Anatomy – investigates how the structure of a body part correlates with its function.
Gross Anatomy (Macroscopic Anatomy) – the study of the larger structures of the body, those visible without the aid of magnification.
Microscopic Anatomy – the study of structures that can be observed only with the use of a microscope or other magnification devices.

- **Cytology** – the study of cells
- **Histology** – the study of tissues

Anatomist – expert in anatomy.
The Field of Anatomy:

- **Systemic Anatomy** – studies body organ-systems.
- **Regional Anatomy** – studies body regions.
- **Surface Anatomy** – studies external features, for example, bone projections.
- **Anatomical Imaging** – using technologies (x-rays, ultrasound, MRI) to create pictures of internal structures.

The Field of Physiology – Helps to understand the chemistry and physics of the anatomical structures of the body and how they work (function).
Some categories of physiology:

- Neurophysiology
- Cardiovascular physiology
- Renal physiology

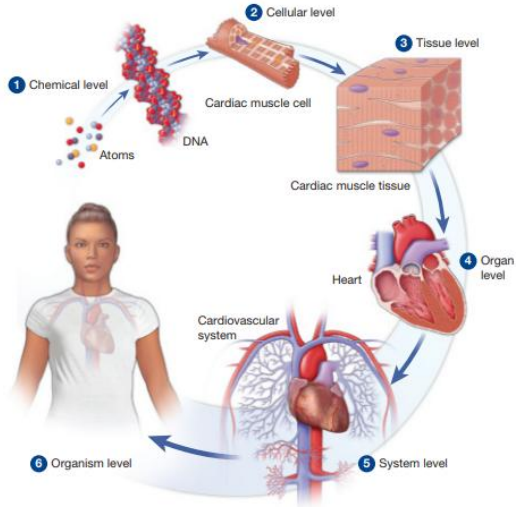
Structure and Function:

- Structure determines function. Ex: Adding a phosphate group to a protein changes the shape of the protein.
- Structure is intimately tied to function. If a body part or tissue is not used, it undergoes atrophy (shrinks).

Characteristics of Life:

- **Organization**: functional interrelationships between parts.
- **Metabolism**: ability to acquire and use energy in support of these changes.
- The chemical and physical changes sustaining an organism.
- **Responsiveness**: ability to sense and respond to environmental changes—both internal and external environments.
- **Growth**: increase in size of cells, groups of cells, extracellular materials.
- **Development**: changes in cell structure—form and size—and function from generalized to specialized—differentiation.
- **Reproduction**: formation of new cells or new organisms.
  - Also tissue repair.

Levels of Structural Organization of the Human Body:



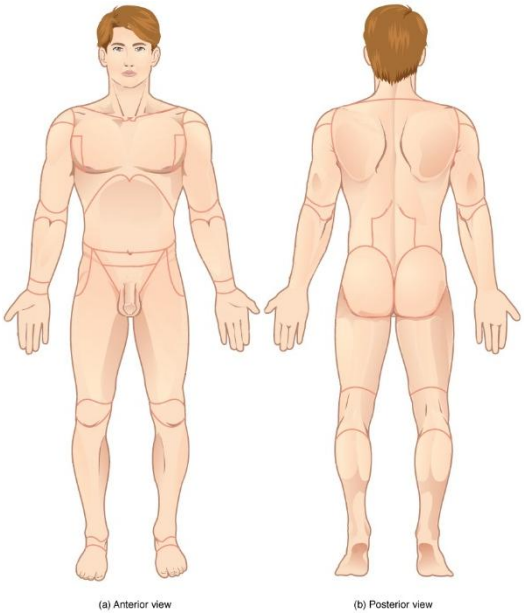
Six levels from chemical to organism:

- **Chemical**: Smallest level (e.g., atoms, chemical bonds, molecules)
- **Cellular**: The basic units of life (the cell) and its compartments and organelles (e.g., mitochondria, nucleus).
- **Tissues**: Group of cells with similar structure and function plus extracellular substances they release (four broad types: Epithelial, Connective, Muscular, and Nervous).
- **Organs**: two or more tissue types acting together to perform function(s)
- At this level, there is usually a parenchyma (the functional tissue) that performs the organ's primary tasks.
- **Organ-System**: group of organs contributing to some function (e.g., digestive system, reproductive system).
- **Organism**: the term given when all organ systems working together regardless of sizes.

Language of Anatomy: Introduction to the Human Body
Anatomical Position: Provides a consistent reference point for describing the locations of body structures in relation to one another.

- ❖ It eliminates ambiguity about the body's orientation, ensuring clarity whether the person is upright or lying down.
- ➢ **Body posture**: Stands erect and upright.
- ➢ **Feet placement**: Positioned shoulder-width apart; Feet are parallel with toes pointing forward.
- ➢ **Upper limb position**: Arms extended at the sides of the body; Palms face forward; Thumbs point outward, away from the body.

➢ Directional terms: Right and left refer to the subject's (patient or cadaver's) own sides, not those of the observer.

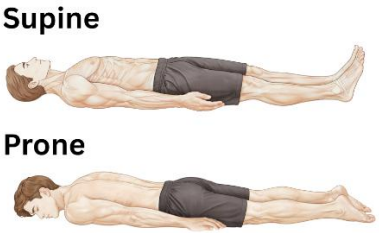


(a) **Anterior**: Refers to the front side of the body.
(b) **Posterior**: Refers to the back side of the body.

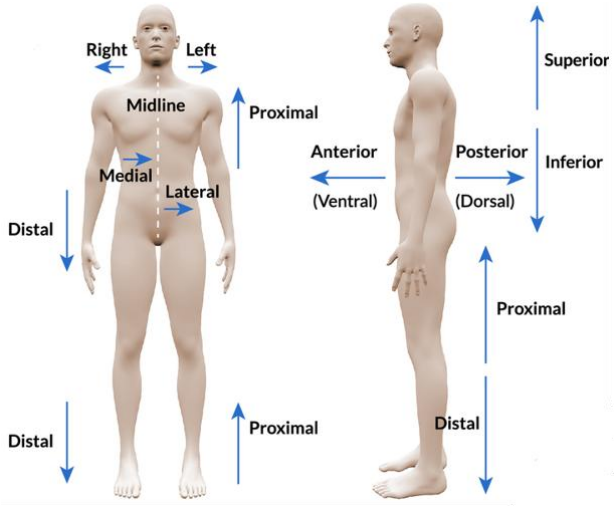
Directional Terms in Anatomy: Essential for describing the relative positions of body structures.

✓ Always assume the body is in the anatomical position when using these terms.

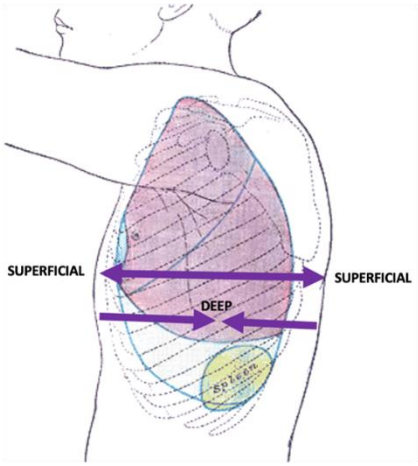
1. **Supine**: describes a face-up orientation.
2. **Prone**: describes a face-down orientation.



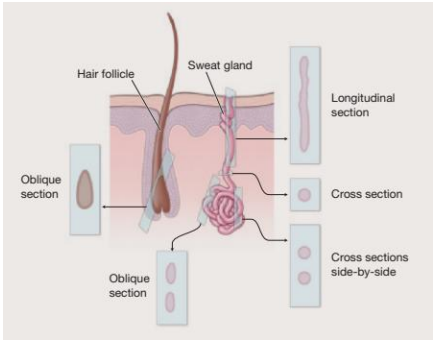
3. **Superior**: Indicates a position above or higher than another body part.
4. **Inferior**: Indicates a position below or lower than another structure.
5. **Lateral**: Describes a structure toward the side of the body.
6. **Medial**: Describes the middle or direction toward the middle of the body.
7. **Proximal**: Describes a position on a limb that is nearer to the point of attachment or the trunk of the body. (Ex: The brachium is proximal to the antebrachium).
8. **Distal**: Describes a position in a limb that is farther from the point of attachment or the trunk of the body. [Ex: The lower leg (crus) is distal to the thigh bone (femur)].



9. **Superficial**: Refers to a position nearer to the body's surface.
10. **Deep**: Refers to a position further away from the surface of the body.



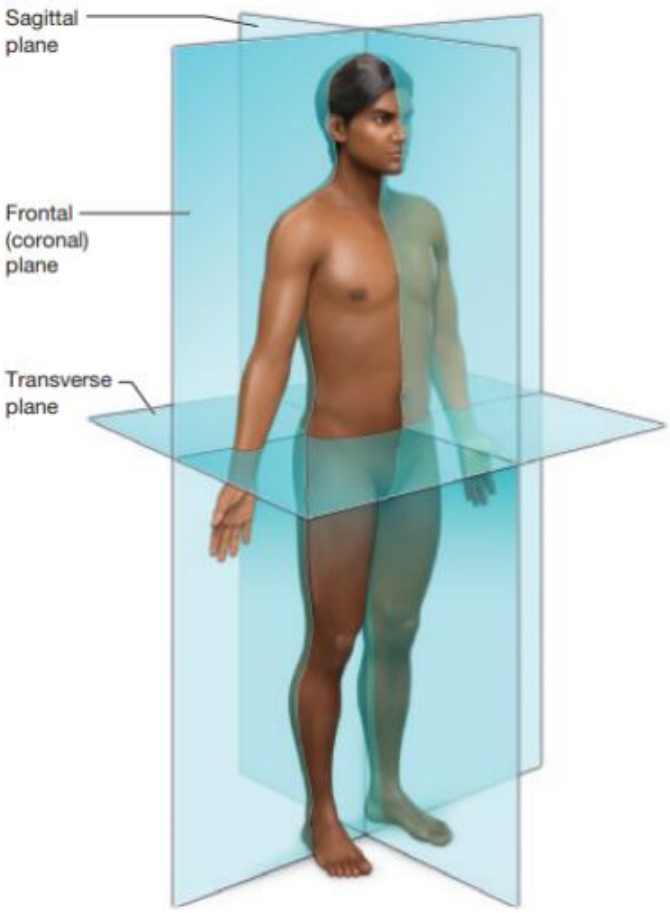
Sections and Planes: A **section** is a slice of a three-dimensional structure that has been cut. A **plane** is an imaginary slice through the body used in imaging.



(d) Sagittal plane: Divides the body into right and left sides. If it cuts exactly in the middle, it's **midsagittal**; if not equal, it's **parasagittal**.

(e) Frontal (coronal) plane: Divides the body into front (anterior) and back (posterior) parts.

(c) **Transverse plane:** Divides the body horizontally into upper and lower parts, creating **cross sections**.

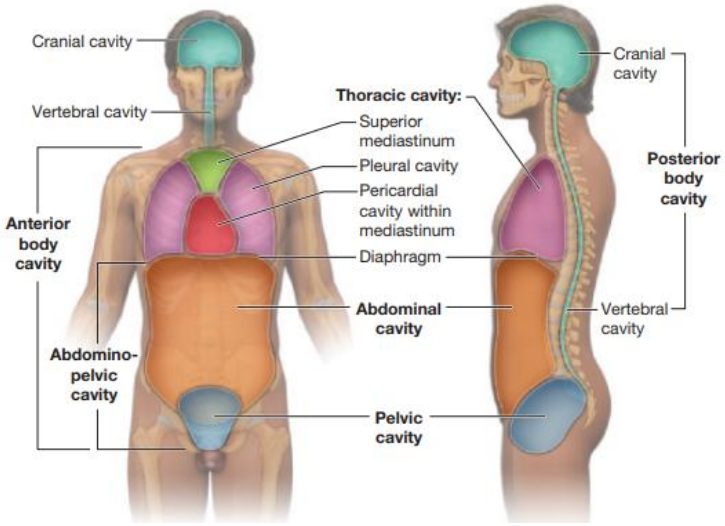


Compartmentalization: The body is organized into distinct internal compartments to separate body fluids from microorganisms and to coordinate cellular activity.

- Compartments are separated by membranes (**cavities**), which function at two levels:
  - **Cellular level:** The **plasma membrane** separates intracellular fluid from the extracellular environment.
  - **Tissue level:** Multicellular sheets (like the **pericardium**) protect and subdivide entire body cavities.

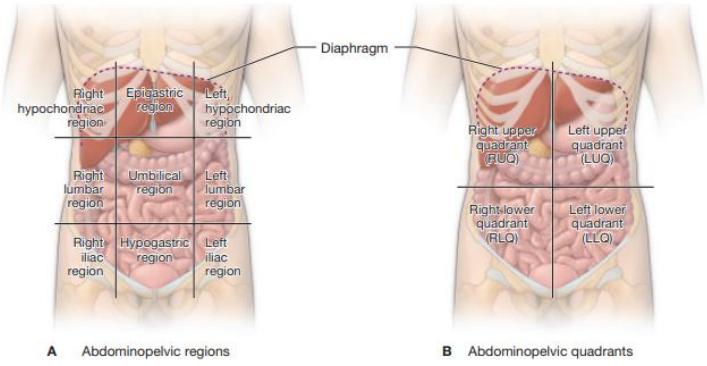
Major Body Cavities

- **Posterior (Dorsal) Cavity:** Located at the back; contains the central nervous system.
  - **Cranial Cavity:** Houses the brain; protected by the skull.
  - **Spinal (Vertebral) Cavity:** Encloses the spinal cord; protected by the vertebral column.
  - Note: These two cavities are continuous and cushioned by **cerebrospinal fluid**.
- **Anterior (Ventral) Cavity:** Located at the front; contains organs that expand/contract (lungs, heart, stomach).
  - **Thoracic Cavity:** The superior subdivision enclosed by the rib cage; contains the heart and lungs.
    - **Mediastinum:** The specific central subdivision of the thoracic cavity (e.g., Thymus, Esophagus, Trachea).
    - **Pericardial Cavity**: Heart
  - **Diaphragm:** The muscular sheet forming the floor of the thoracic cavity and the ceiling of the abdominopelvic cavity.
  - **Abdominopelvic Cavity:** The largest cavity; divided into the **Abdominal cavity** (digestive organs, e.g., Stomach, Spleen, Liver, Small intestine) and **Pelvic cavity** (reproductive organs, e.g., Urinary bladder, Ovaries).



Clinical Divisions

- **Abdominopelvic Quadrants/Regions:** Used by healthcare providers to locate pain or masses.
- The abdomen is divided into quadrants by one horizontal and one vertical line crossing at the umbilicus.
- Because the abdominopelvic cavity is large and contains many organs, it is divided into smaller areas for easier study.
  - **Nine Regions (a):** More detailed division for specific localization
  - **Four Quadrants (b):** Simple division for general clinical use.



Serous Membranes (Serosa): Thin, double-layered membranes covering walls and organs in the anterior cavities.

- ➢ Reduce rubbing and friction as internal organs move.

Serous membranes have two layers:

- **Parietal Layer:** The outer layer that lines the walls of the body cavity.
- **Visceral Layer:** The inner layer that covers the organs (the viscera) directly.

Other components:

- **Serous Space/Cavity:** The thin, fluid-filled gap between the parietal and visceral layers.
- **Serous Fluid:** A lubricating liquid secreted by both layers to reduce friction during organ movement (e.g., heartbeats, breathing).

Specific Serous Membranes:

(a) **Pleura:** Surrounds the lungs in the pleural cavity.

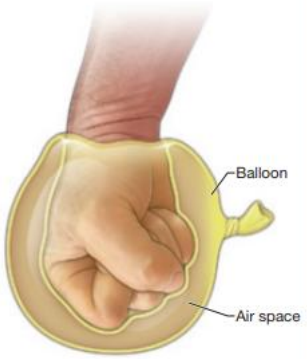
(b) **Pericardium:** Surrounds the heart in the pericardial cavity.

(c) **Peritoneum:** Surrounds various organs within the abdominopelvic cavity.

- ➢ Serous membrane layers develop as the organ develops into the membrane.
- ➢ This is similar to the way that an underinflated balloon forms two separate layers around a fist

Figure 2.16 Serous Membranes

A double-layered serous membrane covers the heart. Serous membranes are composed of a visceral and parietal layer with fluid between them. These membranes develop as a fluid-filled sac and the organ develops onto the membrane, causing it to reflect back to cover the heart—much the same way that an underinflated balloon would form two layers surrounding a fist.



Radiation-Based Imaging:

X-Rays: High-energy **electromagnetic radiation** penetrates solids; beams are blocked by hard tissues.

- ➢ Visualization: Hard tissues (bones, teeth) appear white; soft tissues appear gray.
- ➢ Primary Use: Visualizing fractures, dental issues, and dense body structures.

Computed Tomography (CT): Uses a computer to analyze **multiple cross-sectional X-rays (tomography)**.

