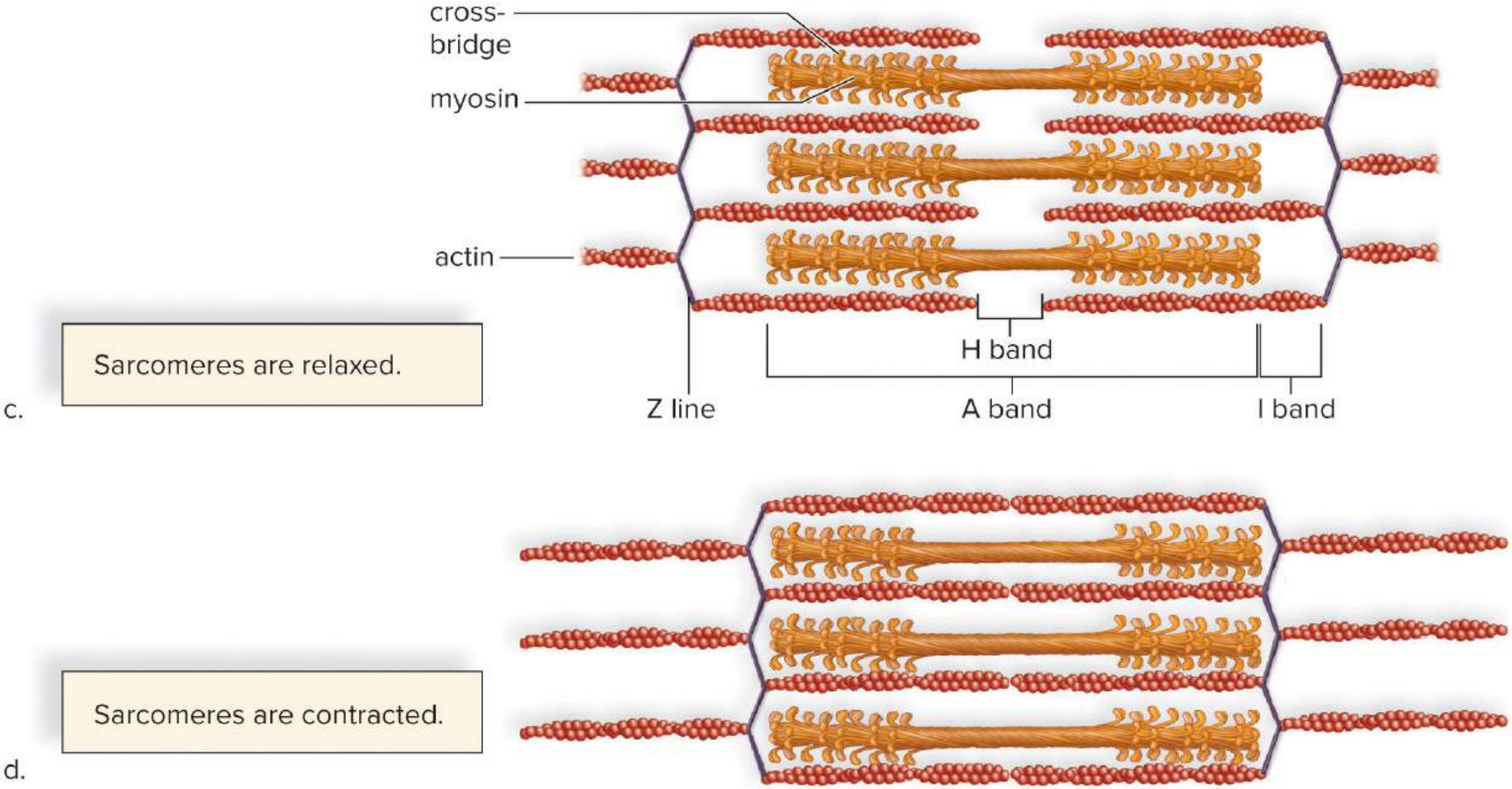


Sliding Filament Model [2]

Sliding filament model, continued:

- **ATP** supplies the energy for muscle contraction.
  - Myosin filaments break down ATP, and their cross-bridges pull the actin filament toward the center of the sarcomere.

Sliding Filament Model (Figure 13.6)



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Muscle Fiber Contraction [1]

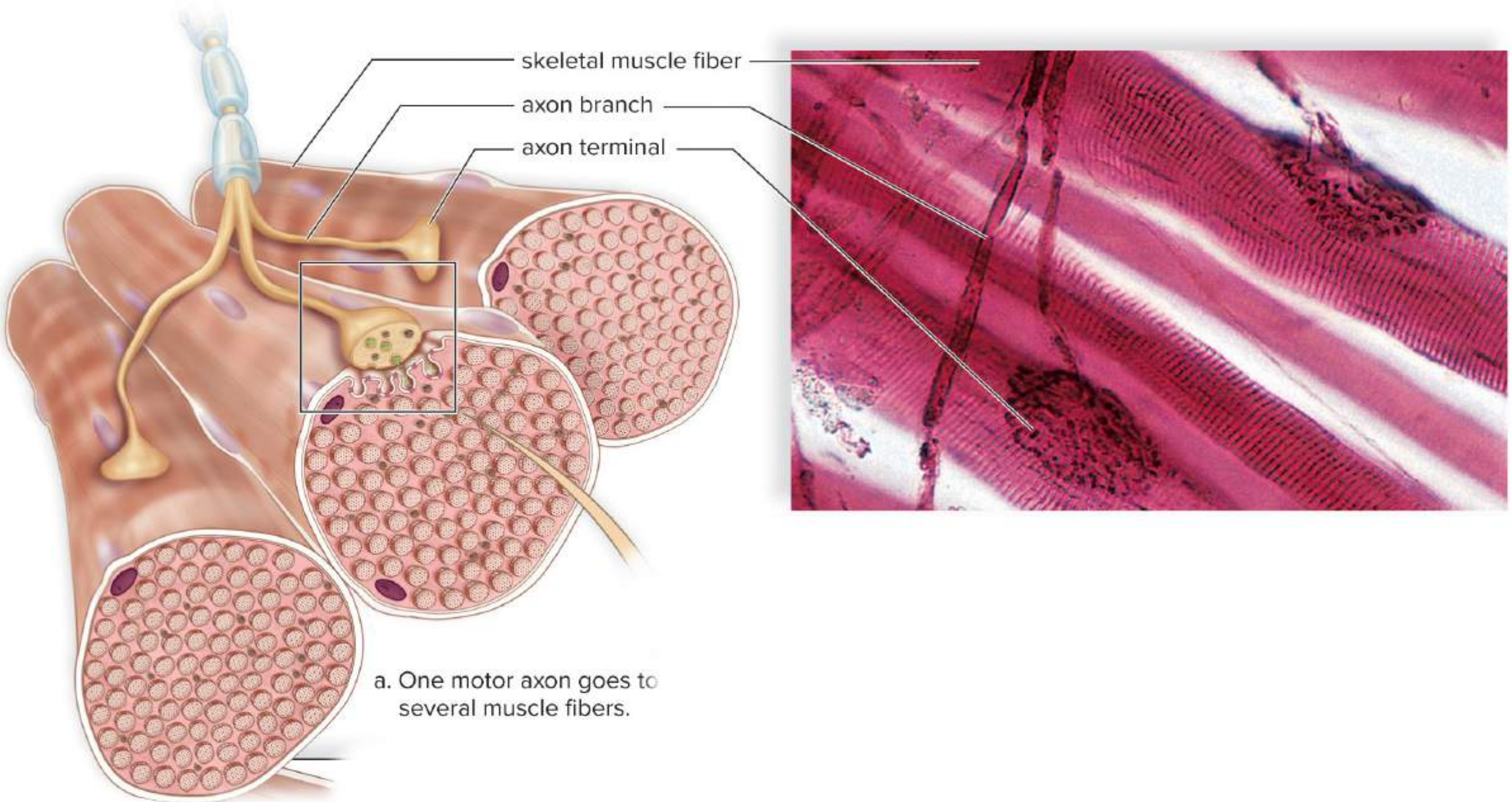
Motor neuron—a type of nervous system cell that stimulates muscle fibers to contract.

Nerve—group of neurons.

Axon—the part of a neuron that stimulates a muscle fiber.

- Branches, so can stimulate several muscle fibers.

Motor Neurons and Skeletal Muscle Fibers Join Neuromuscular Junctions (Figure 13.7a)



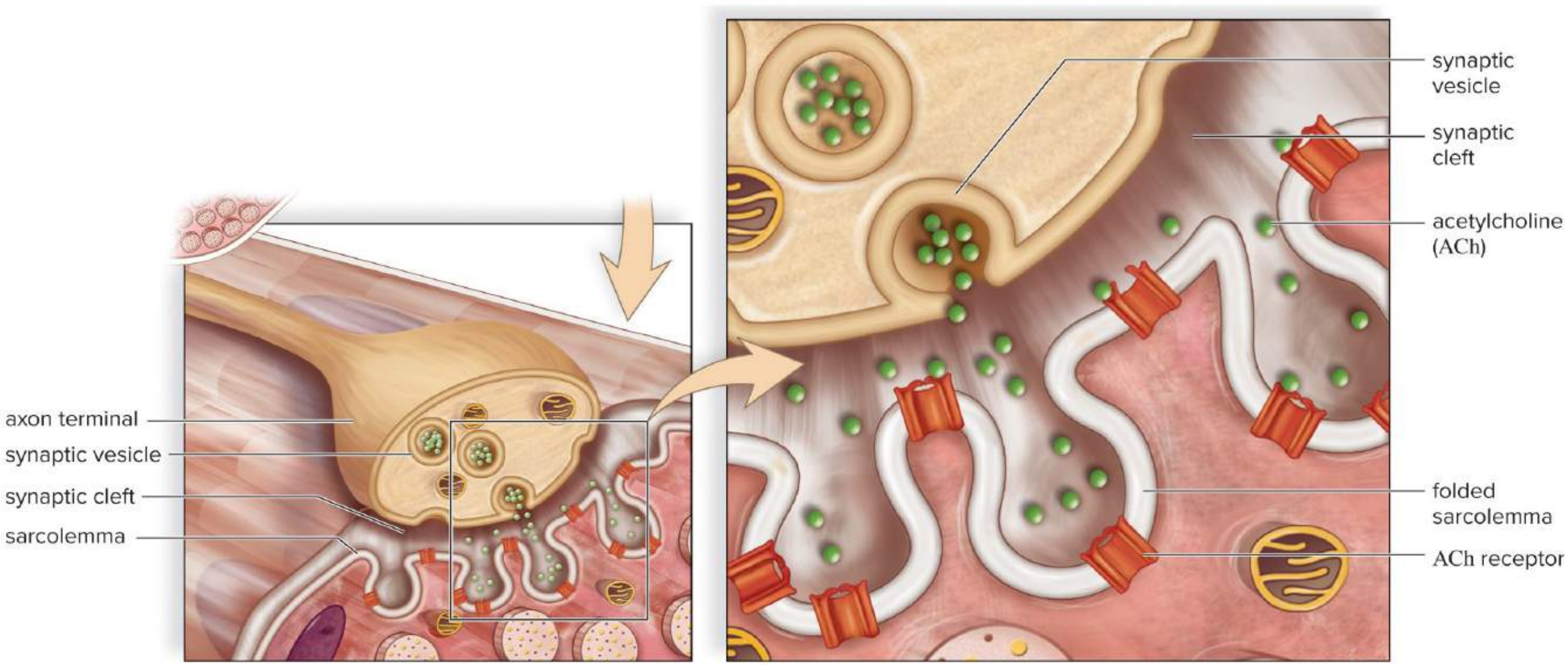
a. One motor axon goes to several muscle fibers.

Muscle Fiber Contraction 2

Neuromuscular junction.

- Where an **axon terminal** (end of an axon) comes near the sarcolemma.
  - **Synaptic cleft**—the space that separates the two.
- Axon terminals contain **synaptic vesicles** filled with the neurotransmitter **acetylcholine (ACh).**
  - synaptic vesicles release ACh into the synaptic cleft.
- ACh diffuses across the cleft and binds to receptors in the sarcolemma.
  - This generates electrical signals that spread across the sarcolemma and down the **T tubules**.
  - This causes **calcium (Ca^{2+})** to be released from the sarcoplasmic reticulum!

Motor Neurons and Skeletal Muscle Fibers Join Neuromuscular Junctions (Figure 13.7b-c)



b. A synaptic cleft exists between an axon terminal and a muscle fiber.

c. Neurotransmitter (ACh) diffuses across synaptic cleft and binds to receptors in sarcolemma.

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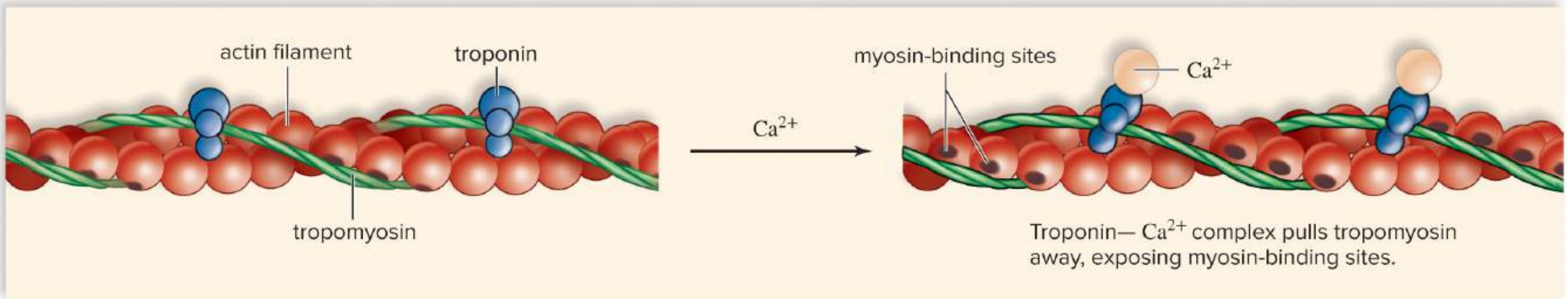
More Muscle Fiber Contraction

Two other proteins are in thin filaments:

- **Tropomyosin** wind around the strands of actin, **covering binding sites for myosin**.
- **Troponin** is attached to tropomyosin.
- When **Ca^{2+}** is released from the sarcoplasmic reticulum, it binds to troponin.
  - The tropomyosin threads move, **exposing myosin-binding sites.**
  - **Now, contraction begins!**

The Role of Calcium Ions and ATP During Muscular Contraction (Figure 13.8a)



a. Function of Ca^{2+}

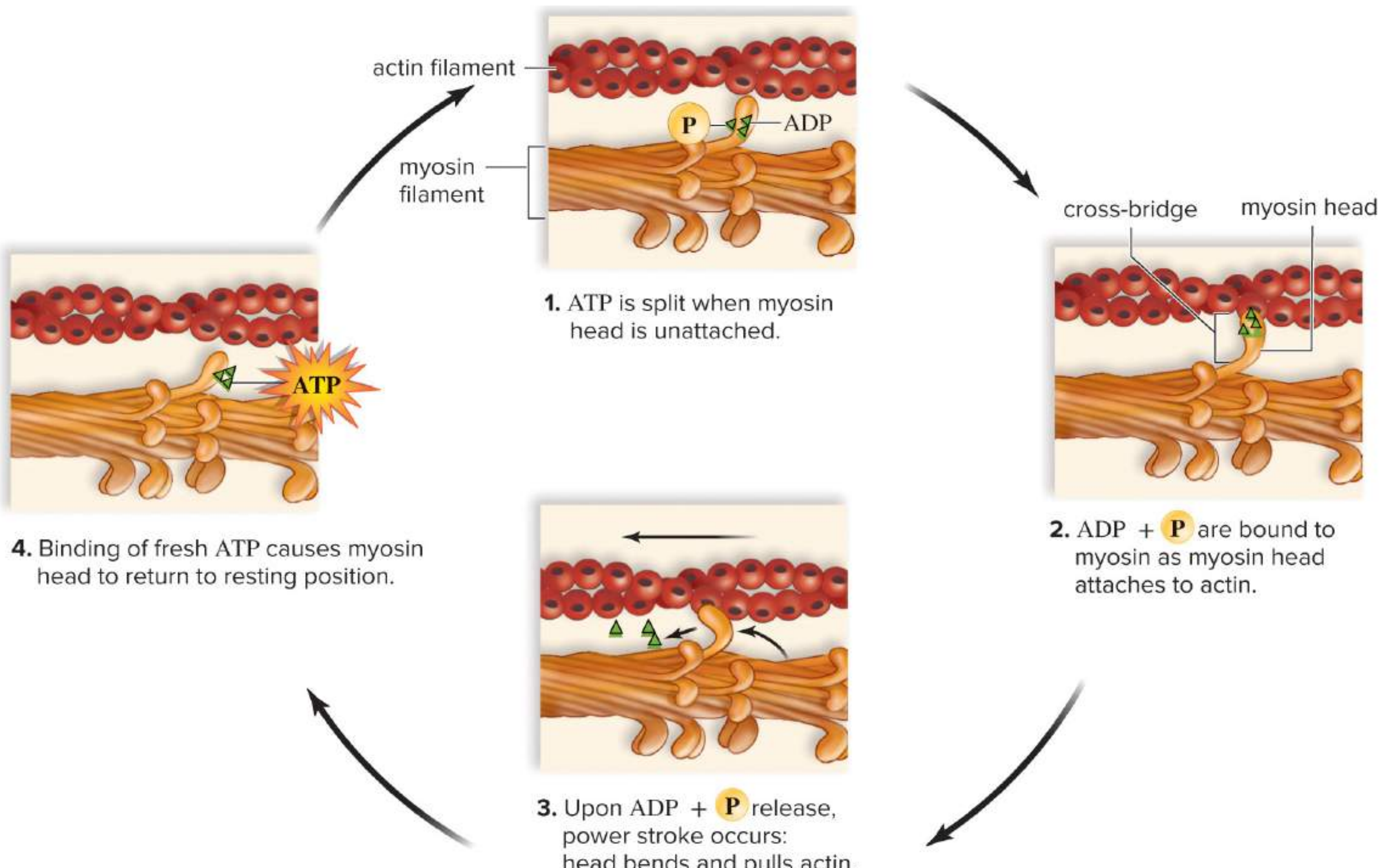
https://www.youtube.com/watch?v=CepeYFvqmk4&t=122s

Steps of the Sliding Filament Theory 1

Steps of the sliding filament theory.

- The myosin heads bind an ATP molecule.
  - At this site, ATP is split to form ADP and P.
- Myosin heads attach to actin.
  - Form temporary bonds called **cross-bridges.**
- ADP and P are then released and the myosin heads bend.
  - This is the **power stroke** that pulls the actin filament toward the center of the sarcomere.

The Role of Calcium Ions and ATP During Muscular Contraction (Figure 13.8b)



b. Function of myosin

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Steps of the Sliding Filament Theory 2

Steps of the sliding filament theory, continued.

- The binding of ATP to myosin heads breaks the cross-bridges.
  - Myosin detaches from actin.
  - The cycle recurs over and over, shortening the sarcomere (and therefore the muscle).
  - **Rigor mortis**—relaxing the muscle is impossible, because ATP is needed to break the cross-bridges.

Muscular Diseases

Myalgia—achy muscles; most often caused by overuse of a muscle.

Myositis—inflammation of the muscles.

- Caused by a viral infection or an immune system disorder.

Fibromyalgia—a chronic condition.

- Pain, tenderness, and stiffness of muscles.
- Precise cause is not known.

Muscular Dystrophy

Muscular dystrophy—a group of disorders characterized by progressive degeneration and weakening of muscles.

- **Duchenne muscular dystrophy**—the most common type.
  - Inherited; a damaged **dystrophin protein.**
  - Calcium leaks into the cell and activates an enzyme that dissolves muscle fibers.

https://www.youtube.com/watch?v=Ebu8W8Osuxk

Anatomical terms

Dorsum – pertaining to the back

Gluteal – pertaining to the buttocks

Lumbar – pertaining to the area of the back between the ribs and the hips

Manus – pertaining to the hand

Occipital – pertaining to the posterior aspect of the head or the base of the skull

Olecranal – pertaining to the posterior aspect of the elbow

Otic – pertaining to the ear

Perineal – pertaining to the region between the anus and external genitalia

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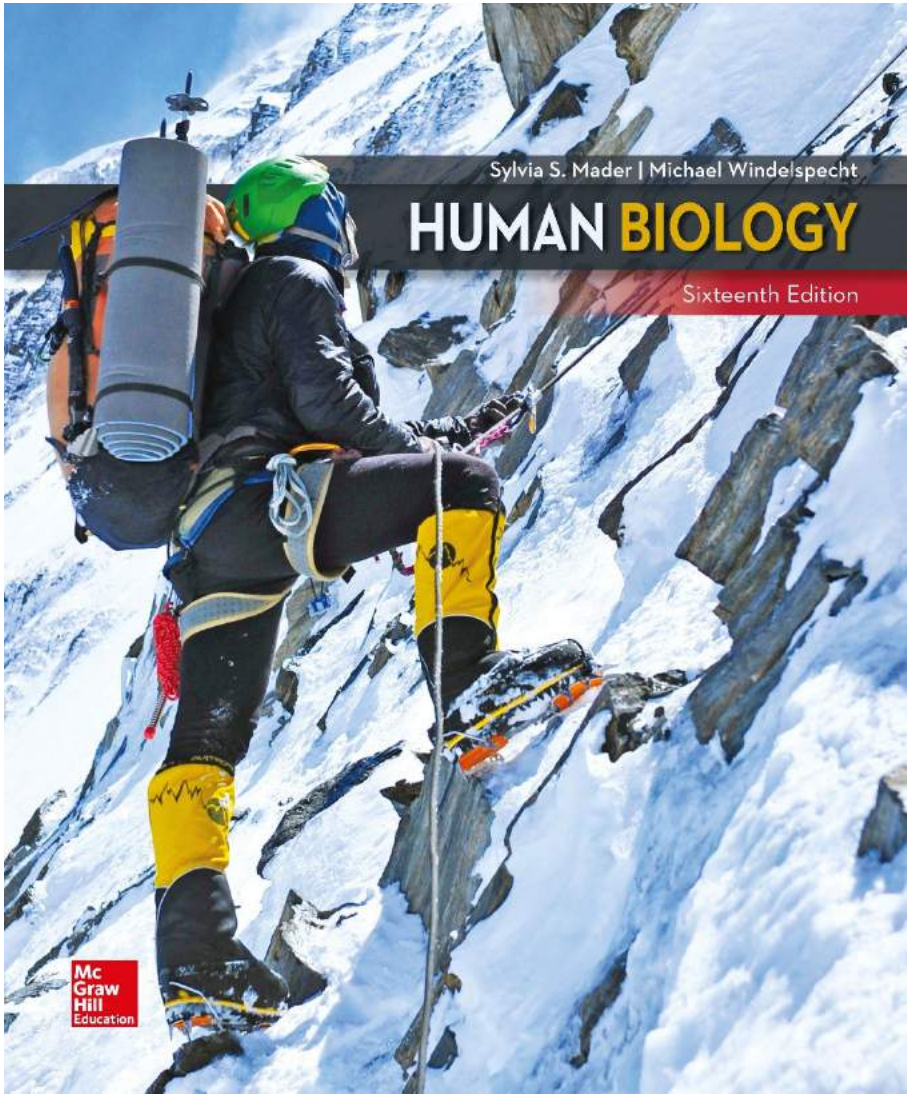


Sylvia S. Mader

Michael Windelspecht

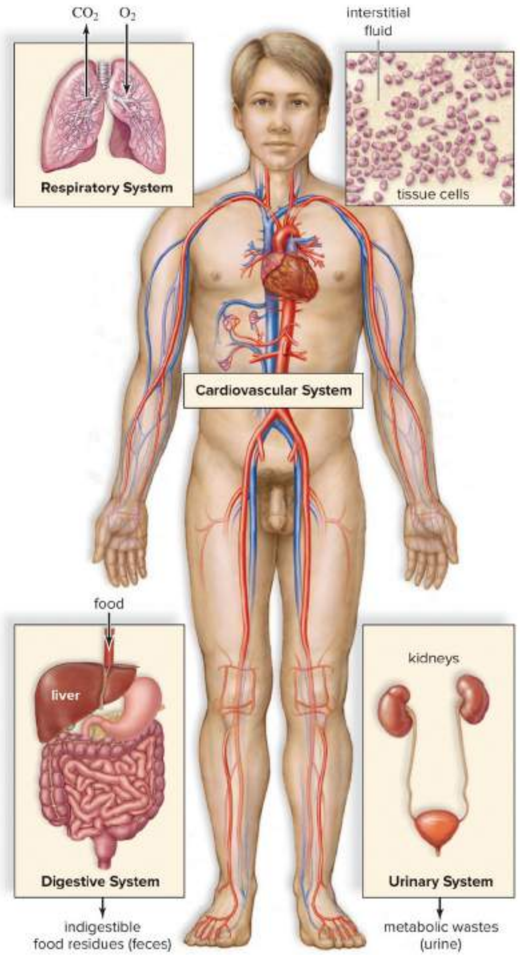
Lab 8 Cardiovascular

Overview of the Cardiovascular System 2

Cardiovascular system.

- Made up of the heart and blood vessels.
- The heart pumps blood through blood vessels.
  - It brings nutrients to cells and helps get rid of wastes.
  - Exchange of substances occurs through interstitial fluid.

The Cardiovascular System and Homeostasis (Figure 5.1)



Functions of the Cardiovascular System

Functions of the cardiovascular system.

- Transport: oxygen, carbon dioxide, and other waste products, nutrients, and hormones.
- Protection: cells of the immune system are transported to help protect the body from infection.
- Regulation: maintains homeostasis of a variety of the body's conditions.
  - That is, pH balance, electrolyte levels.

Lymphatic System

Lymphatic system assists the cardiovascular system by collecting excess tissue fluid and returning it to the blood.

- When fluid enters the lymphatic vessels it is called **lymph.**

The Types of Blood Vessels 1

Learning Outcomes:

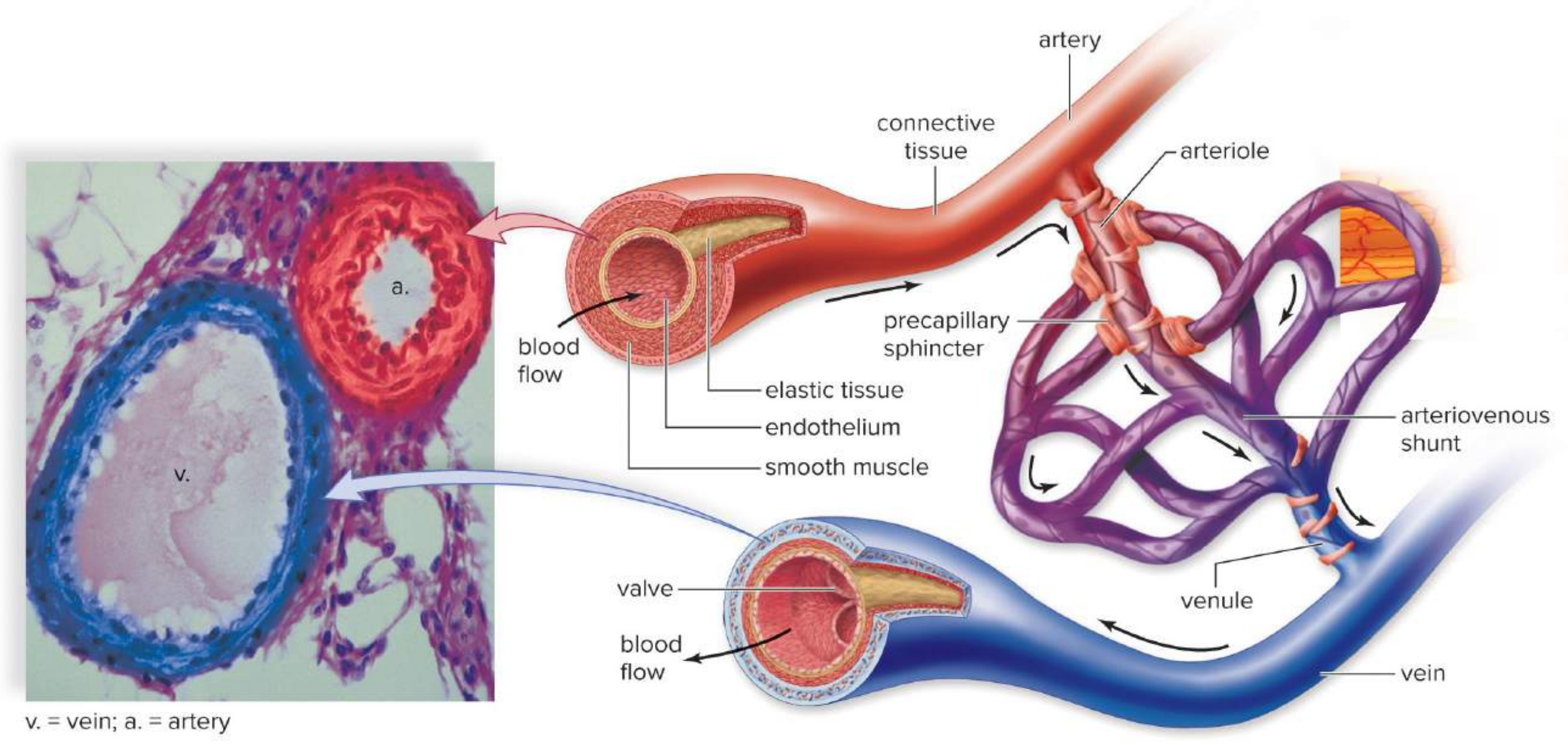
- Describe the structure and function of the three types of blood vessels.
- Explain how blood flow is regulated in each of the three types of blood vessels.

The Types of Blood Vessels 2

There are three types of blood vessels: **arteries**, **veins**, and **capillaries.**

- **Artery**—carries blood away from the heart.
  - Their walls have 3 layers:
    - **Endothelium**—the thin, inner epithelium.
    - Middle layer—smooth muscle and elastic tissue.
      - Allows arteries to expand and recoil.
    - Outer layer—connective tissue.

Structure of Arteries and Veins (Figure 5.2)



v. = vein; a. = artery

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Arterioles

Arterioles.

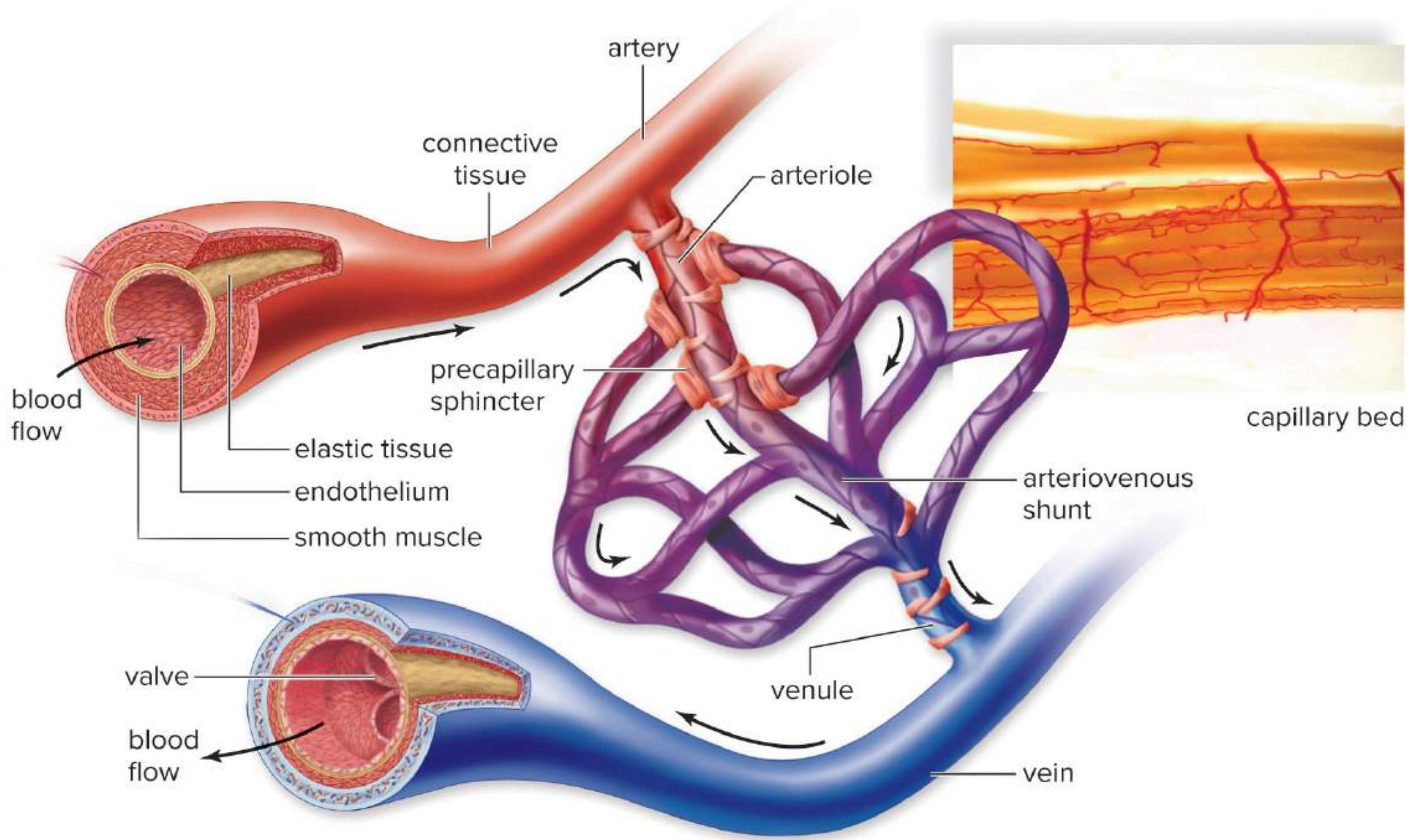
- Small arteries.
- Middle layer has mostly smooth muscle.
  - It contracts to constrict the vessel, reducing blood flow and raising blood pressure.
  - When relaxed, the vessel dilates, increasing blood flow and reducing blood pressure.

The Capillaries: Exchange

Capillaries.

- Microscopic vessels between arterioles and venules.
- Walls of capillaries are made only of endothelium.
- Form **capillary beds** where gas, nutrient, and waste exchange occurs.
- Have **precapillary sphincters**, which control blood flow through the capillary bed.
    - When closed, blood instead flows through an **arteriovenous shunt.**

Structure of a Capillary Bed (Figure 5.2)



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(capillary bed): ©Steve Gschmeissner/Science Photo

The Veins: To the Heart [1]

Venules—small veins that receive blood from the capillaries.

Veins carry blood toward the heart.

- Venule and vein walls have the same 3 layers as arteries, but less smooth muscle in the middle layer.
- Veins that carry blood against gravity have **valves** to keep blood flowing toward the heart.

The Veins: To the Heart 2

Veins, continued.

- Walls of veins are thinner than arteries so they can expand to hold more blood.
  - At any one time, they store 70% of the blood.
  - If blood is lost (that is, hemorrhage), the nervous system causes the veins to constrict to increase blood volume.

Check Your Progress 5.2

List and describe the different types of blood vessels.

Describe how each blood vessel contributes to the flow of blood in the body.

Explain why the structure of the veins is different from that of the arteries.

The Heart is a Double Pump

Learning Outcomes:

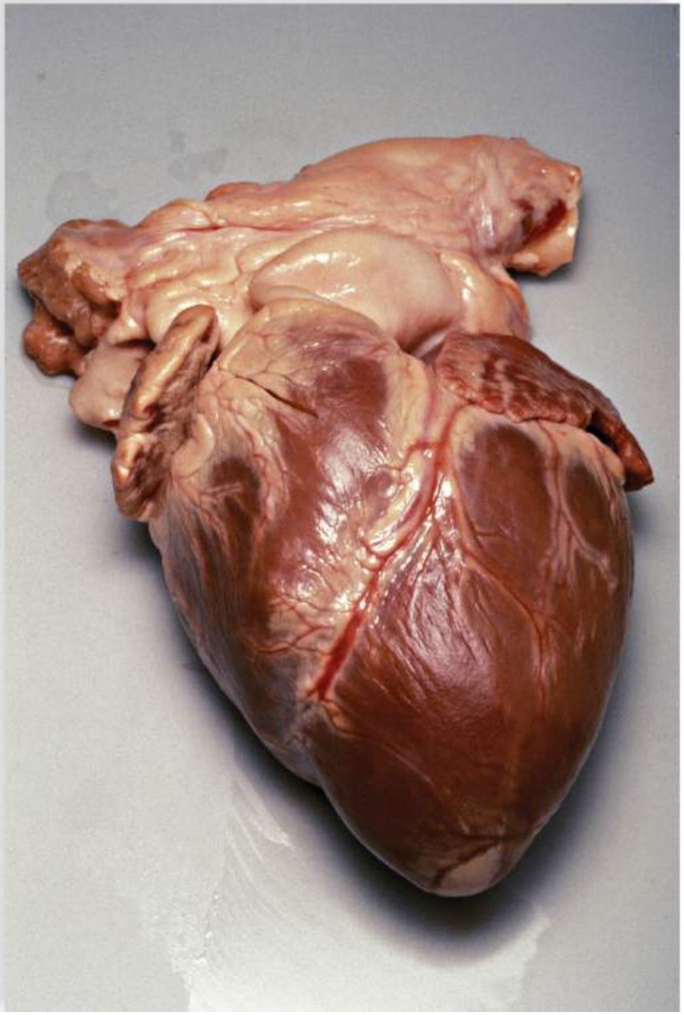
- Identify the structures and chambers of the human heart.
- Describe the flow of blood through the human heart.
- Explain the internal and external controls of the heartbeat.

The Heart [1]

The **heart.**

- Located between the lungs.
- Points toward the left hip.
- Consists mostly of the **myocardium**, which is made of cardiac muscle tissue.
    - Muscle fibers are branched and connected by **intercalated disks**, which contain gap junctions.
        - These allow cells to contract in unison.
    - Also connected by **desmosomes**, a type of cell junction that prevents overstretching by holding adjacent cells together.

The Heart is a Double Pump (Figure 5.4b)



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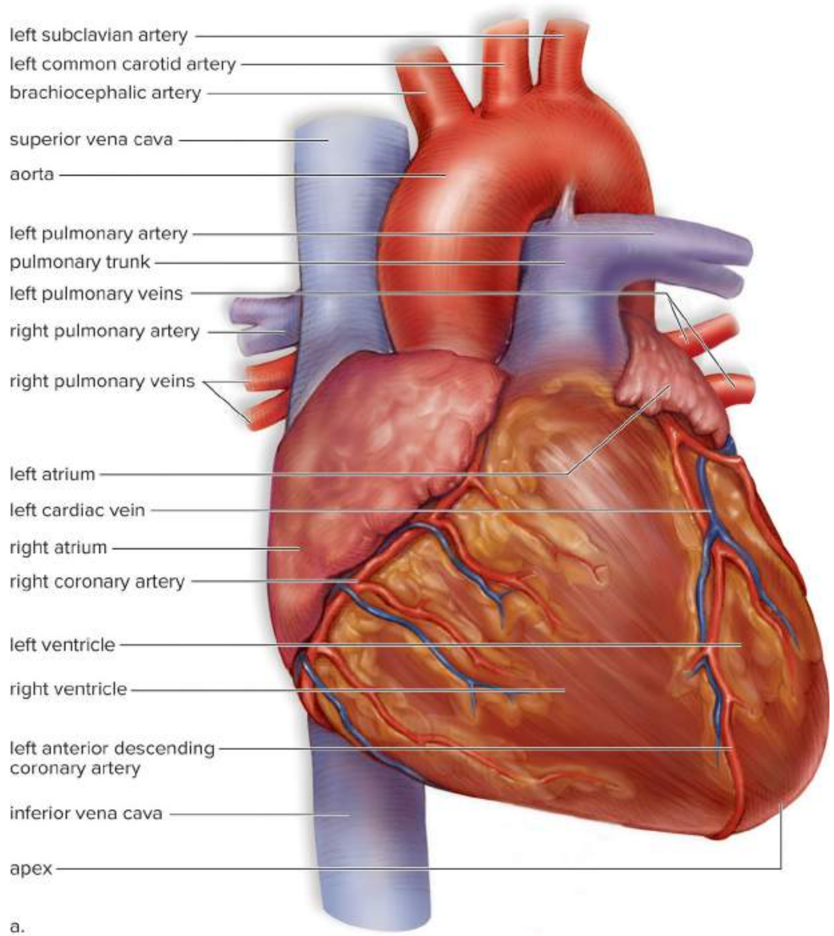
The Heart 2

The **heart, continued.**

- Surrounded by a sac called the **pericardium**, which secretes **pericardial fluid** for lubrication.
- Internally, the **septum** divides the heart into right and left sides.
- Consists of 4 chambers: 2 upper **atria** and 2 lower **ventricles.**

The Arteries and Veins Associated with the Heart (Figure 5.3a)



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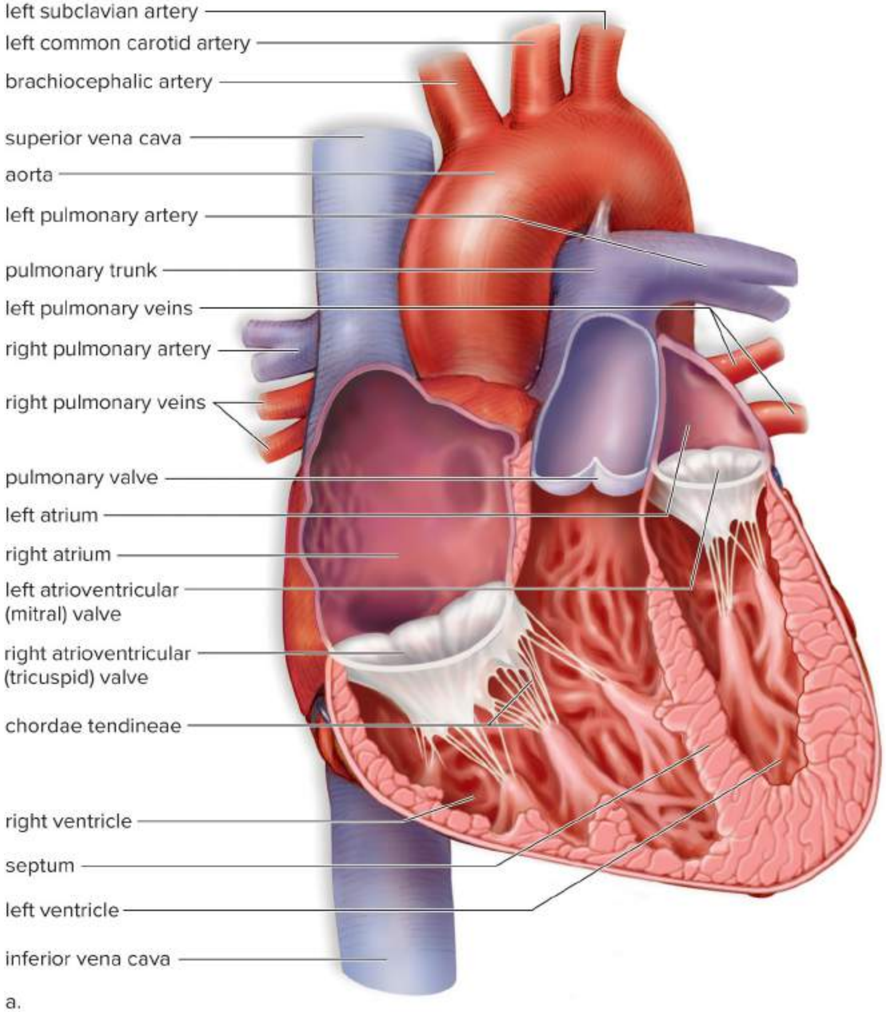
The Heart 3

The **heart, concluded.**

- 2 types of valves: **semilunar valves** and **atrioventricular (AV) valves.**
  - The AV valves are reinforced by **chordae tendineae.**
  - Left AV valve—**bicuspid**, or **mitral valve.**
  - Right AV valve—**tricuspid valve.**
  - Semilunar valves: **pulmonary valve** and **aortic valve.**

The Heart is a Double Pump (Figure 5.4a)



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Coronary Circulation: The Heart’s Blood Supply

The myocardium needs its own blood supply.

- **Coronary arteries** supply it.
  - They are the first branches off the aorta.
- **Coronary veins** drain it.
  - Empty into the right atrium.
- Coronary artery disease—blockage in the coronary arteries causes a **myocardial infarction** (heart attack).

Blood Flow Through the Heart 1

Blood flow through the heart.

- The **superior vena cava** and **inferior vena cava** carry O_2-poor, CO_2-rich blood from the body to the **right atrium.**
- Blood then flows through the **right AV (tricuspid) valve** into the **right ventricle.**
- The right ventricle pumps blood through the **pulmonary valve** into the **pulmonary trunk**, which branches into **right** and **left pulmonary arteries.**
  - They lead to the **lungs.**

Blood Flow Through the Heart 2

Blood flow through the heart, continued.

- The **pulmonary veins** carry O_2-rich, CO_2-poor blood from the lungs to the **left atrium.**
- Blood then flows through the **left AV (bicuspid) valve** into the **left ventricle.**
- The left ventricle pumps blood through the **aortic valve** into the **aorta.**
- The aorta branches into smaller arteries, which lead to arterioles, then capillaries, venules, veins and back to the vena cavae.

Blood Flow Through the Heart 3

The walls of the left ventricle are thicker than the right ventricle because it must pump blood to the entire body, not just to the lungs.

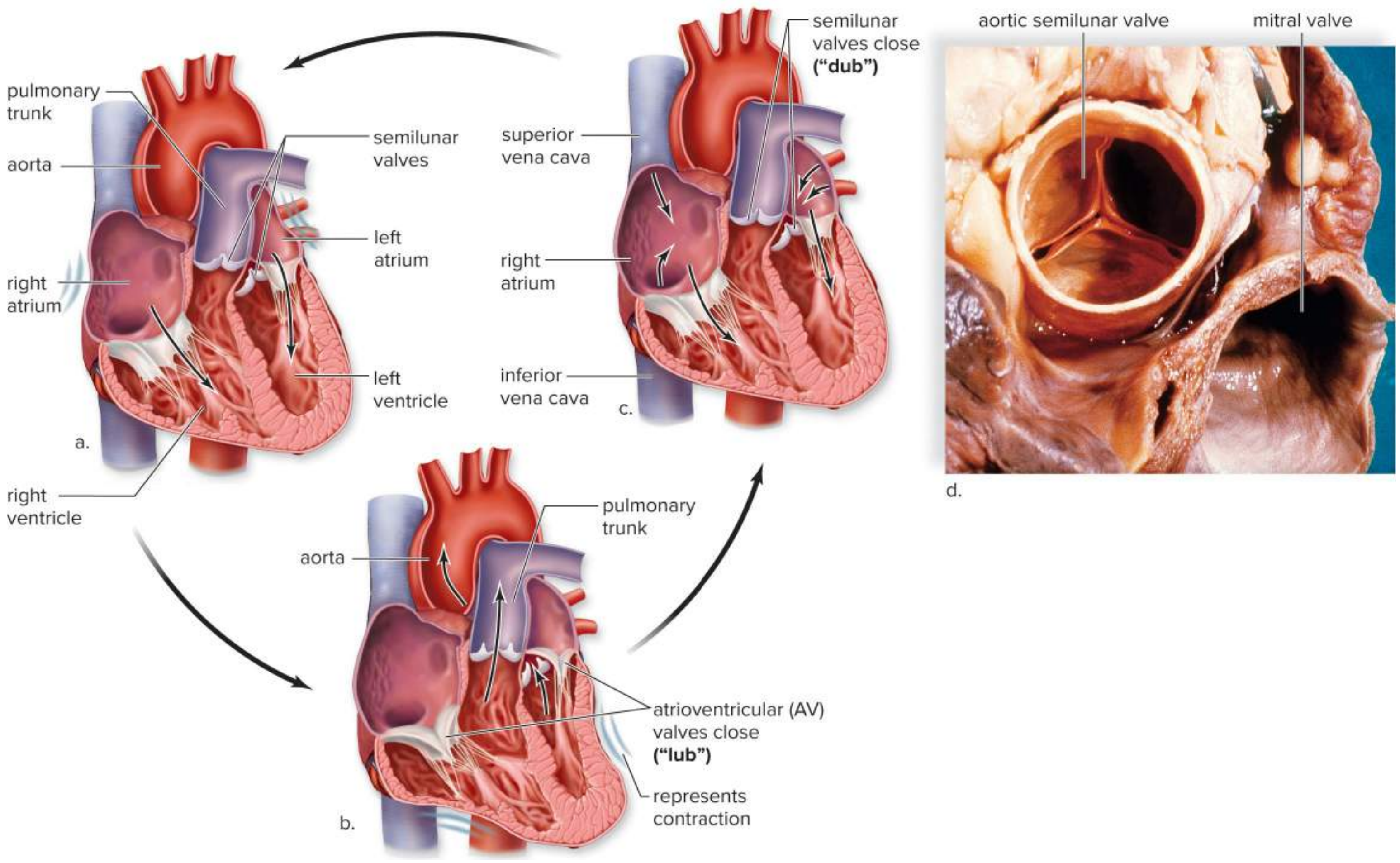
The walls of atria are thinner than ventricles.

The Heartbeat is Controlled

The **cardiac cycle.**

- First the atria contract together, then the ventricles, then the heart relaxes.
- **Systole**—heart contraction.
- **Diastole**—heart relaxation.
- Occurs 70 times per minute on average.
- There are two audible sounds: “lub-dub.”
  - Lub: from the closure of the AV valves.
  - Dub: from the closure of the semilunar valves.
  - **Murmur**: a swishing sound between “lub” and “dub” from regurgitation of blood (leaky valves).

The Stages of the Cardiac Cycle (Figure 5.5)



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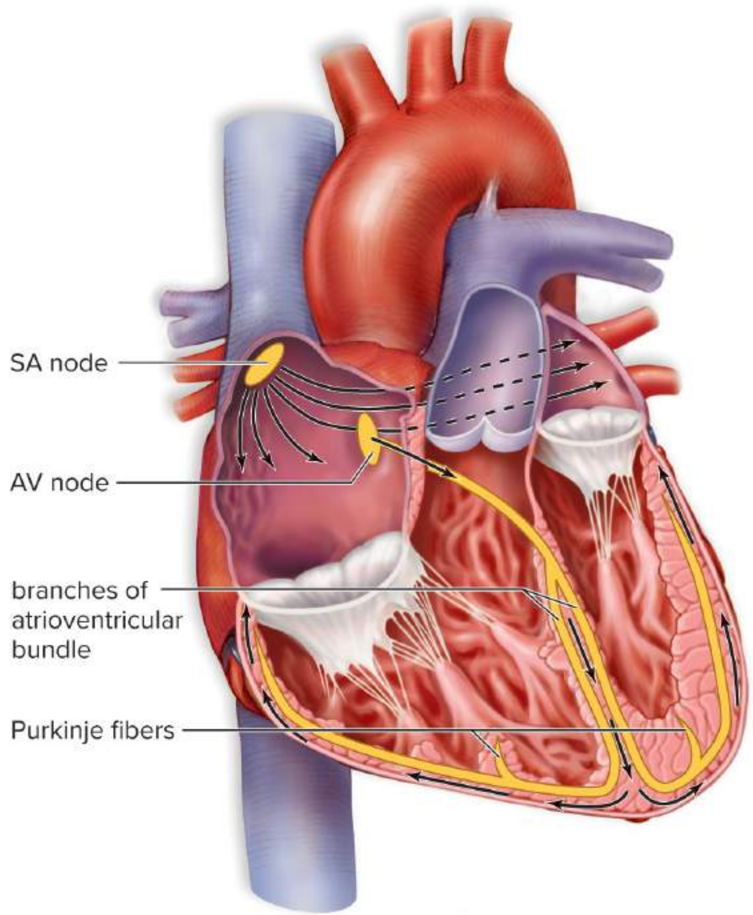
Internal Control of Heartbeat

Internal (intrinsic) conduction system.

- The **SA node** in the right atrium initiates the heartbeat by sending out an electrical signal; this causes the atria to contract.
  - SA node is called the **pacemaker.**
- This impulse reaches the **AV node**, also in the right atrium.
  - AV node sends a signal down the **AV bundle** and **Purkinje fibers**; this causes ventricular contraction.
- These impulses travel through gap junctions in the intercalated disks.

An Electrical Signal Pathway Through the Heart (Figure 5.6)



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External Control of Heartbeat

External (extrinsic) control of heartbeat.

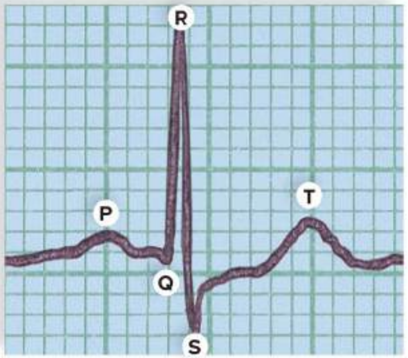
- The cardiac control center in the brain increases or decreases the heart rate depending on the body's needs.
- Some hormones increase heart rate.

An Electrocardiogram is a Record of the Heartbeat 1

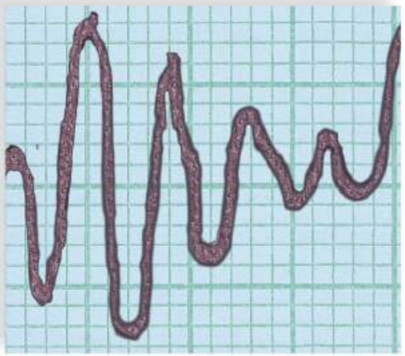
Electrocardiogram (ECG).

- A recording of the electrical changes in the heart muscle during a cardiac cycle.
- The atria produce an electrical current, called the **P wave**, when stimulated by the SA node.
- **QRS complex**—wave of electrical current traveling through the ventricles.
  - Signals that the ventricles are about to contract.
- The recovery of the ventricles is represented as the **T wave.**

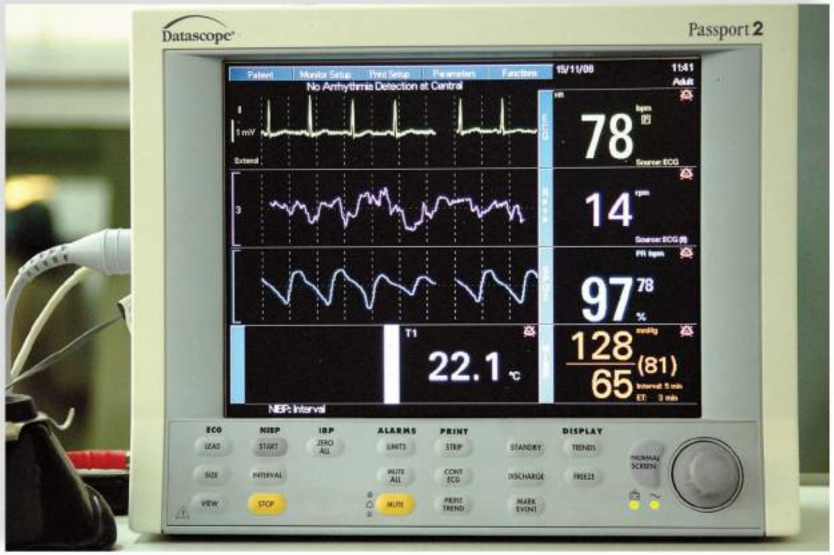
An Electrocardiogram (Figure 5.7)



a. Normal ECG



b. Ventricular fibrillation



c. Recording of an ECG

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An Electrocardiogram Is a Record of the Heartbeat 2

Electrocardiogram (ECG), continued.

- Detects abnormalities.
    - That is, **ventricular fibrillation—**caused by uncoordinated, irregular electrical signals in the ventricles.
        - The heart can't pump blood; tissues become starved of oxygen.
        - **Defibrillation—**applying a strong electrical signal to reset the heart; hopefully, the SA node will start firing again.

Features of the Cardiovascular System 2

Blood Pressure—the pressure that blood exerts against a blood vessel wall.

- Is highest in the aorta, right next to the heart; it gradually decreases as it flows through the vessels in the body.
- **Pulse**—surge of blood into an artery causes the walls to stretch, and then recoil.
    - Usually measured in the radial artery at the wrist or carotid artery in the neck.
    - A measurement of the heart rate; averages 60–80 beats per minute.
- Contraction of ventricles creates blood pressure, which propels blood through the arteries.
- Measured with a **sphygmomanometer**, in the brachial artery of the arm.

Blood Flow is Regulated 2

Blood Pressure, continued.

- **Systolic pressure**—the highest pressure; when blood is ejected from the heart.
- **Diastolic pressure**—the lowest pressure; when the ventricles relax.
  - Average is 120/80 mmHg (systolic/diastolic).
- **Hypertension**—high blood pressure.
- **Hypotension**—low blood pressure.

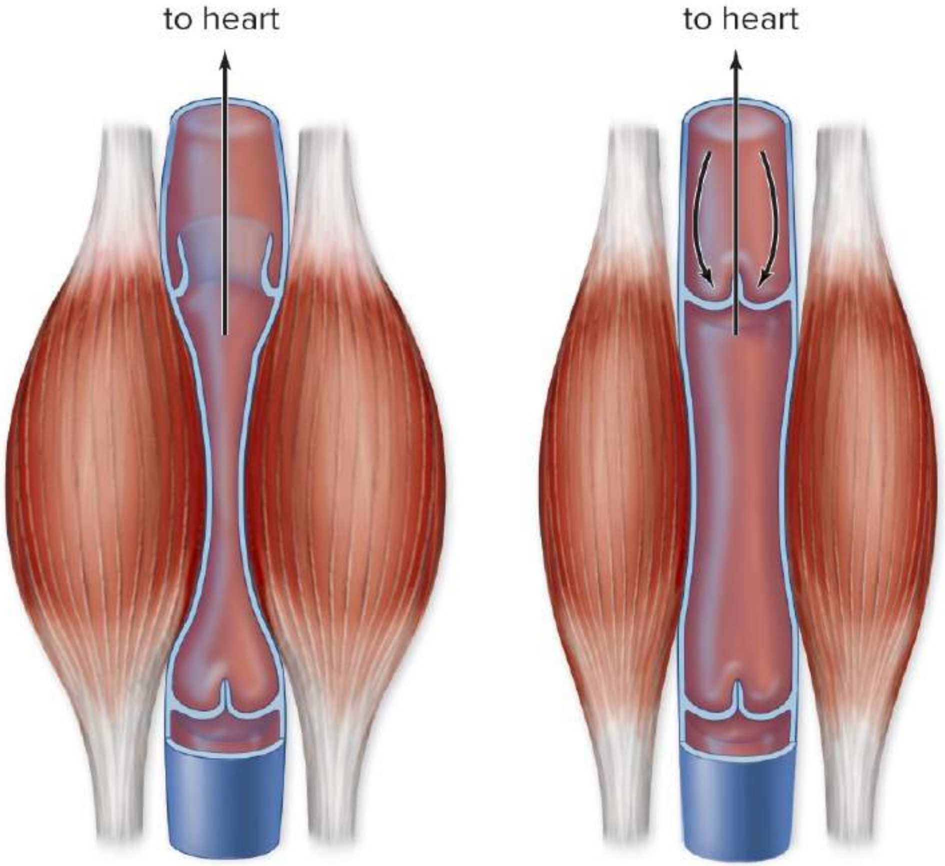
Normal Values for Adult Blood Pressure (Table 5.1)

Table 5.1 Normal Values for Adult Blood pressure*

	Top Number (Systolic)	Bottom Number (Diastolic)
Hypotension	Less than 95	Less than 50
Normal	Below 120	Below 80
Prehypertension	120 to 139	80 to 89
Stage 1 hypertension	140 to 159	90 to 99
Stage 2 hypertension	160 or more	100 or more
Hypertensive crisis (emergency care needed)	Higher than 180	Higher than 110

*Blood pressure values established by the American Heart Association (www.heart.org).

The Skeletal Muscle Pump (Figure 5.10)



a. Contracted skeletal muscle pushes blood past open valve.

b. Closed valve prevents backward flow of blood.

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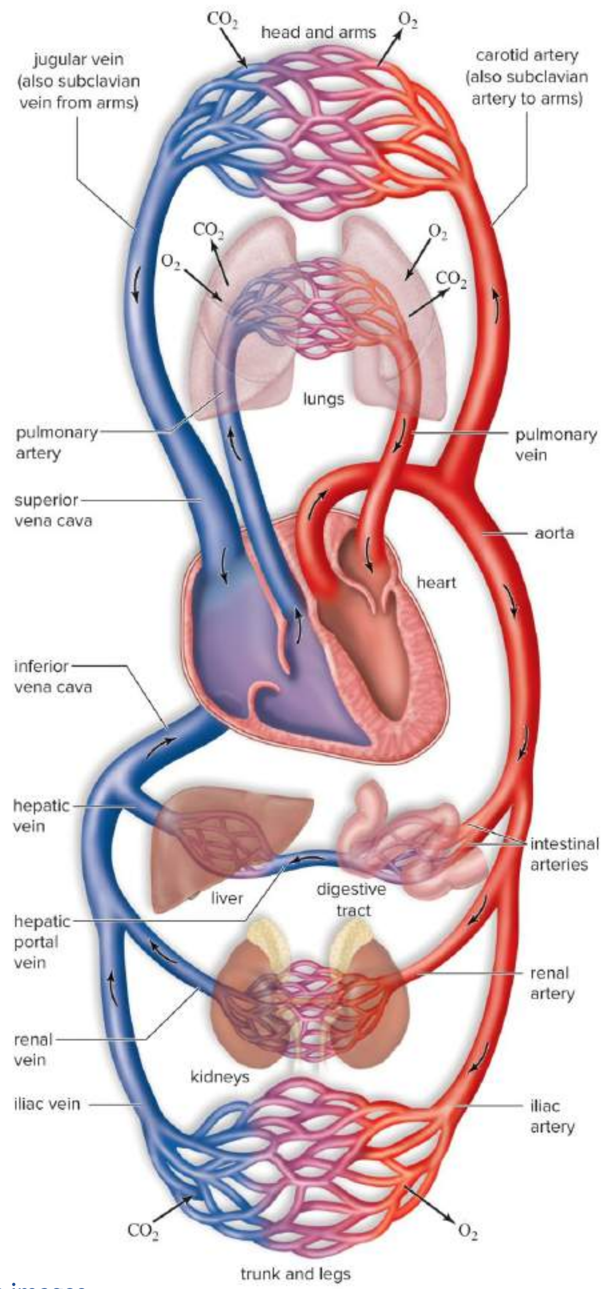
Two Cardiovascular Pathways 2

Blood flows in two circuits: the pulmonary circuit and systemic circuit.

- **Pulmonary circuit** circulates blood through the lungs.
- **Systemic circuit** circulates blood through the body tissues.

Overview of the Cardiovascular System (Figure 5.11)



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The Pulmonary Circuit: Exchange of Gases 1

Pulmonary circuit:

- Right atrium pumps deoxygenated blood into the right ventricle, which pumps it into the pulmonary trunk.
- The pulmonary trunk splits into right and left pulmonary arteries, which go to the lungs.
- In the lungs, the pulmonary arteries branch into arterioles, which lead to capillaries.
    - This is where gas exchange occurs.

The Pulmonary Circuit: Exchange of Gases 2

Pulmonary circuit, continued.

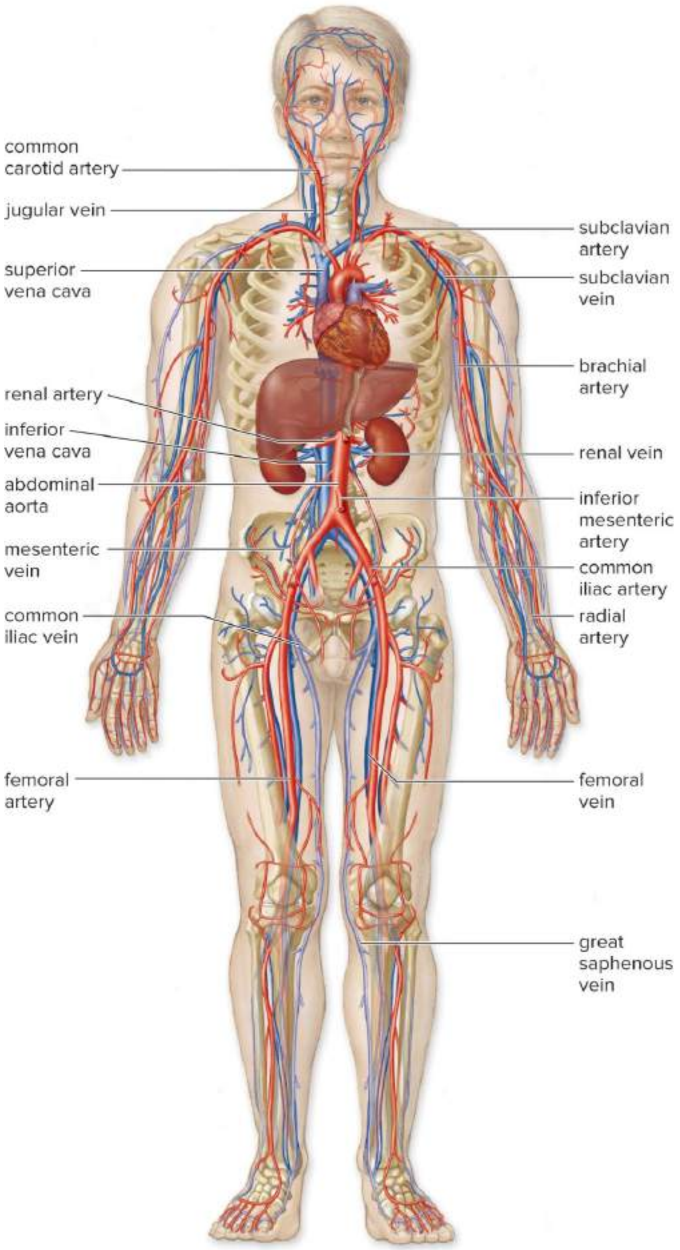
- The pulmonary capillaries lead to venules, which merge into the pulmonary veins.
- The four pulmonary veins empty into the left atrium.
- The pulmonary arteries carry oxygen-poor blood; the pulmonary veins carry oxygen-rich blood.

The Systemic Circuit: Exchanges with Interstitial Fluid 1

The systemic circuit:

- The left ventricle pumps blood into the aorta, which gives off branches to all the tissues of the body.
- Arteries branch into (eventually) arterioles, which lead to capillaries.
- Capillaries lead to venules, which drain into veins, which lead to the superior and inferior vena cavae.
- The vena cavae empty into the right atrium.

The Major Arteries and Veins of the Systemic Circuit (Figure 5.12)



The Systemic Circuit: Exchanges with Interstitial Fluid 2

The systemic circuit, continued.

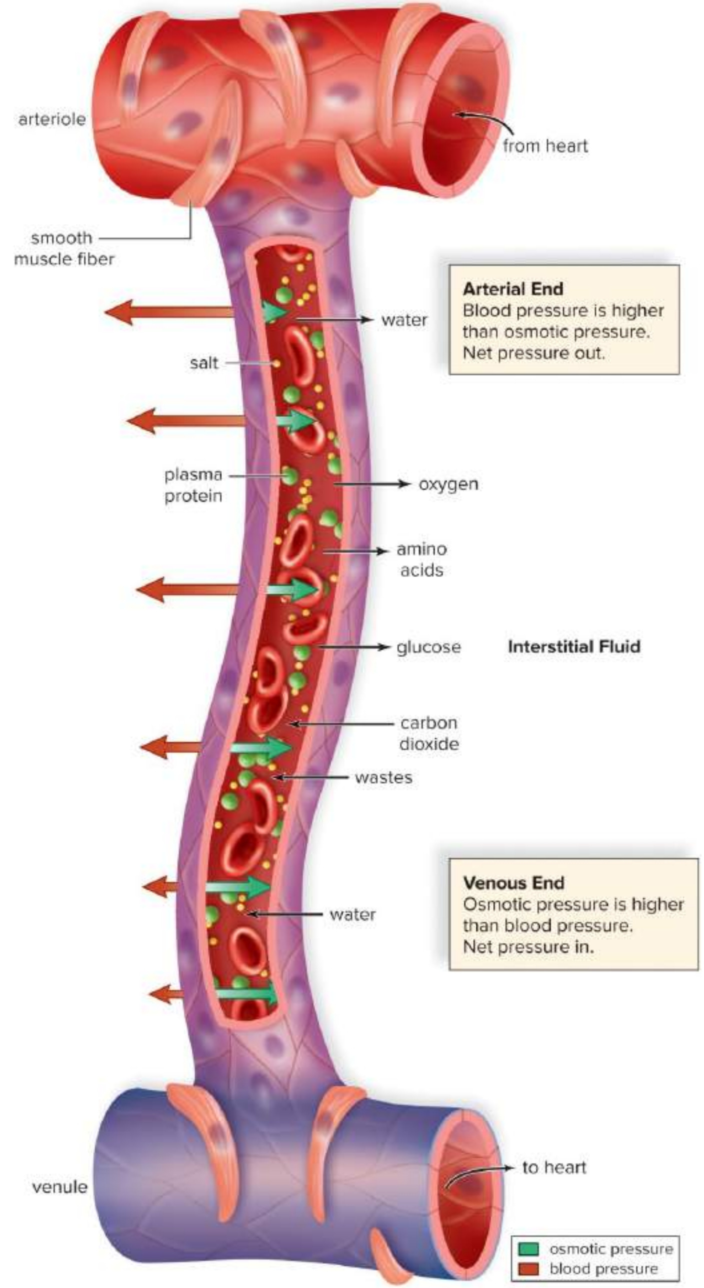
- Usually, blood flows from the aorta into an artery that supplies an organ, then through veins back to one of the vena cavae.
  - That is, aorta > renal artery > kidney > renal vein > inferior vena cava.
- However, there are special routes that don’t follow this pathway.
  - That is, the hepatic portal system.

Exchange at the Capillaries 2

Two forces drive fluid in and out of capillaries:

- Blood pressure drives fluid out of the capillary, mainly at the arterial end of the capillary bed.
  - This fluid contains everything that blood contains except cells and plasma proteins.
- Osmotic pressure draws water into the capillary by osmosis, mostly at the venule end.
- Some tissue fluid enters lymphatic capillaries and becomes **lymph**, which is eventually returned to the cardiovascular system.

The Movement of Solutes in a Capillary Bed (Figure 5.13)



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Check Your Progress 5.6

Explain what happens to the excess fluid created during capillary exchange.

Describe the exchange of materials across the walls of a capillary.

Summarize what occurs when blood and osmotic pressure change at the venous end of a capillary.

Cardiovascular Disorders 2

Cardiovascular disease (CVD).

- Leading cause of early death in Western countries.
- Disorders of the blood vessels.
  - **Hypertension** (high blood pressure) and **atherosclerosis** often lead to a **stroke, heart attack,** or **aneurysm.**

Hypertension

Hypertension (high blood pressure).

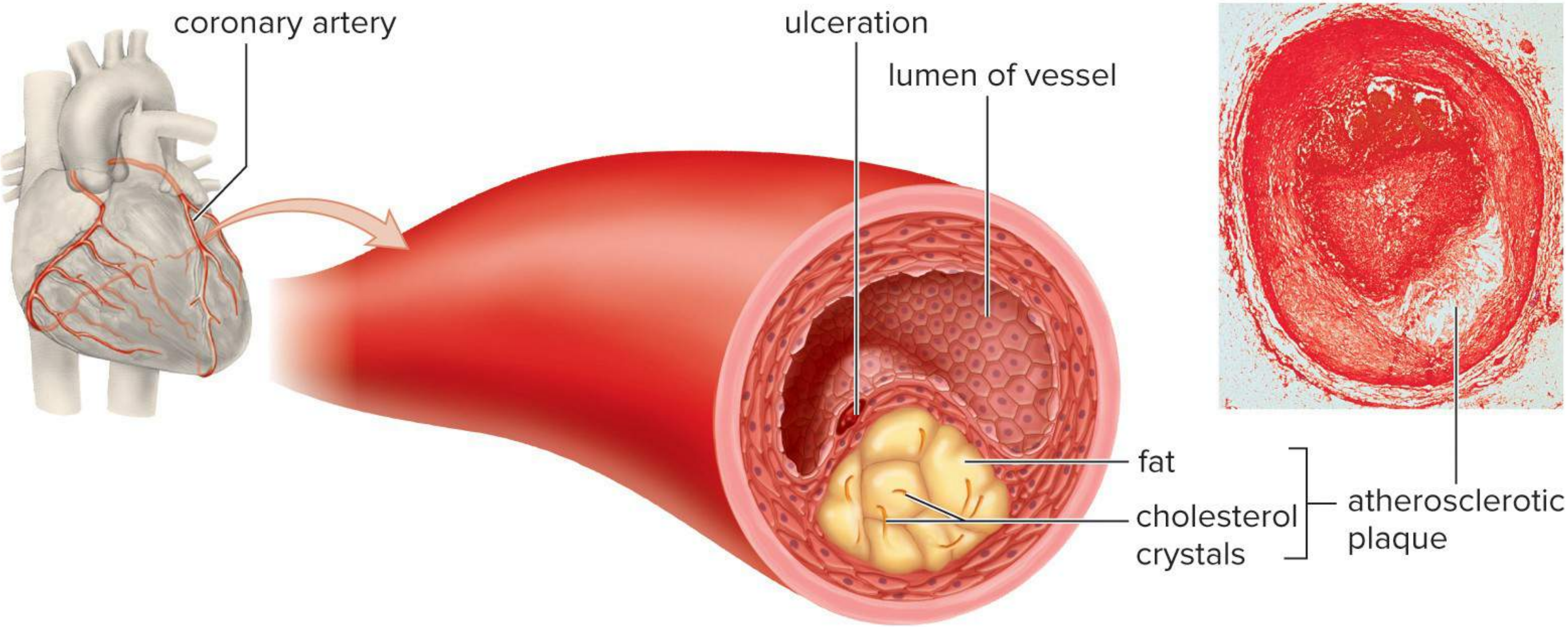
- A systolic pressure of 140 or greater or a diastolic pressure of 90 or greater.
- A "silent killer" because there are few symptoms until it causes kidney failure, a heart attack, or stroke.
- Treated with diuretics, which increase the production of urine, and other drugs.

Atherosclerosis

Atherosclerosis.

- A buildup of **atherosclerotic plaque** in the walls of blood vessels.
- Plaques narrow blood vessel diameter, decreasing blood supply to tissues.
- Can cause clots to form in the roughened walls of arteries.
  - **Thrombus**—a clot that is stationary.
  - **Embolus**—a clot that detaches and moves to distant sites.
  - **Thromboembolism**—an embolus that has become lodged in a blood vessel.

Coronary Arteries and Plaque (Figure 5.15)



Stroke

Stroke (cerebrovascular accident, or **CVA).**

- Occurs when a cranial artery is blocked or bursts.
- Part of the brain dies dues to lack of oxygen.
- Symptoms may include numbness of hands or face, difficulty speaking, and inability to see in one eye.

Heart Attack

Myocardial infarction (MI, or **heart attack).**

- Part of the heart dies due to lack of oxygen.
- Caused by a blocked coronary artery.
- It can begin with **angina pectoris**, pain in the chest from a *partially* blocked coronary artery.
  - Can be treated with drugs that dilate blood vessels.

Aneurysm

Aneurysm.

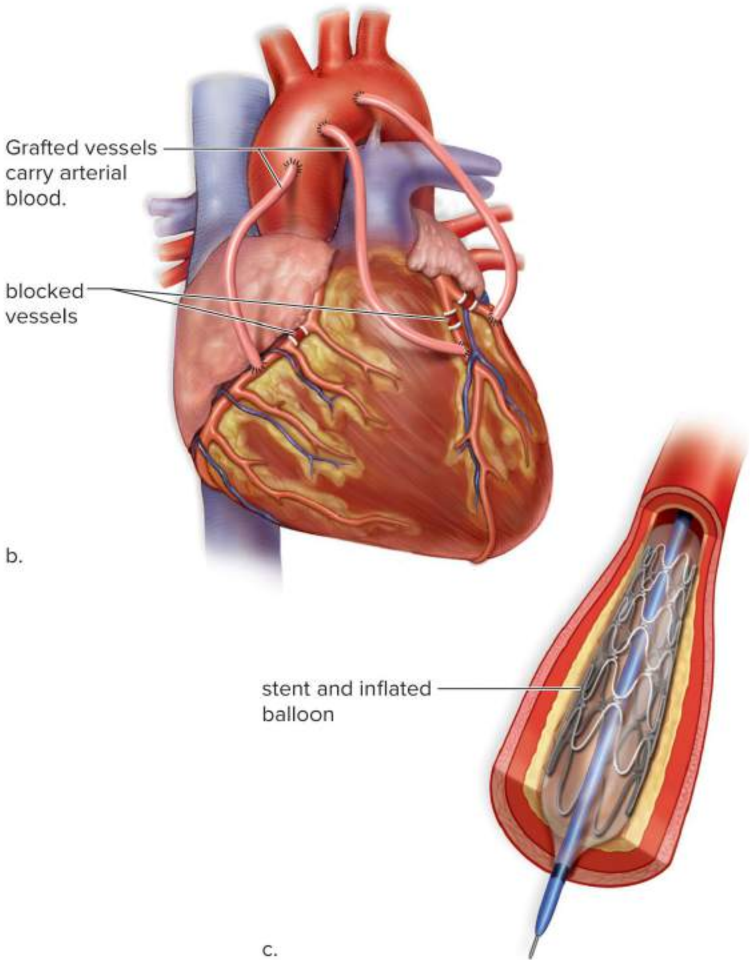
- A ballooning of a blood vessel, most often the abdominal aorta or blood vessels in the brain.
- Atherosclerosis and hypertension can weaken a vessel and cause ballooning.
- If a major artery ruptures, death can result.