- ➢ Visualization: Provides minute details of internal structures in planes.
- ➢ Provides more detail than x-rays alone
- ➢ Risk: High-energy radiation exposure; must be used sparingly to minimize cancer risk.

Positron Emission Tomography (PET): Uses **radiopharmaceuticals** (short-lived radioactive substances) injected into the patient.

- Detect metabolic activity (metabolism and blood flow) rather than just static anatomy.
- Primary Use: Diagnosing heart disease, cancer spread, and brain abnormalities.

Non-Radiation Imaging:

Magnetic Resonance Imaging (MRI): Uses powerful **electromagnets and radio waves** to cause matter to emit radio signals.

- Uses radio signals emitted by internal structures to provide very precise details
- Advantages: Very precise; excellent for soft tissue and tumor detection; no radiation risk.
- Drawbacks: expensive

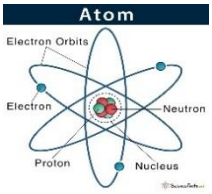
Ultrasonography: Transmits high-frequency **sound waves** into the body to generate echo signals.

- Visualization: Converted by computer into real-time images of anatomy and physiology.
- Advantages: Least invasive technique; no radiation; safest for sensitive situations like pregnancy.

The Role of Energy in Chemical Reactions:

Basic Chemistry:

- **Matter** – anything that occupies space and has mass.
- **Mass** – the amount of matter contained in an object.
- **Mass** is the same regardless of where the object is while **Weight** can vary because it depends on gravity.



- The basic building block of chemistry.
- Most of the atom is empty space. Nucleus consists of **protons** (+) and **neutrons** (0), surrounded by a cloud of **electrons** (–).

Element	Molecule	Compound
• An element is a pure substance made of only one type of atom. • It cannot be broken down into a simpler substance by chemical means.	A molecule is formed when two or more atoms bond chemically. The atoms can be of the same element or different elements.	A compound is a type of molecule that contains atoms of two or more different elements chemically bonded together. All compounds are molecules, but not all molecules are compounds.

Chemical Composition of the Human Body:

Element and Symbol	Percentage in the Body
Oxygen (O)	65.0
Carbon (C)	18.5
Hydrogen (H)	9.5
Nitrogen (N)	3.2
Calcium (Ca)	1.5
Phosphorus (P)	1.0
Potassium (K)	0.4
Sulfur (S)	0.3
Sodium (Na)	0.2
Chlorine (Cl)	0.2
Magnesium (Mg)	0.1
Trace elements include boron (B), chromium (Cr), cobalt (Co), copper (Cu), fluorine (F), iodine (I), iron (Fe), manganese (Mn), molybdenum (Mo), selenium (Se), silicon (Si), tin (Sn), vanadium (V), and zinc (Zn).	less than 1.0

- **Ions**: an atom with an electrical charge. (e.g., **Cation**—positively charged ion—and **Anion**—negatively charged ion).
- An ion is an atom with a net charge due to gaining or losing electrons.

- **Isotopes** – Two atoms of the same element differ in their number of neutrons.
- Radioactive isotopes are unstable and shed subatomic particles

- **Energy** is the ability to do work.

Types of energy:

- **Potential energy** – stored energy that can be released.
- **Kinetic energy** – the energy of motion.
- **Chemical energy** – potential energy that is stored in bonds.

Energy can be stored in chemical bonds.

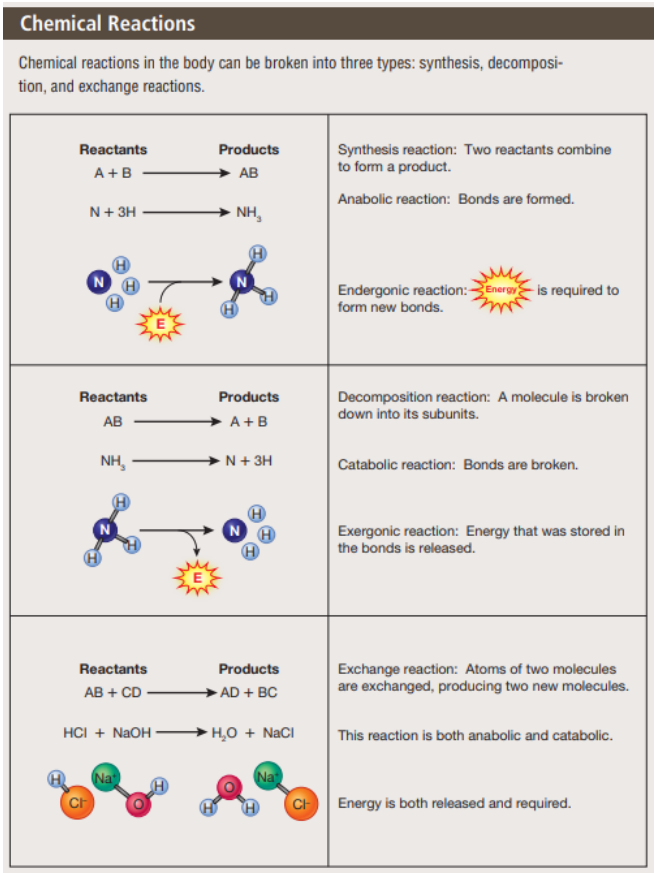
- **Adenosine triphosphate (ATP)** – is a common form of cellular energy.

Energy can be converted from one form to another through chemical reactions.

- Chemical reactions that release more energy than they absorb are characterized as **Exergonic Reactions** (Example: ATP to ADP).
- Chemical reactions that absorb more energy than they release are **Endergonic Reactions** (Example: ATD to ADT).

Characteristics of Chemical Reactions:

- **Reactant** (substrates) – the substances that enter into the reaction.
- **Product** – the substances produced by the reaction.



Exchange reaction *– involves the breaking apart of compounds (decomposition) and the reformation of new compounds (synthesis).*

Concentration of Solutes:

Enzymes and Activation Energy:

- **Enzyme** – a protein that speeds up chemical reactions by lowering activation energy.
- **Activation energy** – the minimum energy needed for a reaction to occur.
- **Enzymes** help reactions happen but aren't used up.

Inorganic versus Organic Compounds:

- An **Inorganic Compound** is a substance that does not contain both carbon (C) and hydrogen (H).
  - e.g., Water (H_2O), salts, acids and bases, carbon dioxide (CO_2)
- An **Organic Compound**, then, is a substance that contains both carbon and hydrogen.
  - e.g., Carbohydrates, lipids, proteins, nucleic acids
  - Oxygen and other elements may be incorporated as well

Common Chemical Formulas in A&P

Table 3.2 Commonly Used Chemical Formulas in A&P

Full Name	Chemical Formula
Oxygen	O_2
Carbon dioxide	CO_2
Potassium ions	K^+
Chloride ions	Cl^-
Calcium ions	Ca^{2+} (also expressed Ca^{++})
Glucose	$C_6H_{12}O_6$
Water	H_2O
Hydrochloric acid	HCl
Sodium chloride	NaCl

Water (H_2O) in the body:

- 50–70% of an adult body.

Functions of water in the body include:

1. Provides lubrication for joints.
2. Provides cushioning for cells and tissues.
3. Aids in temperature regulation.
4. Is a solvent for ions and nutrients needed by cells.

Water as a Solvent:

- Water is considered the "universal solvent" for polar molecule.
- The nutrients required by cells within the body are typically dissolved in water.

A nutrient dissolved in water makes up a solution:

- **Solution** – a mixture where one substance is dissolved (Solute) in another (Solvent).
- **Solvent** – the substance that dissolves another substance in a solution.
- **Solute** – the substance dissolved in the solvent.
- **Solute** – the substance dissolved in the solvent.
- Solute concentration refers to the number of solute particles in a specific matter (e.g., air, water, etc.).
- It can be expressed in a variety of ways:
  - Oxygen is 21% of atmospheric air.
  - Blood glucose is expressed in mg/dL
  - Molarity is moles of the molecule per L.

Different Types of Solutions:

- **Colloid** – the solute particles consist of tiny clumps of molecules large enough to make the liquid mixture opaque.
- **Suspension** – a liquid mixture in which heavier substance is suspended temporarily and settles out over time.
  - Sedimentation = separation of particles.
  - Occurs if blood is left in the air for a period of time

Role of Water in Chemical Reactions:

- Dehydration synthesis forms new molecules while creating water at the same time.
- Hydrolysis reactions break covalent bonds using water

Acids and Bases:

- **Acids** release hydrogen ions (H^+) when dissolved in solution.
- **Bases** - Substances that release hydroxyl ions (OH^-) or accept H^+
- pH scale from 0 to 14 indicates the acidity or alkalinity of a solution.
  - pH of 7 is neutral (Water);
  - The closer to 0, the more acidic the solution.
  - The closer to 14, the more alkaline the solution.
- The pH of human blood normally ranges from 7.35 to 7.45.
  - **Acidosis** means too much acid (pH below 7.35).
  - **Alkalosis** means too much base/alkali (pH above 7.45)
- **Buffers** are used to prevent rapid changes in the pH of a solution.

Organic Biological Macromolecules:

- Organic compounds essential to human functioning.
- Organic biological molecules are often very large.
- **Any large molecule is referred to as a macromolecule.**

Four major organic macromolecules are important within the human body:

1. Carbohydrates
2. Lipids
3. Proteins
4. Nucleic acids

- Macromolecules are built from smaller units called **monomers**.

Monomers of major organic molecules:

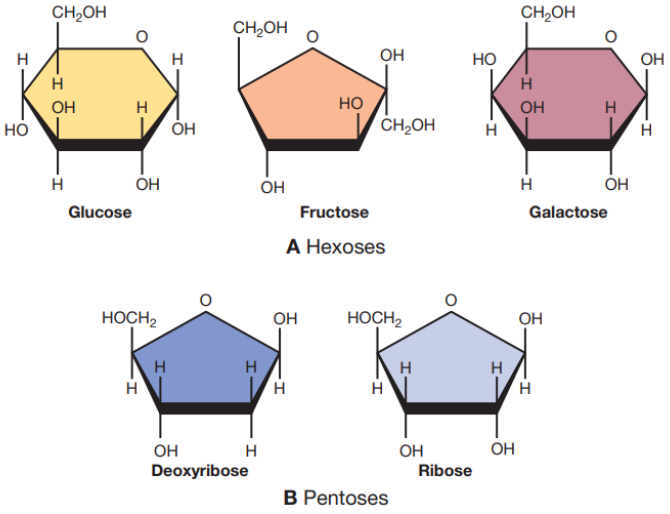
1. Carbohydrates – monosaccharides
2. Lipids – fatty acids and glycerol
3. Proteins – amino acids
4. Nucleic acids – nucleotides

- When monomers bond together, they form a **polymer**.

Monosaccharides:

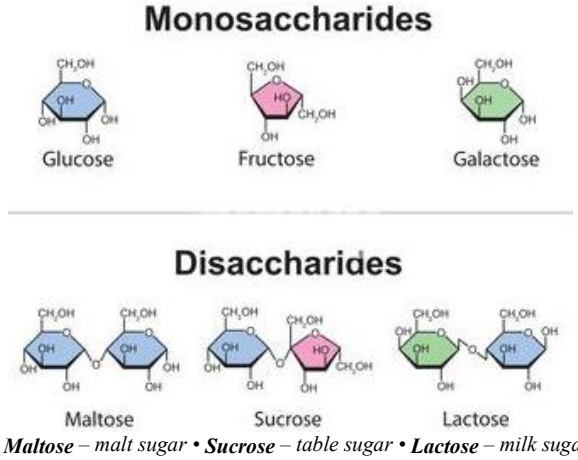
- A **monosaccharide** is the monomer form of carbohydrates.
- Monosaccharides can be used to form disaccharides or polysaccharides.
- Monosaccharides include:

These five monosaccharides are combined in different ways to form the polysaccharides of the body and our diet.



- **Disaccharides** are common in the human diet.

Physiologically important monosaccharides combine to form three common disaccharides:



• ***Maltose*** – *malt sugar* • ***Sucrose*** – *table sugar* • ***Lactose*** – *milk sugar*

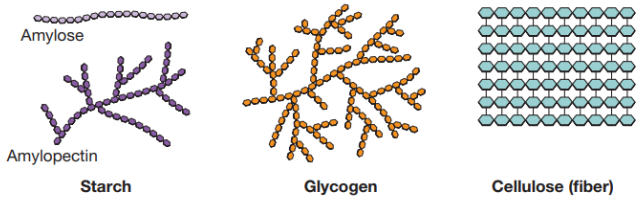
- **Polysaccharides** contain from a few to thousands of monosaccharides.

Important polysaccharides include:

- **Starches** – store glucose in **plants** and are a glucose-rich part of the human diet.
- **Glycogen** – stores glucose in **animals**, mainly in muscles and liver.
  - Starches and glycogen are polymers of glucose used for energy storage.
- **Cellulose** – cell walls of plants.
  - In humans, cellulose/fiber is **indigestible** but provides important health benefits.

Figure 3.21 Three Important Polysaccharides

Three polysaccharides that are particularly important in human health are starches, glycogen, and fiber.

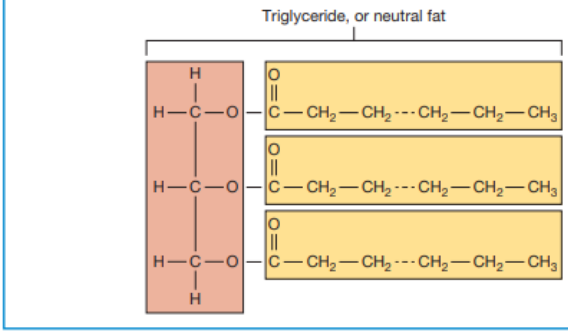


Lipids:

- Made mostly of hydrocarbons.
- Nonpolar (hydrophobic molecules).
- Triglyceride is the most common form of lipid in our diet.
  - ❖ Contain a 3-carbon glycerol molecule.
  - ❖ 3 fatty acids are attached to the glycerol.
  - ❖ Each fatty acid is a long chain of hydrocarbons.

Figure 3.23 Triglycerides

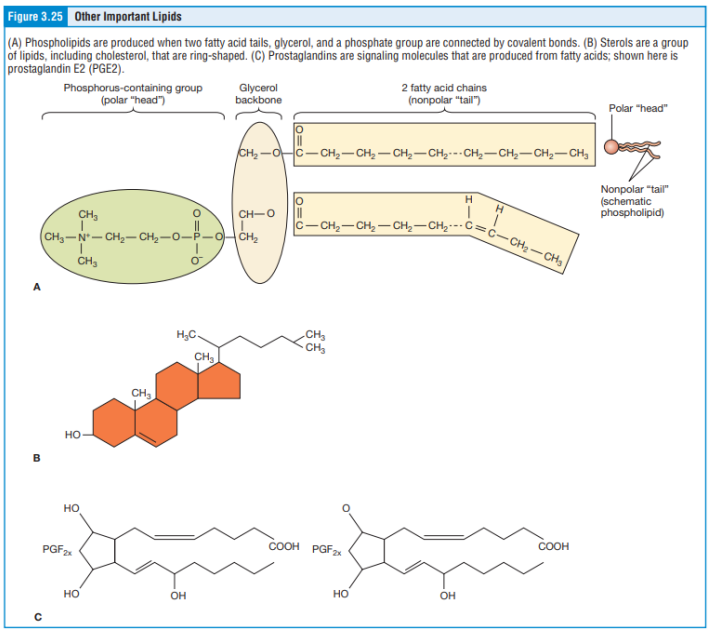
Triglycerides, which are dietary lipids, are produced when glycerol is joined to three fatty acid tails via dehydration synthesis.



- Major energy source for cells.
- Provides insulation.

Other Types of Lipids:

1. **Phospholipids**: Important in cellular membranes.
2. **Cholesterol**: Precursor used to make several hormones and provides stability to the cell membrane
3. **Prostaglandins**: Play a role in inflammation.

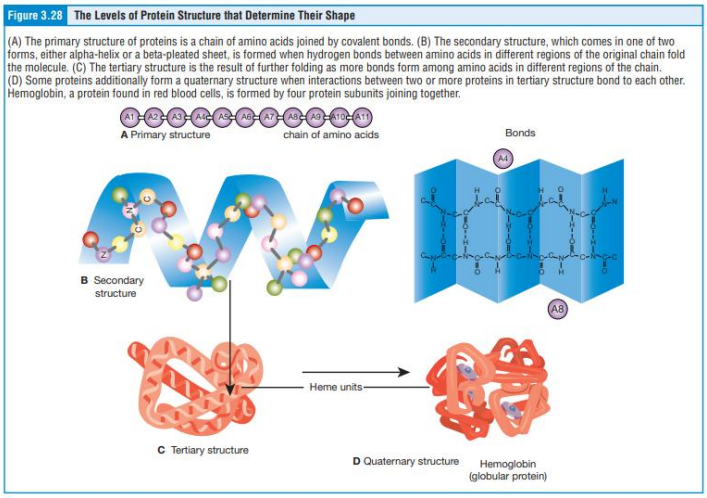


Proteins: Composed of amino acids linked together by peptide bonds.