Treating Clogged Arteries

Treating clogged arteries.

- **Coronary bypass operation**: a vein from the leg is taken and used to bypass a clogged artery.
- **Gene therapy**—injection of the gene for vascular endothelial growth factor (VEGF) induces the growth of new vessels.
  - Then there is no need for bypass surgery.
- **Angioplasty**: a tube is inserted into the clogged artery to insert a **stent**—a mesh cylinder to hold it open.
  - Stents are usually coated in drugs to dissolve blockages.

Treatments for Atherosclerotic Plaque in Coronary Arteries (Figure 5.16b-c)



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Heart Failure

Heart failure.

- The heart no longer pumps properly.
- Treatments:
  - Wrapping the heart to prevent enlargement.
  - Implantable cardioverter-defibrillator (ICD) corrects an irregular rhythm.
  - Heart transplant.
  - Injection of stem cells to repair damaged heart.
  - Left ventricular assist device (LVAD)—battery-powered pump to assist the heart.
  - Total artificial heart (TAH) —temporary solution.

HUMAN BIOLOGY

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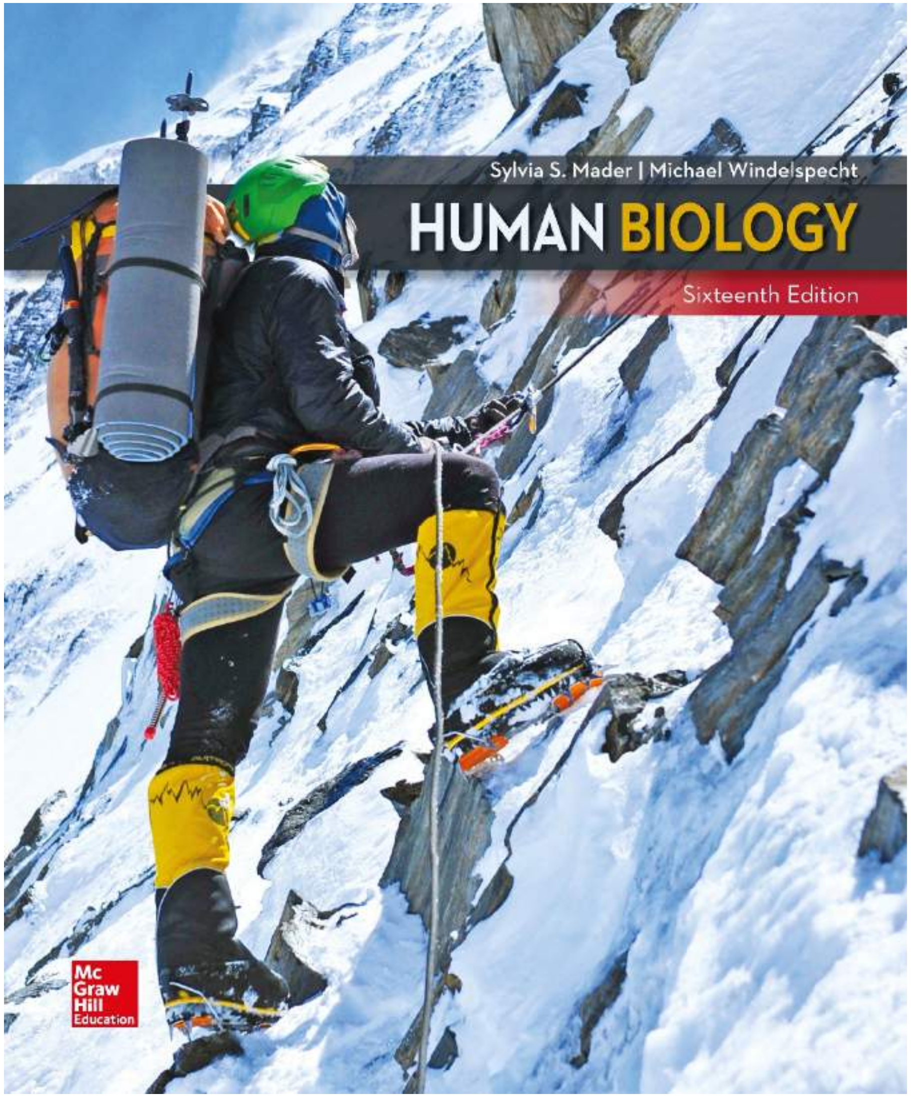


Sylvia S. Mader

Michael Windelspecht

Lab 9
Respiratory System

The Respiratory System 1

Learning Outcomes:

- Summarize the role of the respiratory system in the body.
- Distinguish between inspiration and expiration.
- Identify the structures of the human respiratory system.

The Respiratory System 2

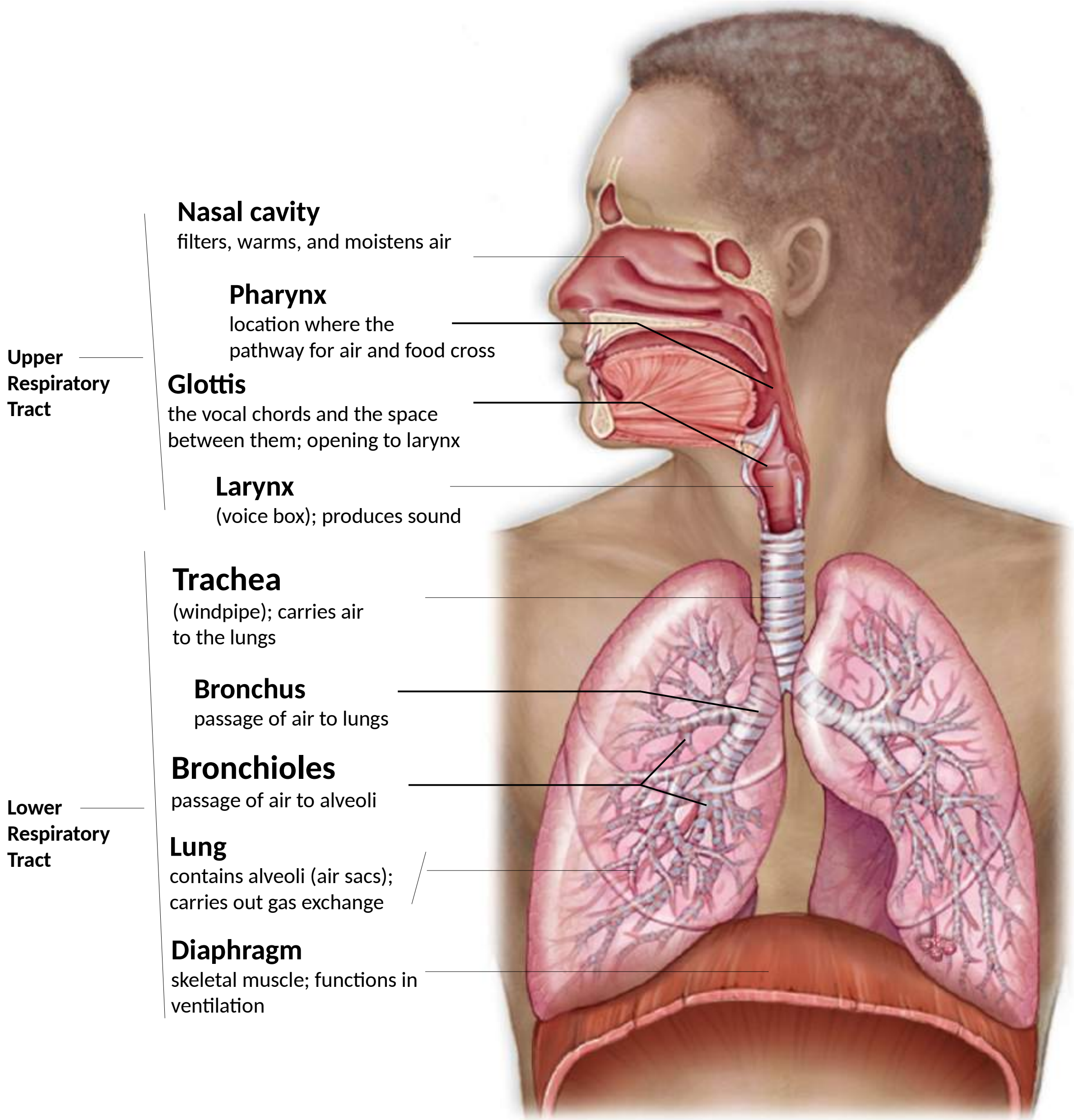
The respiratory system.

- Ensures that oxygen enters the body and carbon dioxide leaves the body.
- During **inspiration**, or inhalation, air moves from the atmosphere to the lungs through cavities and tubes.
- During **expiration**, or exhalation, air moves from the lungs to the atmosphere via the same structures.
- **Ventilation** (breathing)—inspiration and expiration.

Respiratory System Functions

- gas exchange - O_2 and CO_2
- vocalization
- rids body of excess heat and H_2O
- adjusts body pH
- removes and inactivates airborne substances

The human respiratory tract (Figure 10.01)



The Upper Respiratory Tract 1

Learning Outcomes:

- Summarize the role of the nose, pharynx, and larynx in respiration.
- Identify the structures of the upper respiratory system and provide their function.
- Explain how sound is produced by the larynx.

The Upper Respiratory Tract 2

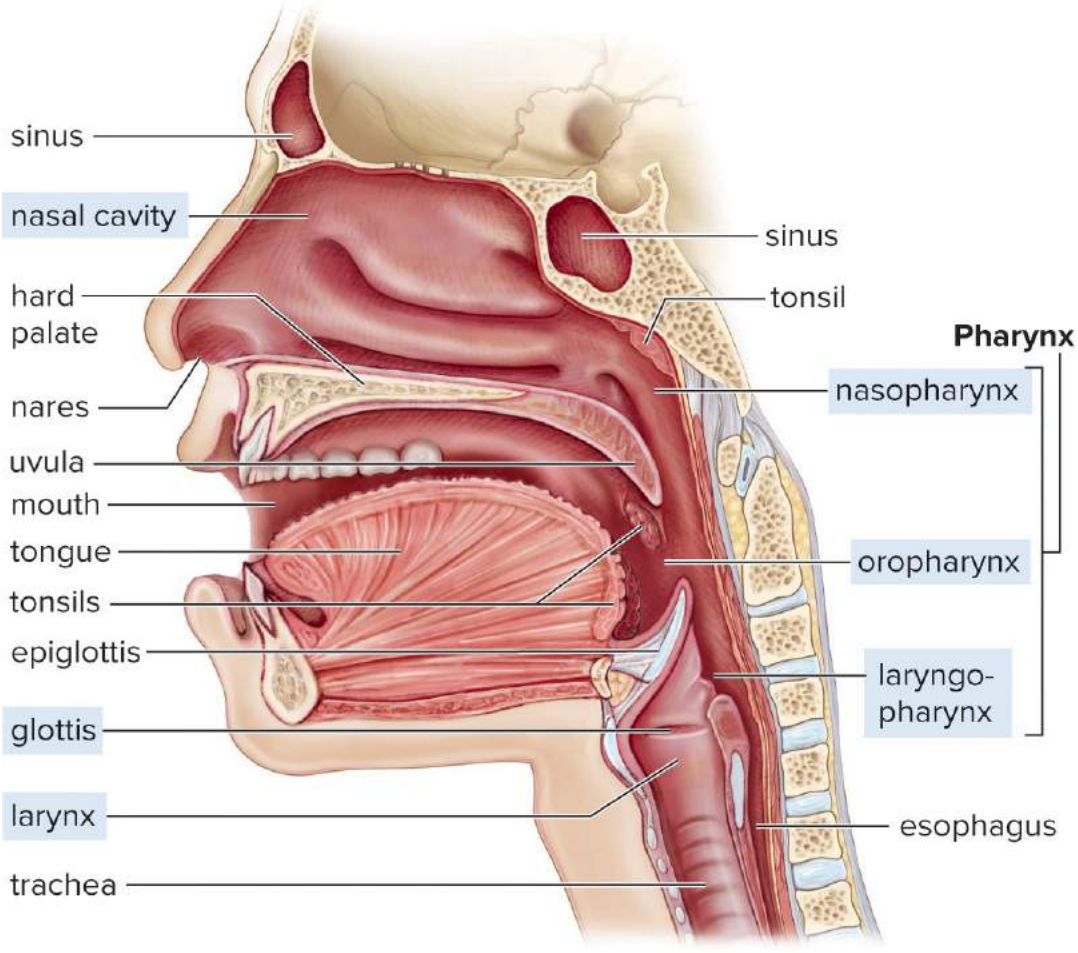
The **upper respiratory tract.**

- Includes the **nasal cavities, pharynx,** and **larynx.**

The **nose** opens at the **nares** (nostrils), which lead to the **nasal cavities.**

- The nasal cavities are separated from each other by a **septum** composed of bone and cartilage.
- **Hairs** filter the air and trap small particles so they don't enter air passages.

The Upper Respiratory Tract (Figure 10.2)



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The Nasal Cavities 1

Nasal cavities, continued.

- Lined with mucous membrane.
  - The mucus helps trap particles and move them to the pharynx, where they can be swallowed or expectorated.
- Under the mucous layer is the submucosa, which contains lots of capillaries that help warm and moisten the incoming air.
  - The abundance of capillaries makes us susceptible to nosebleeds.

The Nasal Cavities 2

Nasal cavities, continued.

- Contain **odor receptors**.
- Tear glands in the eye drain into the nasal cavities by way of tear ducts.
- The nasal cavities also connect with the **sinuses** of the skull.
- Air in the nasal cavities passes into the **nasopharynx**, the upper portion of the pharynx.
- **Auditory tubes (eustachian tubes)** connect the nasopharynx to the middle ear.
  - When air pressure inside the middle ears equalizes with the air pressure in the nasopharynx, the auditory tube openings may create a “popping” sensation.

The Pharynx

The **pharynx** (throat)—funnel-shaped cavity that connects the nasal and oral cavities to the larynx.

- Has three portions: **nasopharynx, oropharynx,** and **laryngopharynx.**

Tonsils—made of lymphoid tissue at the junction of the oral cavity and pharynx.

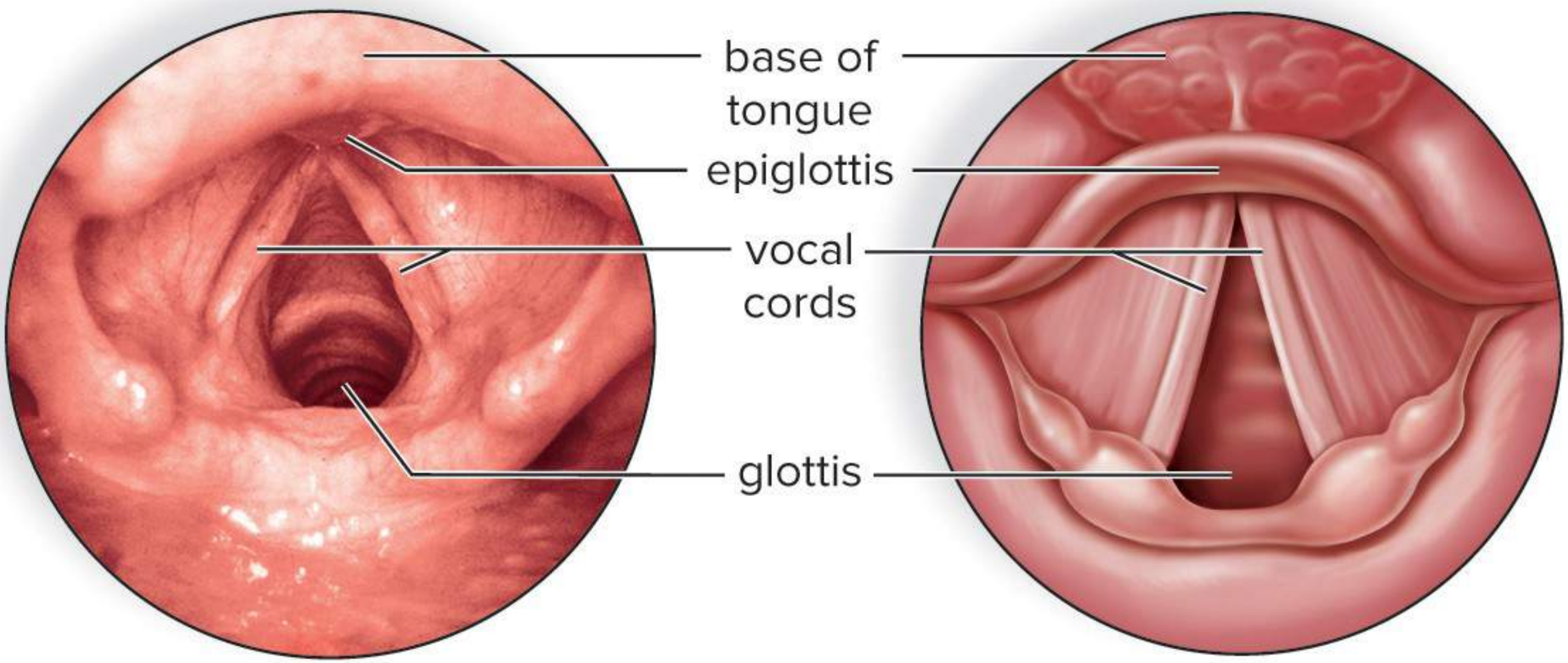
- Provide defense against inhaled pathogens.

The Larynx 1

The **larynx.**

- Cartilaginous structure between the pharynx and the trachea.
- The Adam's apple (laryngeal prominence) is located at the front of the neck.
- Houses the **vocal cords**—mucosal folds supported by elastic ligaments.
  - The slit between the vocal cords is called the **glottis.**
  - When air passes through the glottis, the vocal cords vibrate, producing sound.
  - The greater the tension in the vocal cords, the higher the pitch.
  - When the glottis is wider, the pitch is lower.
  - Loudness depends on the degree to which the vocal cords vibrate.
  - When food is swallowed, the larynx moves upward against the **epiglottis**—a flap of tissue that prevents food from passing into the larynx.

The Vocal Cords (Figure 10.4)



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The Lower Respiratory Tract 2

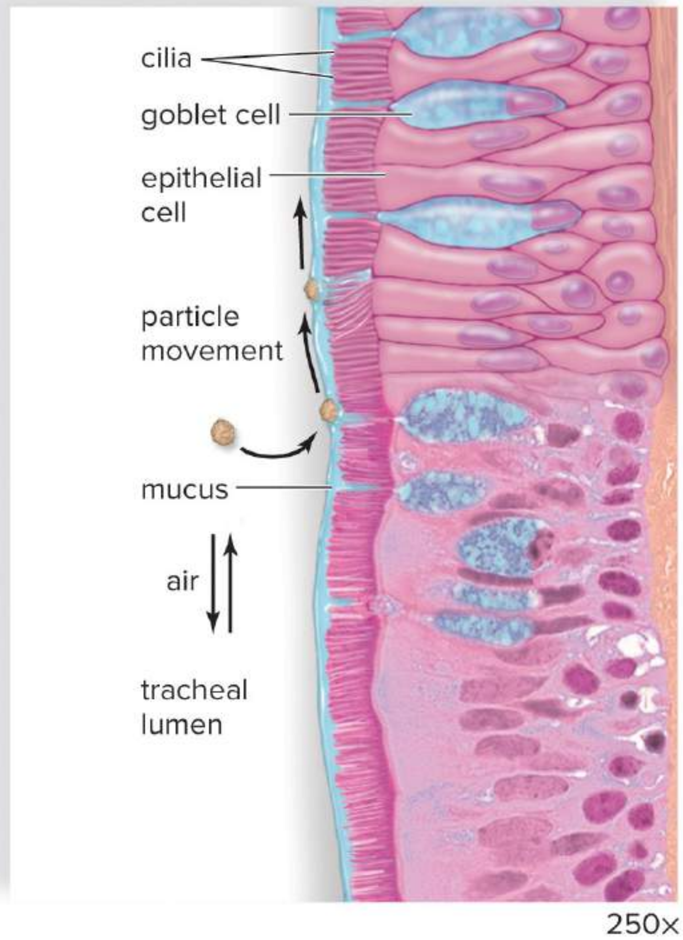
The **lower respiratory tract.**

- Includes the **trachea, bronchial tree,** and the **lungs.**

The **trachea.**

- Commonly called the “windpipe.”
- Connects the larynx to the **primary bronchi.**
- Its walls are reinforced by C-shaped cartilaginous rings, which prevent the trachea from collapsing.
  - The C shape allows the esophagus to expand into the trachea when swallowing.

The Cells Lining the Trachea (Figure 10.5)



The Lower Respiratory Tract 1

Learning Outcomes:

- Summarize the role of the trachea, bronchial tree, and lungs in respiration.
- Identify the structures of the lower respiratory tract and provide their function.
- Explain how the alveoli increase the efficiency of the respiratory system.

The Lower Respiratory Tract 3

The **trachea**, continued.

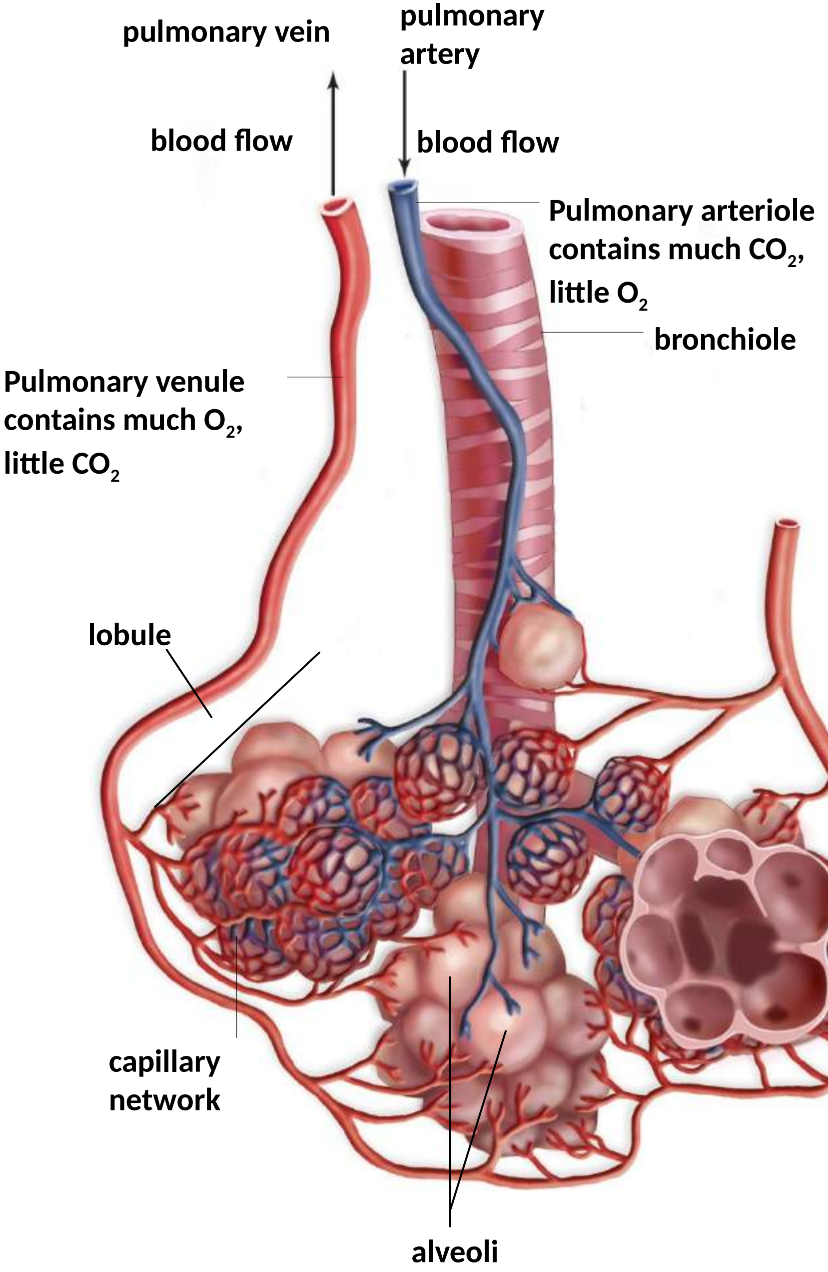
- Lined with pseudostratified ciliated columnar epithelium and goblet cells.
  - The goblet cells produce mucus, which traps debris from the air as it passes through the trachea.
  - The mucus is then swept away from the lungs and toward the pharynx by the cilia.
    - Smoking damages the cilia, causing smoker’s cough.

The Bronchial Tree [1]

The **bronchial tree.**

- Two **primary bronchi** lead from the trachea into the lungs.
- The primary bronchi branch into **secondary bronchi**, which continue to branch until they are small **bronchioles** about 1 mm in diameter.
  - Bronchi have cartilage like the trachea, but as they get smaller, the cartilage disappears.
- During an asthma attack, the smooth muscle of the bronchioles contracts, constricting it and causing wheezing.
- Each bronchiole leads to an elongated space enclosed by many air sacs called **alveoli** (*singular*, alveolus).

Alveoli and Pulmonary Circulation (Figure 10.06)



The Lungs 1

The **lungs.**

- Made up of the secondary bronchi, bronchioles, and alveoli.
- The right lung has three lobes while the left lung has two lobes (to make room for the heart).
- Each lobe is divided into lobules.
- Each lung is enclosed by membranes called **pleurae**, which secrete **pleural fluid.**

The Lungs 2

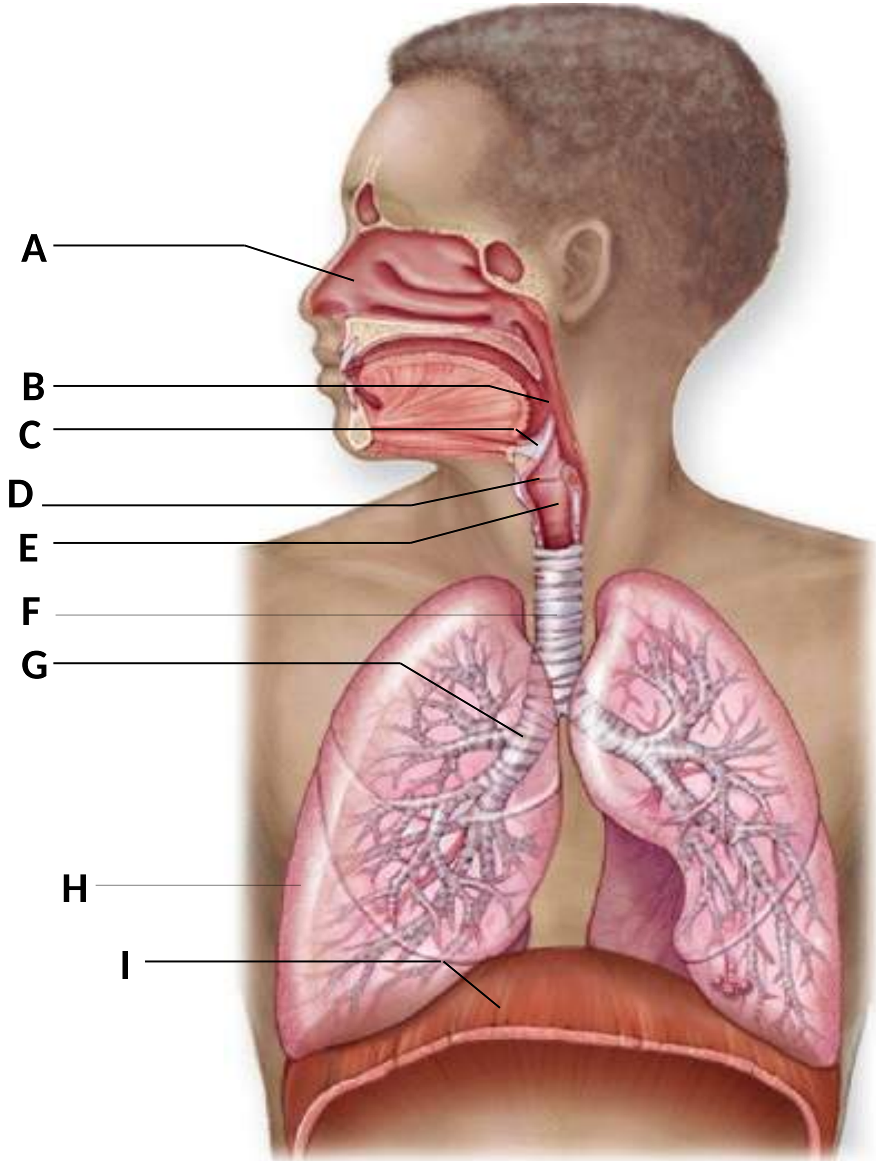
The **lungs**, continued.

- The pleural fluid has surface tension, which adheres the parietal and visceral pleurae.
  - Surface tension is due to hydrogen bonds between water molecules.
  - Because of surface tension, when the thoracic cavity enlarges, the parietal pleura “pulls” the visceral pleura, and therefore the lungs, outward.
    - This increases the size of the lungs.

The Alveoli [1]

- The lungs have about 300 million alveoli.
- Each alveolar sac is surrounded by blood capillaries.
- The walls of the sac and the capillaries are both made of simple squamous epithelium.
- Gas exchange occurs between air in the alveoli and blood in the capillaries.
- Oxygen diffuses across the alveolar wall and enters the bloodstream, and carbon dioxide diffuses from the blood into the alveoli.
- The alveoli are lined with **surfactant**, a film of lipoprotein that lowers the surface tension of water and prevents the alveoli from closing.

Review- Can you name all the parts?



Control of Ventilation [1]

Learning Outcomes:

- Explain how the nervous system controls the process of breathing.
- Explain the role of chemoreceptors and pH levels in regulating breathing rate.

Ventilation [1]

Ventilation (breathing), has two phases: **inspiration** (inhalation) moves air into the lungs, **expiration** (exhalation) moves air out of the lungs.

- To understand ventilation, it is necessary to remember the following facts:
  - Normally there is a continuous column of air from the pharynx to the alveoli of the lungs.

Ventilation 2

Ventilation, continued.

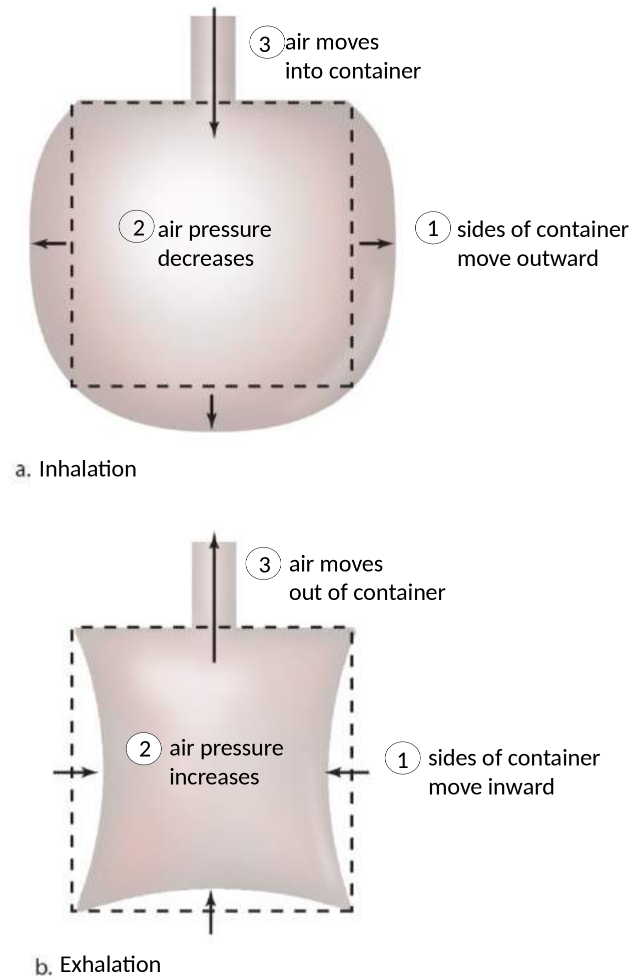
- The lungs lie within the sealed thoracic cavity.
  - **Rib cage**—top and sides of the thoracic cavity.
  - **Intercostal muscles**—between the ribs.
  - **Diaphragm**—floor of the thoracic cavity.
- The lungs adhere to the thoracic wall by way of the pleura.
  - Space between the two pleurae is minimal and filled with **pleural fluid.**
- Ventilation is governed by **Boyle's Law.**
  - At a constant temperature, the pressure of a given quantity of gas is inversely proportional to its volume

Inspiration 1

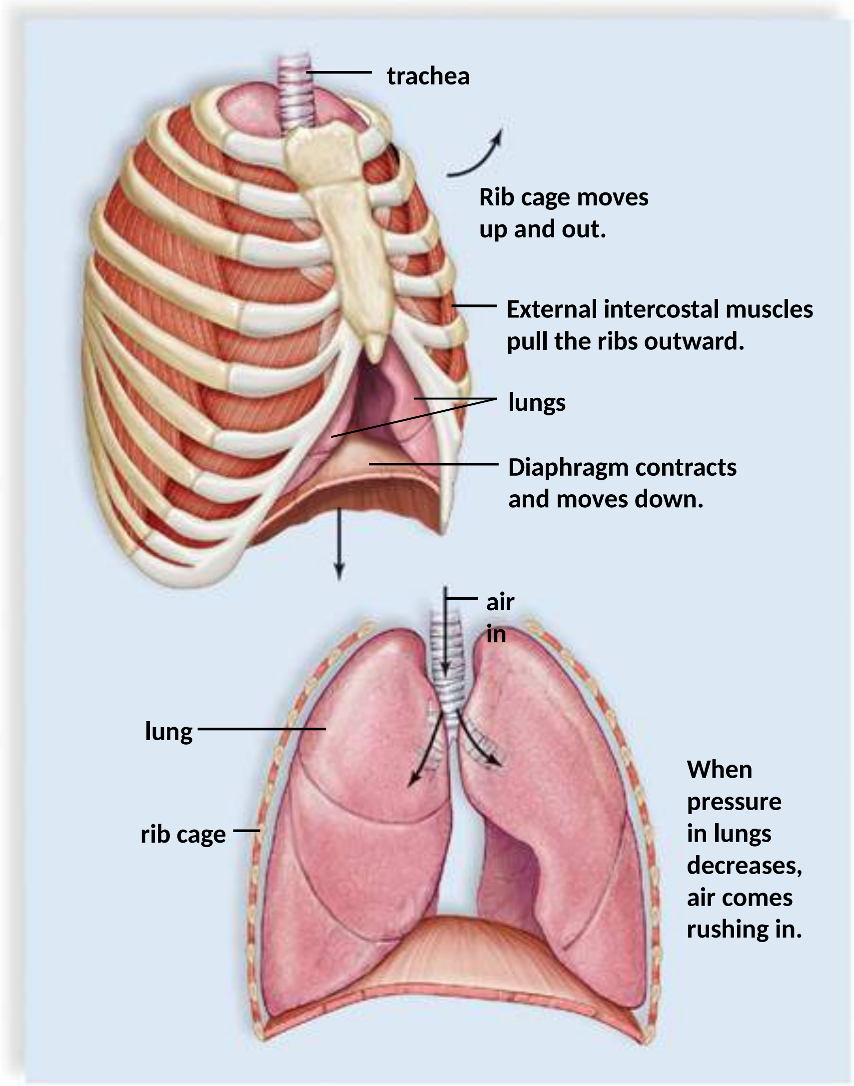
Inspiration.

- The active phase of ventilation.
- The diaphragm and the external intercostal muscles contract.
  - In its relaxed state, the diaphragm is dome-shaped; during inspiration, it contracts and becomes flattened.
  - Contraction of the external intercostal muscles causes the rib cage to move upward and outward.
  - Both actions increase the size of the thoracic cage.
- As the thoracic volume increases, the lungs increase in volume as well, because the lung adheres to the wall of the thoracic cavity.
- As the lung volume increases, the air pressure in the alveoli decreases.
- Alveolar pressure is now less than atmospheric pressure, so air flows from outside the body into the lungs.

The Relationship Between Air Pressure and Volume (Figure 10.7)



The Thoracic Cavity During Inspiration (Figure 10.8a)



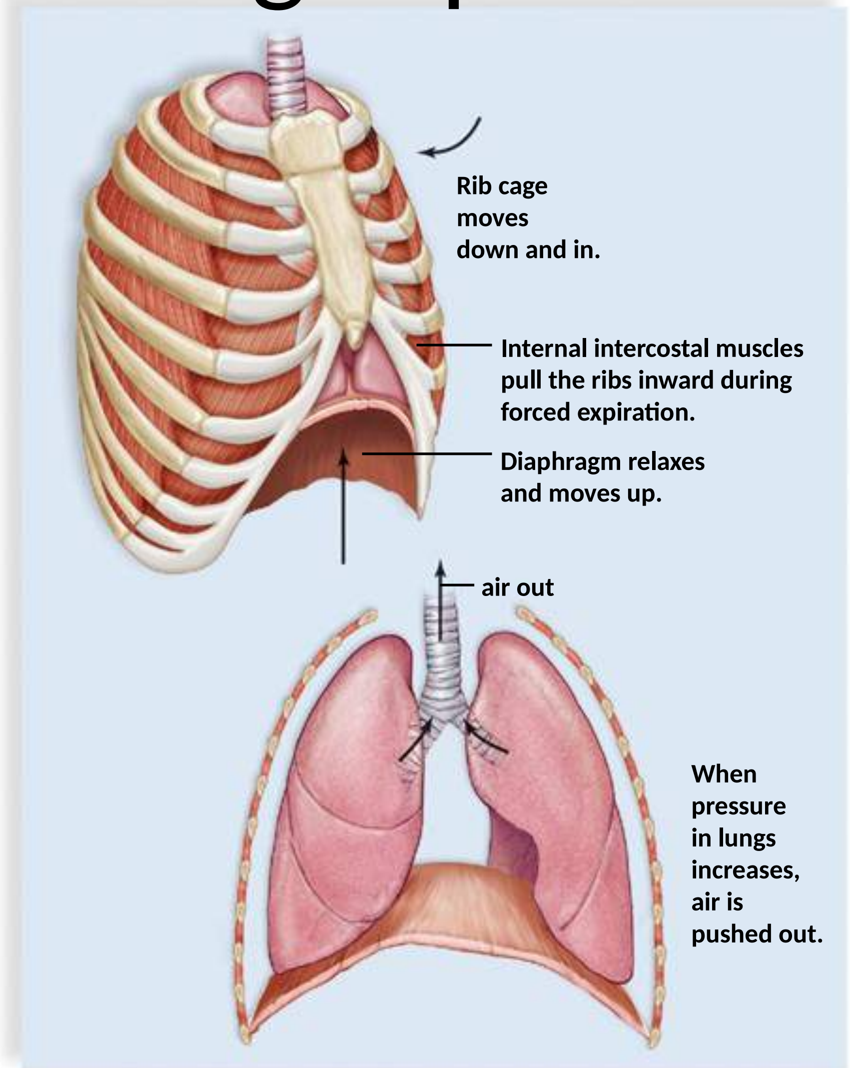
a. Inspiration

Expiration 1

Expiration.

- The passive phase of breathing; the diaphragm and external intercostal muscles relax.
- The rib cage returns to its resting position, moving down and inward.
- The lungs recoil, and the air pressure inside increases; air flows out.
- Surfactant keeps the alveoli from collapsing during expiration.
- Also, as the lungs recoil, the pressure between the pleurae decreases, and this keeps the alveoli open.
    - When, in an accident, the thoracic cavity is punctured (a “punctured lung”), air enters the space between the two pleurae, causing the lung to collapse.

The Thoracic Cavity During Expiration (Figure 10.8b)



b. Expiration

Maximum Inspiratory Effort and Forced Expiration [1]

Breathing hard (maximum inspiratory effort) uses muscles of the back, chest, and neck.

- Increases the size of the thoracic cavity more than usual, allowing maximum expansion of the lungs.

Maximum Inspiratory Effort and Forced Expiration 2

Expiration can also be forced.

- That is, singing, blowing air.
- Contraction of the internal intercostal muscles forces the rib cage downward and inward.
- Also, when abdominal muscles contract, they push on the abdominal organs, which push upward against the diaphragm, forcing air out.

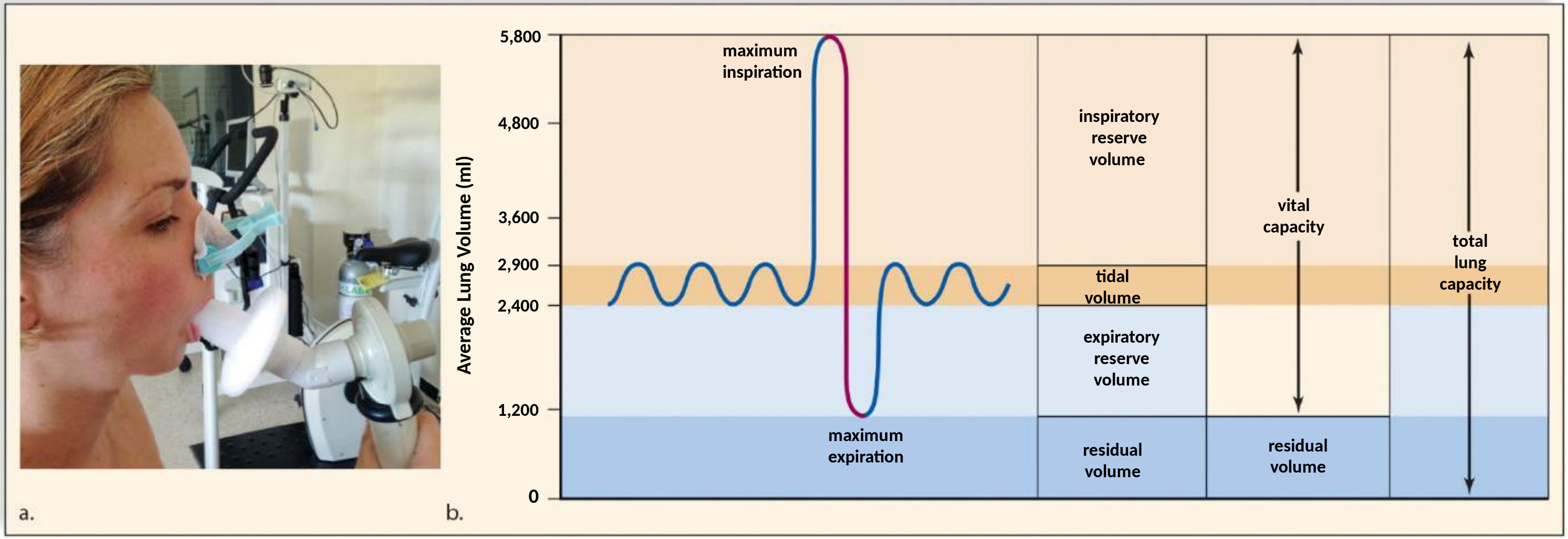
Volumes of Air Exchanged During Ventilation 1

Tidal volume—the amount of air that moves in and out with each normal breath.

Vital capacity—the maximum volume that can be moved in plus the maximum amount that can be moved out during one breath.

Inspiratory and **expiratory reserve volume**—the increased volume of air moving in or out of the body with forced inspiration and expiration.

Measuring the Air Capacity of the Lungs (Figure 10.9)



(a): ©Juan Aunion/123RF

A **spirometer** is used to measure someone's vital capacity

Volumes of Air Exchanged During Ventilation 2

Vital capacity is the sum of tidal, inspiratory reserve, and expiratory reserve volumes.

Some inhaled air never reaches the lungs; it fills the nasal cavities, trachea, bronchi, and bronchioles.

- These passages are not used for gas exchange; they contain **dead air space.**

Residual volume—the air remaining in the lungs after exhalation.

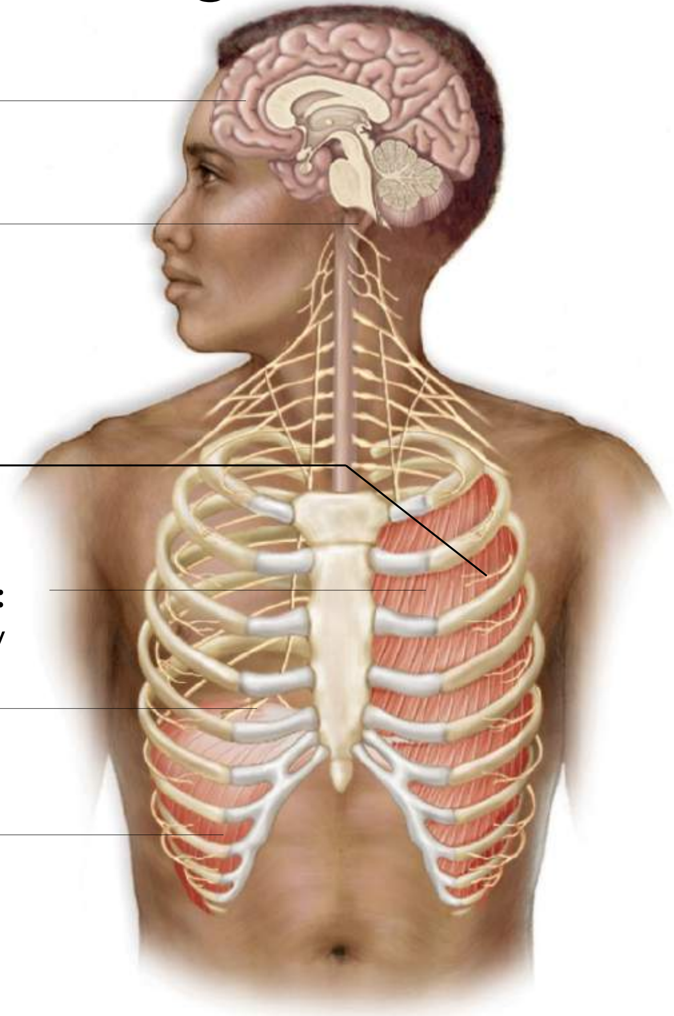
Control of Ventilation 2

Breathing is controlled by the **nervous system** and by certain **chemicals.**

Nervous control of breathing.

- Respiratory control center in the brain automatically sends out nerve signals to the diaphragm and the external intercostal muscles of the rib cage, causing inspiration to occur.
  - When the respiratory center stops sending nerve signals to the diaphragm and the rib cage, the muscles relax and expiration occurs.
- Can voluntarily change our breathing pattern for speaking, singing, eating, swimming underwater.

The Control of Breathing by the Respiratory Center (Figure 10.10)



Chemical Control of Breathing 1

Chemical control of breathing.

- Cells produce CO_2 during cellular respiration.
- CO_2 then enters the blood, where it combines with water, forming an acid that breaks down and gives off hydrogen ions.
  - These H^+ decrease the pH of the blood.
- **Chemoreceptors**—sensory receptors that are sensitive to the chemical composition of body fluids.
- Two sets of chemoreceptors sensitive to pH can cause breathing to speed up.
  - One set is in the medulla oblongata of the brain stem.
  - The other set is the **carotid bodies** of the carotid arteries, and **aortic bodies** of the aorta.
    - These chemoreceptors mostly respond to carbon dioxide levels of the blood.

Chemical Control of Breathing 3

Chemical control of breathing, concluded.

- When blood pH decreases, the respiratory center increases the rate and depth of breathing to remove CO_2 from the blood.
  - This increases the pH, so the breathing rate returns to normal.
- When you hold your breath, CO_2 begins accumulating in the blood, decreasing the pH.
  - The respiratory center, stimulated by the chemoreceptors, is able to override a voluntary inhibition of respiration, forcing breathing.

Gas Exchanges in the Body 1

Learning Outcomes:

- Distinguish between external and internal respiration.
- Summarize the chemical processes involved in external and internal respiration.
- Identify the role of carbonic anhydrase and carbaminohemoglobin in respiration.

Gas Exchanges in the Body 2

Gas exchange in the body.

- Oxygen is needed to produce ATP, so must be supplied to all the cells, and the carbon dioxide produced must be removed from the body.
- Respiration includes the exchange of gases not only in the lungs but also in the tissues.
- The principles of diffusion govern whether O_2 or CO_2 enters or leaves the blood.
- Gases exert pressure, and the amount of pressure each gas exerts is called its partial pressure, symbolized as P_{CO_2} or P_{O_2}.
- If the partial pressure of a gas differs across a membrane, it will diffuse from higher to lower partial pressure

External Respiration [1]

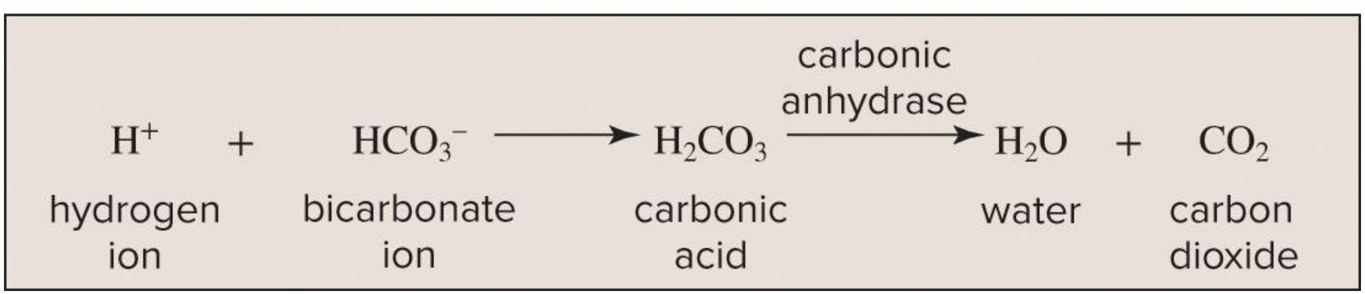
External respiration.

- Exchange of gases between the lung alveoli and the blood capillaries.
- P_{CO_2} is higher in the lung capillaries than the air; thus, CO_2 diffuses out of the blood into the lungs.
- The partial pressure pattern for O_2 is just the opposite, so O_2 diffuses from the alveolar air into the red blood cells in the pulmonary capillaries.

External Respiration 2

External respiration, continued.

- Most of the CO_2 is carried in plasma as bicarbonate ions (HCO_3^-).
- In the low-P_{CO_2} environment of the lungs, this reaction proceeds to the right:



External Respiration 3

External respiration, continued.

- **Carbonic anhydrase**—the enzyme that speeds the breakdown of carbonic acid (H_2CO_3) in red blood cells.
- **Hyperventilation** (breathing at a high rate) pushes the reaction to the right; blood has fewer hydrogen ions; **alkalosis** (high blood pH) occurs.
- **Hypoventilation** (breathing at a low rate) pushes the reaction to the left; **acidosis** (low blood pH) occurs.

More External Respiration

External respiration, concluded.

- Pulmonary capillary blood is low in oxygen, and alveolar air has a higher partial pressure of oxygen.
  - Therefore, O_2 diffuses into the blood in the lungs.
  - Hemoglobin takes up oxygen and becomes **oxyhemoglobin (**HbO_2**).**

$$\underset{\text{deoxyhemoglobin}}{Hb} + \underset{\text{oxygen}}{O_2} \longrightarrow \underset{\text{oxyhemoglobin}}{HbO_2}$$

Internal Respiration 1

Internal respiration.

- Exchange of gases between the blood in systemic capillaries and the tissue cells.
- Blood entering systemic capillaries is bright red because red blood cells contain oxyhemoglobin.
- After HbO_2 gives up O_2, it diffuses out of the blood into the tissues.

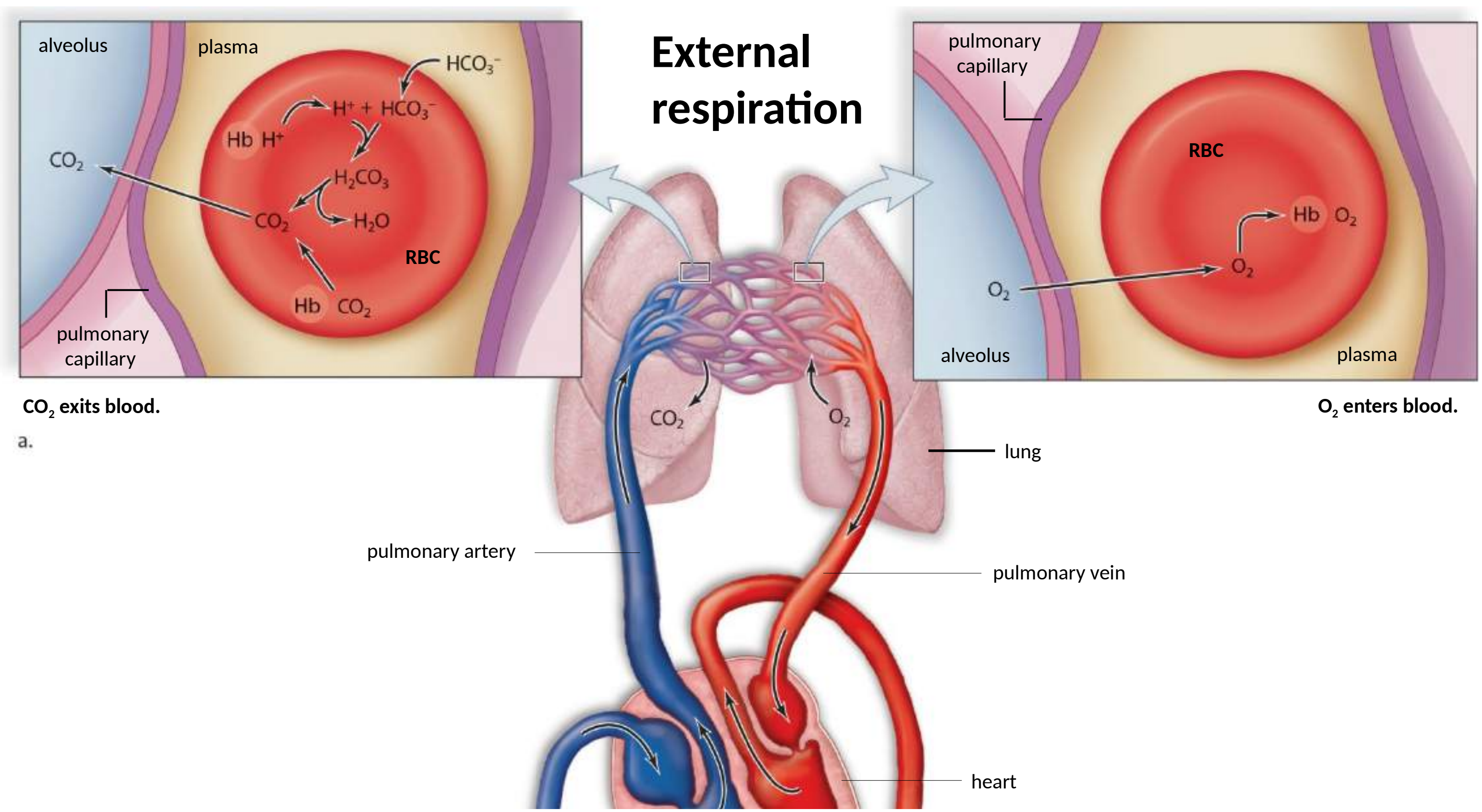
$$\underset{\text{oxyhemoglobin}}{HbO_2} \longrightarrow \underset{\text{deoxyhemoglobin}}{Hb} + \underset{\text{oxygen}}{O_2}$$

Internal Respiration 2

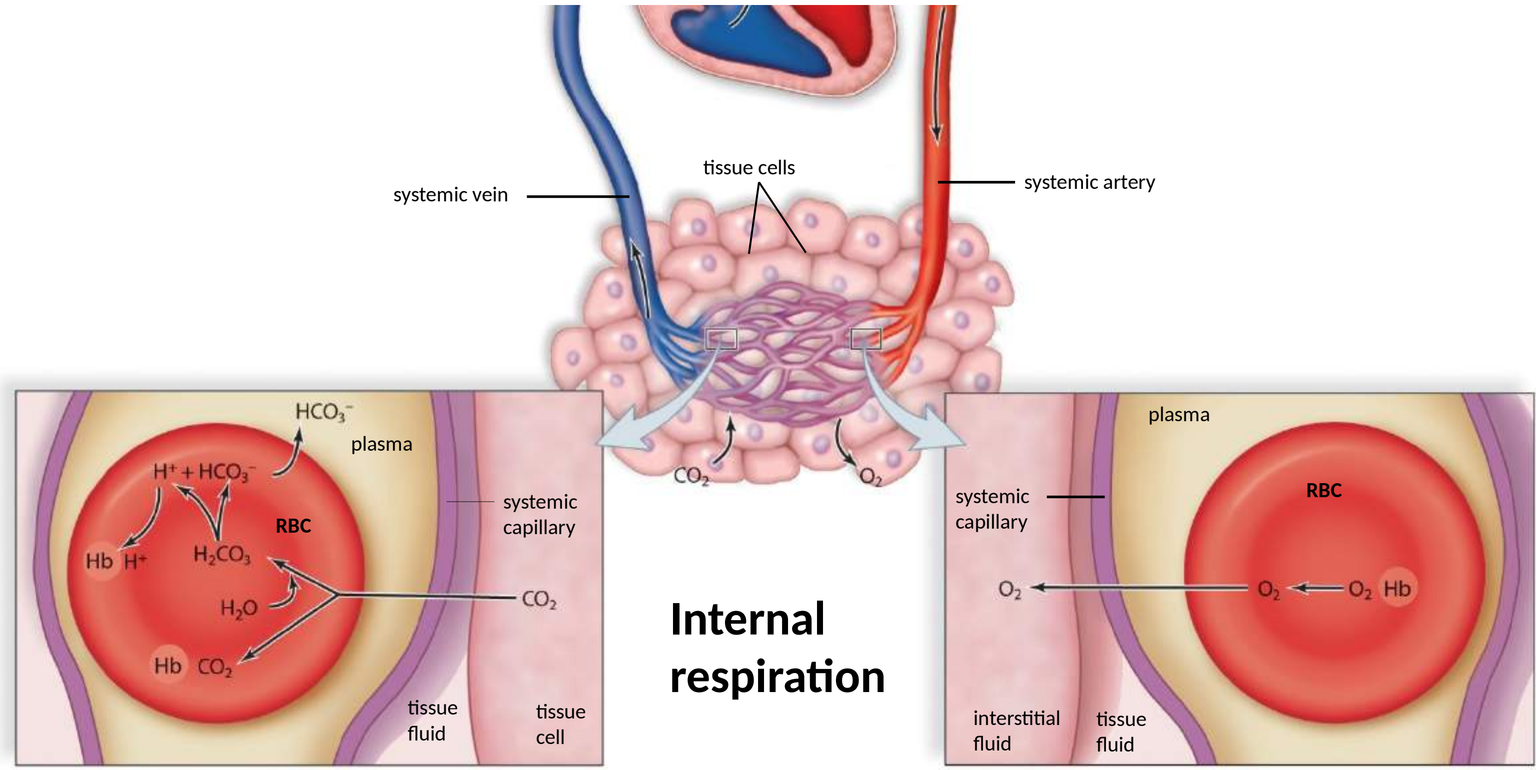
Internal respiration, continued.

- The lower P_{O_2} is due to cells continuously using up oxygen during cellular respiration.
- Carbon dioxide is produced during cellular respiration and collects in interstitial fluid.

Movement of Gases During External Respiration (Figure 10.11)



Movement of Gases During Internal Respiration (Figure 10.11)

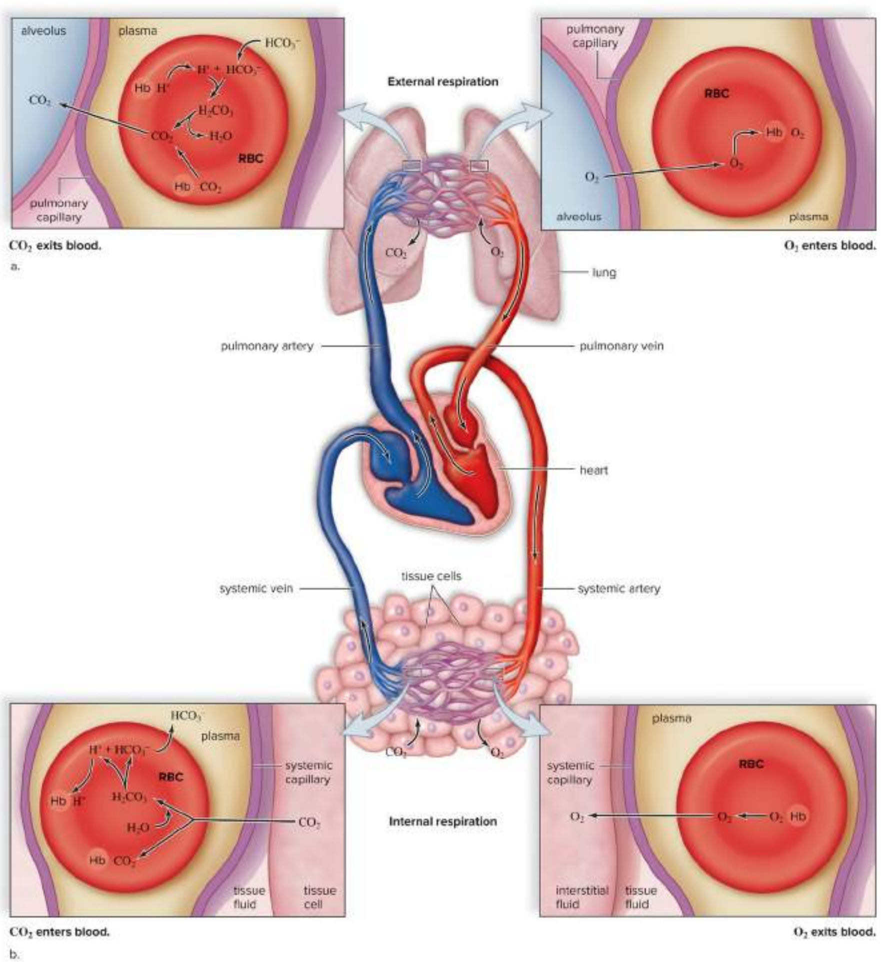


CO_2 enters blood.

b.

O_2 exits blood.

Movement of Gases During External and Internal Respiration (Figure 10.11)



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Cellular Respiration: in the Cells

- Metabolic reactions that occur *within a cell* to produce ATP
- If **O_2** is available our cells use a process called "**aerobic cellular respiration**" to produce ATP

  $$C_6H_{12}O_6 + 6\ O_2 \rightarrow 6\ CO_2 + 6\ H_2O + 34 - 36\ ATP$$

- Most of the reactions involved in aerobic cellular respiration occur in the mitochondria
- If **no O_2** is available our cells undergo an anaerobic process called "**fermentation**" to produce ATP

  $$C_6H_{12}O_6 \rightarrow \text{lactic acid} + 2\ ATP$$

- Fermentation occurs in the cytoplasm

So…Why do we breathe? Why do we exhale CO_2? Why do cells die quickly when deprived of O_2?

Hemoglobin

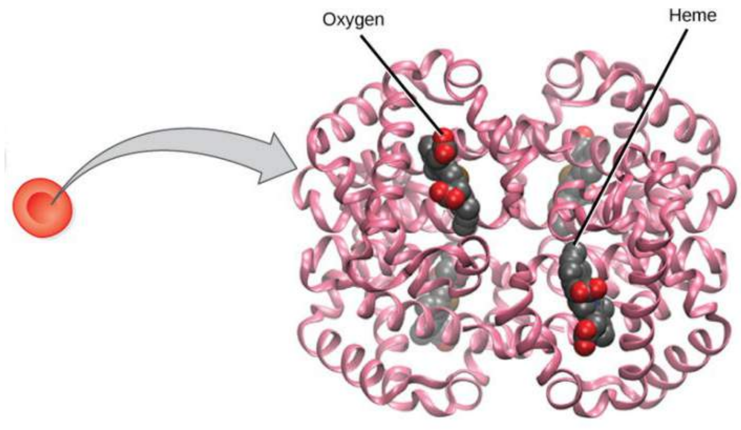
- O_2 transporting pigment in the blood

- 4^o protein structure

- also carries CO_2:
  (*<u>some</u>* CO_2 is carried to the lungs
  bound to hemoglobin for exhalation;
  <u>most</u> CO_2 is converted into H_2CO_3
  and used as a buffer as discussed earlier)

- has *very* high affinity for CO

- binding of CO to hemoglobin results in carbon monoxide poisoning



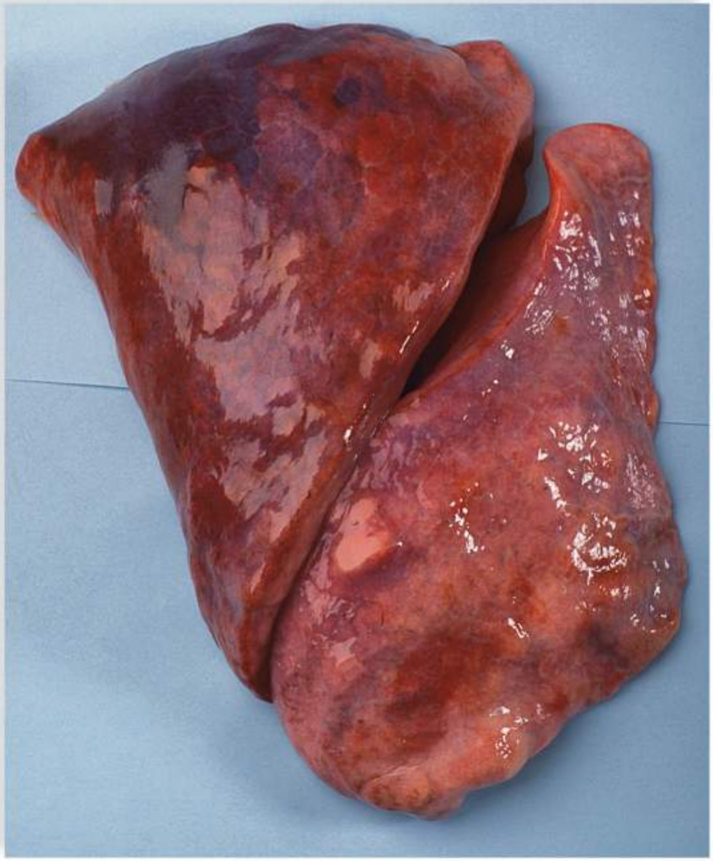
(b) Hemoglobin

Biology Today: Health

Smoking, tobacco, and health.

- All forms of tobacco can cause damage.
- Tobacco use increases the chance of lung, mouth, larynx, esophagus, bladder, kidney, pancreatic, stomach, and cervix cancers.
- Smoking also increases the chance of chronic bronchitis, emphysema, heart disease, stillbirths, and harm to an unborn child.
- Passive smoke can increase a nonsmoker's chance of pneumonia, bronchitis, and lung cancer.

Effect of Smoking on a Human Lung (Figure 10.13)



a. Normal lung

(a): ©Matt Meadows/Getty Images;

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b. Lung cancer

(b): ©Biophoto Associates/Science Source

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Anatomical Terms (review of the first twenty):

ventral: toward the front or belly
dorsal: toward the back or spine
anterior: toward the ventral side
posterior: toward the dorsal side
superior: above
inferior: below
medial: toward the midsagittal plane
lateral: away from the midsagittal plane
proximal: closer to the point of attachment or origin
distal: farther from the point of attachment or origin
superficial: closer to the body surface
deep: farther from the body surface
antebrachial: pertaining to the forearm
axillary: pertaining to the armpit
brachial: pertaining to the arm
buccal: pertaining to the cheek
antecubital: pertaining to the anterior surface of the elbow
axial: relating to the head, neck and trunk; the axis of the body
appendicular: relating to the limbs and their attachments to the body
abdominal: pertaining to the anterior of the body trunk region inferior to the ribs

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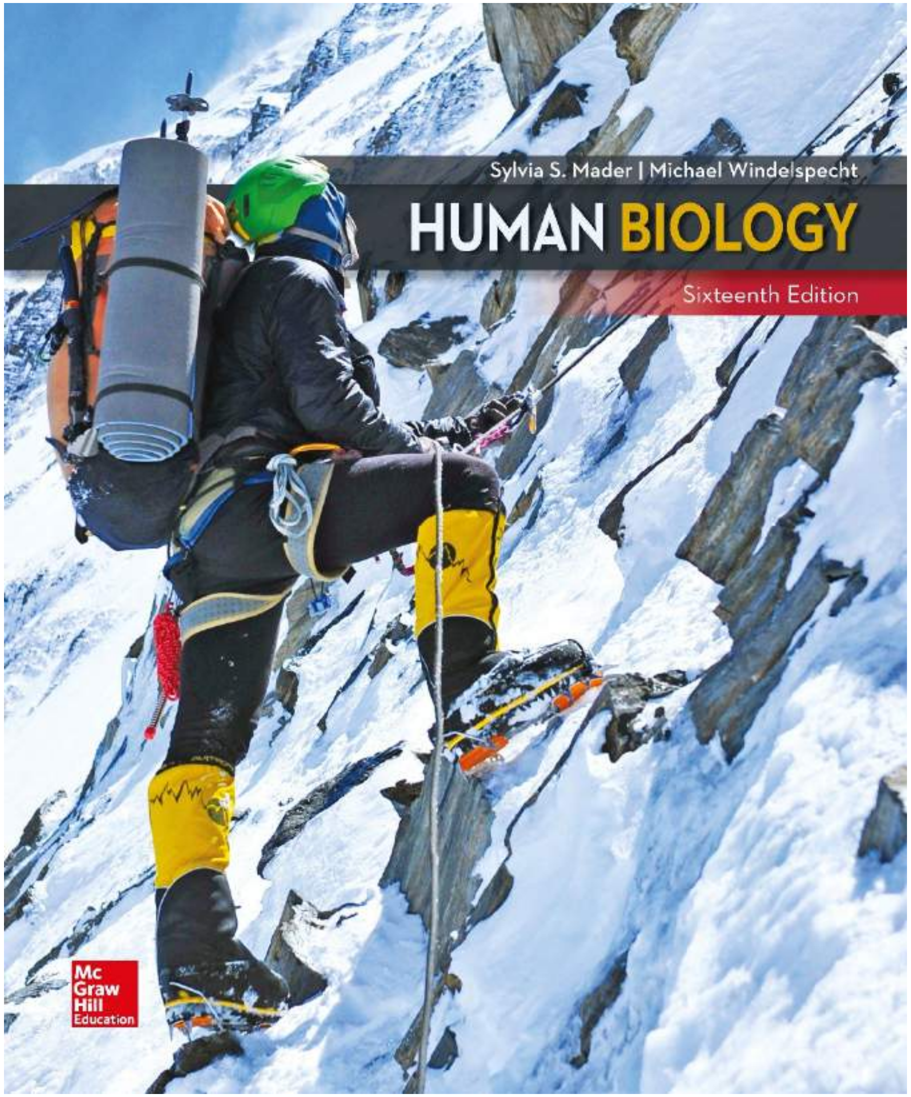
Sixteenth Edition



Sylvia S. Mader

Michael Windelspecht

Lab 10 Digestion

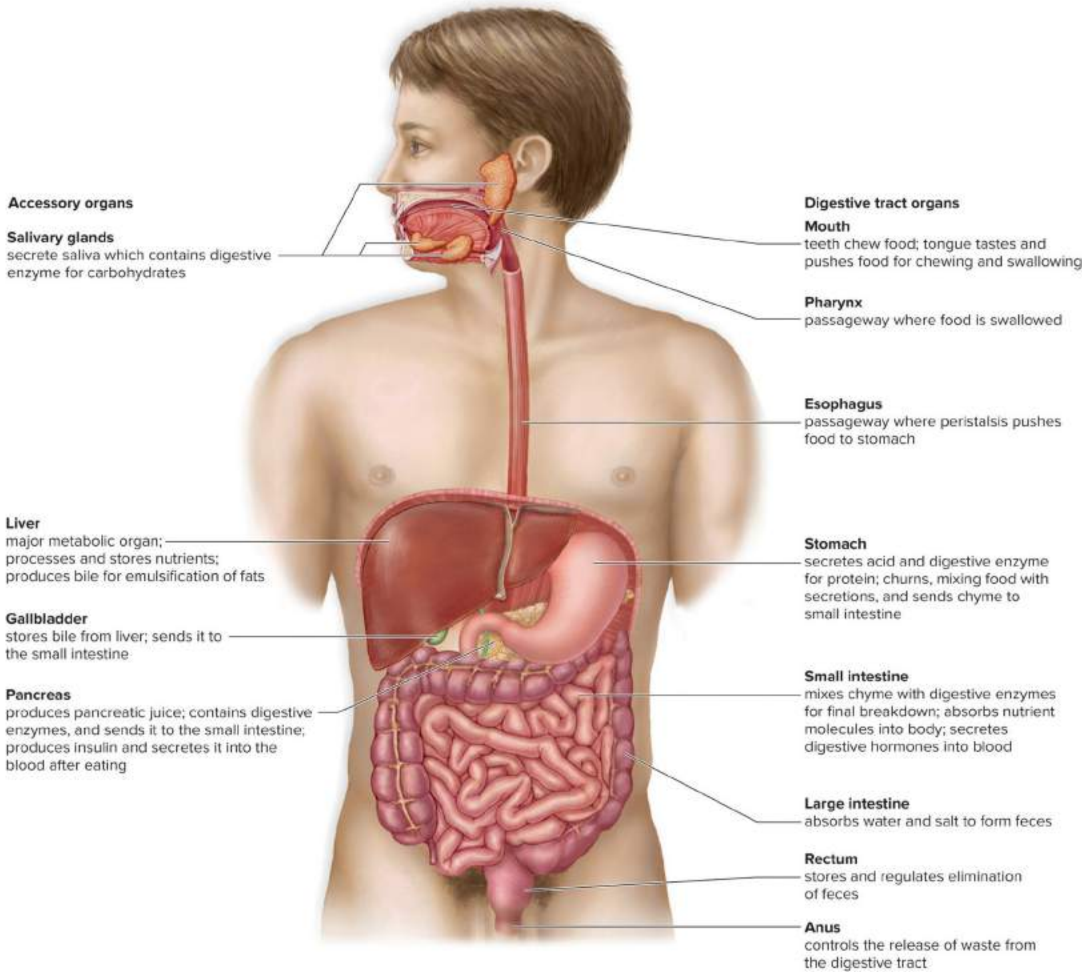
Because learning changes everything.™

Overview of Digestion 2

Overview of the **digestive system.**

- The organs are located within the **gastrointestinal (GI) tract.**
- Function—to **hydrolyze**, or break down, the macromolecules found in food.
  - The subunit molecules (monosaccharides, amino acids, fatty acids, and glycerol) can cross plasma membranes using facilitated and active transport.
- The nutrients made available are transported by the blood to our cells.

Organs of the GI Tract and Accessory Structures of Digestion (Figure 9.1)



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Stages of Digestion [1]

Stages of digestion.

- **Ingestion**—intake of food via the mouth.
- **Digestion**—mechanically or chemically breaking down foods into their subunits.
  - **Mechanical digestion**—chewing in the mouth and contractions of smooth muscles in the stomach.
  - **Chemical digestion**—digestive enzymes hydrolyze macromolecules into subunits.
    - Begins in the mouth, continues in the stomach, and is completed in the small intestine.

Stages of Digestion 2

Stages of digestion, continued.