- ❖ Function to provide cellular structure, transport substances, and catalyze reactions.

The shape of proteins:

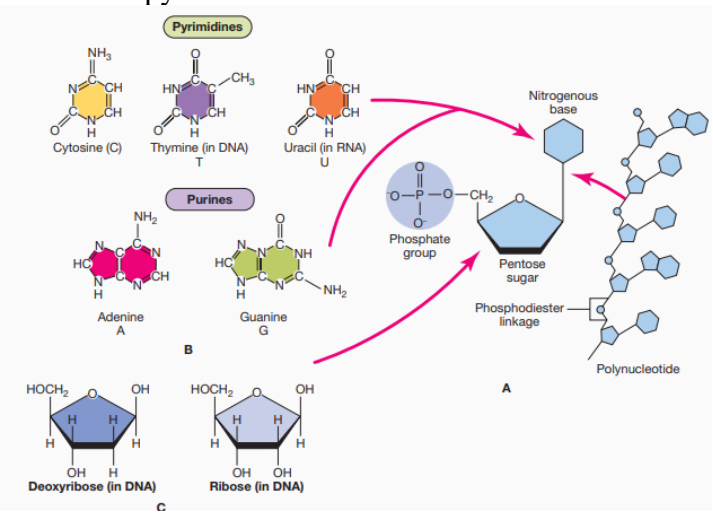
1. Primary structure – the sequence of amino acids.
2. Secondary structure – folding of amino acid chains into alpha-helix or beta-pleated sheet.
3. Tertiary structure – additional folding that occurs between different regions of the same amino acid chain.
4. Quaternary structure – interactions between 2+ proteins, each with its own tertiary structure



Nucleic Acids:

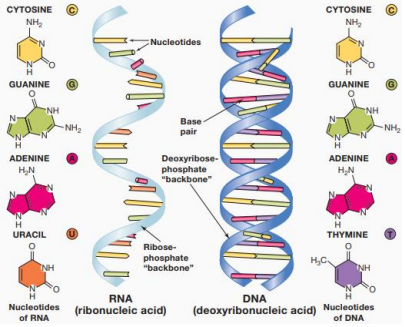
Two types of nucleic acids:

- ❖ Deoxyribonucleic acid (DNA): Monomer bases = adenine, cytosine, guanine, thymine.
- ❖ Ribonucleic acid (RNA): Monomer bases = adenine, cytosine, guanine, uracil.
- ❖ DNA contains the sugar deoxyribose; RNA contains the sugar ribose.
- ❖ Store the genetic code of the cells (DNA) and participate in protein synthesis (RNA).
- ❖ Nucleotides are composed of one or more phosphate groups, a sugar, and a nitrogen base.
  - o Adenine and guanine are purines.
  - o Cytosine, thymine, and uracil are pyrimidines.



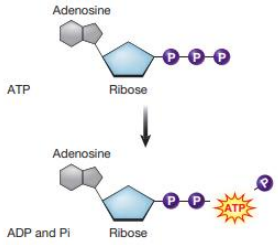
DNA versus RNA

- ❖ DNA is a double-stranded, helical molecule.
- ❖ RNA is a single stranded molecule.



Adenosine Triphosphate (ATP):

- ❖ A modified nucleotide.
- ❖ Energy currency of the cell.
- ❖ Covalent bonds between phosphate groups store energy.
  - o Energy is released when bonds are broken.



Anatomy of Flow:

- ❖ **Flow**: The movement of a substance or molecule.
- ❖ Gradients determine the direction of flow.

- Molecules flow down their concentration gradients.
- Pressure gradients move food, blood, and air through the body.

❖ Flow is directly proportional to the size of a gradient.

❖ Resistance opposes or stops flow.
- Flow is inversely proportional to resistance.
- An increase in resistance will decrease the flow.

Figure 2.5 Flow Rate and Its Determining Factors

Flow is proportional to the size of the gradient and inversely proportional to resistance.

$$\text{Flow} \propto \frac{\text{Gradient}}{\text{Resistance}}$$

Homeostasis: The state of dynamic stability of the body's internal environment.

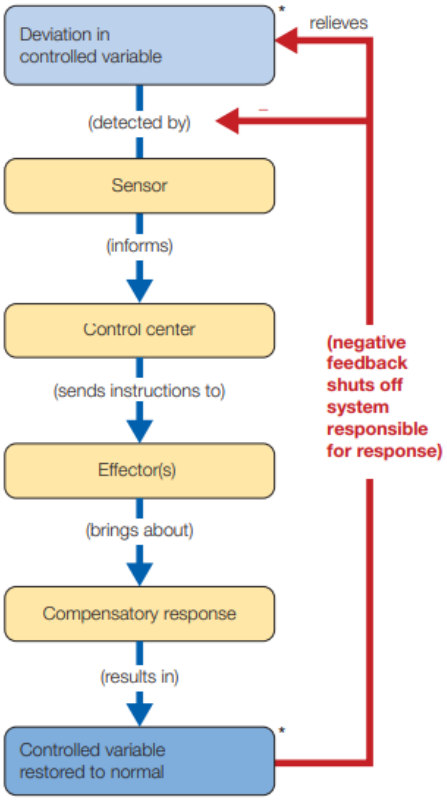
➢ **Function:** Ensures internal conditions (oxygen, pH, nutrients, temperature) remain stable so cells can survive and function.

➢ The body's parameters, or variables, are kept near a normal setpoint.

➢ **Setpoint:** The ideal value a variable is maintained around (e.g., 37°C).

➢ **Normal Range:** Acceptable fluctuations around the setpoint (e.g., 35–38°C).

Components of a Homeostatic Control System



A Components of a negative feedback control system

❖ **Stimulus:** Change that moves a variable from its setpoint.

❖ **Sensor (Receptor):** Detects changes in the variable.

❖ **Control Center:** Compares input to the setpoint and triggers a response (often in the brain).

❖ **Effector:** make changes made to keep parameters, or variables, near the setpoint.

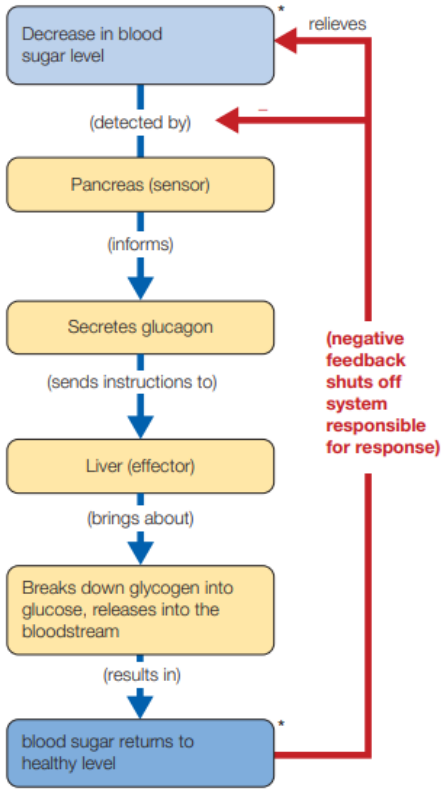
Negative Feedback Mechanisms: A mechanism that reverses a deviation from the setpoint to maintain the normal range.

❖ **Function:** It "turns off" the original stimulus once the setpoint is reached.

❖ A negative feedback response involves: **detection**: of deviation away from set point and **correction**: reversal of deviation toward set point and norm

Example (Blood Glucose):

➢ **Low Glucose:** Pancreas releases **glucagon** ⇒ Liver releases stored sugar ⇒ Blood sugar rises ⇒ System shuts off.



B Components of a negative feedback control system

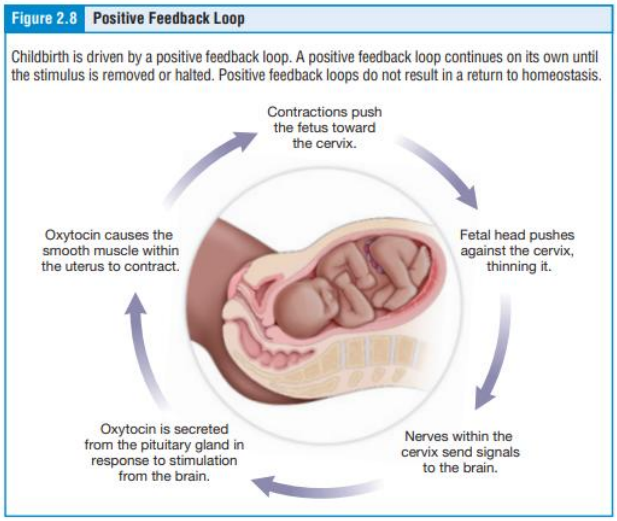
Positive Feedback Mechanisms: A mechanism that intensifies a change rather than reversing it.

❖ **Function:** Moves the body farther away from the normal range until a definitive end-point is reached.

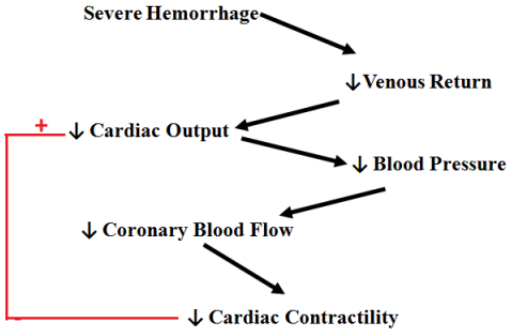
❖ **Nature:** Does **not** maintain homeostasis; it drives a process to completion.

Example (Childbirth):

- **Stimulus:** Fetus pushes against the cervix.
- **Sensor:** Nerve cells in the cervix detect stretching.
- **Control Center:** Brain signals the pituitary gland to release **oxytocin**.
- **Effector:** Oxytocin causes stronger uterine contractions.
- **Result:** More stretching leads to more oxytocin; the cycle only stops once the baby is born.



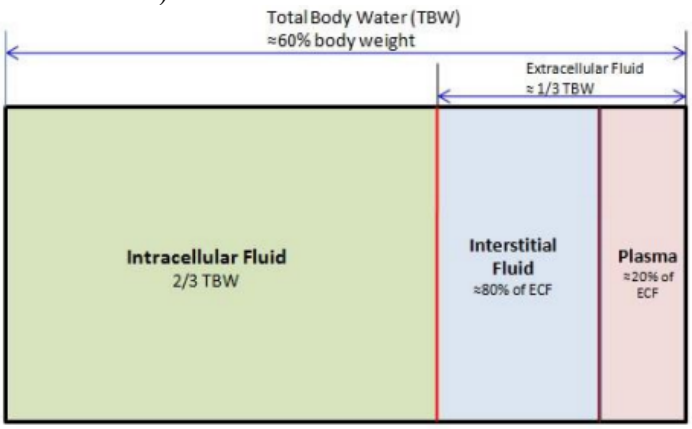
Positive feedback can sometimes cause vicious cycles and death.



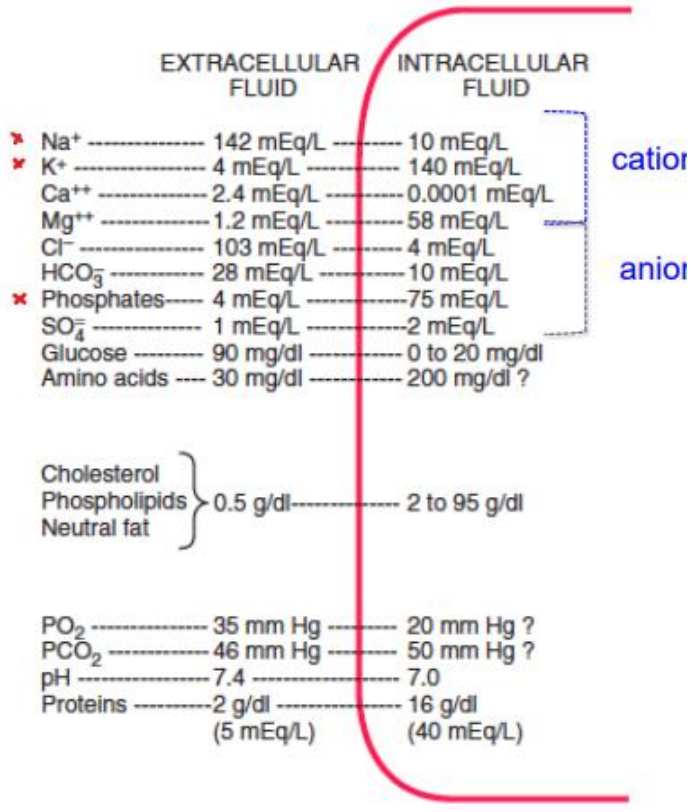
Feedback loop is a downward spiral where a weak heart makes itself even weaker. It starts when severe bleeding leaves the body without enough blood to keep pressure steady. Because the heart is a muscle that needs its own constant supply of oxygenated blood to function, the drop in overall blood pressure "starves" the heart. This lack of fuel causes the heart to pump with less force, which further crashes the blood pressure. Instead of the body fixing the problem, each turn of the cycle makes the heart weaker and the blood pressure lower, pushing the system further away from safety.

The internal environment of the cells:

- Almost 60% of the adult human body is fluid that contains water and solutes dissolved in it.
- Most of the fluid is inside of the cells (**intracellular fluid**) and one third of the fluid is in the spaces outside of the cells (**extracellular fluid**).

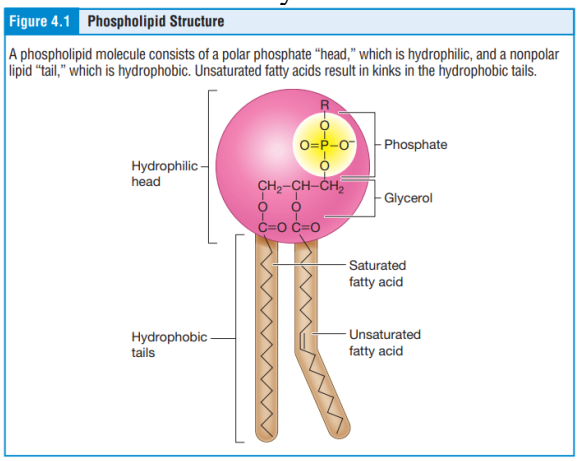


- Cells are capable of living, growing, and performing their special functions as long as the proper concentrations of O_2, nutrients, ions, and other constituents are available in the ECF.
- ECF is known as the "internal environment" or "milieu interieur" – a term coined by French physiologist Claude Bernard.



The Cell Membrane and Its Involvement in Transport:

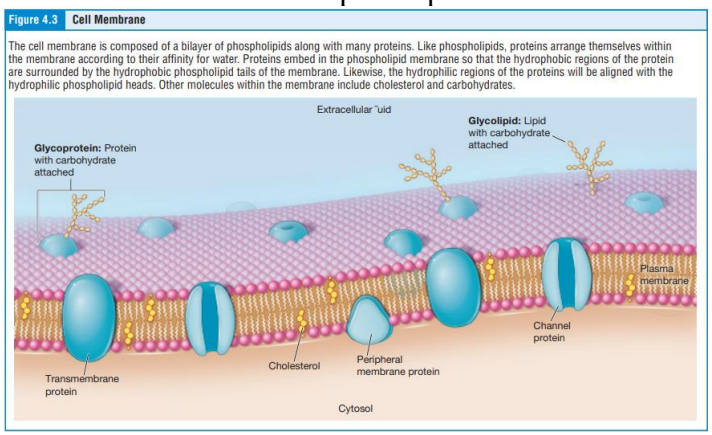
- All living cells, despite differences in structure and function, are surrounded by a membrane.
- The **cell (plasma) membrane** separates the cell's internal contents from the external environment (ECF) and regulates the movement of substances in and out of the cell.
- **The membrane** is a flexible and dynamic structure **composed** mainly of **phospholipids**, **cholesterol**, and **proteins**.
- **Phospholipids** make up about **50% of the cell membrane by weight.**
- Each phospholipid consists of a phosphate "head" and two fatty acid "tails.



- The phosphate group of a phospholipid is **negatively charged**, making the head **polar** and **hydrophilic** (**water-loving**).
- The fatty acid tails are **uncharged**, **nonpolar**, and **hydrophobic** (**water-repelling**).
- The hydrophobic core of the membrane blocks most polar molecules, making the membrane selectively permeable.
- Phospholipids are **amphipathic**.
  - **Amphipathic** means that a molecule has two opposite properties.
- Human tissues are aqueous (watery) environments.
- **Cholesterol** maintains membrane fluidity, allowing lipids and proteins to move within the membrane.
- In aqueous environments, amphipathic phospholipids self-organize with hydrophilic heads exposed to water (ECF and ICF) and hydrophobic tails hidden from water (the formation of bilayer).
- **Intracellular fluid** (**ICF**) - inside the cell.
- **Extracellular fluid** (**ECF**) - outside the cell.
  - ECF includes **interstitial fluid** (**IF**) (outside blood vessels) and **plasma** (within blood vessels).