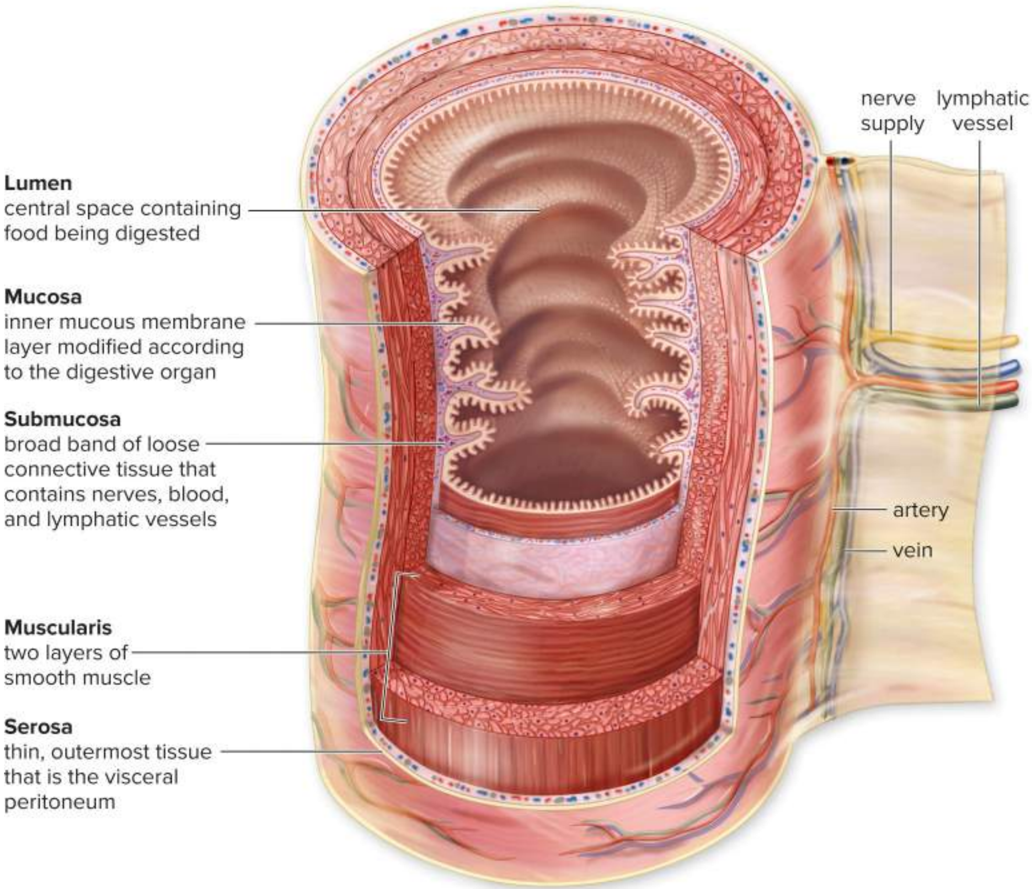
- **Movement**—food is passed from one organ to the next, normally by contractions of smooth muscle called **peristalsis**; indigestibles must be expelled.
- **Absorption**—movement of nutrients across the GI tract wall into the blood; they are then delivered to cells.
- **Elimination**—removal of indigestible wastes.
  - **Defecation.**

Wall of the Digestive Tract

Wall of the digestive tract.

- **Lumen**—open area of a hollow organ or vessel; in the GI tract, it contains food or feces.
- Layers:
  - **Mucosa**—innermost layer; produces mucus for protection; also produces digestive enzymes.
  - **Submucosa**—loose connective tissue; contains blood vessels, lymphatic vessels, and nerves.
  - **Muscularis**—made of 2 layers of smooth muscle (inner, circular layer, and an outer, longitudinal layer) that move food along the GI tract.
  - **Serosa**—outer lining; is part of the peritoneum.

The Layers of the Gastrointestinal Tract Wall (Figure 9.2)



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Diverticulosis

Diverticulosis.

- A condition in which the mucosa of any part of the GI tract (usually the large intestine) pushes through the other layers and forms pouches where food collects.
- **Diverticulitis**—when the pouches become infected.
    - This happens in 10–25% of people with diverticulosis.

Bowel Disease

Inflammatory bowel disease (IBD)—chronic diarrhea, abdominal pain, fever, and weight loss.

Irritable bowel syndrome (IBS)—contractions of the muscularis cause abdominal pain, constipation, and diarrhea.

- The underlying cause is not known.

The Mouth 1

Mouth (oral cavity).

- Receives food and begins mechanical and chemical digestion.
- The roof of the mouth separates the nasal cavity from the oral cavity.
  - Two parts: a bony **hard palate** and a **soft palate.**
    - The soft palate is made of muscle; ends in the **uvula.**
- **Tonsils**—in the back of the mouth on either side of the tongue.
  - Lymphatic tissue; help protect from disease.
  - There is a single pharyngeal tonsil in the nasopharynx, commonly called the **adenoids.**
- Three pairs of **salivary glands** secrete **saliva**, which contains:
  - **Salivary amylase**—begins carbohydrate digestion.
  - **Lysozyme**—antibacterial enzyme.
- **Tongue.**
  - Covered in taste buds.
  - Assists in mechanical breakdown, movement of food.
  - Forms a **bolus** (mass of chewed food) and moves it toward the pharynx.

Teeth 1

Teeth.

- Mechanically digest food.
- 20 smaller **deciduous (baby) teeth**, 32 **adult teeth.**
- Two main divisions:
  - **Crown**—the part of the tooth above the gum line.
  - **Root**—the portion below.

The Pharynx and Esophagus

The mouth and nasal passages lead to the **pharynx.**

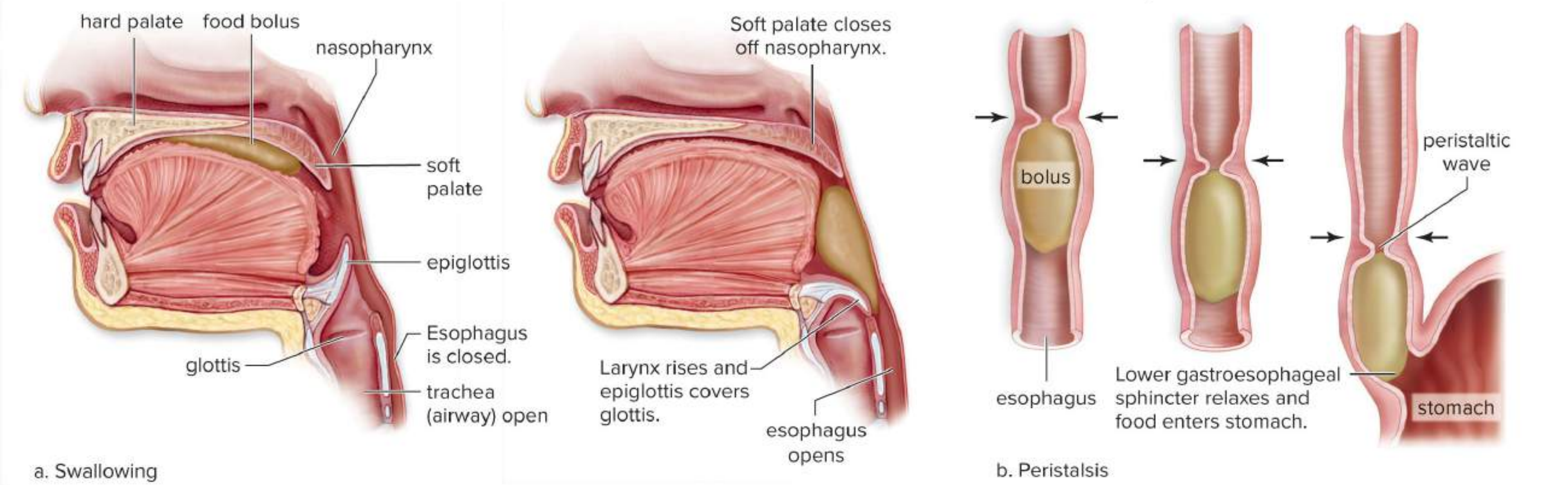
- In turn, the pharynx opens into both the food passage (**esophagus**) and air passage (**trachea**).
    - These two tubes are parallel to each other; the trachea is in front of the esophagus.
    - The esophagus is a muscular tube that leads to the stomach.

Swallowing

Swallowing.

- Starts off voluntary, but once food or drink is pushed back into the pharynx, it becomes an involuntary reflex.
- Food normally enters the esophagus because other possible avenues are blocked.
  - The soft palate moves back to close off the nasal passage, and the trachea moves up under the **epiglottis** to cover the **glottis**, the opening to the **larynx.**

The Process of Swallowing (Figure 9.4)



a. Swallowing

b. Peristalsis

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Peristalsis 1

Peristalsis—contractions that push food through the digestive tract.

Sphincter—a ring of muscle that acts as a valve.

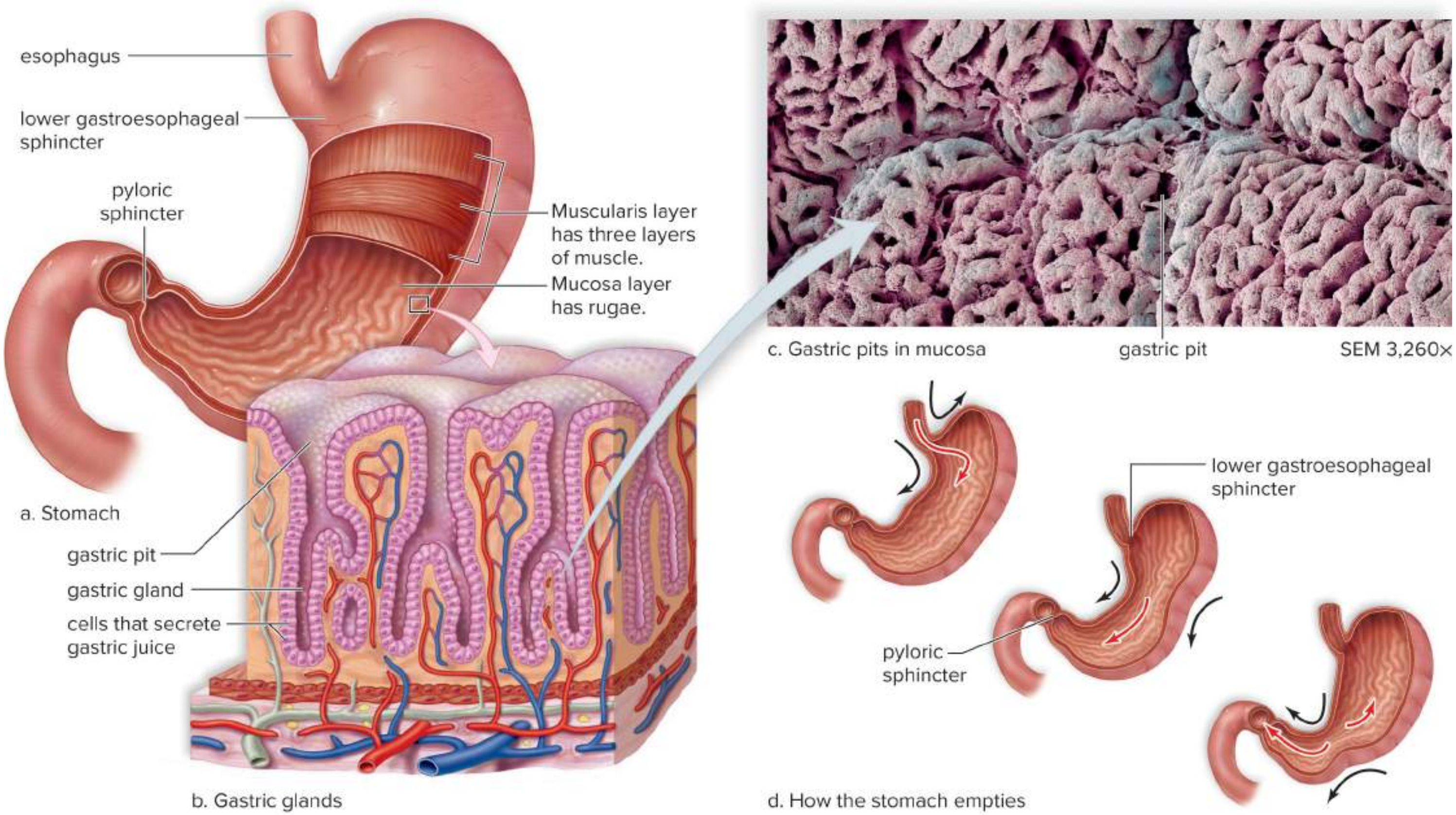
- When it contracts, it stops food from moving through; when it relaxes, it allows food through.
- That is, the **lower esophageal sphincter** is between the esophagus and the stomach.
  - **Heartburn**—failure of this sphincter; stomach contents move from the stomach into the esophagus.
  - Vomiting—when strong contractions of the abdominal muscles and the **diaphragm** (the muscle separating the thoracic and abdominal cavities) force the contents of the stomach into the esophagus and oral cavity.

The Stomach 1

Stomach.

- Stores food, starts digestion of proteins, and of controls movement food into the small intestine.
- Does not absorb nutrients.
  - However, it does absorb alcohol, because alcohol is fat-soluble and can pass through membranes easily.
- There are three layers of muscle in the muscularis layer (instead of two) to help in mechanical digestion.
  - **Circular, longitudinal,** and third **oblique layer.**
- The mucosa has deep folds called **rugae.**
- The mucosa also has **gastric pits**, which contain **gastric glands.**
  - The gastric glands produce **gastric juice**, which contains:
    - **Pepsin**—digests proteins.
    - Hydrochloric acid (HCl)—pH of 2.
      - Kills bacteria and activates pepsin.
    - Mucus.
- Normally, the stomach empties in 2–6 hours.
- Chyme—a mixture of food and gastric juice.
  - **Pyloric sphincter**—allows only a small amount of chyme to enter the small intestine at a time.

The Layers of the Stomach (Figure 9.5)



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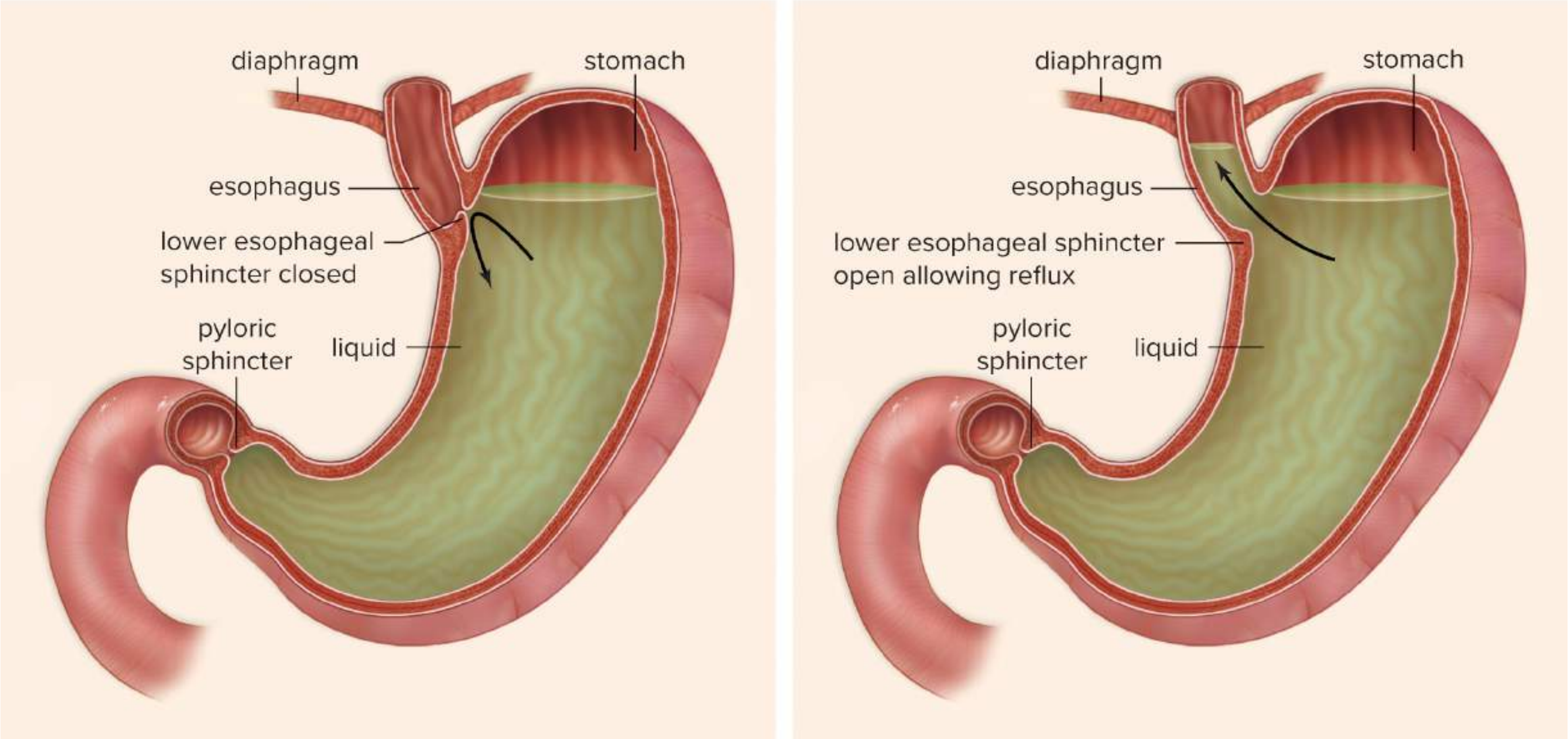
Heartburn (GERD)

Heartburn.

- The lining of the esophagus is thinner than the lining of the stomach; if chyme enters the esophagus, it produces a burning sensation.
- Can be caused by pregnancy and excess fat pushing on the stomach.
- **Gastroesophageal reflux disease (GERD)**—chronic heartburn.

Heartburn (Figure 9A)



Digestion Is Completed in the Small Intestine [1]

Small intestine.

- **Pancreas**—secretes digestive enzymes through a duct into the **duodenum**, the first portion of the small intestine.
- Another duct brings **bile** from the liver and gallbladder into the duodenum.
- Bile **emulsifies** fat.
  - Mechanical digestion; causes fat droplets to disperse in water to expose more of it to **lipase.**
  - Produced by the pancreas, it hydrolyzes fats into glycerol and fatty acids.

Digestion Is Completed in the Small Intestine 2

Small intestine, continued.

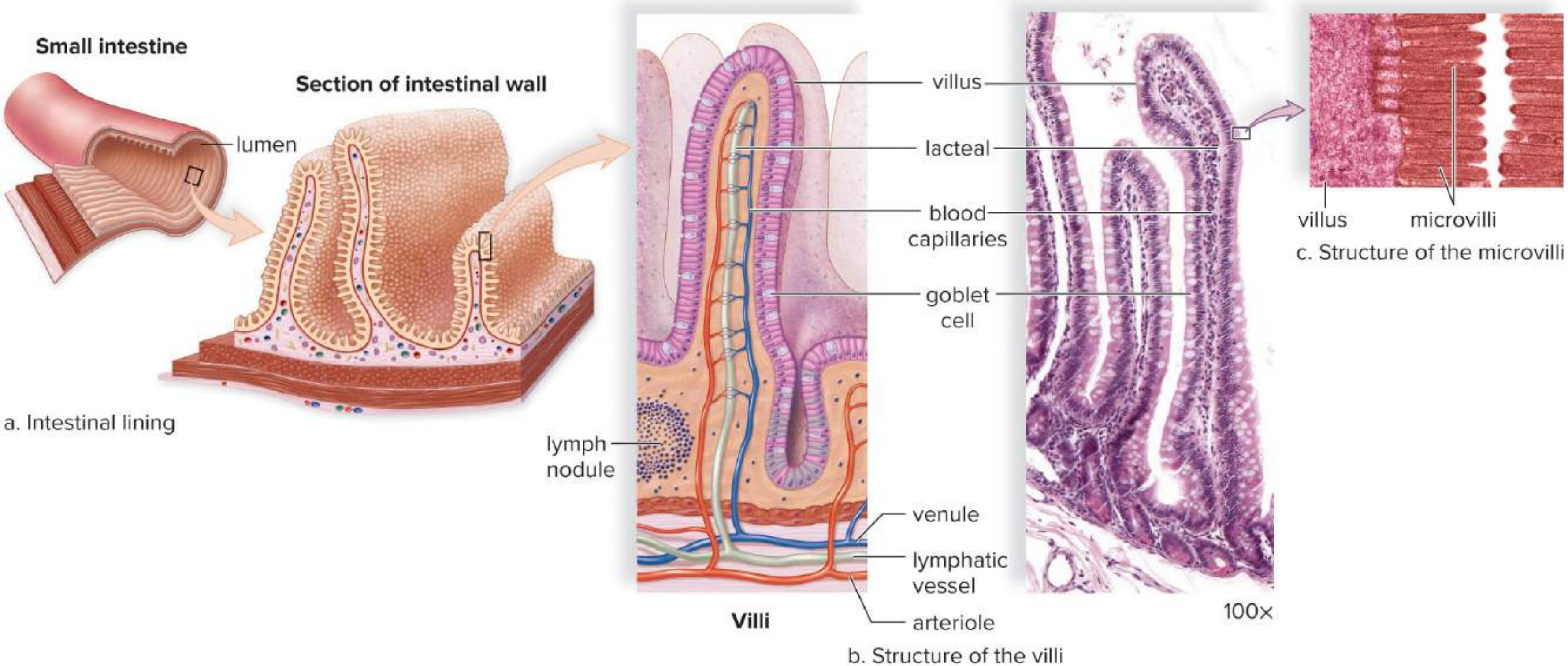
- **Pancreatic amylase**—produced by the pancreas, secreted into the duodenum.
  - Digests carbohydrates.
- **Trypsin**—produced by the pancreas, secreted into the duodenum.
  - Digests proteins, so is a **protease**—a class of enzymes that digest proteins.
- Pancreatic juice contains sodium bicarbonate, which neutralizes acidic chime.

Nutrients Are Absorbed in the Small Intestine 1

Small intestine, continued.

- The mucosa contains fingerlike projections called **villi** (*singular*, villus).
- The cells that cover the villi have **microvilli.**
  - Give the villi a fuzzy "brush border".
  - Contain brush border enzymes that complete digestion.
- These two structures greatly increase the surface area of the small intestine for absorption of nutrients.

Absorption in the Small Intestine (Figure 9.6)



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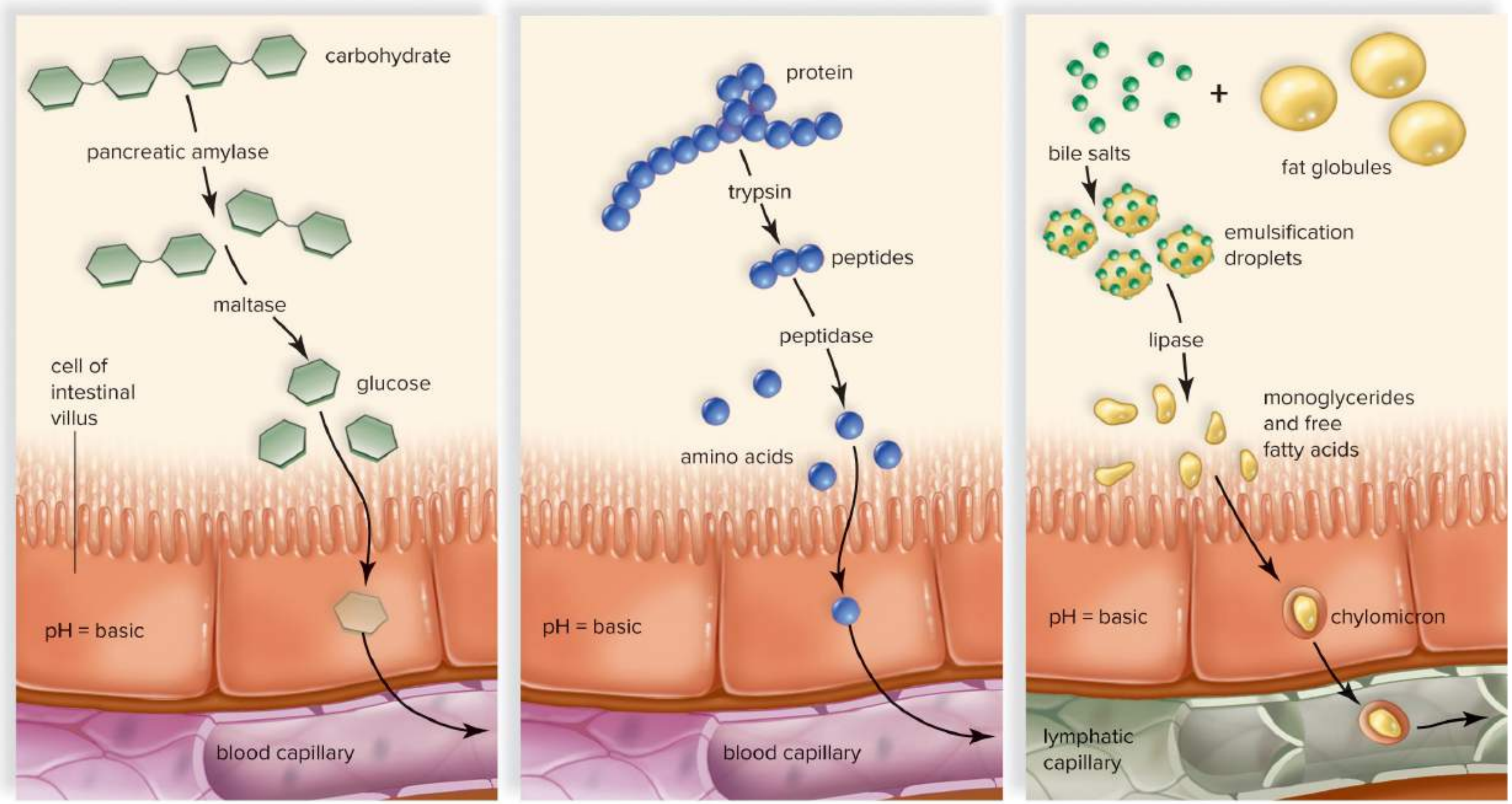
(photo) (b): ©Al Telser/McGraw-Hill Education; (c): ©Science

Nutrients Are Absorbed in the Small Intestine 2

Small intestine, continued.

- Nutrients are absorbed into the villi, which contain blood capillaries and a small lymphatic capillary called a **lacteal.**
  - Monosaccharides and amino acids enter the blood capillaries of a villus.
  - Glycerol and fatty acids form lipoprotein droplets called **chylomicrons**, which then enter a lacteal.
- After nutrients are absorbed, they are eventually carried to all the cells of the body by the blood.

Digestion and Absorption of Organic Nutrients (Figure 9.7)



a. Carbohydrate digestion
b. Protein digestion
c. Fat digestion

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Major Digestive Enzymes (Table 9.1) 1

Table 9.1a Major Digestive Enzymes: Carbohydrate Digestion.

Enzyme	Produced By	Site of Action	Optimum pH	Digestion
Salivary amylase	Salivary glands	Mouth	Neutral	Starch + H_2O → maltose
Pancreatic amylase	Pancreas	Small intestine	Basic	Starch + H_2O → maltose
Maltase	Small intestine	Small intestine	Basic	Maltose + H_2O → glucose + glucose
Lactase	Small intestine	Small intestine	Basic	Lactose + H_2O →"glucose + galactose

Table 9.1b Major Digestive Enzymes: Protein Digestion.

Enzyme	Produced By	Site of Action	Optimum pH	Digestion
Pepsin	Gastric glands	Stomach	Acidic	Protein + H_2O → peptides
Trypsin	Pancreas	Small intestine	Basic	Protein + H_2O → peptides
Peptidases	Small intestine	Small intestine	Basic	Protein + H_2O → amino acids

Major Digestive Enzymes (Table 9.1) 2

Table 9.1c Major Digestive Enzymes: Nucleic Acid Digestion.

Enzyme	Produced By	Site of Action	Optimum pH	Digestion
Nuclease	Pancreas	Small intestine	Basic	RNA and DNA + H_2O → nucleotides
Nucleosidases	Small intestine	Small intestine	Basic	Nucleotide + H_2O→ base + sugar + phosphate

Table 9.1d Major Digestive Enzymes: Fat Digestion.

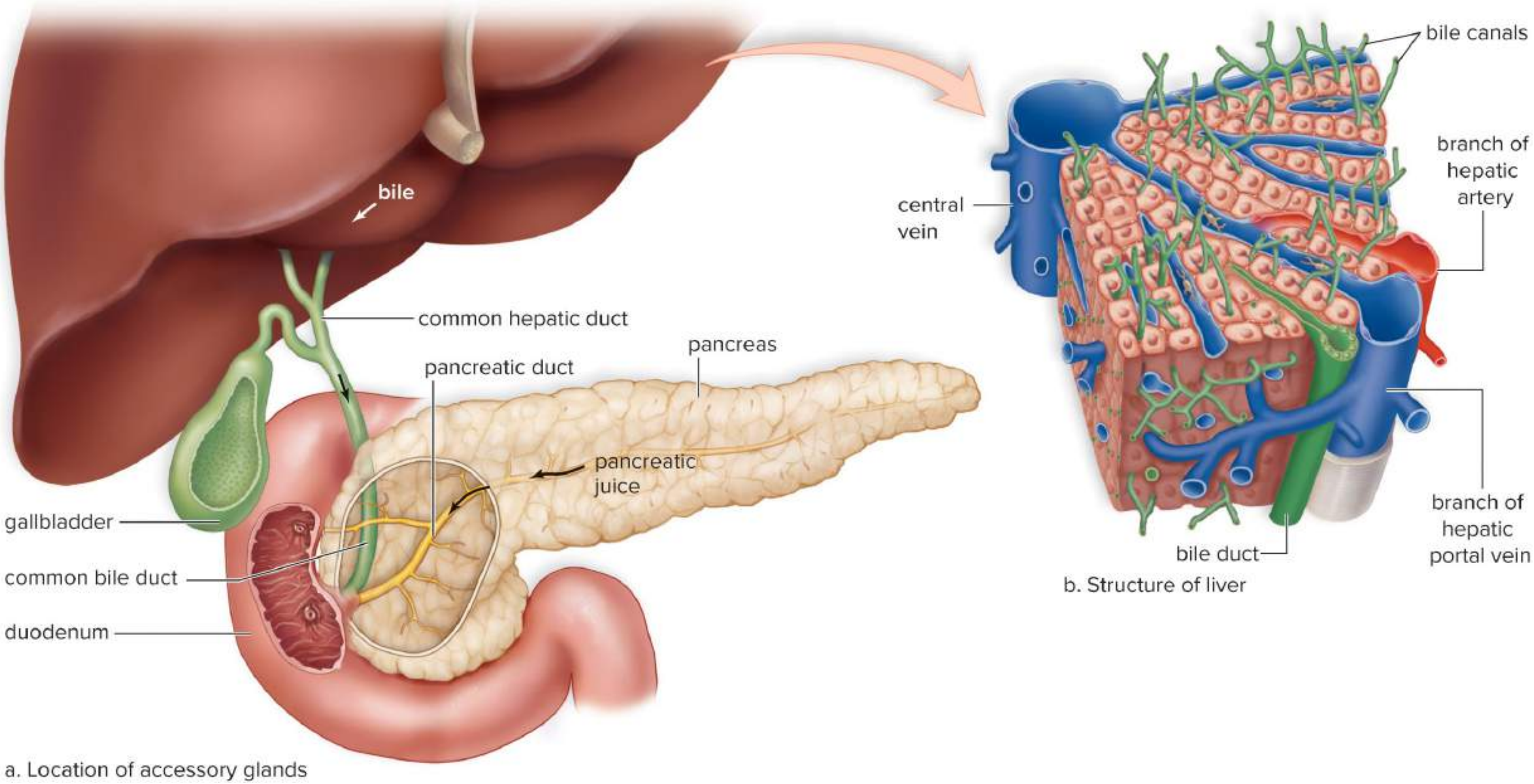
Enzyme	Produced By	Site of Action	Optimum pH	Digestion
Lipase	Pancreas	Small intestine	Basic	Fat droplet + H_2O → monoglycerides + fatty acids

The Accessory Organs [1]

Pancreas.

- Located behind the stomach.
- Most pancreatic cells produce **pancreatic juice**, which enters the duodenum via the **pancreatic duct.**
  - Contains sodium bicarbonate and digestive enzymes.
- Also an endocrine gland; secretes the hormone insulin when the blood glucose levels rise.
- Type 1 diabetes—not enough insulin.
  - Normally diagnosed in childhood.
- Type 2 diabetes—the body's cells are insulin-resistant.
  - Normally occurs in adulthood.
  - Risk factors: obesity, inactivity, family history.

Accessory Organs of the Digestive System (Figure 9.8)



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The Liver [1]

Liver.

- The largest gland in the body.
- Lies mainly in the upper right abdominal cavity, under the diaphragm.
- **Lobules**—structural and functional units.
- The hepatic portal vein brings blood to the liver from the GI tract.
  - The lobules filter this blood, removing poisonous substances.

Functions of the Liver (Table 9.2)

Table 9.2 Functions of the Liver.

1. Destroys old red blood cells; excretes bilirubin, a breakdown product of hemoglobin in bile, a liver product
2. Detoxifies blood by removing and metabolizing poisonous substances
3. Stores iron (Fe^{2+}), the water-soluble vitamin B_{12}, and the fat-soluble vitamins A, D, E, and K
4. Makes plasma proteins, such as albumins and fibrinogen, from amino acids
5. Stores glucose as glycogen after a meal; breaks down glycogen to glucose to maintain the glucose concentration of blood between eating periods
6. Produces urea after breaking down amino acids
7. Helps regulate blood cholesterol level, converting some to bile salts

The Gallbladder

Gallbladder.

- Pear-shaped organ just below the liver.
- Stores bile.
- **Gallstones**—made of a stone-like material.

Liver Disorders

Liver disorders: **hepatitis** and **cirrhosis.**

- Liver disease can cause bile pigments to leak into the blood, causing **jaundice.**
    - Yellowish tint to the whites of the eyes and the skin.
- **Hepatitis.**
    - Inflammation of the liver.
    - Has different forms.

Hepatitis

Hepatitis, continued.

- **Hepatitis A**—usually acquired from sewage-contaminated drinking water and food.
- **Hepatitis B**—usually from sexual contact, but also from blood transfusions or contaminated needles.
  - More contagious than the AIDS virus and is spread in the same way.
  - Vaccines are available for hepatitis A and B.
- **Hepatitis C**—usually acquired by infected blood.
  - Can lead to chronic hepatitis, liver cancer, and death.

Cirrhosis

Cirrhosis.

- Chronic disease; first, liver becomes fatty, and then filled with fibrous scar tissue.
- Often seen in alcoholics due to malnutrition and the excessive alcohol (a toxin) the liver is forced to break down.
- The liver can regenerate and recover if the rate of regeneration exceeds the rate of damage.
  - During liver failure there may not be enough time to let the liver heal so will need a liver transplantation.

Regulation of Digestive Secretions 1

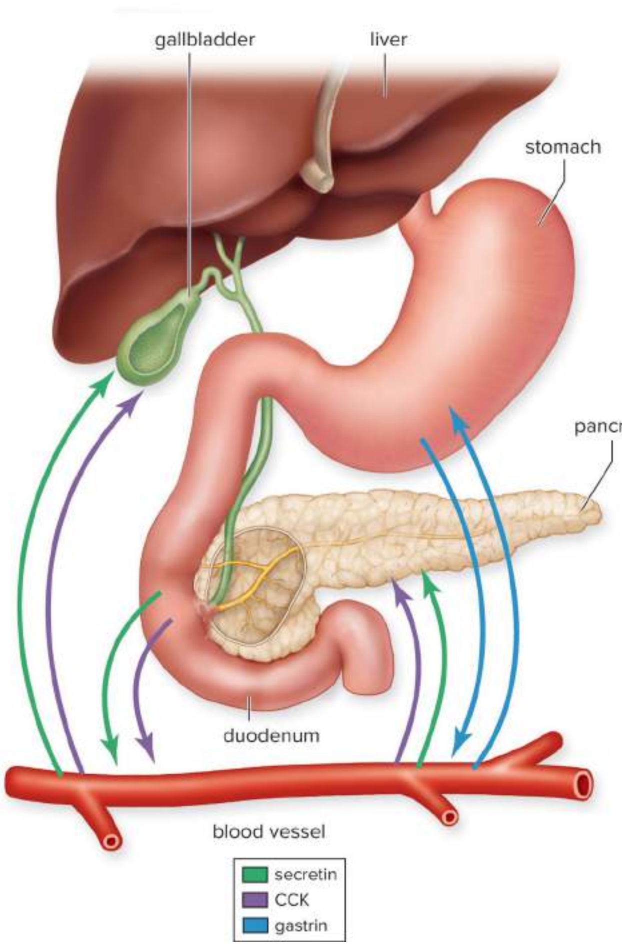
Secretion of digestive **juices** is controlled by the nervous system and digestive hormones.

- When you look at or smell food, the parasympathetic nervous system stimulates gastric secretion.
- A meal rich in protein causes the stomach to produce the hormone **gastrin.**
  - Increases the secretory activity of gastric glands.

Nervous system and hormonal control, continued.

- **Secretin**—secreted by the duodenum.
  - Release is stimulated by HCl (present in chyme).
- **Cholecystokinin (CCK)**—released by the duodenum when proteins and fat are present.
  - Causes the liver to increase production of bile and causes the gallbladder to contract and release stored bile.
  - These hormones increase the production of pancreatic juice.

Hormonal Control and Regulation of Digestion (Figure 9.9)



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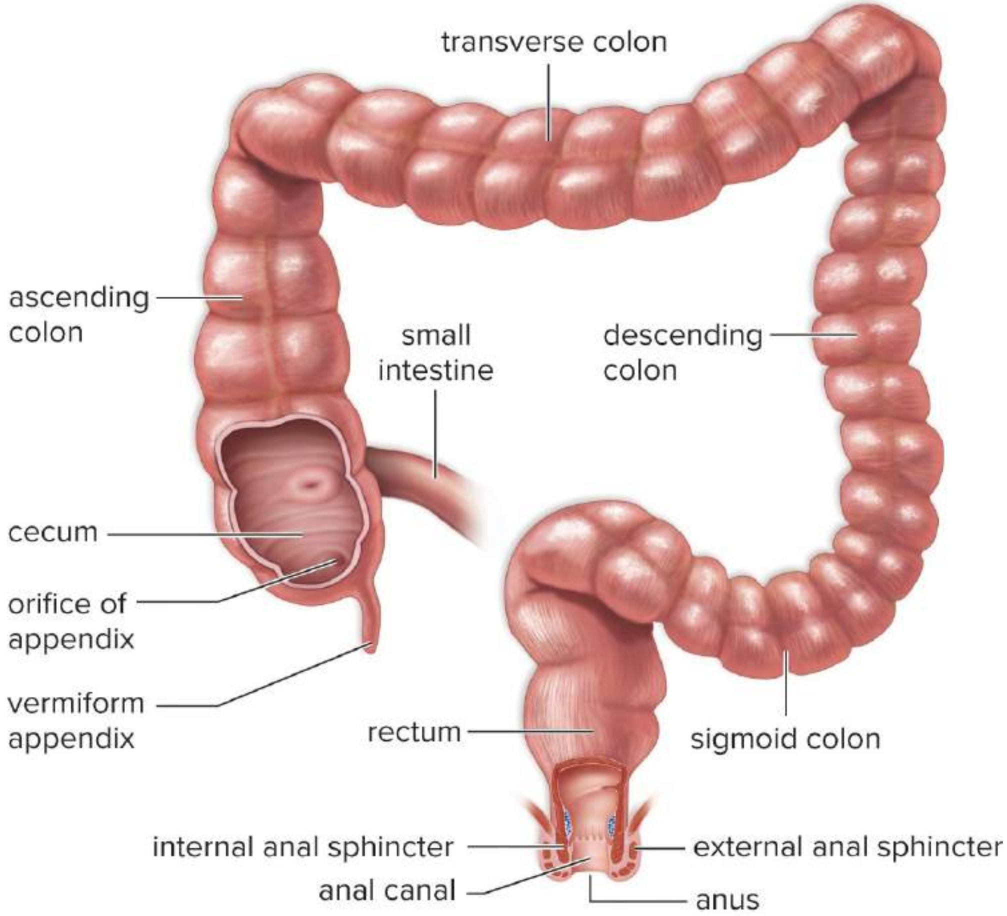
The Large Intestine 1

Large intestine—includes the **cecum**, the **colon**, the **rectum**, and the **anal canal.**

- Larger in diameter than the small intestine, but it is shorter in length.
- **Cecum**—the first portion.
  - **Vermiform appendix**—projection off of the cecum.
    - Fights infections.
    - **Appendicitis**—inflamed appendix; can cause **peritonitis**, a life-threatening infection of the peritoneum.
- **Colon**—includes the **ascending colon**, which goes up the right side of the body; **transverse colon**, which crosses the abdominal cavity; descending colon, which passes down the left side; and the sigmoid colon, which enters the **rectum**, the last portion of the large intestine.
  - The rectum opens at the **anus**, where **defecation**, the expulsion of **feces**, occurs.

The Regions of the Large Intestine (Figure 9.10)



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Functions of the Large Intestine [1]

Functions of the large intestine.

- Does not produce digestive enzymes.
- Does not absorb nutrients except certain vitamins.
- Absorbs water from feces to prevent dehydration.
- Absorbs vitamins produced by **intestinal flora**, the bacteria that inhabit the intestine.
  - Bacteria break down indigestible material and produce B-complex vitamins and vitamin K.

Functions of the Large Intestine 2

Functions of the large intestine, continued.

- Forms feces.
  - ¾ water, ¼ solid wastes.
  - Bacteria and dietary fiber (indigestible remains) make up the solid wastes.
  - Bacteria digesting the indigestible materials causes the odor of feces and accounts for the gas.
  - Stercobilin, a breakdown product of bilirubin, and oxidized iron cause the brown color of feces.

Functions of the large intestine, continued.

- **Defecation**—ridding the body of feces.
  - Peristalsis forces feces into the rectum.
  - Stretching of the rectal wall initiates nerve impulses to the spinal cord.
  - Then the rectal muscles contract and the anal sphincters relax, allowing the feces to exit the body through the anus.
  - Can inhibit defecation by contracting the external anal sphincter, which is made of skeletal muscle.

Disorders of the Colon and Rectum 1

Diarrhea—increased peristalsis and failure to absorb water from feces, due to either an infection or nervous stimulation.

Constipation—dry, hard feces; may be controlled with water and fiber.

Hemorrhoids—enlarged, inflamed blood vessels of the anus due to chronic constipation, pregnancy, aging, anal intercourse.

Diverticulosis—pouches; weak spots in the muscularis layer.

Disorders of the Colon and Rectum 2

Irritable bowel syndrome (IBS), or **spastic. colon**—the muscularis contracts powerfully but without normal coordination.

- Symptoms: abdominal cramps, gas, constipation, and urgent, explosive stools.

Inflammatory bowel disease (IBD)—includes:

- **Ulcerative colitis**—affects the large intestine and rectum.
  - Results in diarrhea, rectal bleeding, abdominal cramps, and urgency to defecate.
- **Crohn's disease**—usually in the small intestine.
  - Ulcers in the intestinal wall; they are painful and bleed as they erode the submucosal layer, where there are nerves and blood vessels.
  - Can't absorb nutrients in the affected areas.
  - Symptoms: diarrhea, weight loss, abdominal cramping, anemia, bleeding, and malnutrition.

Polyps and Cancer

Polyps—small growths in the colon lining.

- Can be benign or cancerous.
- If colon cancer is detected while still confined to a polyp, the expected outcome is a complete cure.
- Increased dietary fat raises the risk of colon cancer.
- Fiber in the diet inhibits colon cancer, and regular elimination reduces the time that the colon wall is exposed to cancer-promoting agents in the feces.

Obesity

Obesity—significantly overweight.

- One of the greatest health problems in the United States.
  - Almost 36% of adults and 17% of children are obese.
  - Excess body fat is associated with a higher risk for premature death, type 2 diabetes, hypertension, cardiovascular disease, stroke, osteoarthritis, and certain types of cancer.
- Having a **body mass index (BMI)** of 30 or greater.
  - Weight in kilograms (kg) is divided by the height in m^2.

Classes of Nutrients

Classes of nutrients.

- **Nutrient**—a required component of food that performs a physiological function in the body.
  - Provides energy, promotes growth and development, and regulates cellular metabolism.
  - Includes **carbohydrates, proteins, lipids, minerals,** and **vitamins.**

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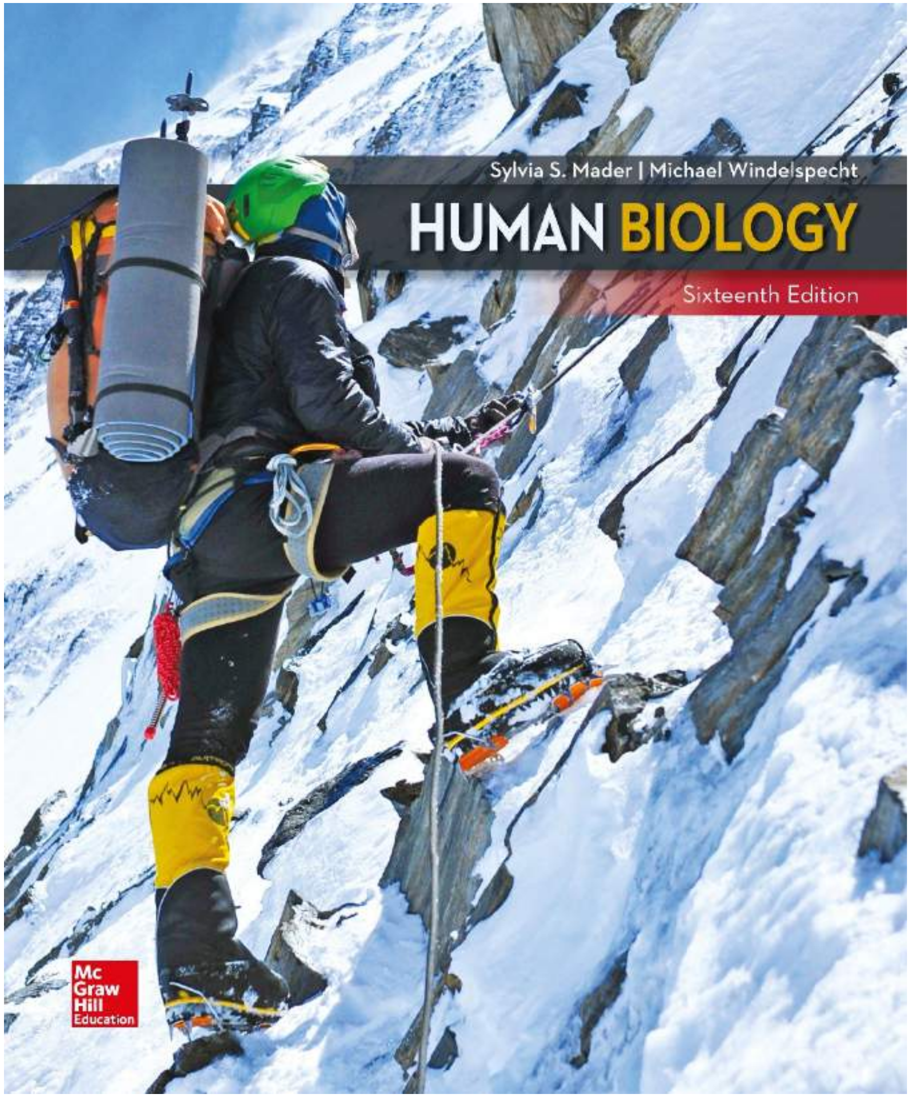


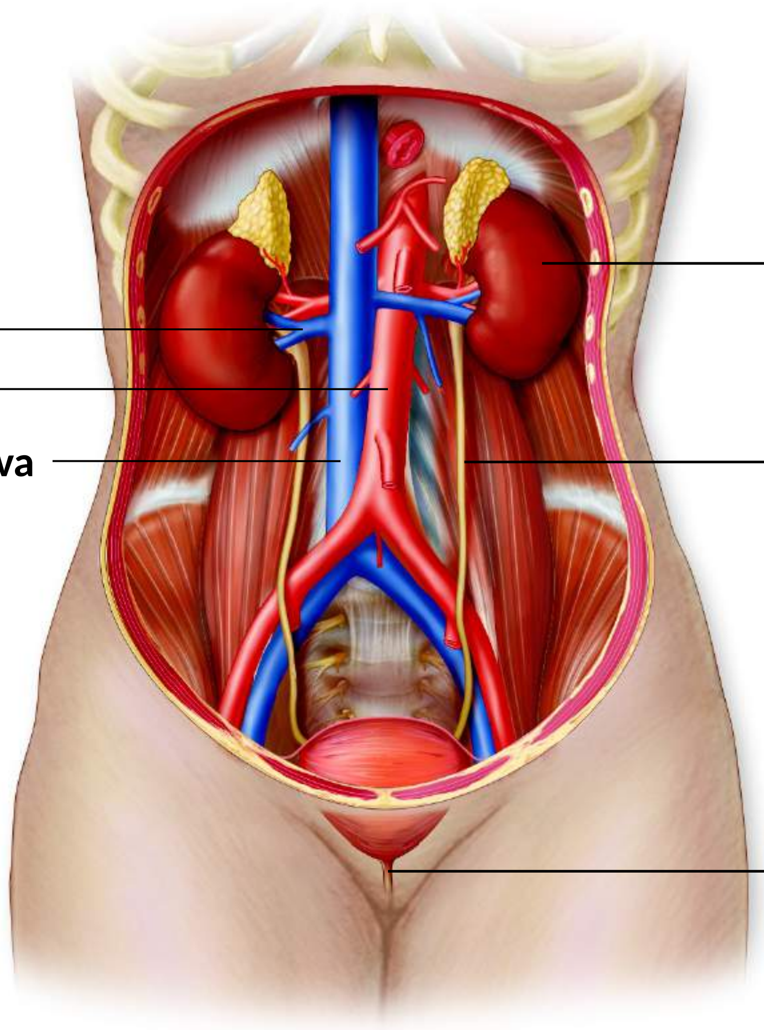
Sylvia S. Mader

Michael Windelspecht

Lab 11 the Urinary System (Chapter 11 Lecture Outline)

Because learning changes everything.™

The Urinary System (Figure 11.1)



*Note the placement of the right kidney vs. left

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Organs of the Urinary System 1

The urinary system consists of the kidneys, ureters, urinary bladder, and urethra.

Kidneys.

- One on each side of the vertebral column in a **retroperitoneal** location; partially protected by the rib cage.
- Bean-shaped and reddish to brown in color.
- Covered by the **renal capsule.**
- The concave side of the kidney is where a **renal artery** enters and a **renal vein** and **ureter** exit.
    - The renal artery transports blood to the kidneys; the renal vein carries filtered blood away from the kidneys.

Ureters

Ureters.

- Conduct urine from the kidneys to the bladder.
- The wall has three layers: an inner mucosa, a smooth muscle layer, and an outer fibrous coat of connective tissue.
- Peristaltic contractions in the ureter push urine into the bladder even when lying down.

Urinary Bladder 1

- Stores urine.
- Has three openings: two for the ureters, and one for the **urethra**, which drains the bladder.
- Folds in the mucosa called **rugae** disappear as the bladder enlarges.
- A layer of transitional epithelium enables the bladder to stretch.
- There are two sphincters where the urethra exits the bladder.
  - The **internal sphincter** is composed of smooth muscle and is involuntarily controlled.
  - The **external sphincter** is composed of skeletal muscle that can be voluntarily controlled.

What are the functions of the urinary system?

1. Excretion of metabolic wastes
2. Maintenance of water-salt balance
3. Maintenance of acid-base balance
4. Hormone secretion: renin and erythropoietin (EPO)
5. Reabsorption of filtered nutrients and the activation of Vitamin D calcitriol

The Urinary System 2

The **urinary system** carries out **excretion*** of metabolic wastes from the body (urea, creatinine, and uric acid).

- **Urea**—a waste product of amino acid metabolism.
  - The main nitrogenous waste of metabolism.
- **Creatinine**—results from the breakdown of creatine phosphate, an energy storage molecule in muscles.
- **Uric acid**—from the metabolic processing of nucleotides.

*Note **excretion** is different from **defecation** which is elimination of feces from the body.

Maintenance of Water-Salt Balance 1

Maintenance of water-salt balance of the blood.

- A principal function of the kidneys.
- Salts, such as NaCl, have the ability to influence the rate and direction of osmosis.
  - Therefore, the more salts there are in the blood, the greater the blood volume and the greater the blood pressure.
  - By regulating the concentration of sodium (Na^+) and potassium (K^+) in the blood, the kidneys regulate blood pressure.
  - The kidneys also maintain the appropriate levels of other ions such as bicarbonate (HCO_3^-) and calcium (Ca^{2+}).

Maintenance of Acid-Base Balance

Maintenance of acid-base balance of the blood.

- A healthy blood pH is about 7.4.
- The kidneys monitor and help control pH by excreting H^+ and reabsorbing HCO_3^- as needed.
- Urine usually has a pH of 6 or lower because the diet contains acidic foods.

Secretion of Hormones

Secretion of hormones.

- The kidneys release **renin**, an enzyme that leads to aldosterone secretion.
- **Aldosterone** is a hormone produced by the adrenal glands, which lie atop the kidneys.
  - Regulates the water-salt balance of the blood.
- The kidneys also release **erythropoietin (EPO)**, a hormone that stimulates the production of red blood cells.

Additional Functions of the Kidneys

Additional functions of the kidneys.

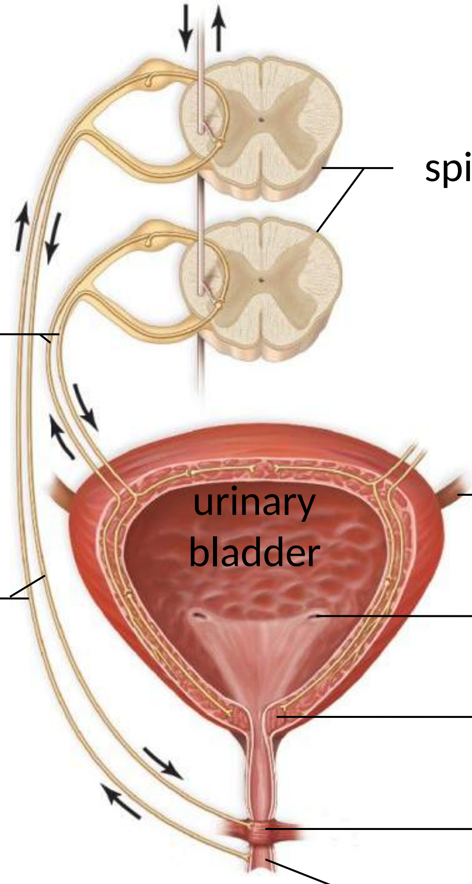
- The kidneys also reabsorb filtered nutrients and participate in the synthesis of vitamin D.
  - Vitamin D is a hormone that promotes calcium ion (Ca^{2+}) absorption in the digestive tract.

Urination

Urination (micturition).

- When the urinary bladder fills with urine, stretch receptors are activated.
- These receptors send sensory nerve signals to the spinal cord.
  - Subsequently, motor nerve impulses from the spinal cord cause the urinary bladder to contract and the sphincters to relax, so that urination is possible.
  - The brain has control over micturition, too, by controlling the external urethral sphincter.

Sensory Impulses Trigger a Desire to Urinate (Figure 11.2)



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Urethra [1]

Urethra.

- Extends from the urinary bladder to an external opening.
- The short length of the female urethra makes women more susceptible to infections.
- In males, as the urethra leaves the male urinary bladder, it is encircled by the prostate gland.
- In females, the reproductive and urinary systems are not connected.
- In males, however, the urethra carries urine during urination and sperm during ejaculation.

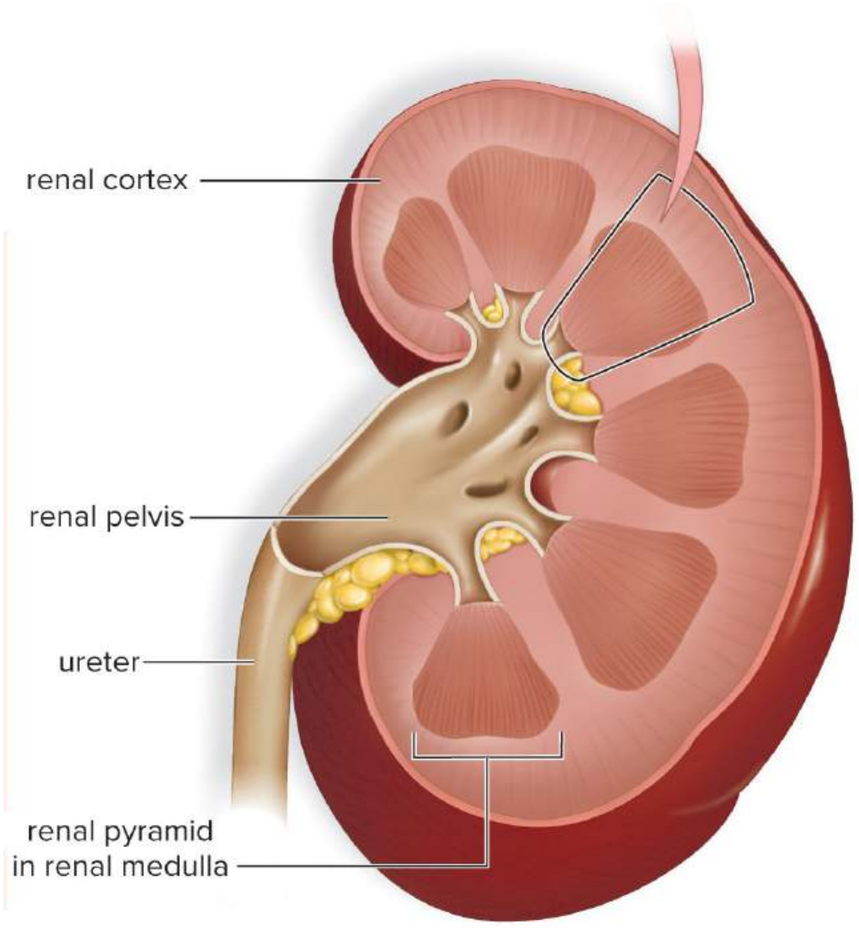
The Anatomy of a Human Kidney (Figure 11.3d)

The three regions of a kidney:

Renal cortex—outer layer that dips down in between the inner layer called the renal medulla.

Renal medulla—consists of cone-shaped tissue masses called **renal pyramids.**

Renal pelvis—a central space that is continuous with the ureter.



d. Gross anatomy, art

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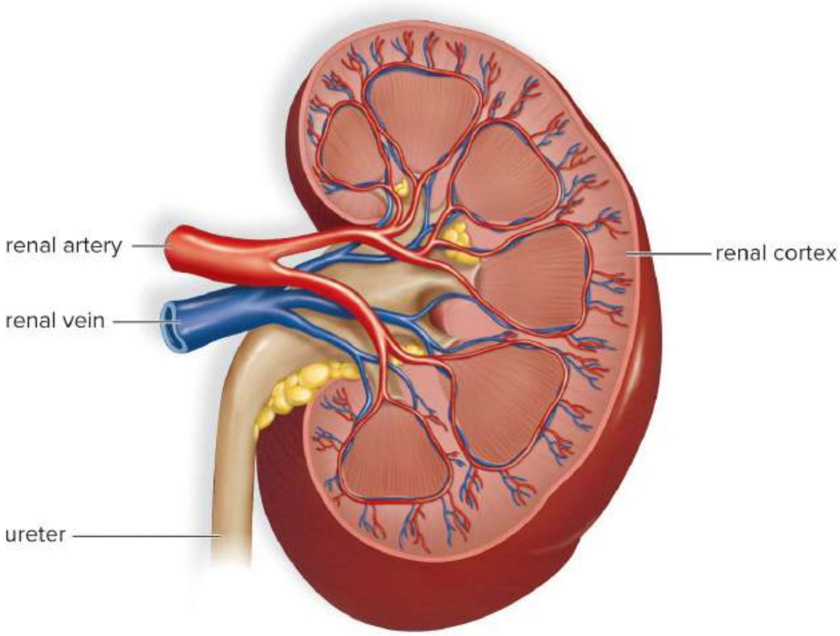
Kidney Structure 2

Kidneys are composed of over 1 million **nephrons.**

- The nephrons filter the blood and produce urine.
- Several nephrons empty urine into one **collecting duct.**
- The collecting ducts empty into the **renal pelvis.**



a. Blood vessels

The renal **hilus** is the Region where the blood vessels enter and exit the kidney

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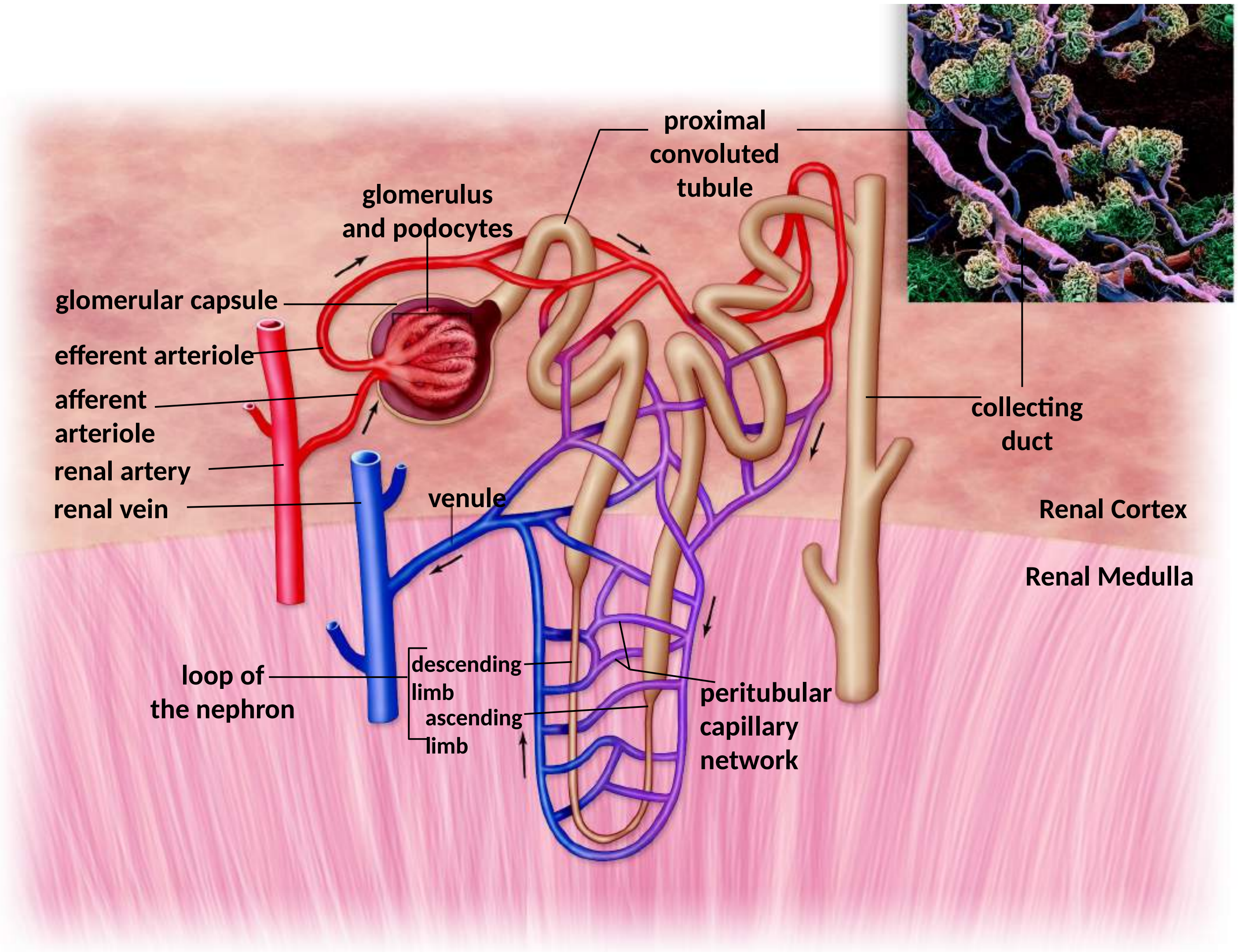
Anatomy of a Nephron [1]

- From the renal artery, an **afferent arteriole** transports blood to the **glomerulus**, a knot of capillaries inside the glomerular capsule.
- The **efferent arteriole** carries blood away from the glomerulus.
- Blood pressure is higher in the glomerulus than anywhere else in the body because the efferent arteriole is narrower than the afferent arteriole.
- The efferent arteriole empties into the **peritubular capillary network**, which surrounds the rest of the nephron.
- Then the blood goes into a venule that carries blood into the renal vein.

The Structure of a Nephron (Figure 11.4)



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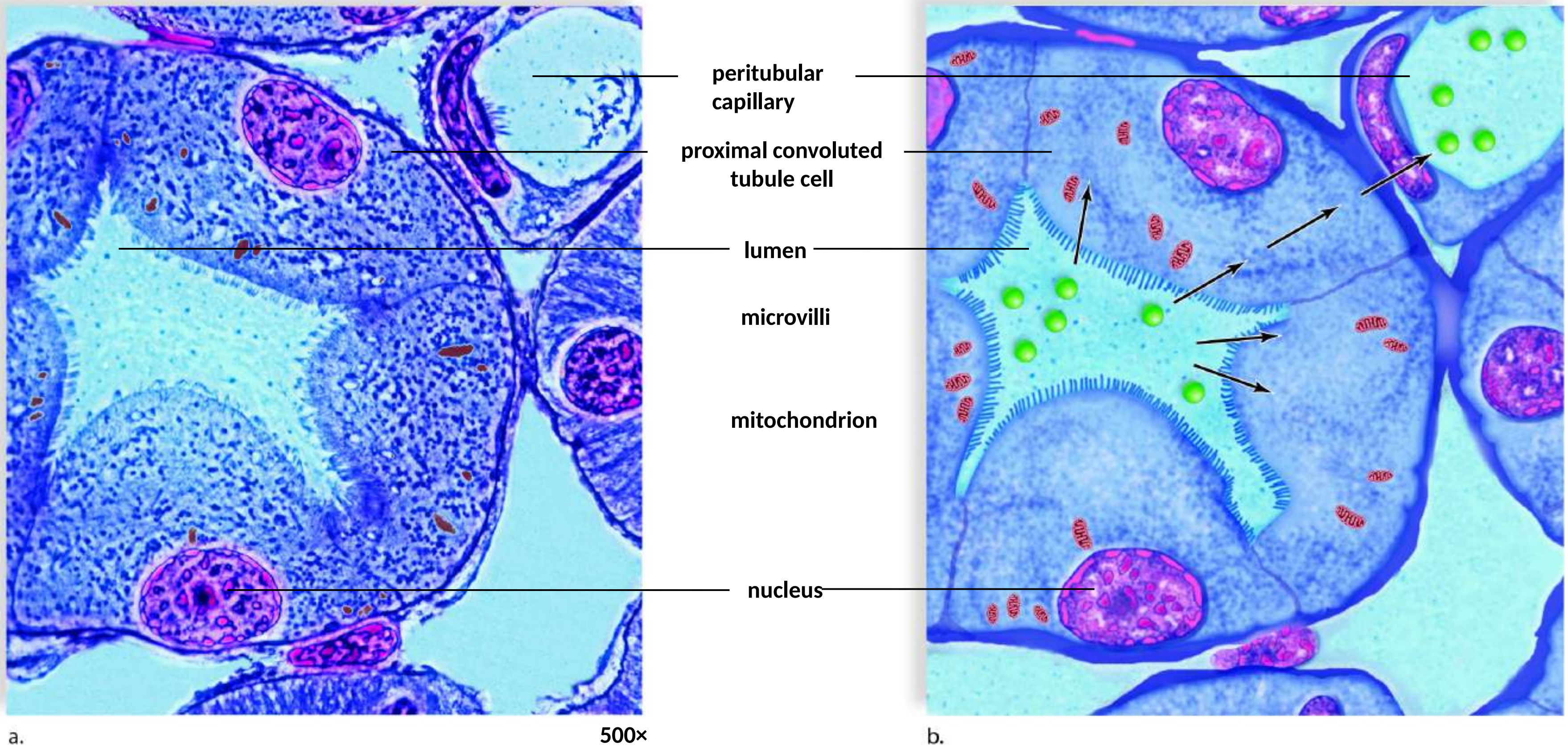
Parts of a Nephron 1

Parts of a nephron.

- **Glomerular capsule.**
  - The outer layer is made of squamous epithelial cells.
  - The inner layer is made of **podocytes** that cover the glomerulus, leaving pores that allow molecules from the blood inside the glomerulus out into the glomerular capsule.
- **Proximal convoluted tubule.**
  - Its cuboidal epithelial cells have numerous microvilli that form a brush border; these increase surface area.

The Specialized Cells of the Proximal Convoluted Tubule (Figure 11.5)



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Parts of a Nephron [2]

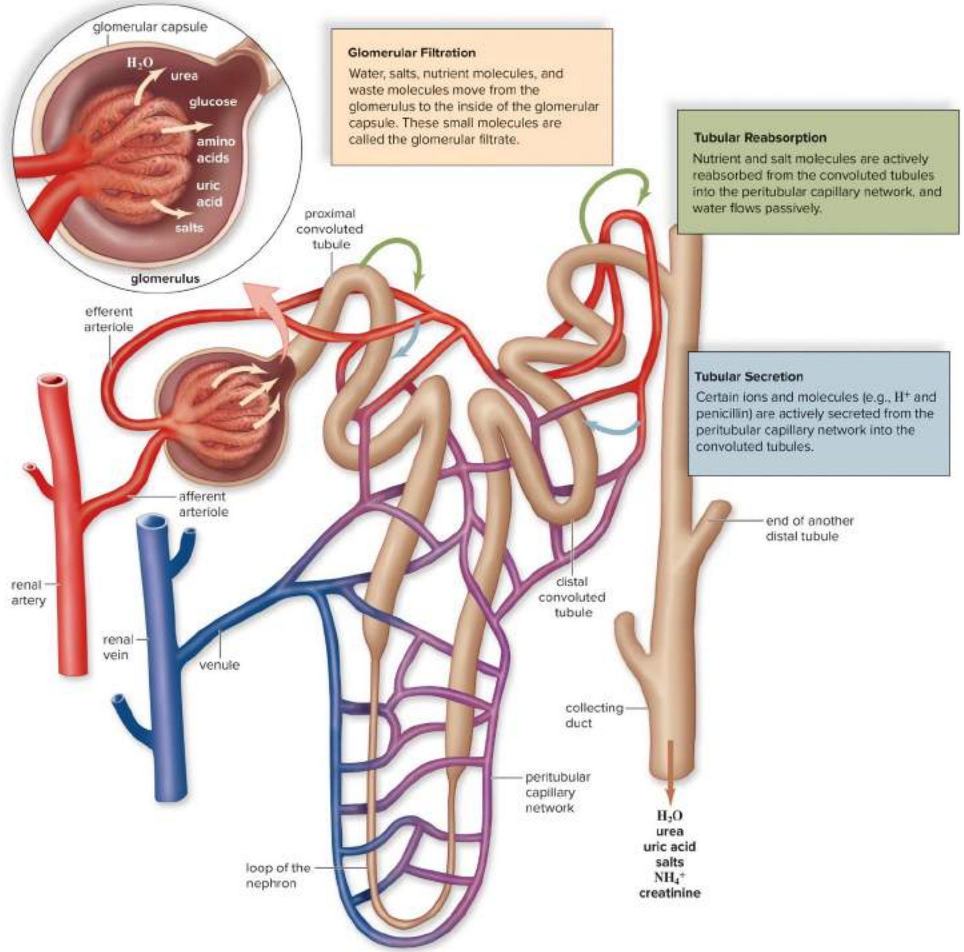
Parts of a nephron, continued.

- **Loop of the nephron** (loop of Henle).
  - Has a **descending limb** and an **ascending limb**; each has different permeabilities to water and solutes.
- **Distal convoluted tubule.**
  - Primary function is ion exchange between the blood and the renal tubule.
  - The distal convoluted tubules of several nephrons enter one **collecting duct**, which carries urine to the renal pelvis.

Urine Formation 2

The formation of urine involves three stages:

- **Glomerular filtration.**
- **Tubular reabsorption.**
- **Tubular secretion.**



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Glomerular Filtration 1

Glomerular filtration.

- Occurs when blood is filtered, and the resulting fluid enters the glomerulus via the afferent arteriole.
- This fluid, called **glomerular filtrate**, enters the glomerular capsule.
- This process is called filtration because large molecules and formed elements are unable to pass through the capillary wall.
  - In effect, then, blood in the glomerulus has two portions: the filterable components and the nonfilterable components.

Glomerular Filtration 3

Filterable components of plasma:

- Water, nitrogenous wastes, nutrients, salts (ions).

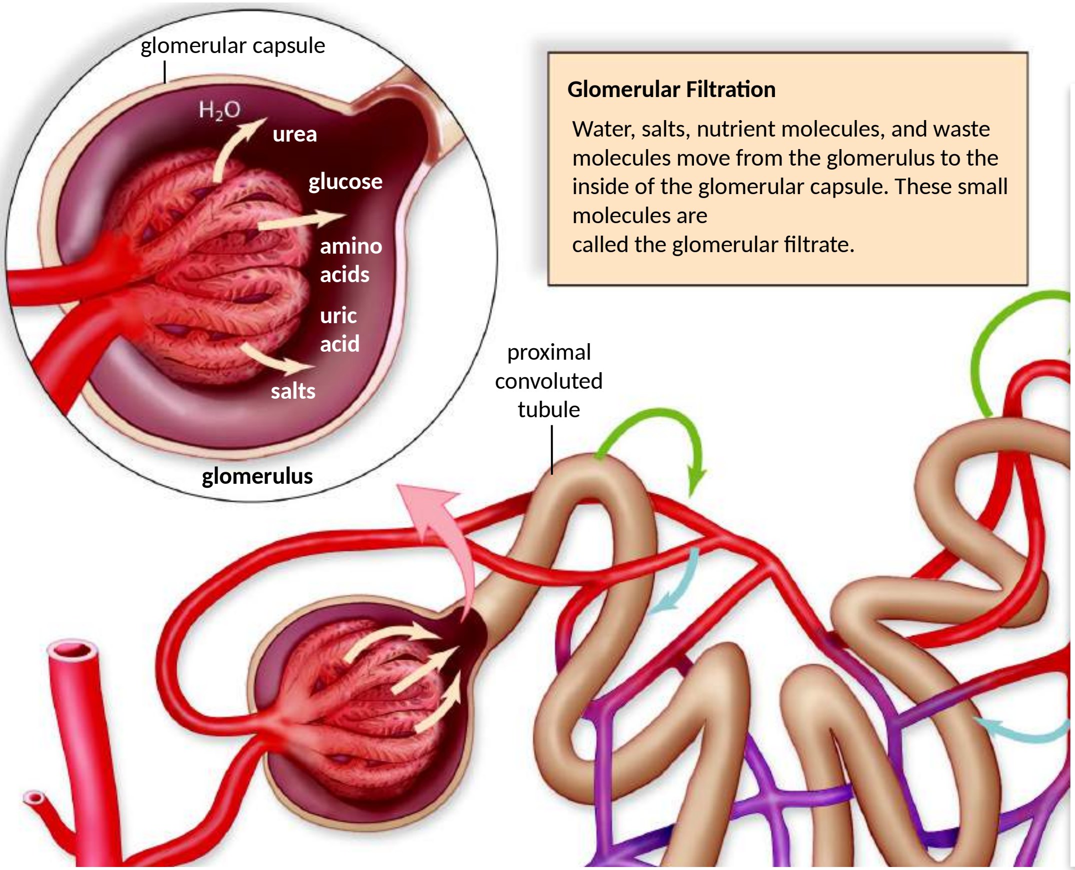
Nonfilterable components of plasma:

- Formed elements (blood cells and platelets), plasma proteins.

The nonfilterable components leave the glomerulus by way of the efferent arteriole

Filtrate has the same concentration of filterable components as plasma.

Glomerular Filtration (Figure 11.6)



Tubular Reabsorption 1

Tubular reabsorption.

- Molecules are passively and actively reabsorbed from the nephron into the blood of the peritubular capillary network.
- As Na^+ is being moved, Cl^- follows passively.
- The reabsorption of salt (NaCl) increases the osmolarity of the blood compared with the filtrate.
  - Therefore, water moves passively from the tubule into the blood.
- About 65% of Na^+ is reabsorbed at the proximal convoluted tubule (active transport requires ATP).

Tubular Reabsorption 3

Tubular reabsorption, concluded.

- Nutrients such as glucose and amino acids are reabsorbed at the proximal convoluted tubule.
  - Glucose is normally reabsorbed completely; there is a plentiful supply of carrier proteins.