Membrane Proteins:

- The lipid bilayer acts as a barrier between (ICF) and (ECF), while proteins provide specialized functional roles.
  - **Lipid bilayer** → double layer of phospholipids
- Proteins associated with cell membrane add functionality.
  - Serve as channel proteins, receptors, enzymes, and in cell-cell recognition.
  - **Membrane proteins are categorized into two types based on their position**:
    - Transmembrane proteins (integral, proteins).
    - Peripheral proteins



Transmembrane Proteins:

- Proteins that span the entire width of the membrane from the intracellular side to the extracellular side.
- Types of Transmembrane Proteins:
- **Channel Proteins:** Act as tunnels to allow specific materials, such as ions, to enter or exit the cell.
- **Receptors:** Proteins on the extracellular side that bind to specific molecules to trigger an internal chemical reaction.
- **Ligand:** The specific molecule that binds to and activates a receptor (e.g., dopamine).
- **Dual-Role Proteins:** Some proteins function as both a receptor and an ion channel simultaneously.
- **Glycoprotein:** A transmembrane protein with attached carbohydrate molecules.
- These molecules act as identification markers for cell recognition.
- **Glycocalyx:** A fuzzy coating formed by a high density of glycoproteins on the cell surface.
- Facilitates cell-to-cell binding, contains hormone receptors, or houses enzymes for nutrient breakdown.

- Immune Identity: The glycocalyx serves as a genetic "ID tag" that prevents immune cells from attacking the body's own cells.
- Organ Rejection: Variations in glycocalyx identity are the primary cause of the body rejecting donated organs.

Peripheral Proteins:

- Proteins that are anchored to either the interior or exterior surface of the membrane.
- Position: Do not cross through the lipid bilayer.

Transport across the Cell Membrane:

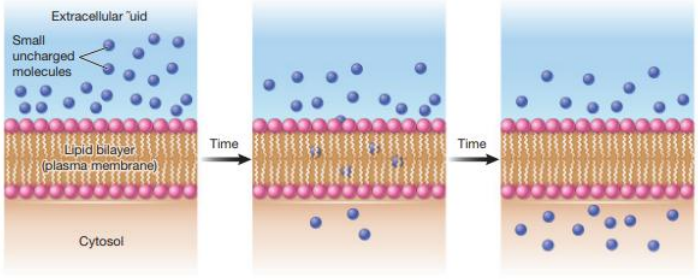
- Cell membrane is selectively permeable.
- The membrane allows small, nonpolar substances to cross freely while blocking polar, charged, or large molecules.
- Some substances are too large or too polar to cross the lipid "tails" and require the help of transmembrane proteins.
- Large particles or large volumes of fluid are moved in "sacs" called vesicles. This requires energy (ATP).
- Substances move via **Passive Transport** (no energy required) or **Active Transport** (requires ATP).

Passive Transport:

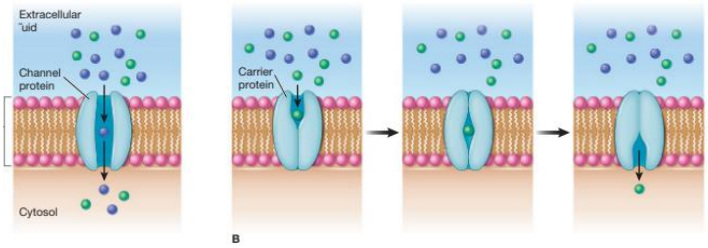
- Concepts to Remember for Understanding Passive Transport:
- **Concentration Gradient:** The difference in the concentration of a substance across a specific space (from low concentration to high concentration).
- **Diffusion:** The net movement of molecules from an area of higher concentration to lower concentration.
- Higher temperatures increase the rate of diffusion by increasing molecular motion.
- **Equilibrium:** A state where molecules move randomly but there is no net change in concentration (equal movement in all directions).

Simple vs. Facilitated Diffusion

- **Simple Diffusion:** Direct movement of small, nonpolar molecules (like O_2 and CO_2) through the lipid bilayer.



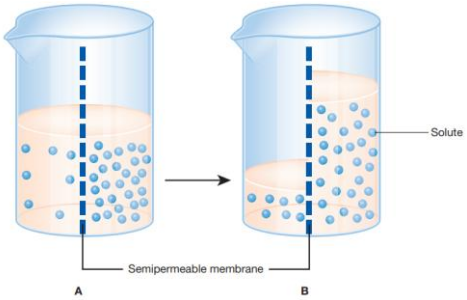
- **Facilitated Diffusion:** Movement of polar or large molecules [like glucose (glucose transporter) and ions] using transmembrane proteins.



- **Leak channels:** constantly allow ions to pass through.
- **Gated channels:** limit the movement of ions across the membrane by opening and closing.

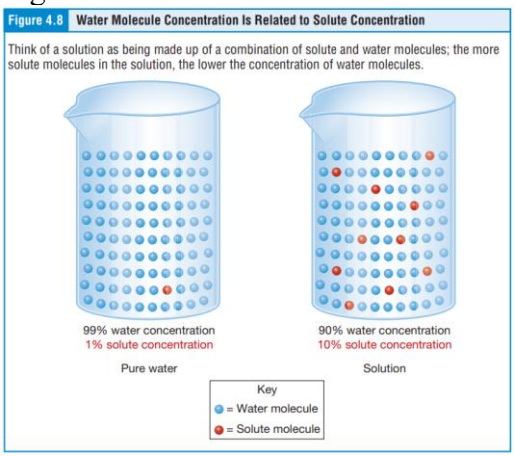
Osmosis and Water Movement

- **Osmosis:** The diffusion of water through a semipermeable membrane toward a higher solute concentration.



Water Gradient:

- Low solute concentration to high solute concentration.
- High water content to low water content.

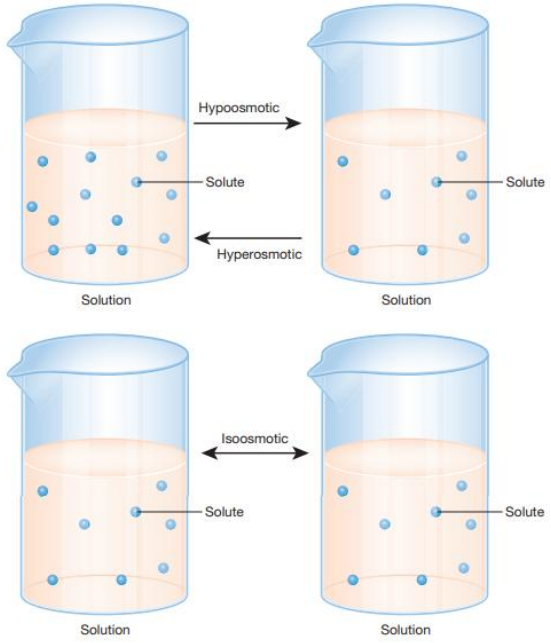


- **Volume Change:** Unlike simple diffusion of solutes, osmosis results in a change in the volume of the solutions.

Solution Comparisons (Osmolarity):

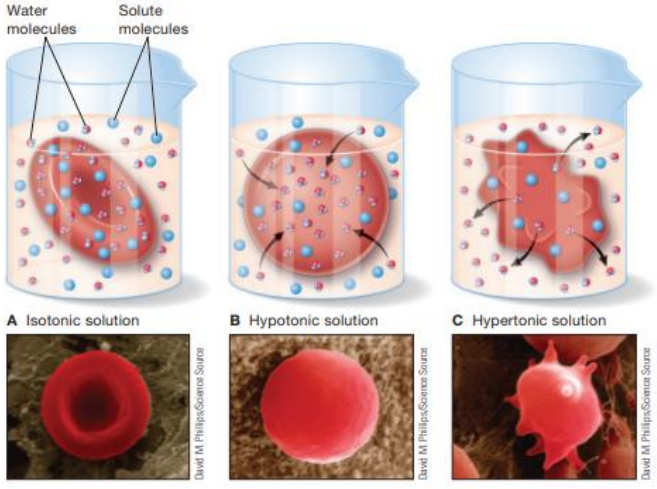
- **Isosmotic:** Two solutions with the same solute concentration.
- **Hyperosmotic:** The solution with a higher concentration of solutes.

- **Hypoosmotic:** The solution with a lower concentration of solutes.



Tonicity and Cell Volume:

- **Tonicity:** The effect of extracellular solute concentration on cell volume and shape.
- **Isotonic:** ECF and ICF concentrations are equal; the cell maintains a normal, healthy shape.
- **Hypertonic:** ECF has higher solute concentration than the cell; water leaves the cell, causing it to **shrivel**.
- **Hypotonic:** ECF has lower solute concentration than the cell; water enters the cell, causing it to **swell** or burst.



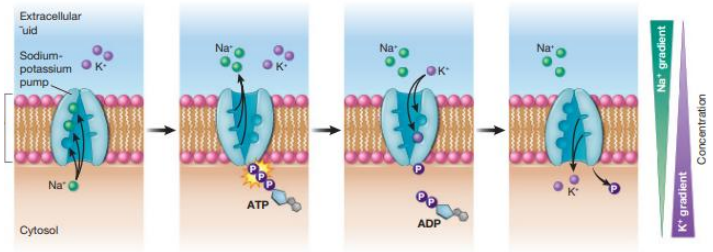
Active transport:

- The movement of substances across a cell membrane using energy (ATP).
- Moves substances **against** their concentration gradient.
- **Pumps**: Specialized carrier proteins that facilitate active transport.
- **Primary Active Transport -** uses ATP as energy source.
- **Secondary Active Transport** - Uses the energy from an existing gradient (created by primary active transport) to move a second substance.

Primary Active Transport:

The Sodium-Potassium Pump:

- **Function**: Transports 3 Na^+ ions out of the cell and 2 K^+ ions into the cell.
- **Electrical Gradient**: Creates a difference in charge across the membrane because more positive ions leave than enter.
- **Importance**: Essential for nerve and muscle cell function; consumes a large portion of daily calories.
- **Concentration Gradients**: Maintains high Na^+ outside the cell and high K^+ inside the cell.

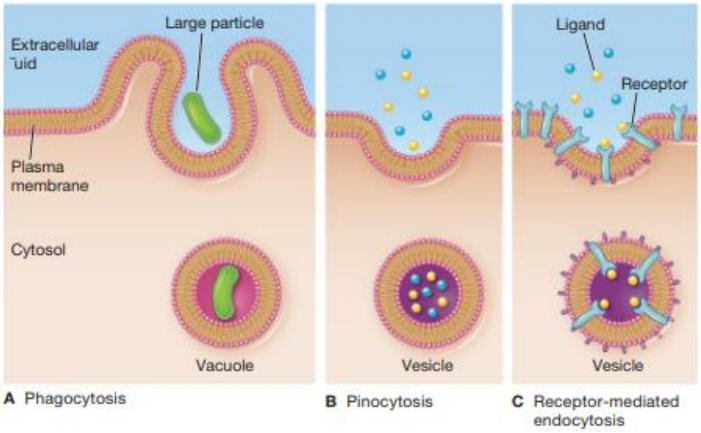


Secondary Active Transport:

- **Symporters**: Move two different substances in the **same direction** (e.g., Na^+ pulling glucose into the cell).
- **Antiporters**: Move two different substances in **opposite directions** (e.g., Na^+ moving in to push H^+ out).
- **pH Homeostasis**: Maintained by antiporters that remove excess hydrogen ions.

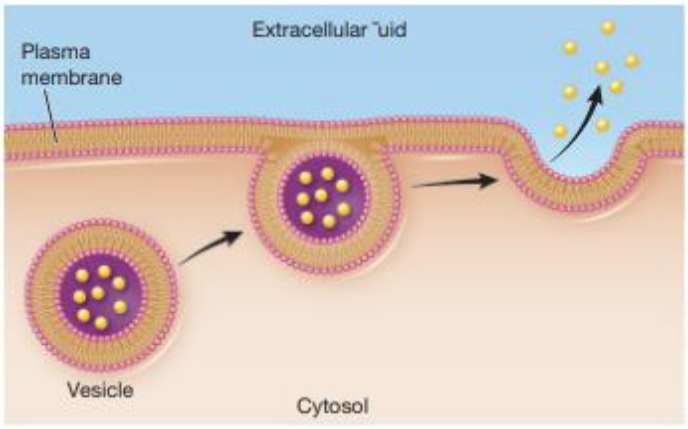
Vesicular Transport: **Endocytosis**

- The process of bringing materials into the cell by enveloping them in a piece of the cell membrane.
- **Vesicle**: Cell membrane pinches off to form a vesicle and material enters cell.
- A small intracellular sac made of a lipid bilayer that contains the engulfed material.
- **Phagocytosis**: "Cell eating"; the engulfing of large particles or pathogens (e.g., immune cells attacking bacteria).
- **Pinocytosis**: "Cell drinking"; the non-selective intake of extracellular fluid and dissolved substances.
- **Receptor-Mediated Endocytosis**: A selective process triggered only when specific ligands bind to membrane receptors.

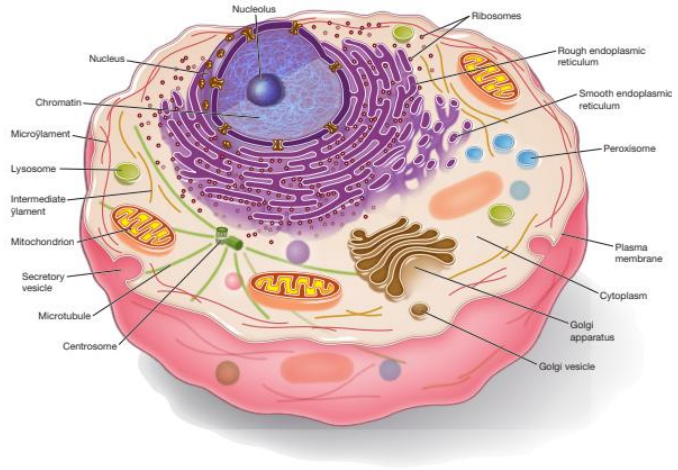


Exocytosis:

- The process of exporting materials out of the cell.
- A vesicle fuses with the plasma membrane, releasing its contents into the interstitial fluid.
- **Membrane Integration**: The vesicle membrane becomes part of the cell's outer membrane after fusion.
- **Applications**: Used for secreting hormones, digestive enzymes, and histamine.



Internal Components of Cells:



Major components of the inside of cells include:

- **Cytoplasm**: The fluid-like interior of cells including its compartments and organelles
  - **Cytosol**: The jellylike fluid medium where biochemical reactions occur.
    - The gel-like substance within the cytoplasm.
    - Contains organelles and molecules needed by cell.
  - **Organelles**: Specialized, membrane-enclosed bodies that perform specific cellular functions.

The Endomembrane System:

- A coordinated "factory assembly line" of three major organelles.
- **Components**: Endoplasmic Reticulum (ER), Golgi apparatus, and vesicles.
- **Purpose**: Produces, packages, and exports cellular products (gene expression products).

Endoplasmic Reticulum (ER)

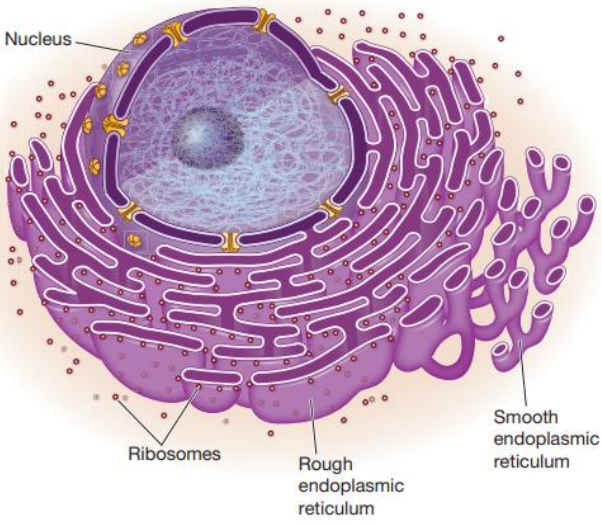
- series of channels continuous with the nuclear membrane; provides passages for synthesis, transportation and storage.

Rough ER (RER):

- Primary site for protein synthesis (translation) and modification (e.g., glycosylation/adding sugars).
- **Appearance**: Studded with **ribosomes**, giving it a bumpy look.

Smooth ER:

- Involved in lipid synthesis.
- Creates phospholipids and steroid hormones (abundant in ovaries/testes).
- Breaks down toxins and metabolizes carbohydrates (abundant in liver cells).
- Stores Ca^{2+} ions (essential for muscle contraction).
- **Appearance**: Lacks ribosomes; smooth surface.

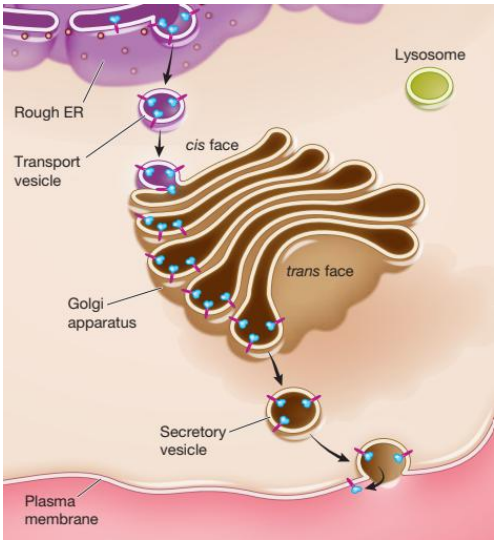


Golgi Apparatus:

- Acts as the "post office" of the cell; sorts, modifies, and ships products from the RER.

Two distinct sides of Golgi Apparatus:

- **Cis-face**: The side facing the nucleus/ER that receives incoming vesicles.
- **Trans-face**: The side facing the cell membrane where repackaged products are released.
- Products destined for export are packaged into vesicles that undergo exocytosis at the cell surface.



Membranous Organelles for Detoxification and Energy Production:

- **Cells require energy** to power biochemical reactions, often converted from nutrients.
- **Detoxification** is essential to neutralize environmental toxins and harmful cellular byproducts.
- **Hepatocytes** (liver cells) are specialized for high-volume detoxification.

Lysosomes: The Recycling Center

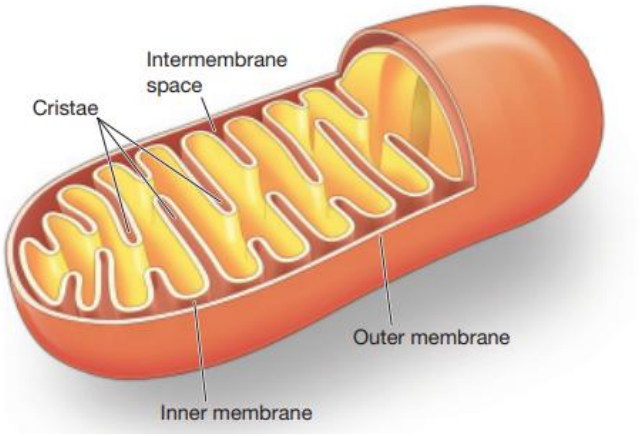
- Membrane-bound organelles containing digestive enzymes.
- Breakdown and recycling of nonfunctional or unneeded molecules.
- **Intracellular Digestion:** Degrades damaged organelles to keep the cell healthy.
- **Phagocytosis Support:** Merges with vesicles containing external material (like bacteria) to digest them.
- **Autolysis:** A "self-destruct" mechanism where lysosomes release enzymes to kill a damaged or unhealthy cell.
- **Apoptosis:** Purposeful cellular death necessary for proper human development.
- **Specialization:** Found in high concentrations within phagocytic immune cells.

Peroxisomes: The Chemical Neutralizers

- Membrane-bound organelles containing enzymes for lipid metabolism and detoxification.
- **Structure**: Stacked, flattened membranous discs.
- **Function:** Transfers hydrogen atoms from molecules to oxygen to neutralize poisons (e.g., alcohol).
- **H_2O_2 Production:** The detoxification process produces hydrogen peroxide (**H_2O_2**) as an intermediate.
- **H_2O_2 Conversion:** Contains specific enzymes to convert toxic **H_2O_2** into harmless water (H_2O) and oxygen (O_2).
- **Specialization:** Found in exceptionally high numbers in liver cells.

Mitochondria: The Energy Transformers

- Site of aerobic respiration
- Double-membrane organelles responsible for "transforming" energy.
- **Structure:** Consists of an outer membrane and a highly folded inner membrane.
- **Cristae:** The folds of the inner membrane that increase surface area for reactions.
- **Cellular Respiration:** The process of converting nutrient energy (like glucose) into **ATP** (Adenosine Triphosphate).
- **ATP:** The primary molecule used for functional cellular energy.
- **Oxygen Requirement:** Oxygen is essential for the chemical reactions occurring within the mitochondria.
- **Specialization:** Concentrated in highly active cells, such as muscle and nerve cells; less abundant in bone cells.

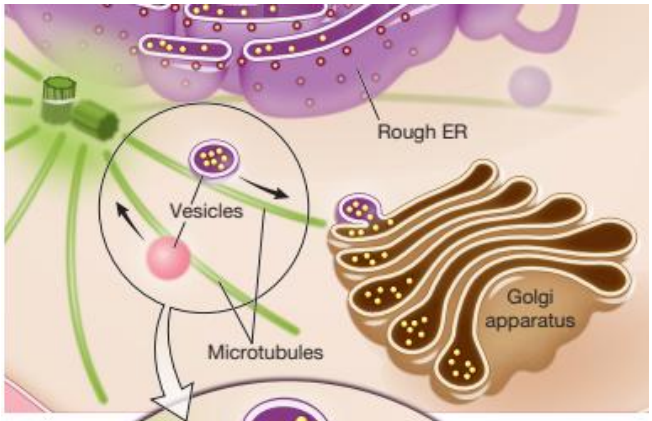


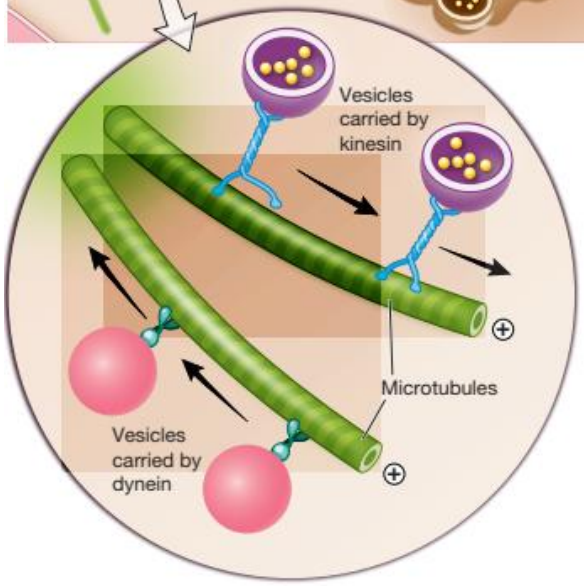
The Cytoskeleton:

- A complex network of fibrous proteins providing structural support to the cell.
- Maintains cell shape, enables cell motility, assists in reproduction, and acts as a transportation system for organelles.
- Organizes cytoplasm.
- Aids in separation during cellular division.

Microtubules (The Thickest Filaments)

- Made of protein subunits called **tubulin**.
- **Structural Role:** Resists compression and maintains overall cell shape.
- **Transportation:** Acts as "tracks" for moving vesicles (e.g., from RER to Golgi) and genetic material.
- **Dynamic Nature:** Can rapidly elongate or shorten by adding or removing tubulin subunits.
- **Centrioles:** Two microtubule structures near the nucleus that serve as origin points for growth and assist in DNA separation during division.



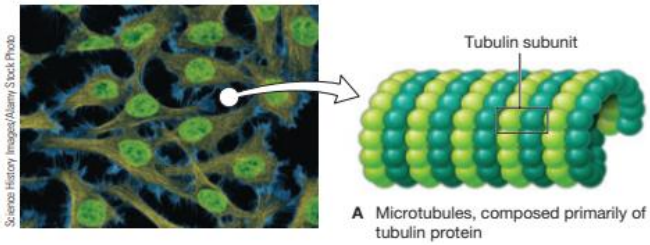


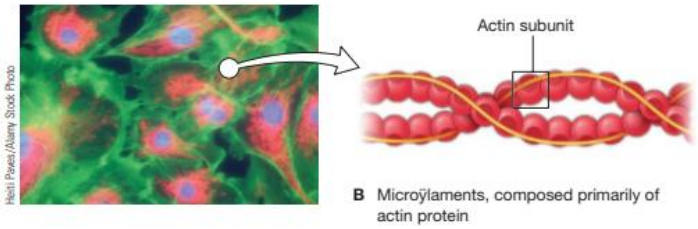
Microfilaments (The Thinnest Filaments)

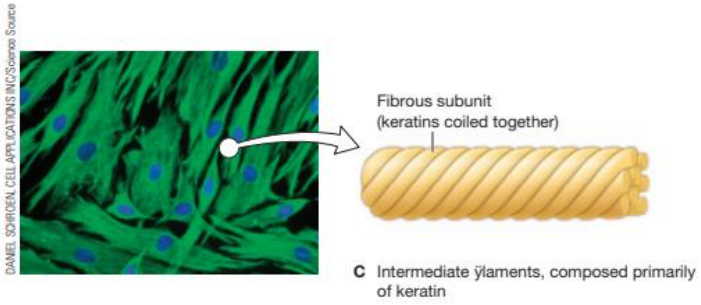
- Long chains of the protein **actin**.
- Primary function is to move the entire cell.
- **Cell Division:** Works with other proteins to create a **cleavage furrow** to pinch a cell into two during replication.

Intermediate Filaments

- Fibrous subunits of **keratin** wound together like rope.
- Provides structural strength to resist forces that could pull cells apart (e.g., in skin cells).
- Stabilizes the position of organelles and links cells together through specialized junctions.
- Composed of protein filaments that provide support.







Cell Surface Specializations

Microvilli

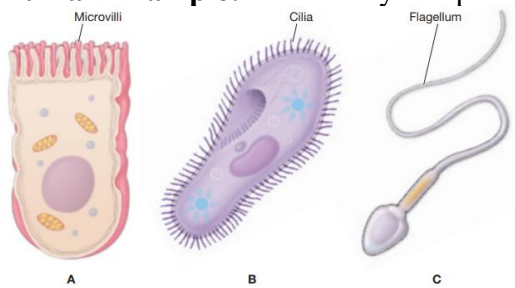
- Tiny, non-motile projections anchored by actin.
- Increases surface area to maximize membrane transport.
- **Location Example:** Small intestine (absorbing nutrients).

Cilia

- Hair-like projections capable of rhythmic movement.
- Moves materials (mucus, dust, bacteria) across the cell surface.
- **Location Example:** Respiratory tract (moving waste away from lungs).

Flagella

- A single, long tail-like appendage used for locomotion.
- Propels the entire cell through liquid.
- **Human Example:** Found only on sperm cells.



The Nucleus

- Acts as the control center containing the cell's genetic instructions (**genome**).
- Most human cells have a single nucleus.
- **Structure**: The largest organelle, enclosed by its own membrane.

Variations in Cells:

- **Multinucleated:** Cells with more than one nucleus (e.g., skeletal muscle).
- **Anucleated:** Cells with no nucleus (e.g., mature red blood cells), resulting in a limited lifespan.

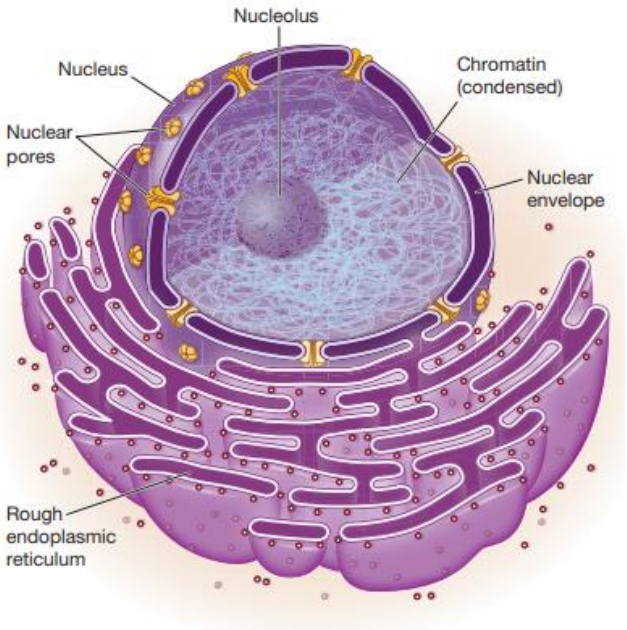
Structure of the Nucleus:

The Nuclear Envelope (Nuclear Membrane)

- A double membrane consisting of two adjacent lipid bilayers.
- **Nuclear Pores:** Tiny passageways that regulate the movement of proteins, RNA, and solutes between the nucleus and cytoplasm.

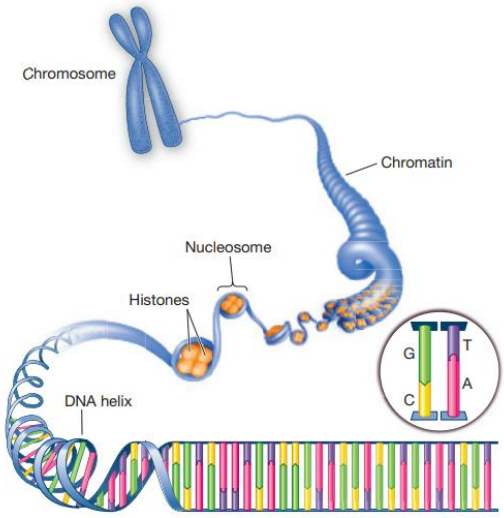
The Nucleoplasm and Nucleolus

- **Nucleoplasm:** The fluid inside the nucleus, similar to cytoplasm.
- **Nucleolus:** A dark-staining region responsible for manufacturing the RNA needed to build **ribosomes**.



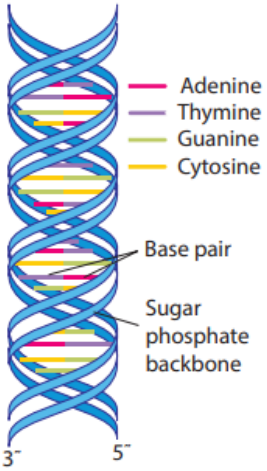
DNA Organization and Structure

- **Nucleosome:** A single complex of DNA wrapped around a set of **histone proteins** (like thread on a spool).
- **Chromatin:** Loosely organized "beads-on-a-string" DNA; this form allows the cell to access genes for protein synthesis.
- **Chromosome:** The highly condensed form of chromatin; used to safely transport DNA during cell division.
- Humans have **46 chromosomes** containing approximately **22,000 genes**.

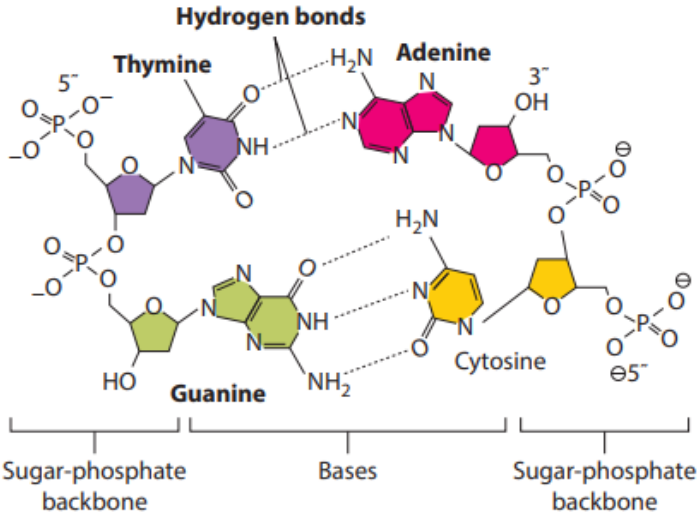


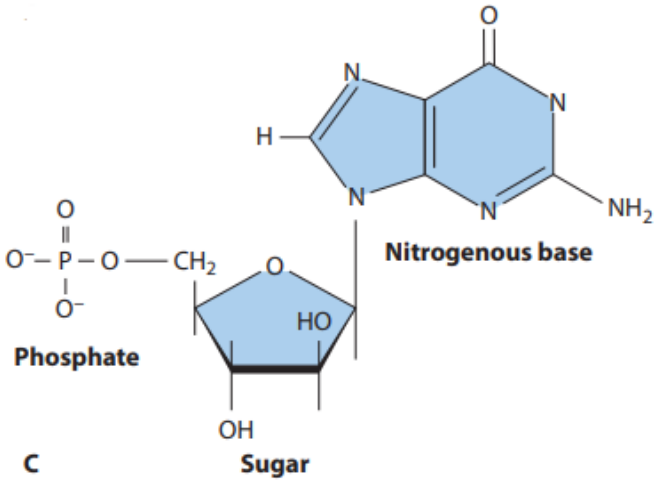
The Double Helix Structure

- **Composition:** Two complementary strands forming a twisted ladder shape.
- **Rails:** Made of alternating sugar and phosphate groups.



- **Rungs (Nitrogenous Bases):**
  - **Purines (Larger):** Adenine (A) and Guanine (G).
  - **Pyrimidines (Smaller):** Thymine (T) and Cytosine (C).





C

- **Base Pairing Rules:** To maintain uniform width, bases always pair as **A-T** and **G-C**.
- **Complementarity:** Because of specific pairing, one strand acts as a template for the other (e.g., AGTGCCT pairs with TCACGGA).

Protein Synthesis: From DNA to Protein

- DNA contains the genetic code of the cell.
- **The Genetic Code:** DNA is read three bases at a time. Each group of three bases (called a *codon*) tells the cell which amino acid to add to a protein.
  - Provides the instructions to produce cellular proteins.
- Proteins perform nearly all cellular functions, including acting as **enzymes** for biochemical reactions (building or breaking molecules).
  - Protein production begins in the nucleus and ends in the cytoplasm.
- **The Gene:** A specific segment of DNA that holds the instructions to build one single protein.
  - Genes are transcribed into messenger RNA (mRNA).
  - mRNA is then translated into proteins.