Reabsorption from Nephrons (Table 11.1)

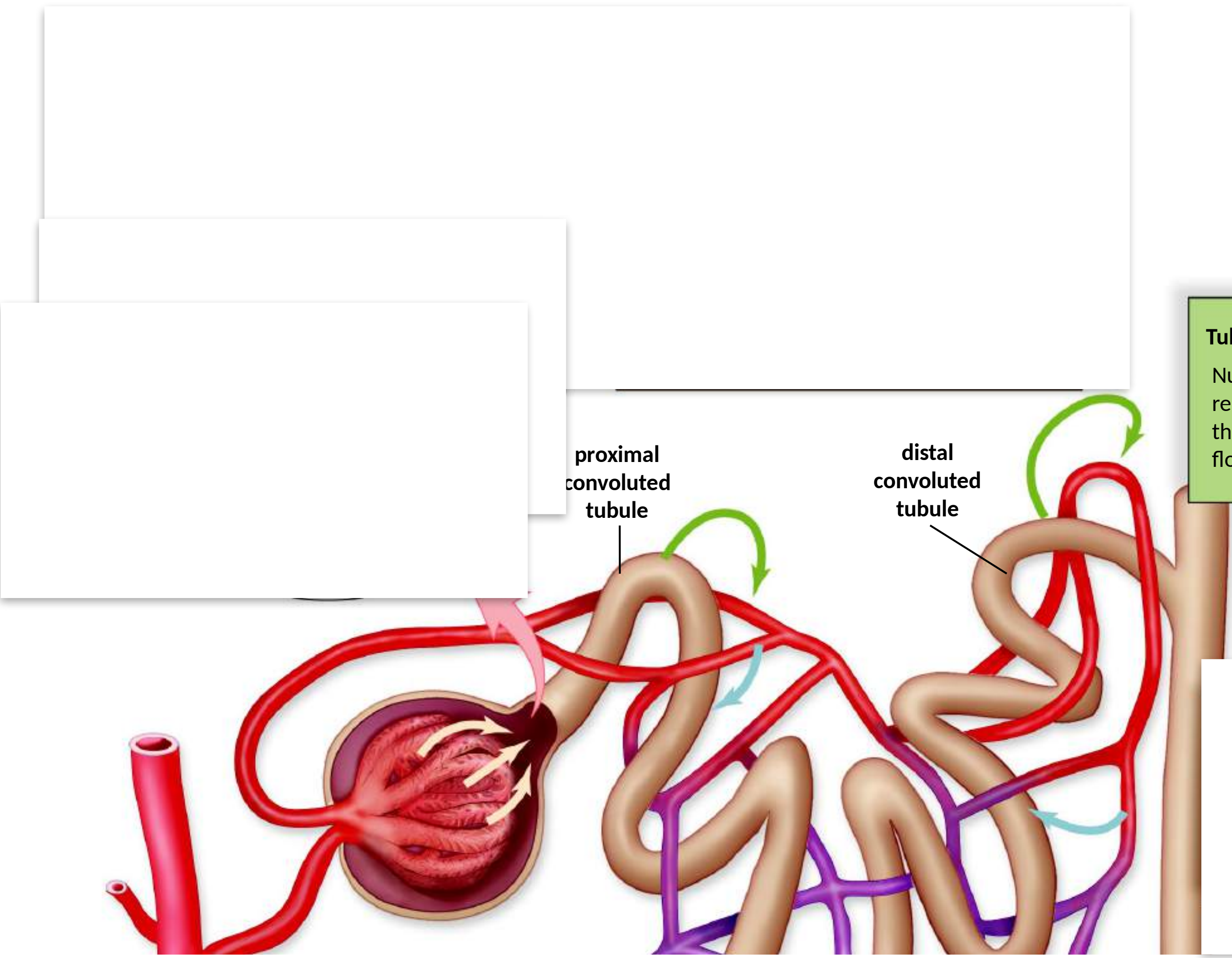
Table 11.1 Reabsorption from Nephrons.

Substance	Amount Filtered (per Day)	Amount Excreted (per Day)	Reabsorption (%)
Water (liters)	180	1.8	99.0
Sodium (g)	630	3.2	99.5
Glucose (g)	180	0.0	100.0
Urea (g)	54	30.0	44.0

g = grams

The kidneys also excrete or reabsorb other ions, such as potassium ions (K^+), bicarbonate ions (HCO_3^-), and magnesium ions (Mg^{2+}), as needed.

Tubular Reabsorption (Figure 11.6)



Tubular Reabsorption

Nutrient and salt molecules are actively reabsorbed from the convoluted tubules into the peritubular capillary network, and water flows passively.

Diabetes Mellitus

Diabetes mellitus.

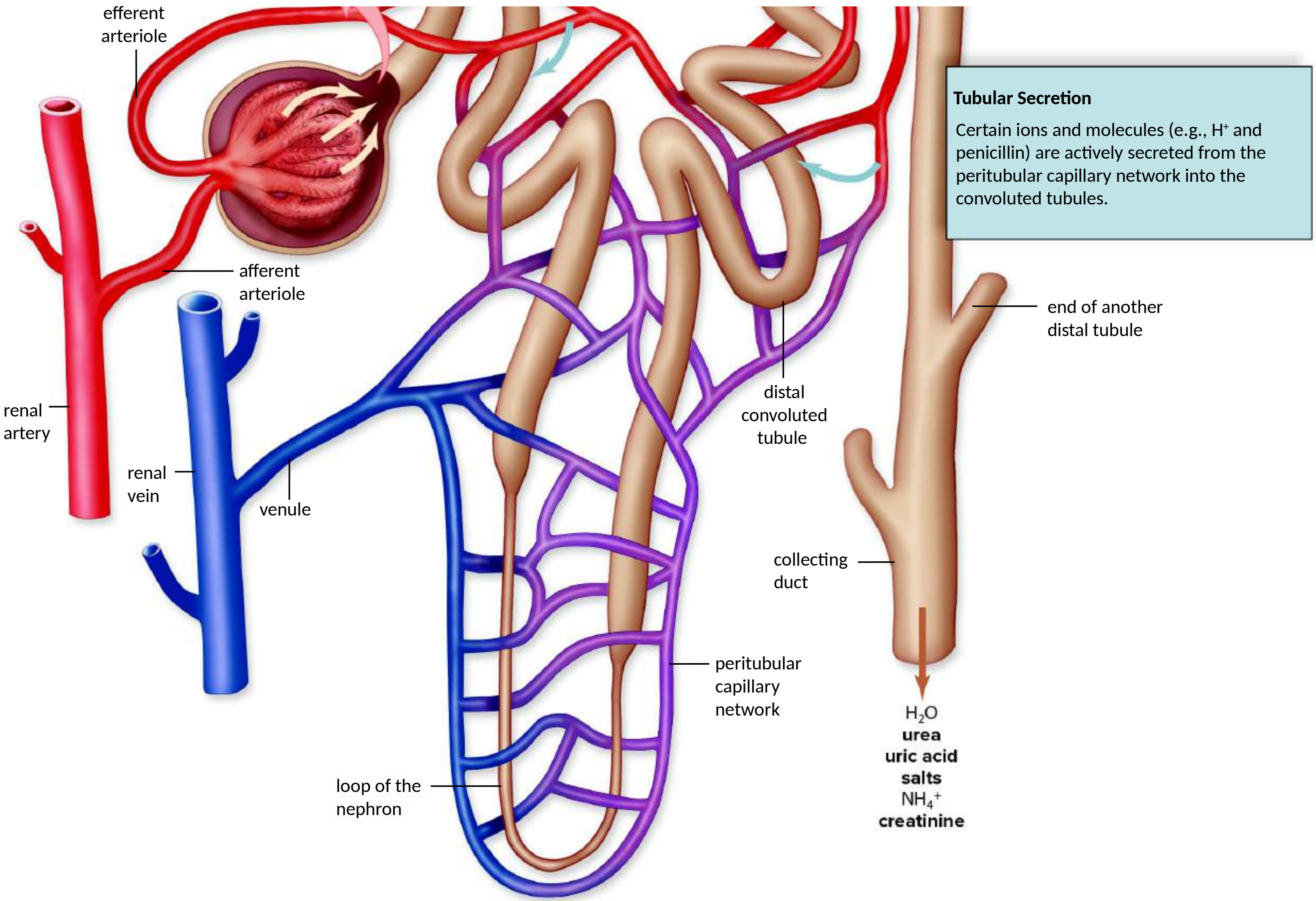
- Blood glucose is above normal and glucose appears in the urine.
  - The glucose transporters are overwhelmed; they can't reabsorb all of the glucose in the filtrate.
- The presence of excess glucose in the filtrate raises its osmolarity.
- The frequent urination and increased thirst experienced by people with untreated diabetes are due to less water being reabsorbed from the filtrate into the blood.

Tubular Secretion

Tubular secretion.

- The second way by which substances move from blood to the tubular fluid (the first is filtration).
- H^+, creatinine, and drugs such as penicillin are secreted.
- Occurs along the length of the kidney tubule.
- In the end, urine contains:
  - Substances that have been filtered, but not reabsorbed, plus what has been secreted.

Tubular Secretion (Figure 11.6)



Kidneys and Homeostasis 1

Learning Outcomes:

- Summarize how the kidney maintains the water-salt balance of the body.
- State the purpose of ADH and aldosterone in homeostasis.
- Explain how the kidneys assist in the maintenance of the pH levels of the blood.

Water-Salt Balance 1

Water-salt balance.

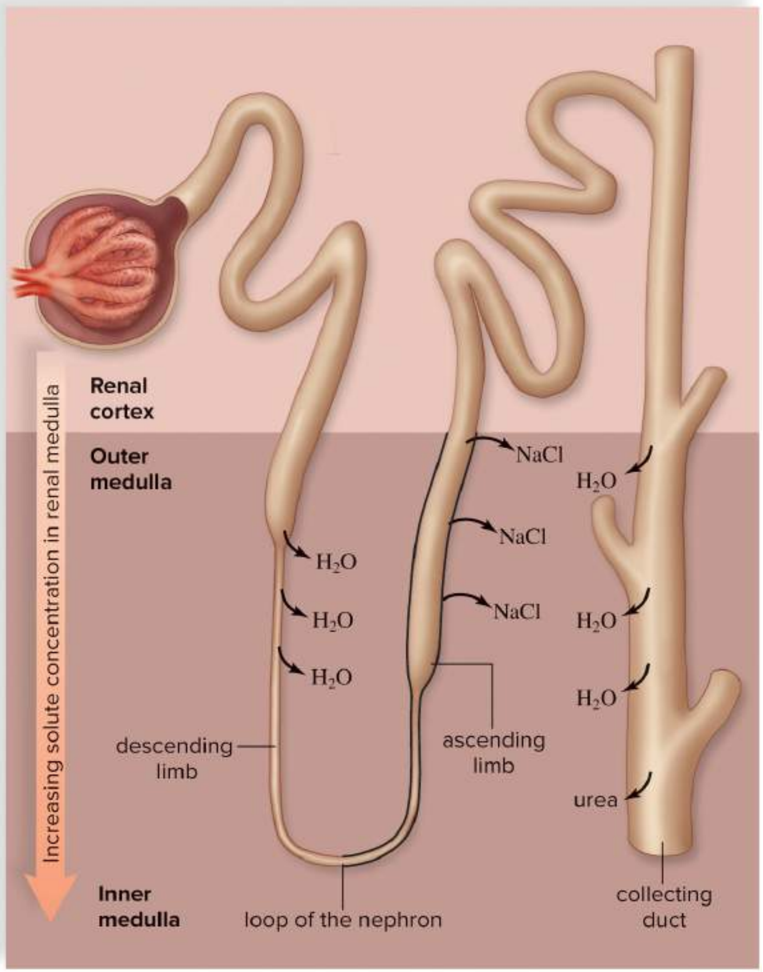
- Most water in the filtrate is reabsorbed into the blood, concentrating the urine.
  - All parts of a nephron and the collecting duct participate in the reabsorption of water.
- The reabsorption of salt always precedes the reabsorption of water, which occurs by osmosis.
- During the process of reabsorption, water passes through water channels within the plasma membrane called **aquaporins.**

Antidiuretic Hormone

Without **antidiuretic hormone (ADH)**, water cannot be reabsorbed in the distal convoluted tubule.

- ADH is produced by the hypothalamus and secreted by the posterior pituitary gland in response to an increase in blood osmolarity.
- Water then moves from the distal convoluted tubule and the collecting duct into the blood.

Movement of Salt and Water Within a Nephron (Figure 11.9)



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The Collecting Duct 2

Collecting duct, continued.

- **Diuresis** means “increased amount of urine,” and **antidiuresis** means “decreased amount of urine”.
- ADH increases water reabsorption (so blood volume and blood pressure rise), decreasing urine volume.
- Alcohol causes diuresis by inhibiting secretion of ADH.
- Caffeine increases the rate of glomerular filtration and decreases tubular reabsorption of Na^+

Acid-Base Balance of Body Fluids

Normal pH for body fluids is 7.35 to 7.45.

- This is the pH at which our proteins, like cellular enzymes, function properly.
- Ingested food adds basic or acidic substances to the blood; so does metabolism.
- The pH of body fluids is maintained via several mechanisms: **acid-base buffer systems**, the **respiratory center**, and the **kidneys.**
- **Buffer**—can take up excess H^+ or excess hydroxide ions (OH^-).
- One of the most important buffers in the blood is a combination of carbonic acid (H_2CO_3) and bicarbonate ions (HCO_3^-).

Buffer Systems (blood and respiratory system)

When H^+ enters the blood, this reaction occurs:

$$H^+ + HCO_3^- \longrightarrow H_2CO_3$$

When OH^- enters the blood, this reaction occurs:

$$OH^- + H_2CO_3 \longrightarrow HCO_3^- + H_2O$$

A blood buffer, however, can be overwhelmed.

The next adjustment to keep the pH of the blood constant occurs in the lungs.

Increasing the breathing rate rids the body of H^+, because the following reaction takes place in pulmonary capillaries:

$$H^+ + HCO_3^- \rightleftharpoons H_2CO_3 \rightleftharpoons H_2O + CO_2$$

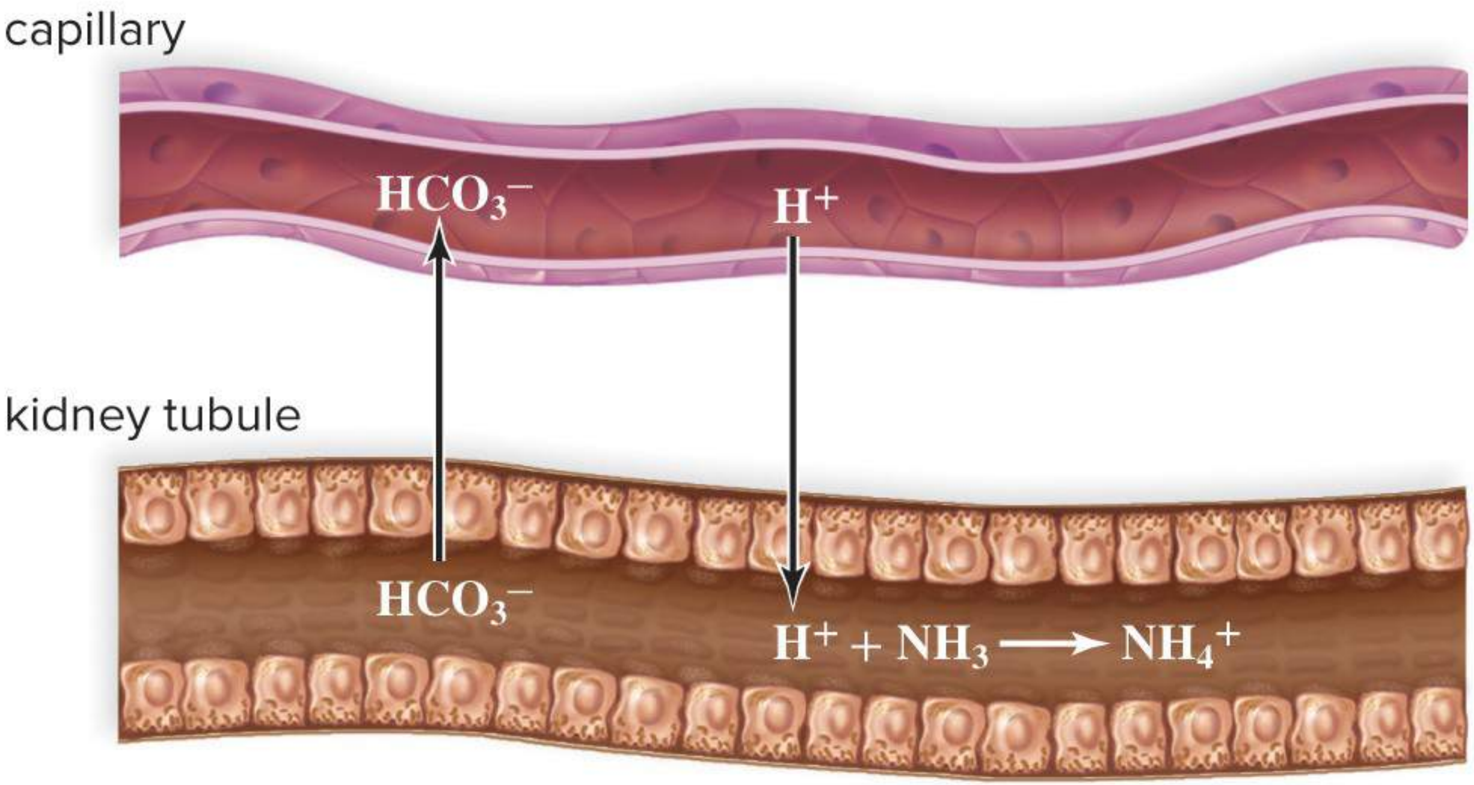
The Kidneys

The kidneys are slower than the other two mechanisms, but are more powerful.

- Reabsorb HCO_3^- and excrete H^+ as needed.
  - If the blood is acidic, H^+ are excreted and bicarbonate ions are reabsorbed.
- Ammonia (NH_3) provides another means of buffering and removing the hydrogen ions in urine:

$$H^+ + NH_3 \longrightarrow NH_4^+$$

Blood pH is Maintained by the Kidneys (Figure 11.10)



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The Kidneys Assist Other Systems 1

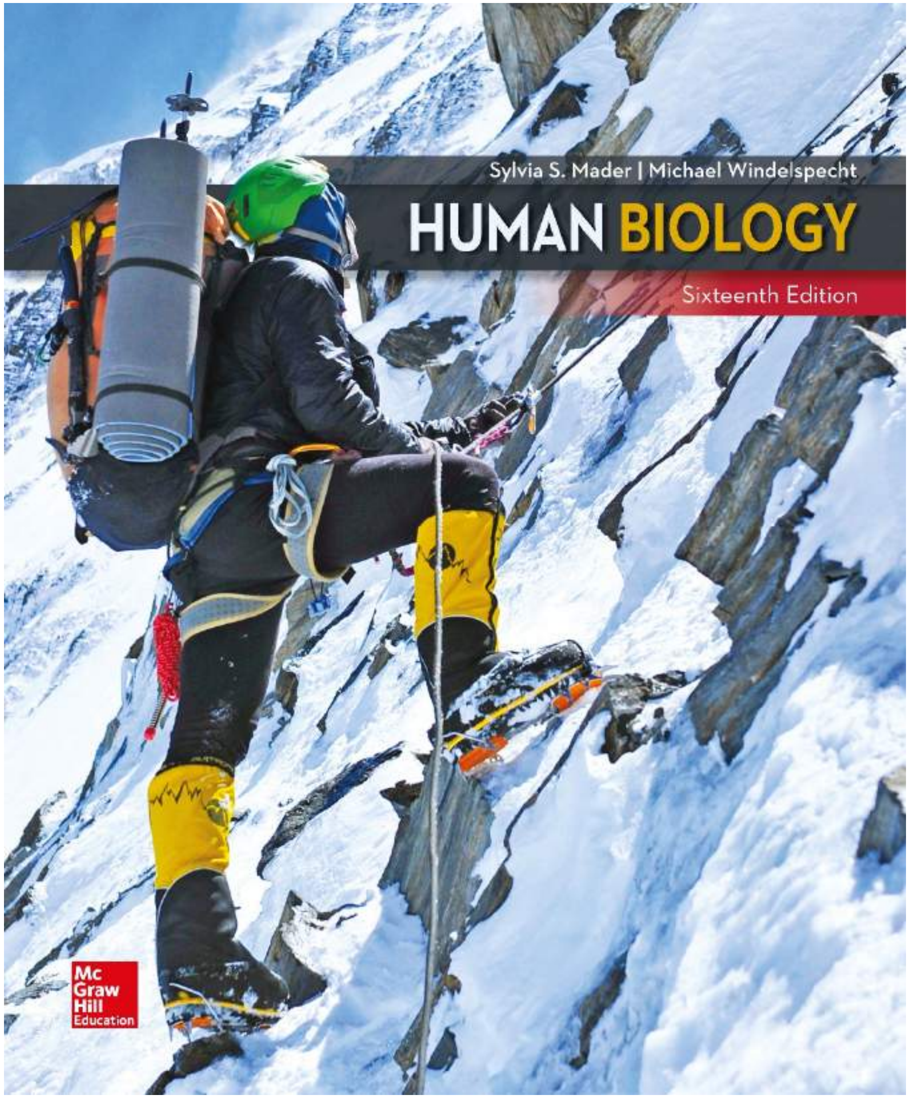
The kidneys assist other systems

- They secrete erythropoietin (EPO), a hormone that stimulates the production of RBCs in the red bone marrow.
- They regulate the amount of Ca^{2+} in the blood by converting vitamin D to its active form, which is needed for Ca^{2+} absorption in the digestive tract.
  - They also regulate the excretion of electrolytes, including Ca^{2+}.
- The kidneys regulate the Na^{+} and K^{+} content of the blood.
  - These ions are needed for nerve conduction and contraction of the heart and other muscles in the body

- Anatomical Terms
- **pubic**-pertaining to the genital region
- **sternal**-pertaining to the region of the breastbone
- **tarsal**-pertaining to the ankle
- **thoracic**-pertaining to the chest
- **umbilical**-pertaining to the naval
- **acromial-**pertaining to the point of the shoulder
- **calcaneal**-pertaining to the heel of the foot
- **cephalic**-pertaining to the head
- **dorsum**-pertaining to the back
- **gluteal**-pertaining to the buttocks
- **lumbar**-pertaining to the area of the back between the ribs and hips
- **manus**-pertaining to the hand
- **occipital**-pertaining to the posterior aspect of the head or base of the skull
- **olecranal**- pertaining to the posterior aspect of the elbow
- **otic**-pertaining to the ear
- **perineal**- pertaining to the region between the anus and external genitalia
- **plantar**- pertaining to the sole of the foot
- **popliteal**-pertaining to the posterior aspect of the knee
- **sacral**-pertaining to the region between the hips
- **scapular**-pertaining the shoulder blade region
- **sural**-pertaining to the posterior surface of the leg
- **vertebral**-pertaining to the area of the spinal column

HUMAN BIOLOGY

Sixteenth Edition



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Lab 12 Reproductive Anatomy

Because learning changes everything.™

Functions of the Reproductive Organs 1

The reproductive organs, or **genitals**, have the following functions:

- Males produce sperm within **testes**, and females produce eggs within **ovaries.**
- Males transport sperm in ducts; females transport eggs in **uterine tubes** to the **uterus.**
- The **penis** delivers sperm to the **vagina**, which also transports menstrual fluid to the exterior and acts as the birth canal. The uterus allows the fertilized egg to develop within the body.
  - After birth, the breast provides nourishment.
- The testes and ovaries produce sex hormones.
  - Bring about masculinization or feminization.

Puberty

Puberty.

- The time period during which a child becomes a sexually competent adult.
- Sexual maturity typically occurs between the ages of 10 and 14 in girls and 12 and 16 in boys.
- At the completion of puberty, the individual is capable of producing children.

Male Reproductive System 2

Male reproductive system.

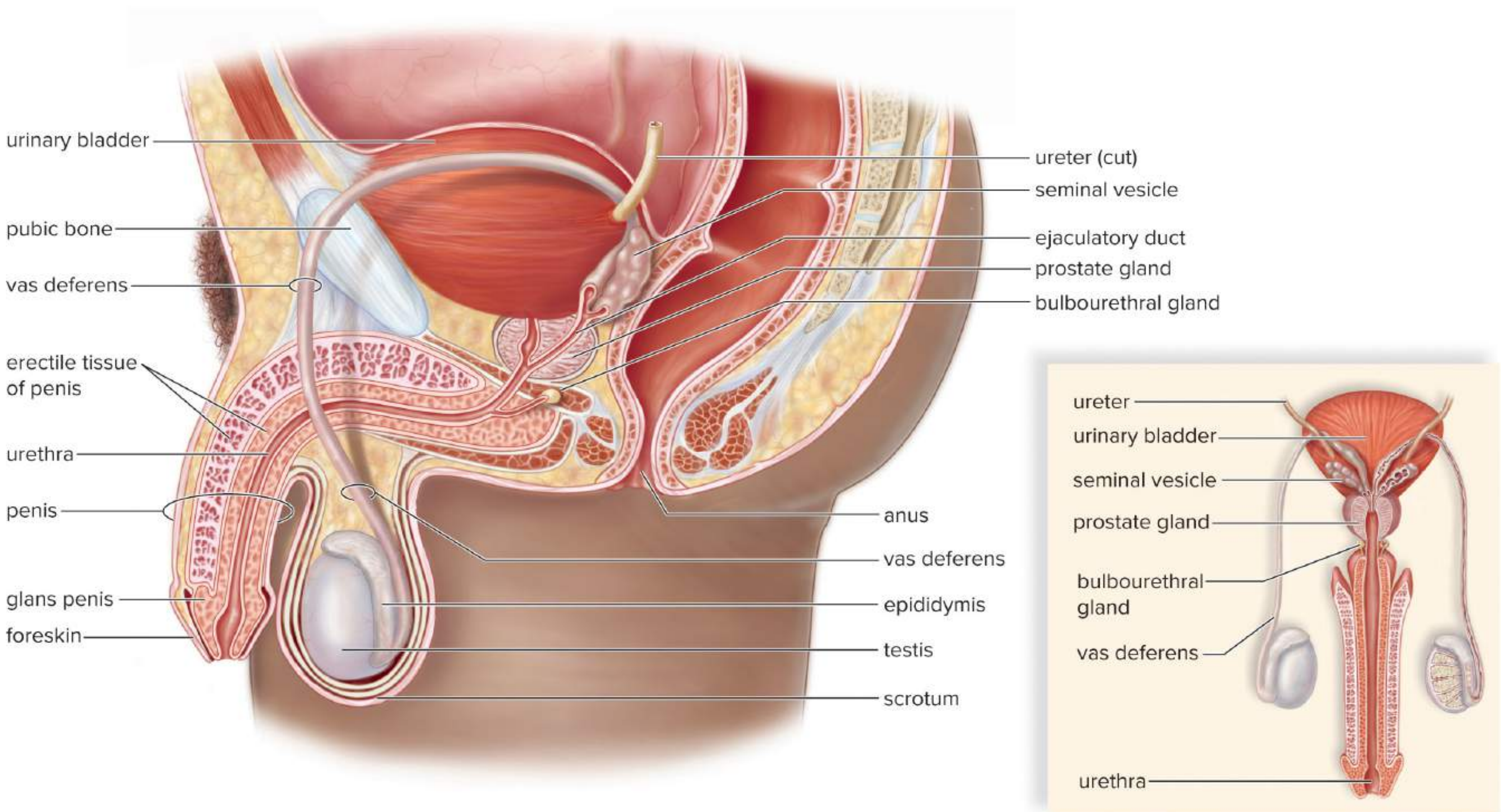
- **Testes** (*singular*, testis)—male **gonads** (primary sex organs).
- **Scrotum—**sac that contains the paired testes.
- **Epididymis** (*pl.*, epididymides)—where sperm mature.
- **Vas deferens** (*pl.*, vasa deferentia)—passes into the abdominal cavity, where it passes sperm into the **ejaculatory duct**, then the **urethra.**
- During **ejaculation**, sperm leave the penis in a fluid called **semen.**
    - Produced by two **seminal vesicles,** the **prostate gland,** and two **bulbourethral glands.**
        - **Prostate gland—**surrounds the urethra just below the bladder.
            - Can enlarge in older men and squeeze off the urethra, making urination painful and difficult.

Male Reproductive Organs (Table 17.1)

Table 17.1 Male Reproductive Organs.

Organ	Function
Testes	Produce sperm and sex hormones
Epididymides	Ducts where sperm mature and some sperm are stored
Vasa deferentia	Conduct and store sperm
Seminal vesicles	Contribute nutrients and fluid to semen
Prostate gland	Contributes fluid to semen
Urethra	Conducts sperm
Bulbourethral glands	Contribute mucus-containing fluid to semen
Penis	Organ of sexual intercourse

The Male Reproductive System (Figure 17.2)



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Semen

Semen (seminal fluid).

- Slightly basic pH (about 7.5).
- Contains the sugar fructose, which serves as an energy source.
- Contains prostaglandins, which cause the uterus to contract to propel the sperm toward the egg.

The Penis and Male Orgasm 1

Penis—the male organ of sexual intercourse.

- Also contains the urethra of the urinary system.
- Has a long shaft and an enlarged tip called the **glans penis.**
- **Foreskin—**layer of skin covering the glans penis.
  - **Circumcision**—surgical removal of the foreskin.
- As sexual stimulation intensifies, sperm enter the urethra from each vas deferens, and semen is secreted from the three glands.
- Once seminal fluid is in the urethra, rhythmic muscle contractions expel it from the penis.
- **Orgasm**—the physiological and psychological sensations that occur at the climax of sexual stimulation.
- There may be 400 million sperm in the 3.5 milliliters of semen expelled during ejaculation.
  - Fertilization can still take place if the sperm count is much lower than this.

Male Gonads: The Testes

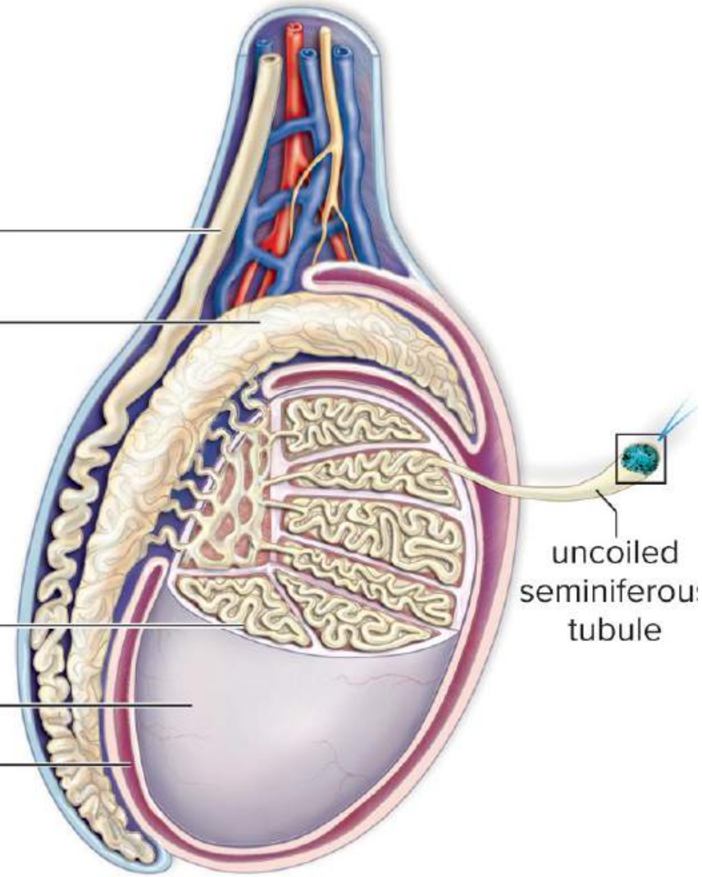
Testes.

- Begin development in the abdominal cavity, and descend into the scrotum the last 2 months of fetal development.
  - If the testes do not descend, **sterility** (the inability to produce offspring) usually follows.
    - The internal temperature of the body is too high to produce viable sperm.
    - The scrotum regulates their temperature; it holds them closer to or farther away from the body, depending on the temperature.

Seminiferous Tubules [1]

- Testes have compartments called **lobules**, each of which contains **seminiferous tubules.**
  - **Spermatogenesis**—the production of sperm; occurs in the seminiferous tubules.
- Spermatids then develop into sperm.
- **Sertoli cells—**support, nourish, and regulate the process of spermatogenesis.
- Takes 74 days for development from spermatogonia to sperm.

Spermatogenesis Produces Sperm Cells (Figure 17.4a)



a. Testis (cut to show lobules)

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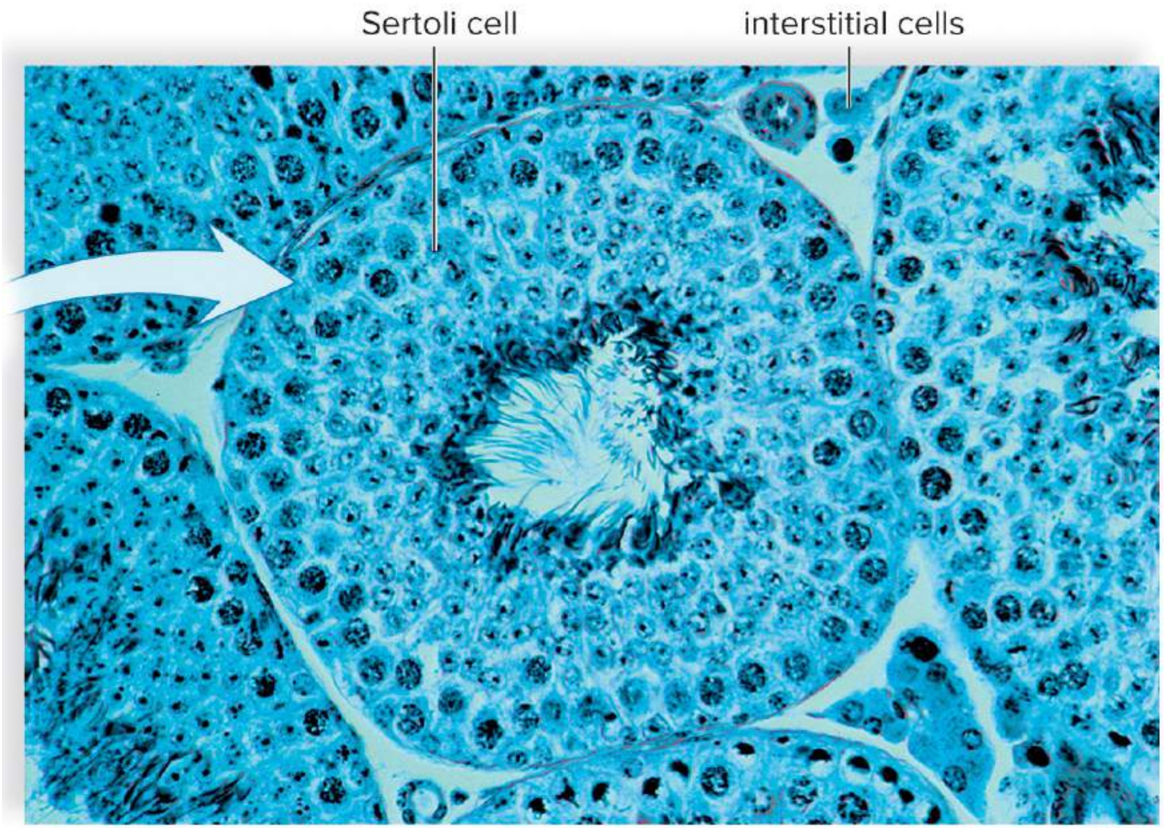
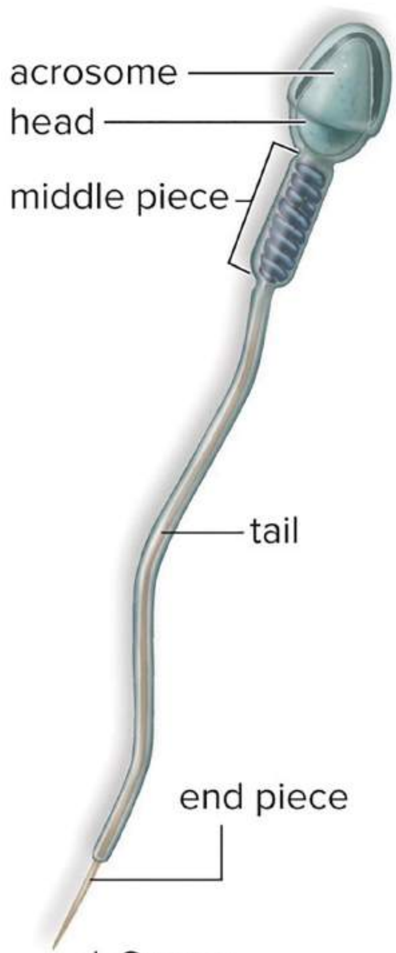
Spermatogenesis Produces Sperm Cells (Figure 17.4b)



b. Seminiferous tubules

Sperm (spermatozoa)

- Sperm contain three parts: **head, middle piece,** and **tail.**
  - Mitochondria in the middle piece provide energy for the movement of the tail, which is a flagellum.
  - The head contains a nucleus covered by the **acrosome**, which contains enzymes needed to penetrate the egg.



d. Sperm

Interstitial Cells

Interstitial Cells.

- Produce the male sex hormones (**androgens**).
  - The most important of the androgens is **testosterone.**
- Lie between the seminiferous tubules.

Hormonal Regulation in Males 1

Hypothalamus secretes **gonadotropin-releasing hormone (GnRH)**, which stimulates the secretion of **follicle-stimulating hormone (FSH)** and **luteinizing hormone (LH).**

- In males, FSH promotes the production of sperm.
- LH stimulates the production of testosterone.
  - Controlled by negative feedback; this maintains the fairly constant production of sperm and testosterone.

Hormonal Regulation in Males 2

Testosterone—main sex hormone in males.

- Essential for normal development and functioning of male sex organs.
- Brings about and maintains the male secondary sex characteristics that develop at puberty.
    - Males are generally taller than females.
    - Broad shoulders, longer legs relative to trunk length.
    - Deeper voices due to a larger larynx with longer vocal cords.
    - Hair growth on the face, chest, other regions.
    - Receding hairline, male-pattern baldness.
    - Greater muscular development.

Female Reproductive System 2

Ovaries—the female gonads.

- Lie in shallow depressions, one on each side of the upper pelvic cavity.
- Produce **eggs,** also called **ova** (*singular*, ovum).
- Produce the female sex hormones **estrogen** and **progesterone.**

The Genital Tract [1]

Uterine tubes (oviducts, fallopian tubes) extend from the uterus to the ovaries.

- Are not attached to the ovaries; they have fingerlike projections called **fimbriae** (*singular*, fimbria).
  - After ovulation, the fimbriae sweep the egg into a uterine tube.
  - In the uterine tube, the egg is propelled by ciliary movement toward the uterus.

An egg lives approximately 6 to 24 hours

Fertilization usually takes place in the uterine tube.

An embryo **implants** after several days.

- Embeds in the uterine lining.

The Genital Tract [3]

Uterus—thick-walled, muscular organ.

- The uterine tubes join the uterus at its upper end; at its lower end, the **cervix** enters the vagina.
  - Cancer of the cervix is a common form of cancer in women.
  - **Pap test—**the removal of a few cells from the cervix for microscopic examination.
  - **Hysterectomy**—surgical removal of the uterus.
  - **Ovariohysterectomy—**removal of ovaries and uterus.

Female Reproductive Organs (Table 17.2)

Table 17.2 Female Reproductive Organs.