Genome vs. Proteome:

- **Genome:** The full complement of a cell's DNA.
- **Proteome:** The full complement of proteins a cell produces.

Transcription: DNA to RNA

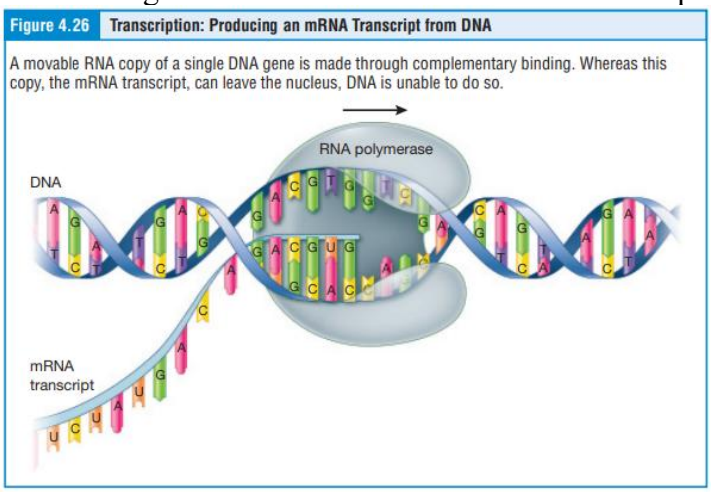
- Occurs within the nucleus of the cell
- **Purpose:** To create a portable "messenger" copy (**mRNA**) of a gene so the original DNA (template) can stay safely inside the nucleus.
- mRNA is made from a gene of one strand of DNA.
- mRNA will leave the nucleus for translation.

RNA Characteristics:

- Single-stranded (unlike double-stranded DNA).
- Contains **ribose** sugar (with an extra oxygen atom).
- Uses **Uracil (U)** instead of Thymine (T); therefore, **A pairs with U**.

The Three Stages of Transcription:

1. **Initiation:** DNA strands separate; **RNA polymerase** binds to the start of the gene.
2. **Elongation:** RNA polymerase adds nucleotides to build the complementary mRNA strand.
3. **Termination:** The enzyme reaches the end of the gene and releases the new mRNA transcript.

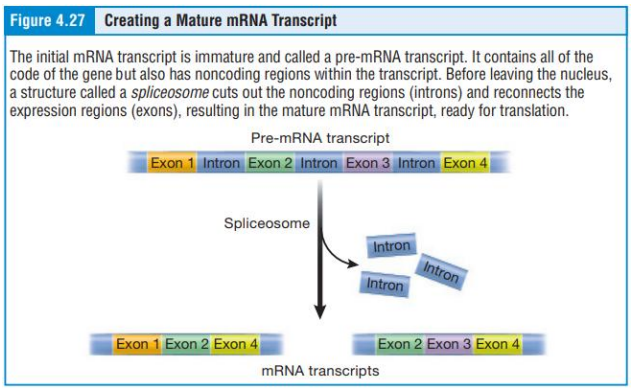


Post-Transcriptional Processing:

- **Pre-mRNA:** The initial transcript before it is modified.
- **Splicing:** The process of removing non-coding regions from the pre-mRNA.
- **Mature mRNA:** The final version that exits the nucleus through a nuclear pore.

Translation: RNA to Protein

- Process of creating a protein from a mRNA template.
- Each three nucleotide sequences of mRNA is a codon.

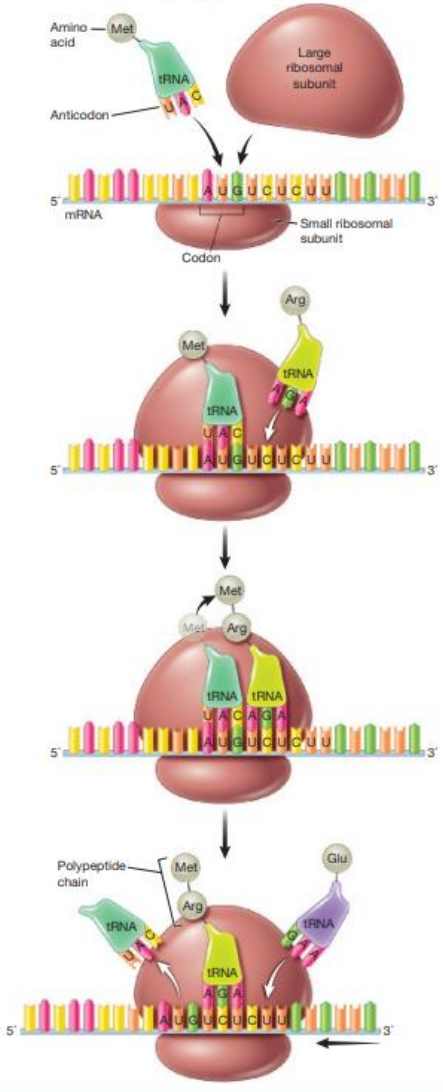


- **Location:** Occurs at the **ribosome** (found in the cytoplasm or on the Rough ER).
  - Ribosomes read codons.

- **Key Players:**
  - **Ribosome:** Provides the physical space for the process; made of **rRNA** and protein.
  - **tRNA (Transfer RNA):** Shuttles specific amino acids to the ribosome.
  - **Anticodon:** A three-base sequence on tRNA that matches the complementary **codon** on the mRNA.
- ➢ Amino acid: The individual building blocks that make up a protein.
- ➢ Amino acids are linked by peptide bonds to form proteins according to the mRNA code.
  - A **polypeptide** is a **chain of amino acids** linked together by peptide bonds.

Figure 4.28 Translation from RNA to Amino Acid Sequence

During the process of translation, the mRNA transcript moves through a ribosome in the RER or cytosol. tRNA molecules pair the appropriate amino acids to the mRNA sequence. Each amino acid is joined to the one before it and a polypeptide, or protein, elongates into the cytosol.



The Three Stages of Translation:

1. **Initiation:** Ribosome subunits assemble around the mRNA transcript.
2. **Elongation:** tRNA molecules match their anticodons to mRNA codons, adding amino acids one by one to the growing chain.
3. **Termination:** The ribosome reaches a "stop" codon, releasing the finished protein.

1st base	2nd base U		2nd base C		2nd base A		2nd base G		3rd base
U	UUU	(Phe/F) Phenylalanine (np)	UCU	(Ser/S) Serine (p)	UAU	(Tyr/Y) Tyrosine (p)	UGU	(Cys/C) Cysteine (p)	U
	UUC		UCC		UAC		UGC		C
	UUA	(Leu/L) Leucine (np)	UCA		UAA	Stop (*Ochre*) [note 2]	UGA	Stop (*Opal*) [note 2]	A
	UUG ⇒		UCG		UAG	Stop (*Amber*) [note 2]	UGG	(Trp/W) Tryptophan (np)	G
C	CUU		CCU	(Pro/P) Proline (np)	CAU	(His/H) Histidine (b)	CGU	(Arg/R) Arginine (b)	U
	CUC		CCC		CAC		CGC		C
	CUA		CCA		CAA	(Gln/Q) Glutamine (p)	CGA		A
	CUG		CCG		CAG		CGG		G
A	AUU	(Ile/I) Isoleucine (np)	ACU	(Thr/T) Threonine (p)	AAU	(Asn/N) Asparagine (p)	AGU	(Ser/S) Serine (p)	U
	AUC		ACC		AAC		AGC		C
	AUA		ACA		AAA	(Lys/K) Lysine (b)	AGA	(Arg/R) Arginine (b)	A
	AUG ⇒	(Met/M) Methionine (np)	ACG		AAG		AGG		G
G	GUU	(Val/V) Valine (np)	GCU	(Ala/A) Alanine (np)	GAU	(Asp/D) Aspartic acid (a)	GGU	(Gly/G) Glycine (np)	U
	GUC		GCC		GAC		GGC		C
	GUA		GCA		GAA	(Glu/E) Glutamic acid (a)	GGA		A
	GUG ⇒		GCG		GAG		GGG		G

Example:

- **Genetic code:** CAG
- **mRNA codon:** GUC (this is the code copied from DNA)
- **tRNA codon:** CAG
- **Amino acid:** Valine (Val) — the amino acid made from the mRNA codon

Special codons:

- **Start codon: AUG** → signals the beginning of protein synthesis
- **Stop codons: UAA, UAG, UGA** → signal the end of protein synthesis

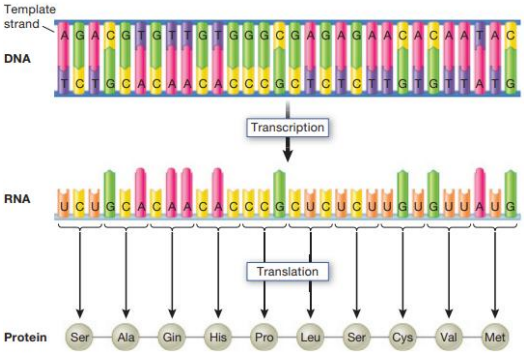
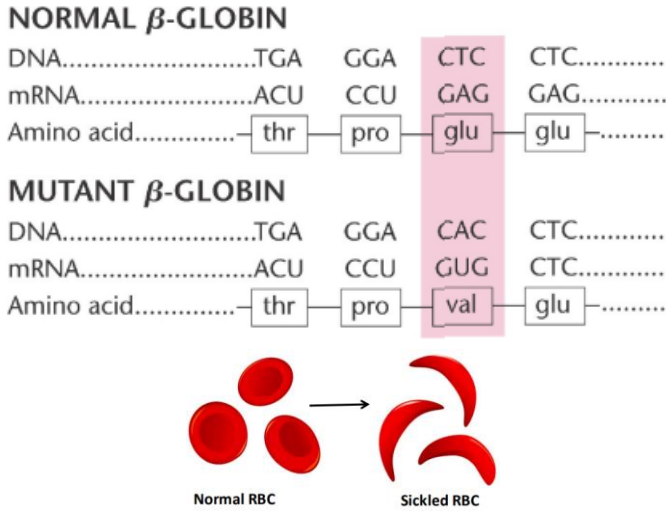


Table 4.1 The Types of Nucleic Acids in Healthy Human Cells

Nucleic Acid Molecules	Description	Nucleotides	Sugar	Function
DNA	Double-stranded linear Found in chromatin and chromosome forms	ATCG	Deoxyribose	Storage form of the genome
mRNA	Single-stranded linear	UAGC	Ribose	Copy of a single gene that leaves the nucleus to be translated into a protein
tRNA (base pairing)	Single-stranded 3-D, non-linear shape held together by complementary base pairing	AUCG	Ribose	Matches mRNA code with an amino acid
rRNA	Globular with protein interactions	AUCG	Ribose	Provides the structure within which RNA can be translated into a protein

- ➢ **tRNA** moves amino acids during translation.
- ➢ **rRNA** is structural component of ribosomes.

Sickle Cell Disease:



Introduction to Cell Replication

All humans begin as a single fertilized egg that undergoes trillions of replications.

- Cell replication is lifelong; it replaces worn-out cells (e.g., stomach lining, skin) and produces white blood cells.

Terms and definitions:

- **Somatic Cells**: General term for body cells (excluding sperm and egg cells).
- **Gametes**: Is a reproductive cell.
- **Diploid (2n)**: Human somatic cells contain 46 chromosomes (23 homologous pairs).
- **Haploid (n)**: Refers to 23 chromosomes; the number found in human gametes.
- **Homologous Pair**: Two copies of a single chromosome, one inherited from each parent.

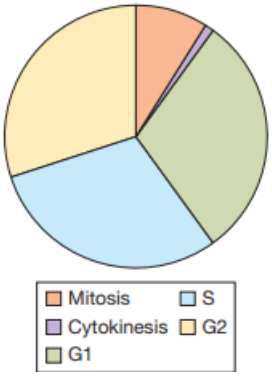
The Cell Cycle: The sequence of events in a cell's life from its creation until it divides into two new cells.

- Three phases: Interphase, mitosis, and cytokinesis.

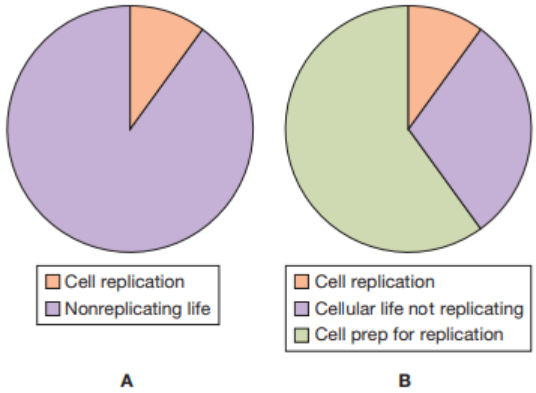
- **Interphase (Non-Replicating Phase)**
  - The period where the cell grows, performs metabolic functions, and prepares for division.
  - The cell spends most of its time in interphase.

Interphase is split into:

- **G1 Phase (Gap 1)**: The primary growth phase where the cell produces proteins and carries out normal cellular functions.
- **S Phase (Synthesis)**: The specific period during which the cell replicates its entire genome (DNA).
- **G2 Phase (Gap 2)**: The final preparation phase where the cell continues to grow and prepares for mitosis.



Life of a cell:



(B) Nonreplicating cellular life is actually spent preparing for cell replication, including replicating organelles or DNA.

Cellular Replication:

- Occurs as the parent cell divides to form two daughter cells.
  - **Mitosis** occurs in somatic cells.
    - Daughter cells are identical to parent cell.
    - Cells contain 46 chromosomes or the diploid number.
  - **Meiosis** occurs for reproductive cells
    - Resulting cells have half the amount of genetic material from one parent and half from the other parent
    - Cells contain 23 chromosomes or the haploid number

DNA Replication (Occurs in S Phase)

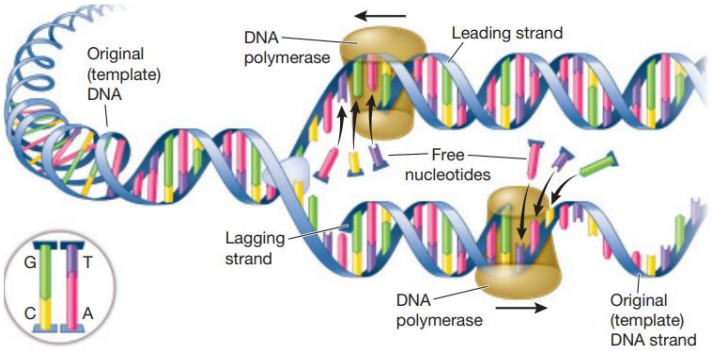
- The process of copying DNA.
- Enzymes separate and stabilize the two complementary DNA strands.

Three phases:

- **Initiation**: the DNA strands are separated by helicase
- **Elongation**: DNA polymerase adds free nucleotides to a template strand to build a new complementary strand.
- **Termination**: Replication stops once two identical DNA molecules are complete.

Table 4.2 Phases of Nucleic Acid Processes

Initiation	Elongation	Termination	
RNA polymerase	RNA polymerase	pre-mRNA	TRANSCRIPTION
ribo some mRNA	polypeptide, mRNA	folded protein, mRNA	TRANSLATION
Original double DNA strands pulled apart	New complementary strands built to complement each original	Two double strands. Each 1/2 old, 1/2 new	S PHASE - DNA Replication



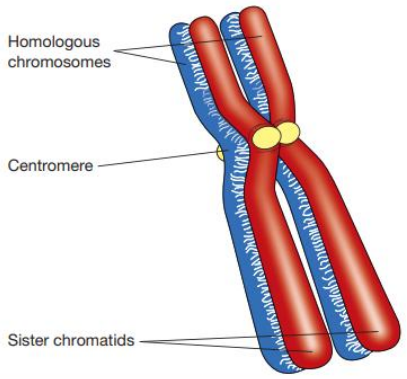
- Each new DNA molecule consists of one original strand and one newly synthesized strand.
- **DNA Proofreading**: Special enzymes scan and correct mistakes to prevent dysfunctional genes.

Chromosome Structure

- **Sister Chromatid**: One of two identical copies of a replicated chromosome.
- **Centromere**: The structure that physically binds sister chromatids together.

Figure 4.31 A Homologous Pair of Chromosomes during Cell Replication

The red and blue colors represent a homologous pair of chromosomes. Remember that human cells have 23 unique chromosomes, but 2 copies (1 that came from sperm and 1 that came from the egg) of each; these are the homologous chromosomes. After DNA replication, each chromosome has been duplicated and has an identical copy called a sister chromatid. Until anaphase of mitosis, these sister chromatids will be bound together at a centromere.



Mitosis and Cytokinesis

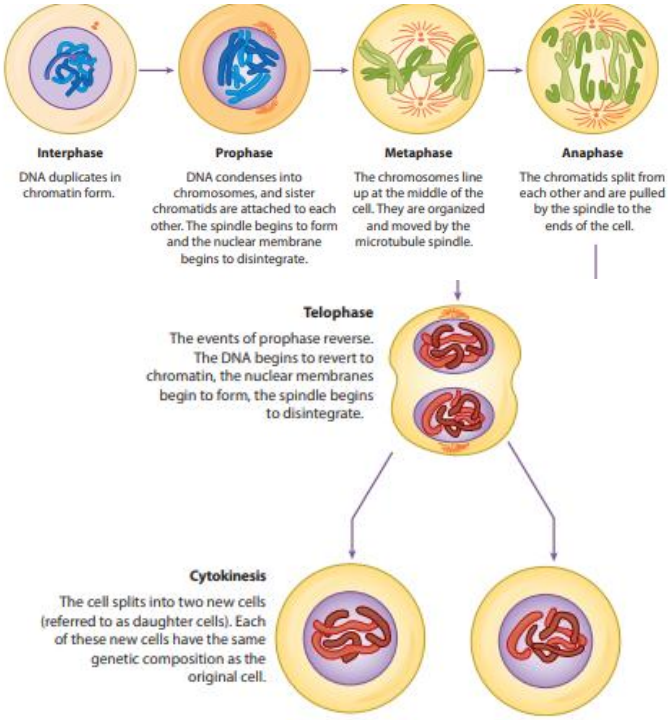
- **Mitosis**: The division of the nucleus and genetic material into two identical nuclei.
- Chromatids separate during mitosis.
  - Chromatid separation during mitosis ensures each daughter cell receives an identical, complete set of DNA for proper growth and repair.

Cell replication consists of four major phases, followed by cytokinesis: **Stages of Mitosis**

- **Prophase**: Chromatin condenses into visible X-shaped chromosomes; the centrioles migrate to opposite sides of the cell; the nuclear envelope disappears; the mitotic spindle forms.
- **Metaphase**: Sister chromatids line up along the middle (equator) of the cell, attached to spindle microtubules.
- **Anaphase**: Sister chromatids are pulled apart toward opposite poles, becoming individual chromosomes again.
- **Telophase**: Chromosomes uncoil back into chromatin; two new nuclear membranes form; the mitotic spindle breaks down. Nucleoli and nuclear membranes start to form; chromosomes return to chromatin form.
- **Cytokinesis**: The physical division of the cytoplasm, resulting in two distinct cells.

Cytokinesis Process

- **Cleavage Furrow**: A contractile band of actin fibers (microfilaments) that forms around the cell midline.
- Divides cell into two distinct cells.



Cell Cycle Control and Regulation

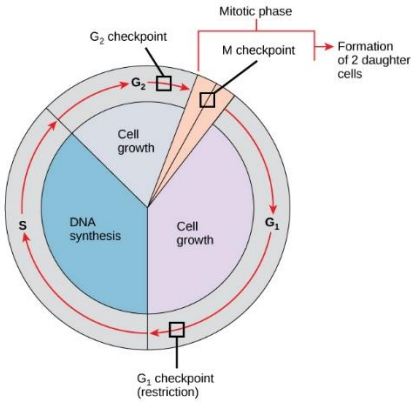
- **Significance**: Precise regulation prevents diseases like cancer; loss of control leads to uncontrolled tumor growth.

Environmental Factors

- **Growth Factors**: Hormones (like estrogen) and chemical signals that trigger cells to divide.
- **Contact Inhibition**: Normal cells stop dividing when they are surrounded on all sides by other cells.
- **Surface Area-to-Volume Ratio**: Large cells divide to improve efficiency in transporting materials.

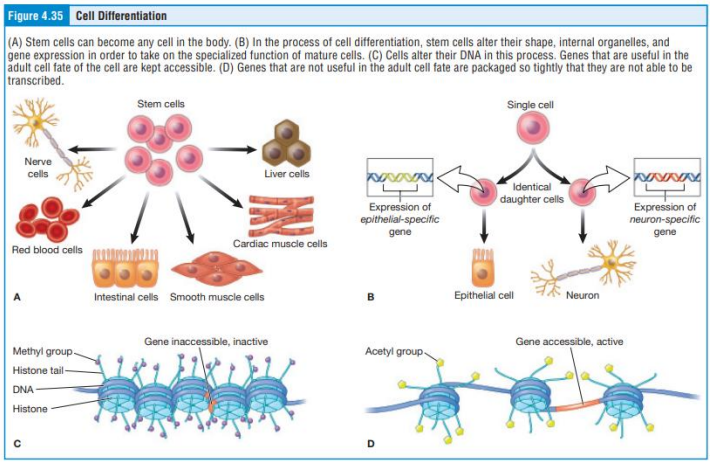
Internal Checkpoints

- **G1 Checkpoint**: Verifies the cell is ready for DNA synthesis.
- **G2 Checkpoint**: Verifies the cell is fully prepared for mitosis.
- **Metaphase Checkpoint**: Ensures all sister chromatids are properly attached to microtubules before separation.



Cellular Differentiation: The process by which unspecialized cells become specialized to carry out distinct functions.

- ❖ Stem cells are undifferentiated yet can become required cell types.
- ❖ Cells become specialized for a specific function through differentiation.
- ❖ **Core Concept**: Every cell in a human originates from a single fertilized egg; differentiation allows these cells to assume unique structures (e.g., nerve, muscle, or blood cells).



- ❖ **Genetic Control**: Differentiation is a genetic "on/off" process where specific genes are activated while others are silenced.
  - Turning specific genes on in stem cells produces certain proteins needed for the differentiated cell's function.
- ❖ **Gene Expression**: Genes required for a cell's specific function are kept accessible, while unneeded genes are highly condensed and deactivated.
- ❖ **Transcription Factors**: Specialized proteins that bind to DNA to either promote or inhibit the expression of specific genes.

Stem Cells: Unspecialized cells capable of infinite replication and, under certain conditions, transforming into specialized cells.

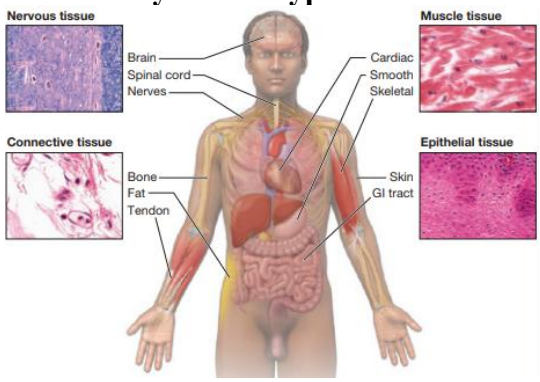
Embryonic vs. Adult Stem Cells

- **Embryonic Stem Cells**: Found in early embryos; these cells are "blank slates" that can become any cell type in the entire body.
- **Adult Stem Cells**: Limited to specific "lineages" or cell groups; they serve as a repair system for specific tissues.

Introduction to Tissues

- **Tissue**: A group of cells that function together to perform specialized activities.
- **Histology**: The microscopic study of tissue appearance, organization, and function.
- **Pathology**: The study of changes in tissues and organs caused by disease.
- **Homeostasis**: Tissues work together to maintain a stable internal environment in the body.

The Four Primary Tissue Types



- **Epithelial Tissue**: Sheets of cells that cover body surfaces (coverings), line internal cavities (linings), and form glands.
- **Connective Tissue**: Diverse tissue that binds organs together and provides protection and support.

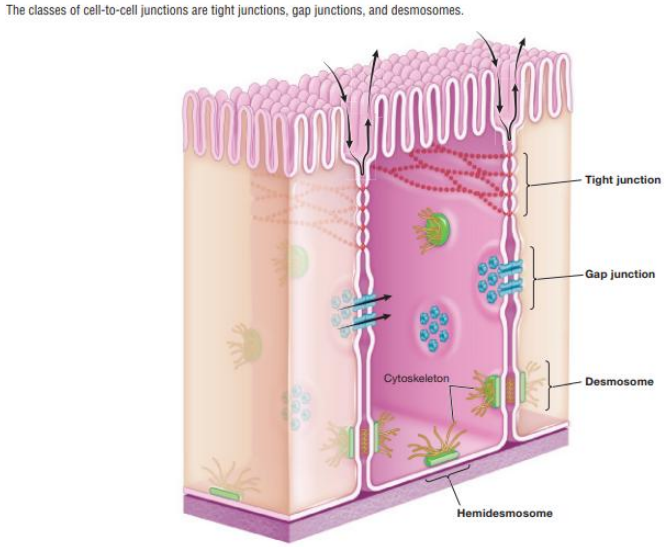
- **Muscle Tissue**: Contractile tissue responsible for movement (e.g., heart contraction, skeletal movement).
- **Nervous Tissue**: Specialized for communication via electrical signals throughout the body.

Extracellular Matrix (ECM)

- ❖ A network of substances surrounding and supporting cells within a tissue.
- ❖ Material found outside of a tissue.
- ❖ Created by the cells residing within the tissue.
- ❖ The ECM is changeable depending on the activity of the cells.
- ❖ **Consistency**: Varies by tissue type, ranging from liquid (blood) to solid (bone).

Major components:

- ➢ **Collagen**: The most abundant protein in the body; it provides tough, leather-like flexibility and structural support and functions as protective protein fibers.
- ➢ **Proteoglycans**: Molecules composed of proteins and carbohydrates that attract water, creating a gel-like consistency; they are negatively charged.
  - **Function**: Supports cells, keeps them hydrated, and stores nutrients and growth factors.
- ➢ **Cellular Connections**: attachments between cells.



Cell Junctions: Specialized points of contact between the plasma membranes of adjacent cells.

- ❖ **Tight Junctions**: Fuses membranes together to block the movement of substances between cells (e.g., intestinal lining).
- ❖ **Anchoring Junctions**: Provide strong but flexible structural stabilization.
  - ➢ **Desmosomes**: Connect two neighboring cells together like "buttons" on a shirt.
  - ➢ **Hemidesmosomes**: Link a cell to the extracellular matrix.
- ❖ **Gap Junctions**: Channels that allow small molecules and ions to pass directly between the cytoplasm of adjacent cells.
  - ➢ **Metabolic/Electrical Coupling**: Gap junctions coordinate the functions of large groups of cells by sharing signals.

Introduction to Epithelial Tissue:

Large sheets of cells covering all body surfaces, including the skin and internal linings.

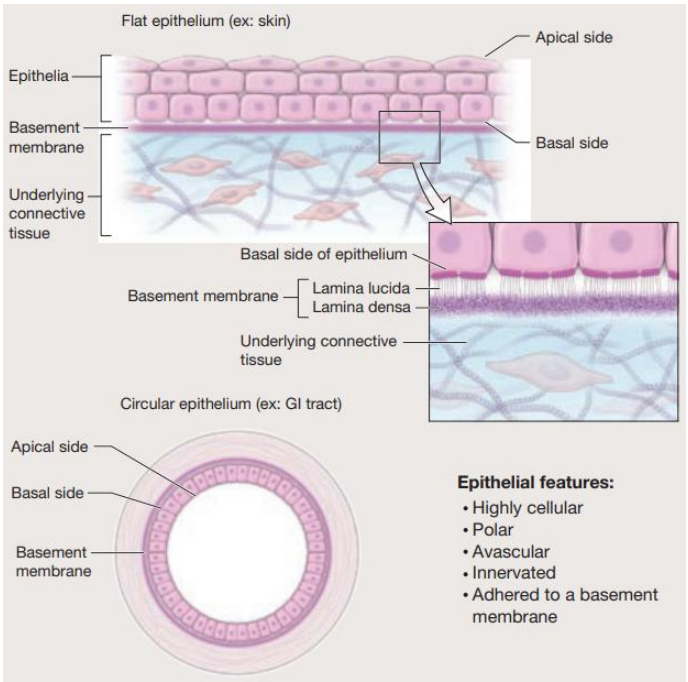
- Basement membrane anchors epithelia to ECM (extracellular matrix).
- **Primary Function**: Acts as a protective barrier and "gatekeeper" to control permeability.

Terminology:

- ❖ **Epithelium**: (plural = epithelia) Lines surfaces exposed to the "outside" world (e.g., airways, digestive tract).
- ❖ **Endothelium**: (plural = endothelia) Lines sterile "inside" structures (e.g., blood vessels).

General Characteristics

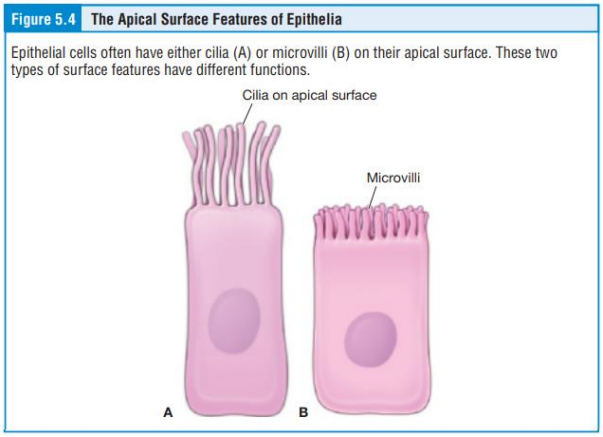
- ➢ **Polarity**: Cells have two distinct sides:
  - ❖ **Basal Surface**: The side attached to the underlying tissue via the basement membrane.
  - ❖ **Apical Surface**: The "free" side exposed to the external environment or a body space/ internal space (lumen).
- Apical and basal membranes may have different functions.



- **Highly Cellular**: Composed almost entirely of cells with very little extracellular material.
- **Avascular**: Contains no blood vessels; nutrients must reach cells via **diffusion** from underlying connective tissue.
- **Highly Regenerative**: Rapidly replaces damaged or dead cells (sloughing) due to high exposure to friction.

Specialized Apical Features

- **Cilia**: Microscopic, moving extensions that sweep fluids and particles (e.g., moving mucus in airways or eggs in Fallopian tubes). move materials across surface.
- **Microvilli**: Non-moving extensions that increase surface area for enhanced absorption (e.g., in the small intestine).



Classification of Epithelia

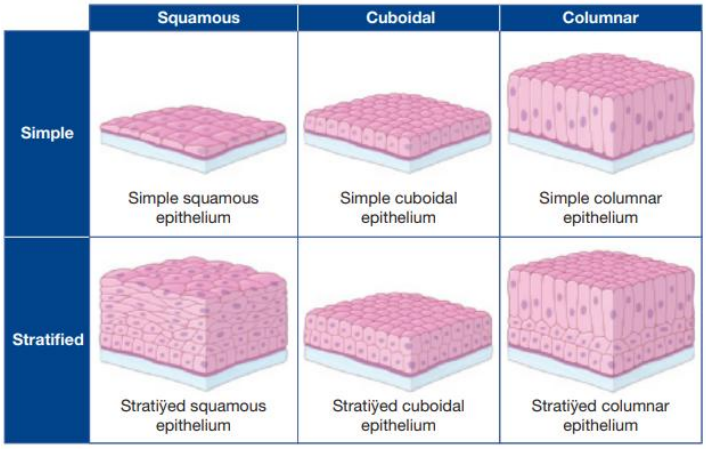
Epithelia are named based on **layers** (first name) and **cell shape** (second name).

1. Cell Shapes

- **Squamous**: Flat cells and thin.
- **Cuboidal**: Box-shaped; as wide as they are tall.
- **Columnar**: Tall and narrow; rectangular. column-like cells

2. Cell Layers

- **Simple**: A single layer of cells; ideal for diffusion and absorption.
- **Stratified**: Multiple stacked layers; protects against physical and chemical wear.



- **Pseudostratified**: A single layer of irregularly shaped columnar cells that *appears* layered but all cells touch the basal lamina.
- **Transitional**: Specialized stratified cells that change shape (stretch) to accommodate liquid volume (found in the urinary bladder).

Simple Epithelium: A single layer of epithelial cells where every cell touches the basal lamina.

- General Function: The specific shape of the cells directly reflects their physiological role.

Simple Squamous Epithelium

- Nucleus: Flat, horizontal, and centrally located.
- Function: Facilitates the rapid passage or diffusion of chemical compounds.

Simple Cuboidal Epithelium

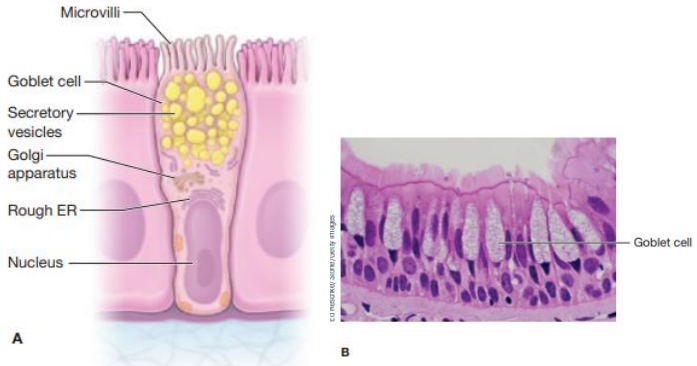
- Nucleus: Round and typically located near the center of the cell.
- Function: Primarily involved in the transport of substances.