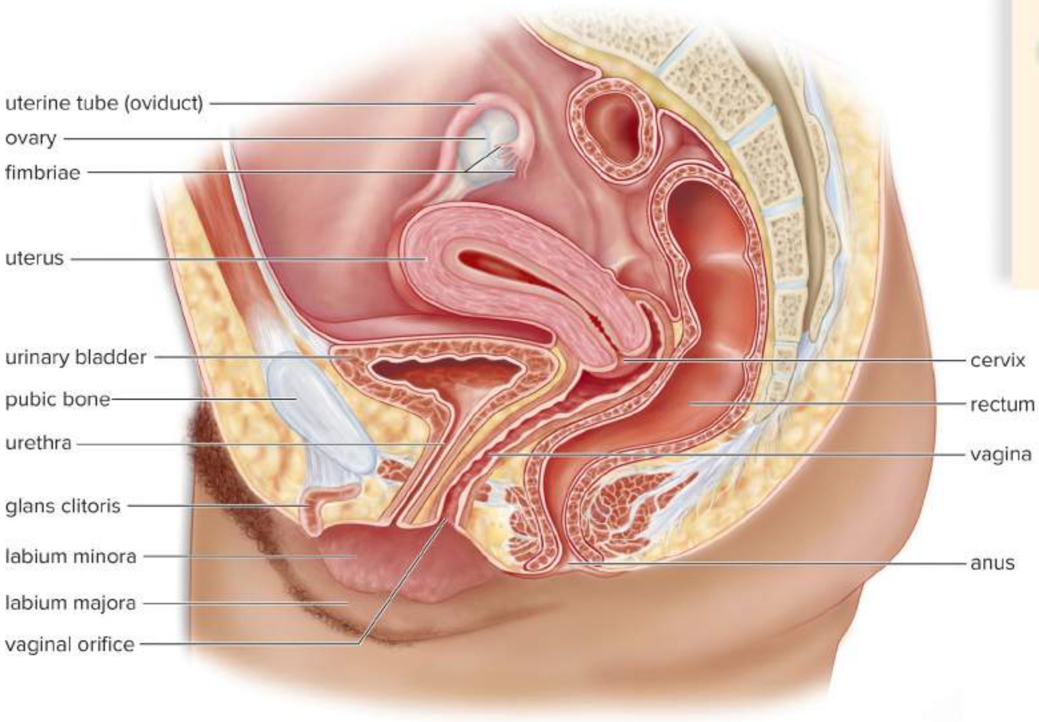
Organ	**Function**
Ovaries	Produce eggs and sex hormones
Uterine tubes	Conduct eggs; location of fertilization
Uterus	Houses developing fetus
Cervix	Contains opening to uterus
Vagina	Receives penis during sexual intercourse; serves as birth canal and as an exit for menstrual flow

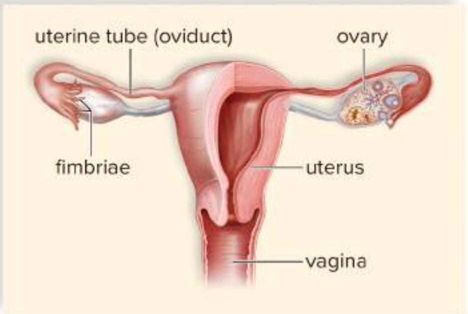
Uterus

Endometrium—the lining of the uterus.

- Supplies nutrients needed for embryonic and fetal development.
- Has two layers: a **functional layer** that is shed during each menstrual period and a **basal layer** of reproducing cells.
  - The functional layer varies in thickness according to a monthly cycle called the uterine cycle.

The Female Reproductive System (Figure 17.6)





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Vagina

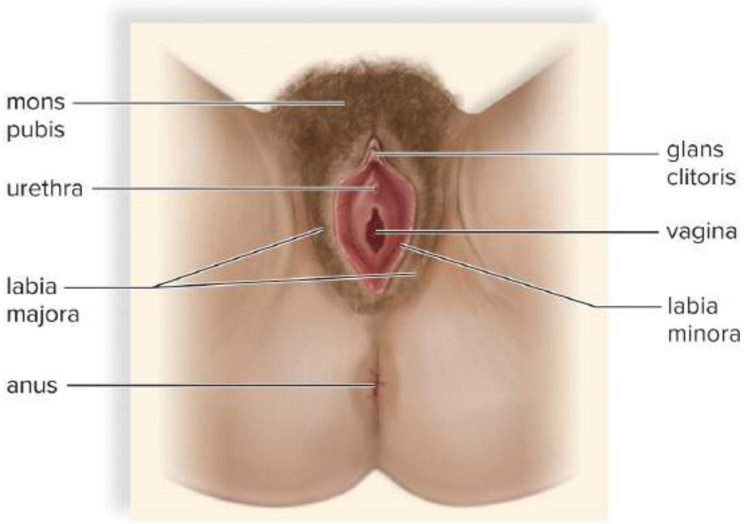
Vagina—its mucosal lining is folded and can stretch.

- Important during sexual intercourse and birth.
- Allows menstrual flow to exit.
- Several different types of bacteria reside in the vagina and create an acidic environment.
    - Prevents growth of pathogenic bacteria, but sperm prefer the basic environment provided by seminal fluid.

External Genitals 1

Vulva—external genitals of the female.

- **Labia majora—**large, hair-covered folds of skin.
- **Mons pubis—**a fatty prominence overlying the pubic bones.
  - Covered in pubic hair.



External Genitals 2

Vulva, continued.

- **Labia minora—**small folds lying just inside the labia majora.
  - Form a foreskin for the **glans clitoris**, the organ of sexual arousal in females.
    - Contains erectile tissue that becomes engorged with blood during sexual stimulation.

The cleft between the labia minora contains the openings of the urethra and the vagina.

The vagina may be partially closed by a ring of tissue called the **hymen.**

The urinary and reproductive systems in the female are entirely separate.

- The urethra carries only urine; the vagina serves only as the birth canal and sexual intercourse.

Orgasm in Females [1]

Orgasm in females.

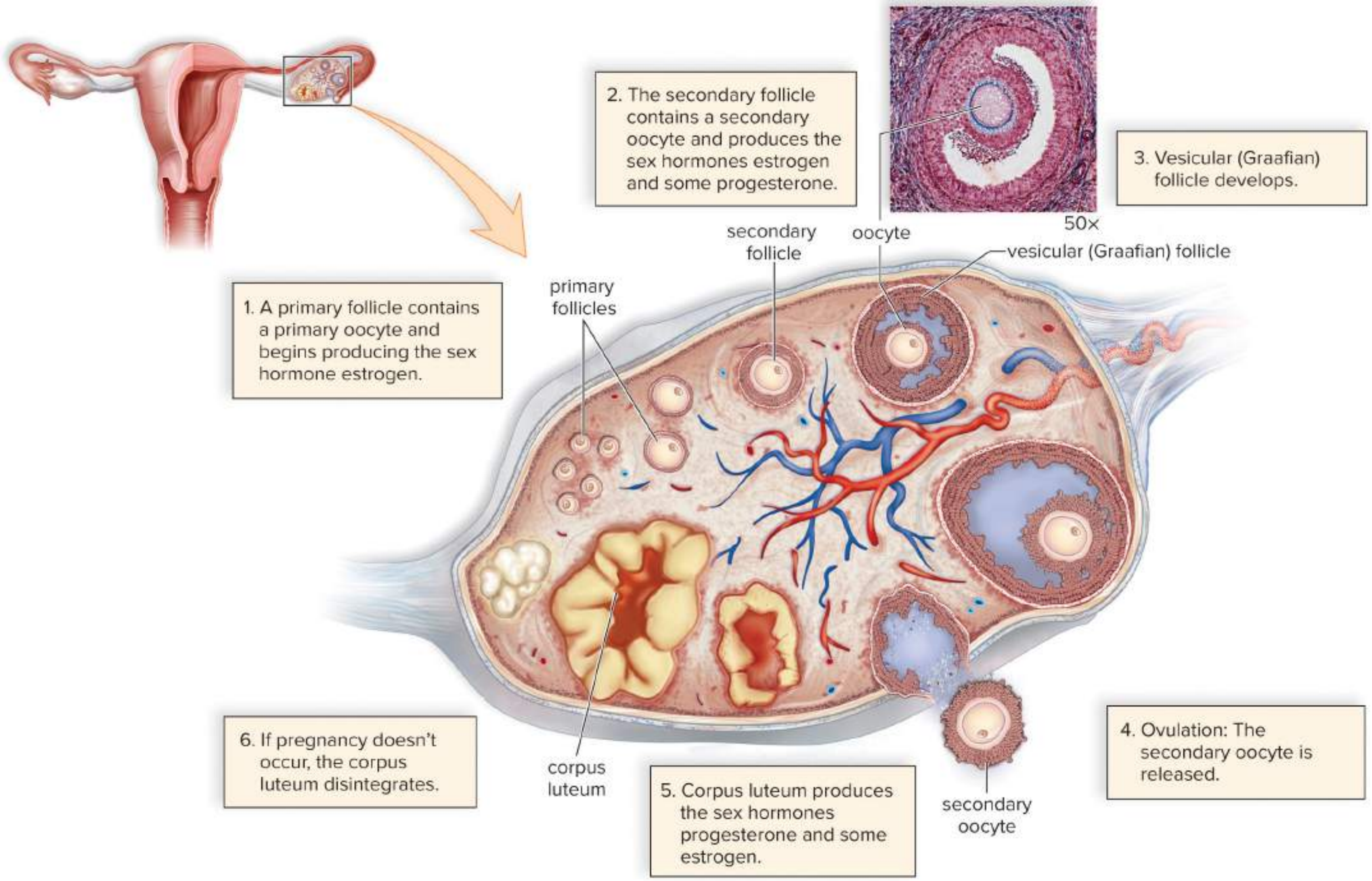
- Upon sexual stimulation, the labia minora, the vaginal wall, and the clitoris become engorged with blood.
- The breasts also swell, and the nipples become erect.
- The labia majora enlarge, redden, and spread away from the vaginal opening.
- Fluid seeps into the vagina to lubricate it.
- Mucus-secreting glands beneath the labia minora provide lubrication
- The extremely sensitive clitoris can swell to two or three times its usual size.
- Blood pressure and pulse rate rise, breathing quickens, and the walls of the uterus and uterine tubes contract rhythmically.
- A sensation of intense pleasure is followed by relaxation when organs return to their normal size.
- Females have no refractory period, and multiple orgasms can occur during a single sexual experience.

Ovarian Cycle: Nonpregnant 1

Oocyte—immature egg; contained within a **follicle.**

- Females are born with 2 million follicles, but have only 300,000—400,000 by puberty.
- Only 400 ever mature; a female produces only one egg per month during her reproductive years.
- As the follicle matures during the **ovarian cycle,** it changes from a **primary** to a **secondary** to a **vesicular (Graafian) follicle.**
- Primary follicle—epithelial cells surround a **primary oocyte.**
- Secondary follicle—follicular fluid surrounds the **secondary oocyte.**
- Vesicular follicle—the fluid-filled cavity enlarges to the point that the follicle wall balloons out on the surface of the ovary.

The Ovarian Cycle (Figure 17.8)



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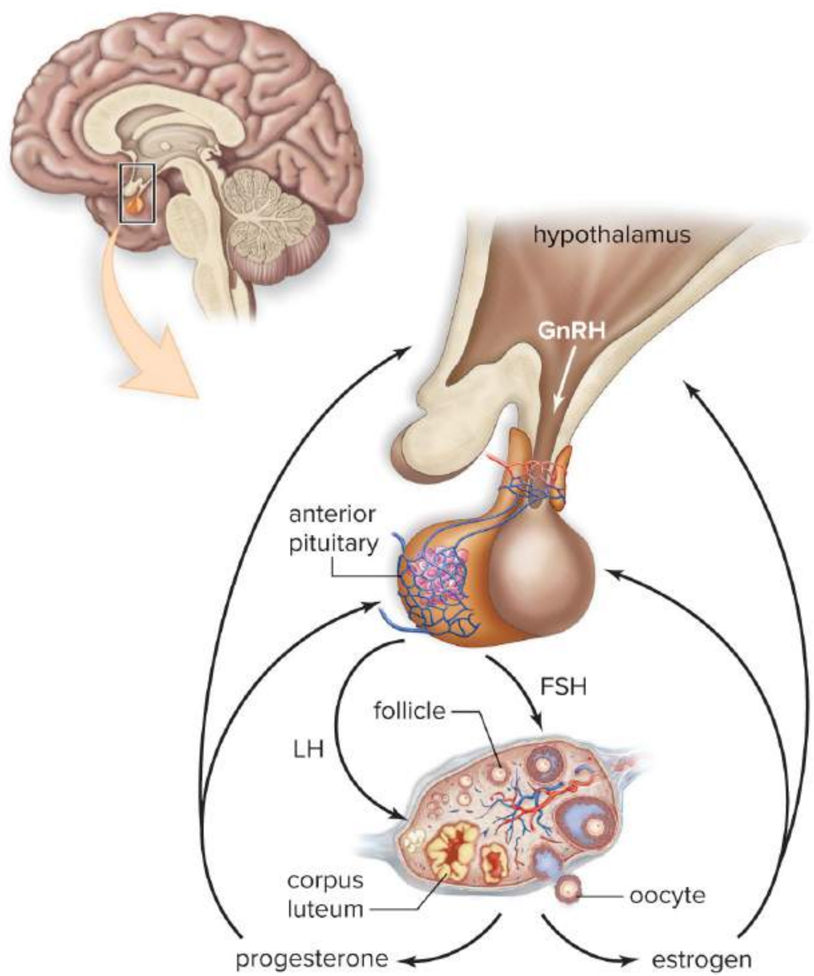
(photo): ©Ed Reschke

Phases of the Ovarian Cycle 1

Like in males, the hypothalamus secretes GnRH.

GnRH stimulates the anterior pituitary to produce FSH and LH; these hormones control the ovarian cycle.

The Hormones that Control the Production of Estrogen and Progesterone by the Ovaries (Figure 17.10)



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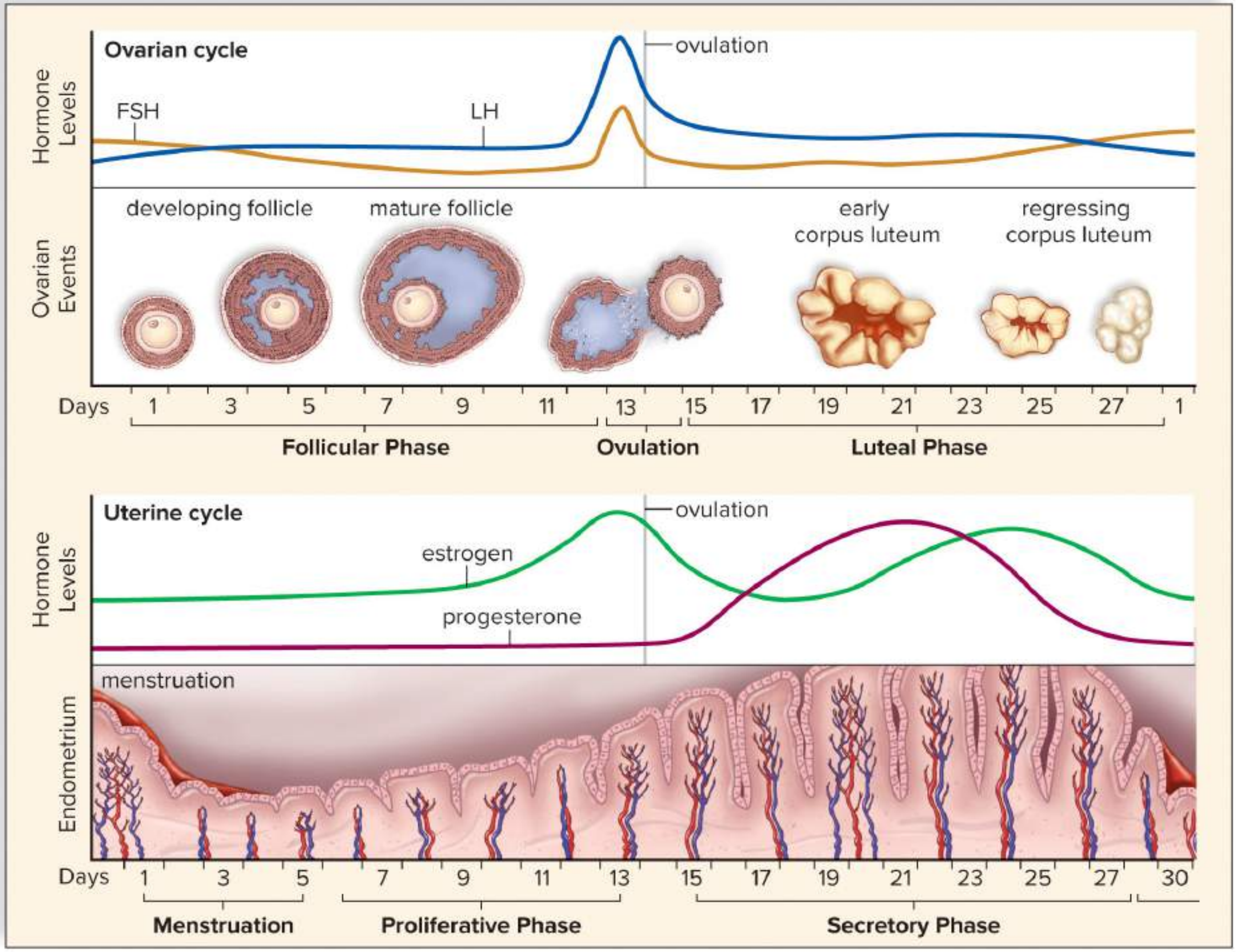
Phases of the Ovarian Cycle 2

Follicular phase—the first half of the cycle.

- FSH promotes the development of primary follicles, which primarily secrete estrogen.
  - As estrogen rises, it exerts negative feedback control over the anterior pituitary secretion of FSH, ending the follicular phase.
- A surge of LH is released from the anterior pituitary, triggering ovulation on day 14 of a 28-day cycle.

Female Hormone Levels During the Ovarian and Uterine Cycles (Figure 17.11)



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Phases of the Ovarian Cycle 3

Luteal phase—LH promotes the development of the corpus luteum, which secretes high levels of progesterone and some estrogen.

- If pregnancy does not occur, it regresses and a new cycle begins.

Estrogen and Progesterone 1

Estrogen and **progesterone.**

- Responsible for the secondary sex characteristics:
    - Axillary and pubic hair.
    - Greater fat accumulation under the skin.
- Both estrogen and progesterone are also required for breast development.
- **Prolactin** is involved in milk production after pregnancy.
- **Oxytocin** induces milk letdown when a baby begins to nurse.
- The pelvic girdle is wider and deeper in females, so the pelvic cavity is larger.
    - Females have wider hips than males and their thighs converge at a greater angle toward the knees.
- The female pelvis tilts forward, so females tend to have more of a lower back curve than males and protruding buttocks.

Menopause—when the ovarian cycle ceases.

- Usually between ages 45 and 55.
- The ovaries no longer respond to gonadotropic hormones, and they no longer secrete estrogen or progesterone.
- At the onset of menopause, menstruation becomes irregular, but it is not complete until menstruation is absent for 1 year.

Ovarian and Uterine Cycles: Nonpregnant (Table 17.3)

Table 17.3 Ovarian and Uterine Cycles: Nonpregnant.

Ovarian Cycle	Events	Uterine Cycle	Events
Follicular phase—days 1 to 13	FSH secretion begins. Follicle maturation occurs. Estrogen secretion is prominent.	Menstruation—days 1 to 5 Proliferative phase—days 6 to 13	Endometrium breaks down. Endometrium rebuilds.
Ovulation-day 14[1]	LH spike occurs.		
Luteal phase-days 15 to 28	LH secretion continues. Corpus luteum forms. Progesterone secretion is prominent.	Secretory phase—days 15 to 28	Endometrium thickens, and glands are secretory.

[1] assuming a 28-day cycle.

Fertilization and Pregnancy 1

Only one sperm is needed to fertilize the egg, which is then called a **zygote.**

As the zygote travels down the uterine tube to the uterus, it begins mitosis.

- Once it is made of many cells, it is called an **embryo.**

The endometrium is now prepared to receive the developing embryo.

Fertilization and Pregnancy[2]

The embryo implants in the endometrial lining several days following fertilization.

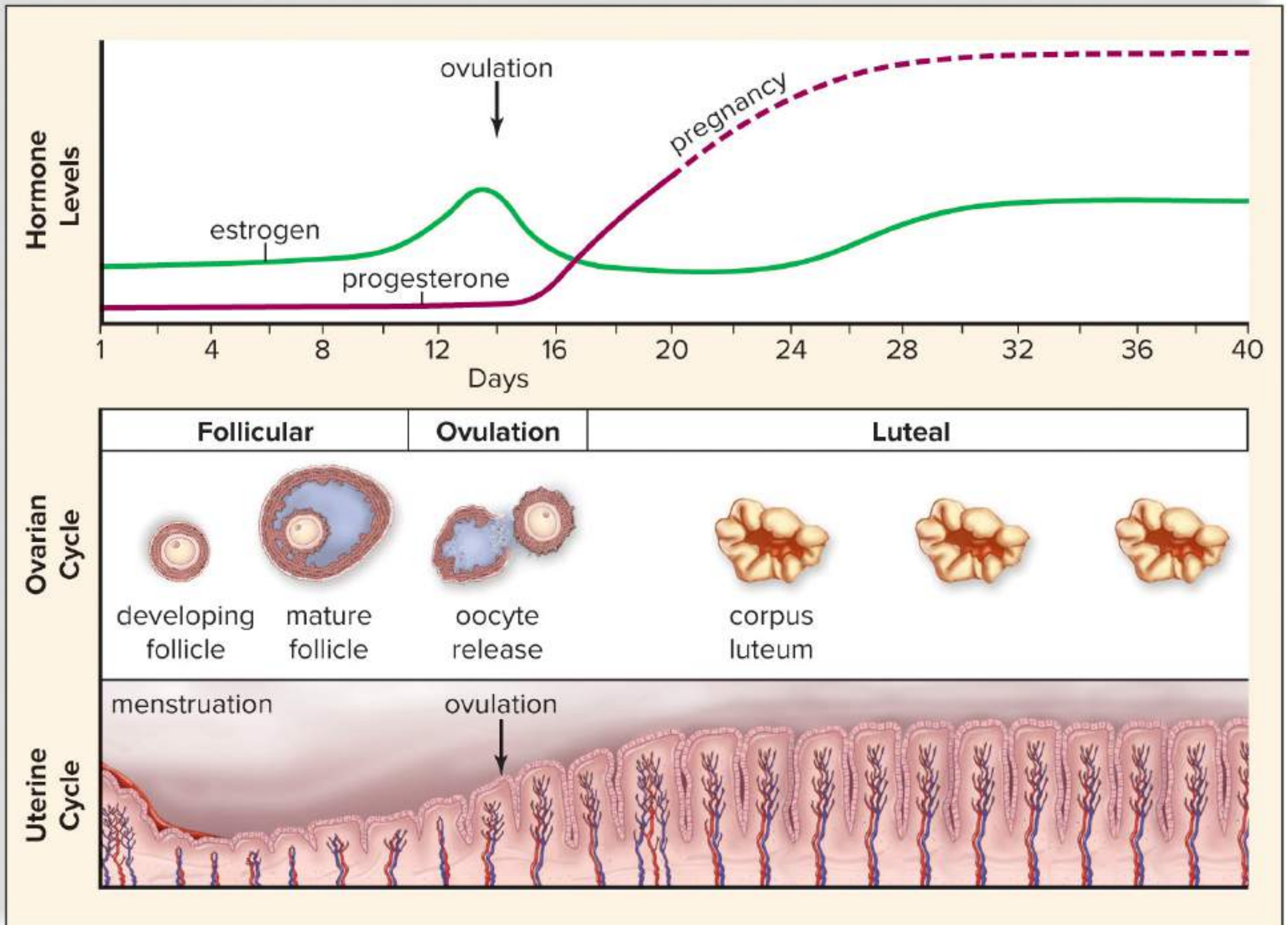
- **Implantation** signals the beginning of a pregnancy.
- An abortion may be spontaneous (referred to as a **miscarriage**) or induced.
    - Both end with loss of the embryo or fetus.

Placenta 1

Placenta—sustains the developing embryo.

- Originates from both maternal and fetal tissues.
- Where exchange between fetal and maternal blood occurs.
- Produces **human chorionic gonadotropin (HCG)—**maintains the corpus luteum.
  - A pregnancy test detects HCG in the blood or urine.
- Rising amounts of HCG stimulate the corpus luteum to produce increasing amounts of progesterone.
  - This progesterone shuts down the hypothalamus and anterior pituitary, so no new follicles begin to develop.
  - The progesterone maintains the uterine lining where the embryo now resides, preventing menstruation.
- Eventually, the placenta produces progesterone and some estrogen.
  - So the corpus luteum is no longer needed and it regresses.

The Effect of Pregnancy on the Corpus Luteum and Endometrium (Figure 17.12)

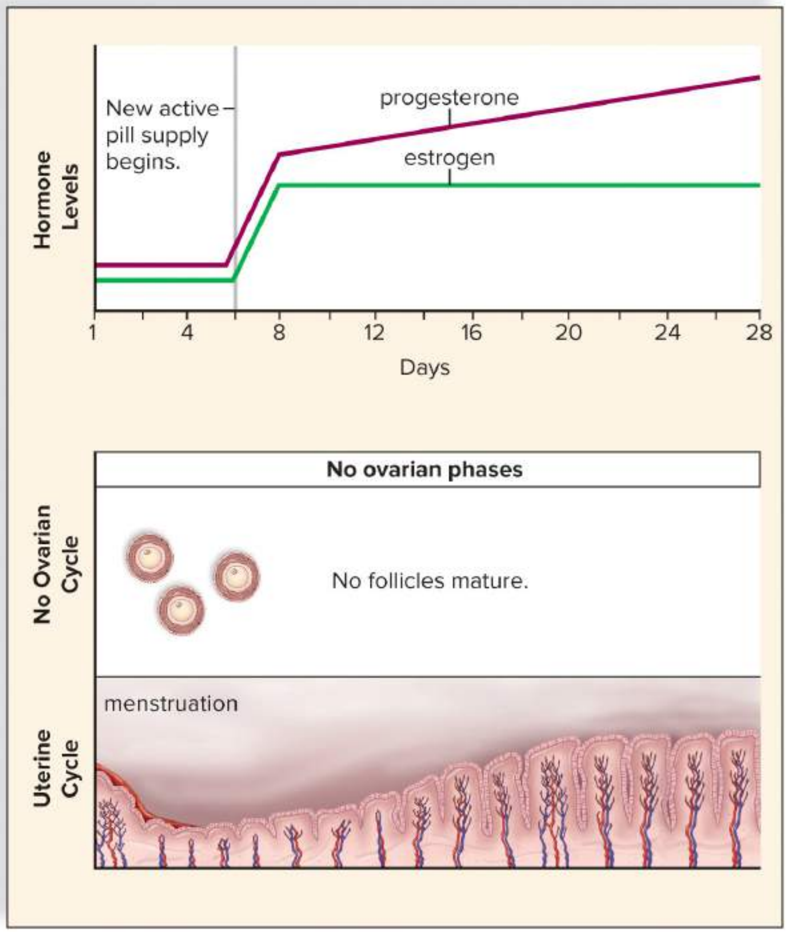


Birth Control Pills

Birth control pills to prevent pregnancy usually involve taking active pills (contain estrogen and progesterone) for 21 days, then inactive pills (do not contain them) for 7 days.

- The uterine lining builds up while the active pills are being taken.
- Progesterone decreases after the last active pills are taken, causing menstruation.

The Effect of Birth Control Pills on the Ovarian Cycle (Figure 17.13)



Birth Control Methods [1]

The most reliable method of birth control is abstinence (no sexual intercourse).

- Also prevents transmission of sexually transmitted diseases.

Birth control methods' effectiveness.

- For example, birth control pill is 98% effective: in a given year, 2% of sexually active women using this form of birth control may get pregnant.
- For example, the withdrawal method is 75% effective.

Birth Control Methods 2

Contraceptives—medications and devices that reduce the chance of pregnancy.

- **Birth control pills—**the most effective form of contraception.
- Can also administer hormones through a patch applied to the skin; this also shuts down the pituitary production of both FSH and LH.
  - Ovulation does not occur.

Birth Control Methods 3

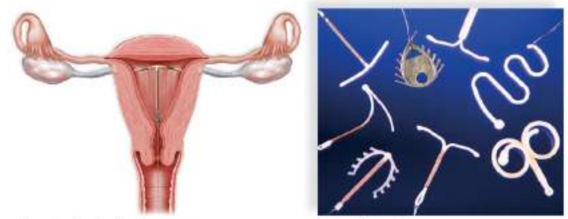
Intrauterine device (IUD)—inserted into the uterus by a physician.

- Alters the environment of the uterus to reduce the possibility of fertilization.
  - If fertilization occurs, implantation cannot take place.

Diaphragm—a soft latex cup with a flexible rim that fits over the cervix.

- Must be used with spermicidal jelly or cream and should be left in place at least 6 hours after sex.

Placement of Birth Control Devices (Figure 17.14)



a. Intrauterine device placement

Intrauterine devices

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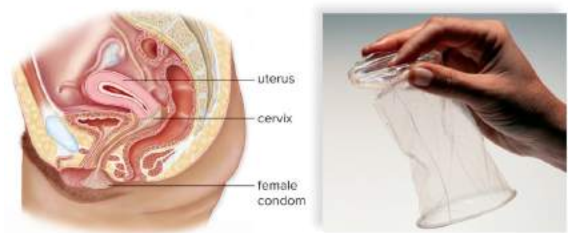


b. Female condom placement

Female condom

(b): ©Keith Brofsky/Getty Images;

c. Male condom placement

Male condom

(c): ©Lars A. Niki

More Birth Control Methods

The male and female **condoms** offer protection against sexually transmitted diseases in addition to helping prevent pregnancy.

- Female condoms—large polyurethane tube with a flexible ring that fits onto the cervix.
- Male condom—latex sheath that fits over the erect penis.
  - Semen stays inside; doesn't enter the vagina.

Contraceptive Injections and Vaccines

A vaccine is in development that immunizes women against HCG, the hormone necessary to maintain implantation of the embryo.

Contraceptive implants use synthetic progesterone to prevent ovulation.

Contraceptive injections are available as progesterone only or a combination of estrogen and progesterone.

- Length of time between injections: a few months.

Emergency Contraception

Emergency contraception ("morning-after pills")—medications that can prevent pregnancy after unprotected intercourse.

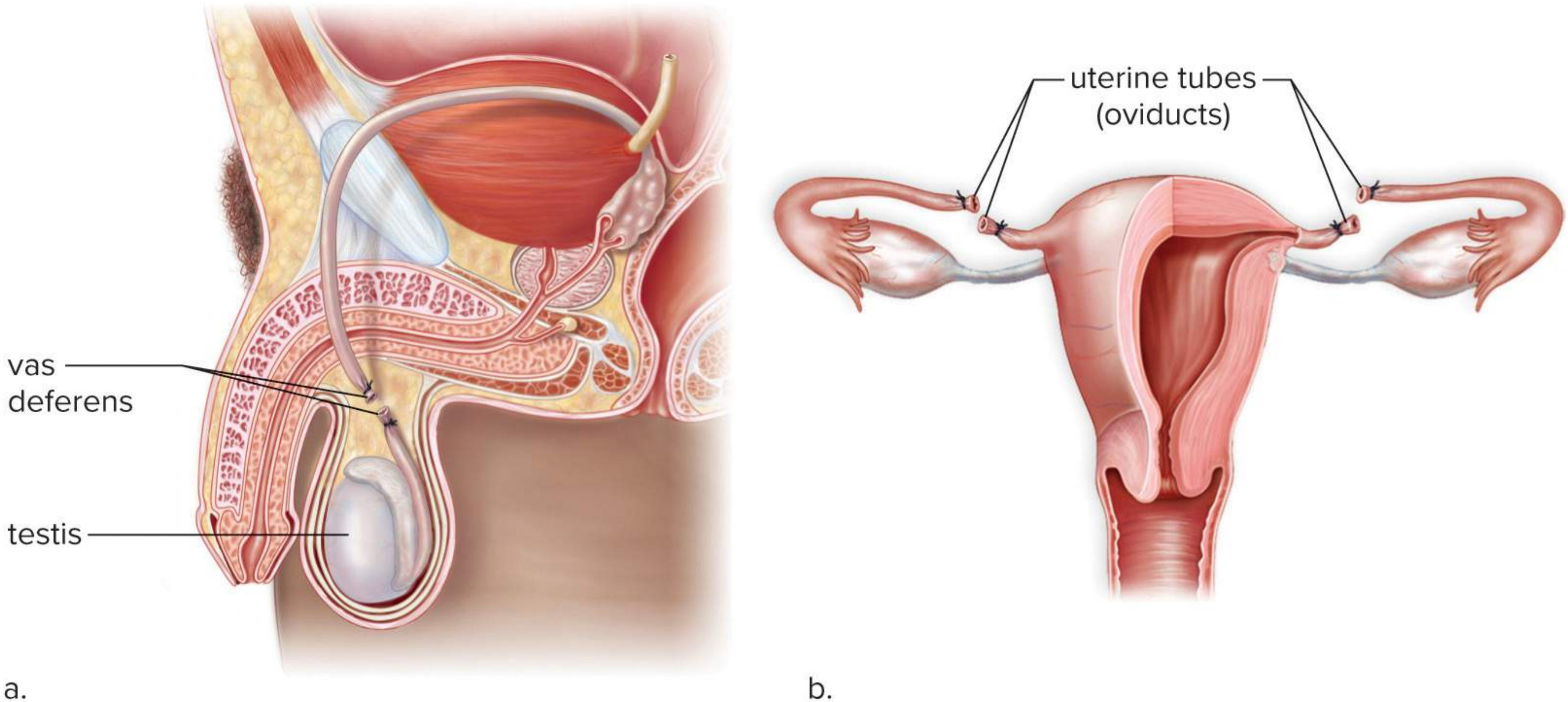
- Some treatments can be started up to 5 days after unprotected intercourse.

Surgical Methods

Surgical methods.

- **Vasectomy—**cutting and sealing the vas deferens from each testis.
  - The amount of ejaculate remains normal; sperm make up only 1% of the volume of semen.
  - Testosterone is still produced normally.
- **Tubal ligation—**cutting and sealing the uterine tubes.

Vasectomies and Tubal Ligations (Figure 17.15)



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STDs Caused by Viruses

STDs caused by viruses.

- Treatment is available but cannot eliminate the virus from the body.
  - Drugs can merely slow replication of the viruses; thus, they are not curable.
  - Antiviral drugs have serious, debilitating side effects.

HIV Infections [1]

HIV causes **AIDS.**

- There is no vaccine to prevent an HIV infection, nor is there a cure for AIDS.
- Infects helper T cells, which stimulate an immune response; HIV impairs the immune system.
- During the first stage of an HIV infection, symptoms are few, but the individual is highly contagious.
- Several months to several years after infection, the helper T-lymphocyte count falls.
    - Opportunistic infections begin to appear.
- **Highly active antiretroviral therapy (HAART)—**is usually able to stop the reproduction of HIV to the extent that the virus becomes undetectable in the blood.
    - As soon as HAART is discontinued, the virus rebounds.

Genital Warts

Genital warts—caused by the **human papillomavirus (HPV).**

- Warts are often on the penis and foreskin of men and near the vaginal opening in women.
- Can remove with surgery, freezing, or burning with lasers or acids.
- There is a vaccine for HPV.
- Genital warts and HPV are associated with cancer of the cervix, vulva, vagina, anus, and penis.

Genital Herpes 1

Genital herpes—caused by the herpes simplex virus.

- Type 1 usually causes cold sores, type 2 causes genital herpes.
- Some exhibit no symptoms; others feel a tingling or itching sensation before blisters appear.
- Ulcers are painful and take 5 to 20 days to heal.
- The blisters may be accompanied by fever; pain on urination; swollen lymph nodes in the groin; and in women, a copious discharge.
- When ulcers are present, there is an increased risk of acquiring HIV.
- After the ulcers heal, the disease is latent, and blisters can recur.
- Fever, stress, sunlight, and menstruation are associated with recurrence of symptoms.
- Exposure to herpes during birth can cause an infection in the newborn, which leads to neurological disorders and even death.
- Drugs can decrease outbreaks but are not a cure.
- Latex or polyurethane condoms prevent the transmission of the virus.

Hepatitis 1

Hepatitis—infects the liver and can lead to liver failure, liver cancer, and death.

- Six viruses cause hepatitis, designated A, B, C, D, E, and G.
  - Hepatitis A—usually acquired from sewage-contaminated drinking water, but can also be sexually transmitted through oral-anal contact.
  - Hepatitis B—spread through sexual contact and by blood-borne transmission (accidental needlestick, contaminated blood transfusion, sharing infected needles, from mother to fetus, etc.).
  - Hepatitis C causes most cases of posttransfusion hepatitis.
  - Hepatitis D and G are sexually transmitted, and hepatitis E is acquired from contaminated water.

STDs Caused by Bacteria

STDs caused by bacteria.

- Curable with antibiotics.
- Antibiotic resistance in these bacteria may require intensive treatment to achieve a cure.

Chlamydia

Chlamydia.

- Usually mild or asymptomatic in women.
- 18 to 21 days after infection, men may experience a burning sensation on urination and a mucoid discharge.
- Women may have a vaginal discharge.
  - Also causes cervical ulcerations, which increase the risk of acquiring HIV.
  - Can cause **pelvic inflammatory disease (PID).**

Gonorrhea

Gonorrhea.

- Males often have pain upon urination and a thick, greenish-yellow urethral discharge.
- Females can get PID.
- If a baby is exposed during birth, an eye infection leading to blindness can result.
- Can spread to internal parts of the body, causing heart damage or arthritis.

Syphilis 1

Syphilis.

- Has three stages, often separated by latent periods.
  - Primary stage—a hard chancre (sore) at the site of infection.
  - Secondary stage—rash that does not itch.
  - Tertiary stage—lasts until the patient dies.
    - May affect the cardiovascular system, nervous system, and gummas (large, destructive ulcers) may develop on the skin or within internal organs.
- Congenital syphilis is caused by syphilitic bacteria crossing the placenta.
  - The child is born blind and/or with numerous anatomical malformations.

Vaginal Infections[1]

Vaginitis—any vaginal infection or inflammation.

- Bacterial vaginosis (BV) can be sexually transmitted.
  - Symptoms: vaginal discharge with a strong odor, burning during urination, itching or pain in the vulva.
  - Douching increases the incidence of BV.

Vaginal Infections 2

Vaginitis, continued.

- A yeast and a protozoan are two other causes of vaginitis.
  - A yeast infection—thick, white vaginal discharge.
  - Trichomoniasis—caused by a protozoan.
    - The urethra is usually the site of infection in males.
    - Females get a foul-smelling, yellow-green, frothy discharge and itching of the vulva/vagina.
    - Having trichomoniasis greatly increases the risk of infection by HIV.