Simple Columnar Epithelium

- Nucleus: Elongated and usually positioned at the basal end (bottom) of the cell.
- Function: Highly active in the absorption and secretion of molecules.

Pseudostratified Columnar Epithelium

- Appears layered (stratified) but is actually a single layer of irregularly shaped cells.
- Nuclei Placement: Nuclei are found at different levels, creating the illusion of multiple strata.
- Basal Contact: Every cell is in direct contact with the basal lamina, even if they do not all reach the apical surface.
- **Goblet Cells**: Unicellular exocrine glands interspersed in this tissue that secrete mucus.
  - Common feature of simple and pseudostratified epithelia.

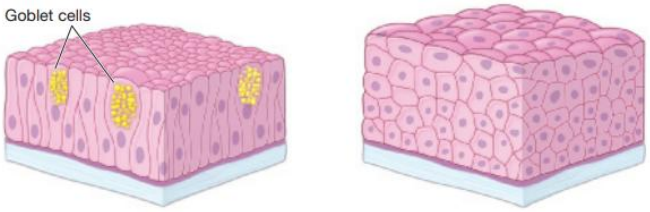


(A) Goblet cells, unicellular mucous glands, are common features of columnar epithelium.

(B) Goblet cells in a micrograph from the respiratory tract.

Figure 5.6 Two Types of Epithelia that Defy the Naming Convention

(A) Pseudostratified columnar epithelium: this epithelium has cells so closely packed together that the tissue occasionally appears stratified when a thin slice is used to create a slide. While every cell contacts the basement membrane, not every cell contacts the apical surface, so it is actually a simple epithelium. (B) Transitional epithelium: this epithelium is stratified, but the cells lack shape because this is a stretchy tissue and the cell shape changes depending on the degree of stretch.



A Pseudostratified columnar epithelium

B Transitional epithelium

Stratified Epithelia: Consists of multiple stacked layers of cells designed to protect underlying tissues.
Function: Located in areas subject to high friction and "wear and tear."

- Cell Renewal: Basal cells undergo constant mitosis; new cells push older cells toward the surface.

Stratified Squamous Epithelium: The most common stratified type in the human body.

- Nonkeratinized: Found in moist areas (e.g., inside of cheeks); apical cells remain living.
- . Keratinized: Found on dry surfaces (e.g., skin); apical layers are dead cells filled with keratin to retain moisture.

Other Stratified Types

- **Stratified Cuboidal/Columnar**: Uncommon; found only in select large glands and ducts.

Figure 5.8 Stratified Epithelia

In stratified epithelia, often the basal layer cells are stem cells and do not demonstrate the characteristics of the epithelium.

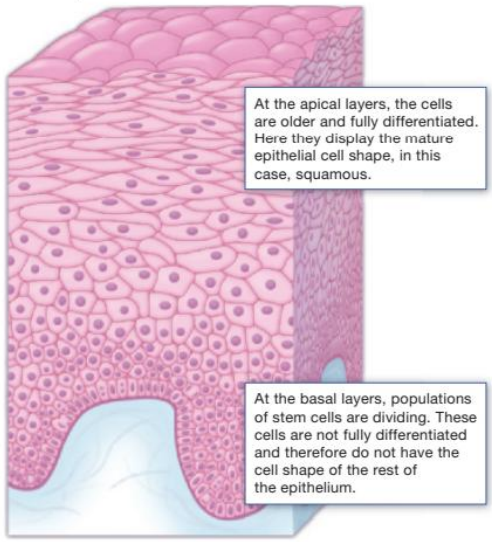
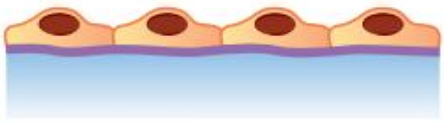
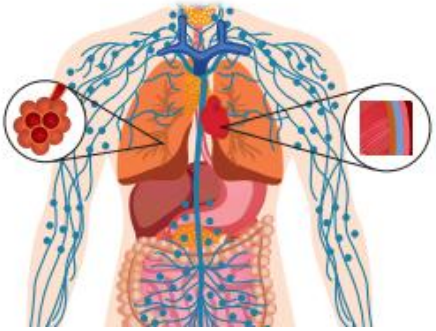
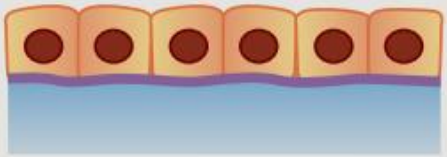
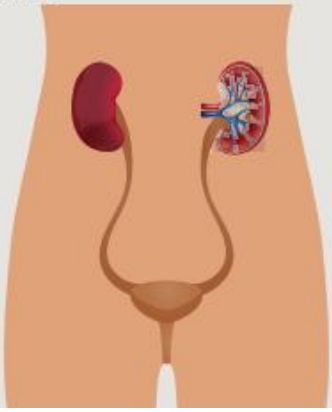
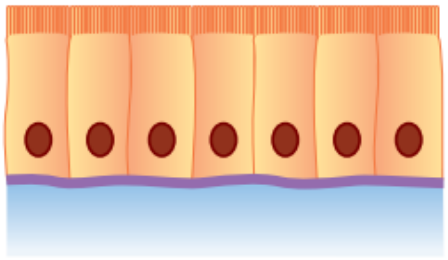
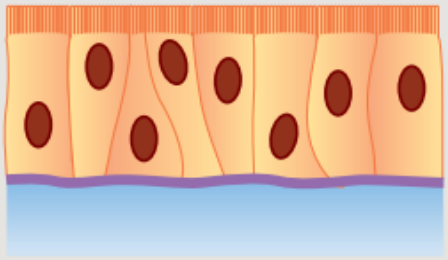
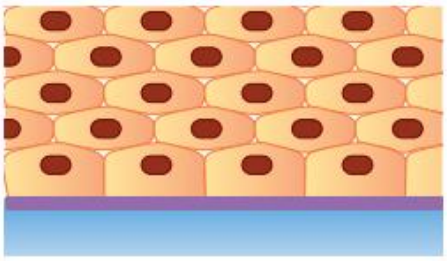
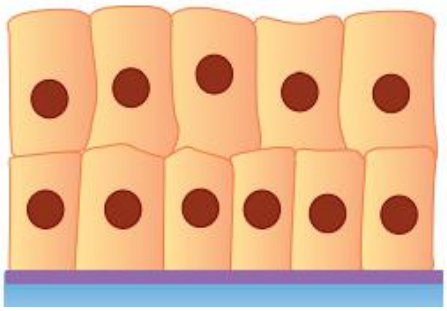
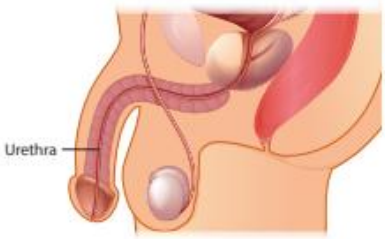
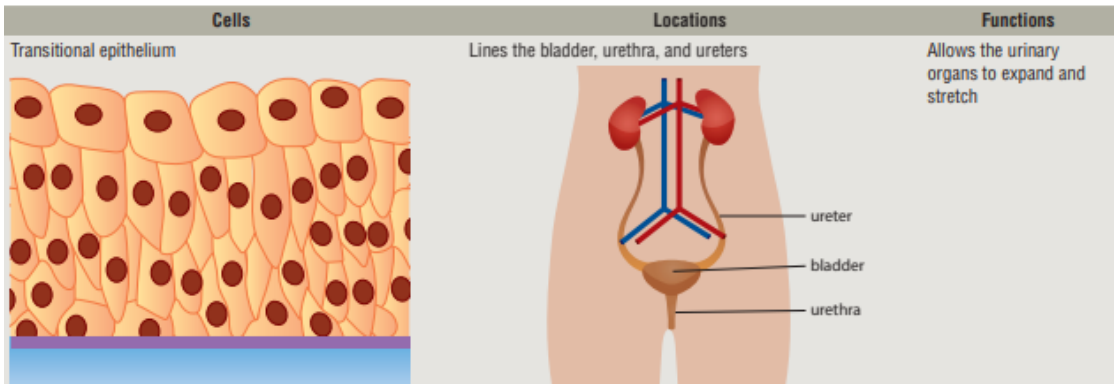


Table 5.1 Types of Epithelia

Cells	Locations	Functions
Simple squamous epithelium 	Air sacs of lungs and the lining of the heart, blood vessels, and lymphatic vessels 	Allows materials to pass through by diffusion and filtration, and secretes lubricating substance
Simple cuboidal epithelium 	In ducts and secretory portions of small glands and in kidney tubules 	Secretes and absorbs

Simple columnar epithelium 	Ciliated tissues are in bronchi, uterine tubes, and uterus; smooth (non-ciliated) tissues are in the digestive tract and bladder 	Absorbs; it also secretes mucus and enzymes
Pseudostratified columnar epithelium 	Ciliated tissue lines the trachea and much of the upper respiratory tract 	Secretes mucus; ciliated tissue moves mucus
Stratified squamous epithelium 	Lines the esophagus, mouth, and vagina 	Protects against abrasion
Stratified cuboidal epithelium 	Sweat glands, salivary glands, and the mammary glands 	Secretes and protects
Stratified columnar epithelium 	The male urethra and the ducts of some glands 	Secretes and protects

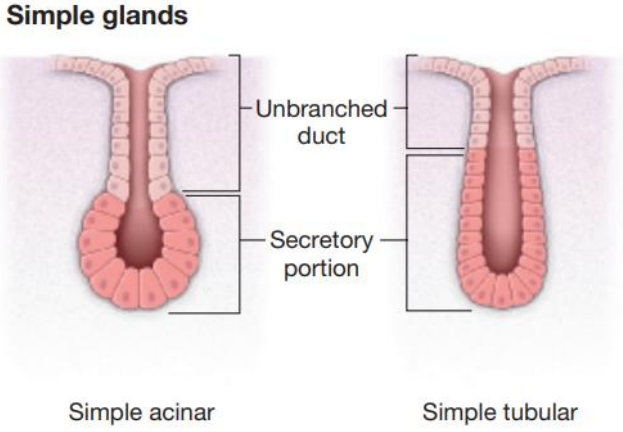


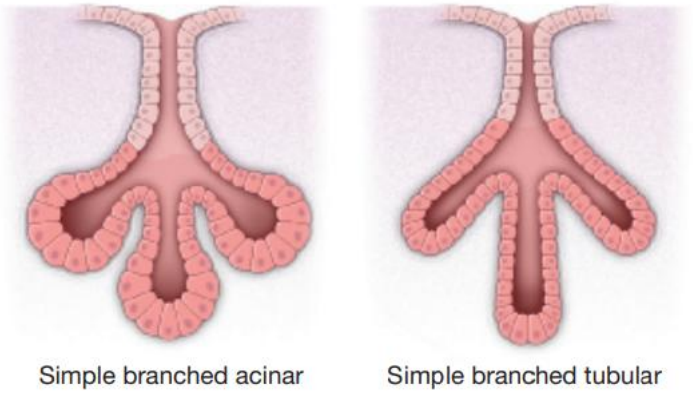
Glandular Epithelia: A gland is a structure (unicellular or multicellular) that synthesizes and secretes chemicals.

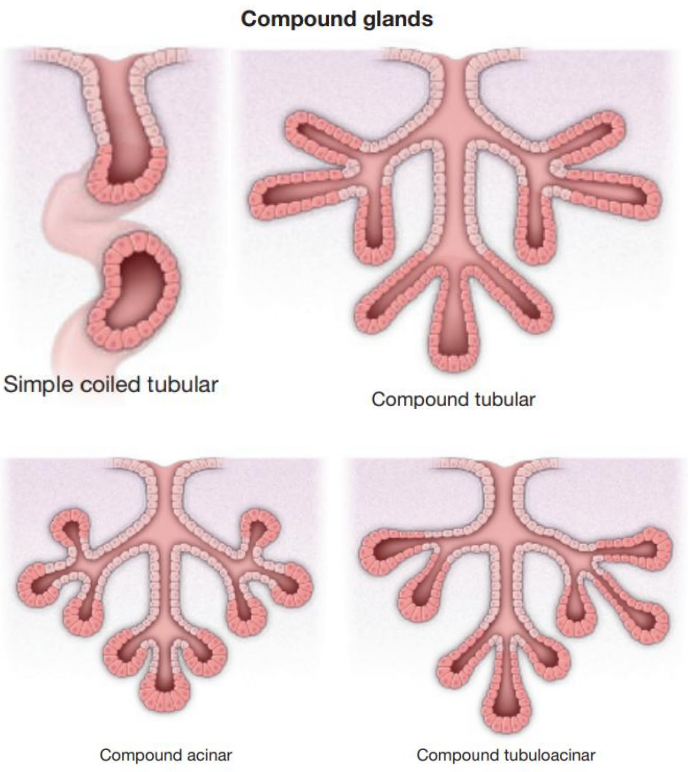
- **Endocrine Glands**: **Ductless** glands that secrete hormones directly into interstitial fluid and the bloodstream.
- Examples: Thymus, pituitary gland, adrenal glands
- **Exocrine Glands**: Glands that secrete products through **ducts** onto an epithelial surface (the "outside" of the body).
- Examples: Sweat glands and glands of digestive system
- Secrete mucus, sweat, saliva, and breastmilk

Exocrine Gland Structure:

- Tubular glands form tubes.
- Simple glands have one duct.
- Compound glands combine formats.
- Unicellular: Single cells, such as goblet cells, scattered within an epithelium.
- Multicellular: Consist of a secretory unit and a tubular duct (can be simple, branched, or coiled).
- Single layer of cells that fold into surrounding tissue.
- **Tubular glands** form tubes.
- **Simple glands** have one duct.
- **Compound glands** combine formats.
- Acini (**Acinar glands**): Pocket-like formations at the end of some ducts.



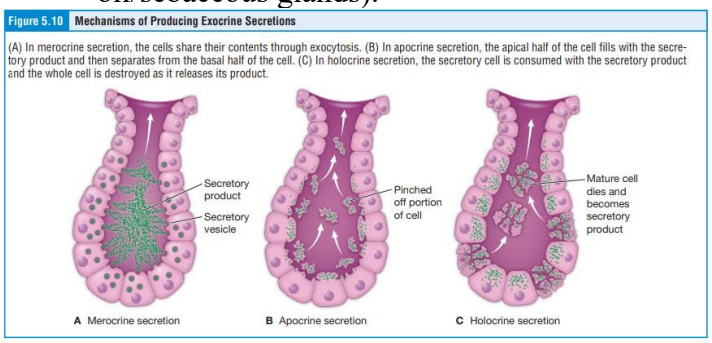




Modes of Exocrine Secretion

- **Merocrine Secretion**: Most common method; products are released via **exocytosis** with no loss of cell material (e.g., watery sweat).
- **Apocrine Secretion**: Secretory products accumulate at the apical tip; the entire top portion of the cell pinches off (e.g., axillary sweat).

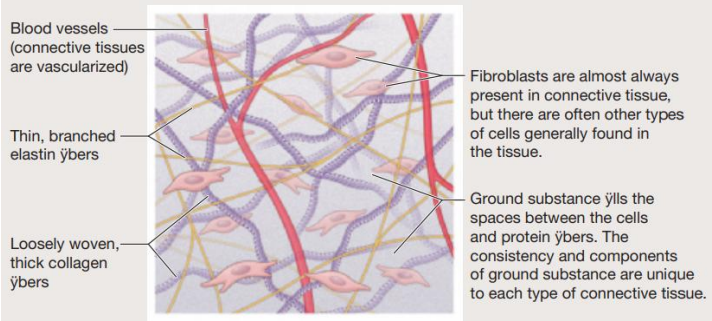
- **Holocrine Secretion**: The entire cell ruptures and dies to release its contents (e.g., oil/sebaceous glands).



Glandular Products:

- **Serous Glands**: Produce watery secretions rich in enzymes (derived from blood plasma).
- **Mucous Glands**: Release viscous products (thick secretions) rich in the glycoprotein mucin.
- **Mixed Glands**: Contain both serous and mucous cells (common in salivary glands).

Anatomy of Connective Tissue: Unlike epithelia, cells are widely dispersed and rarely touch.



Three Core Components:

- **Cells:** Varying types depending on tissue function.
- **Ground Substance:** Fluid or semi-solid material filling spaces between cells and fibers.
- **Protein Fibers:** Secreted by cells to provide structure.

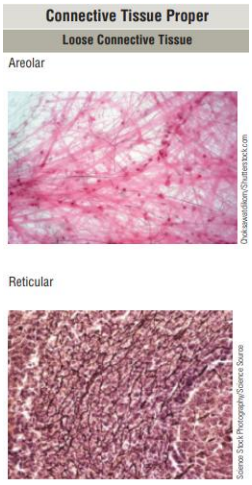
- **Extracellular Matrix (ECM):** Formed by the combination of ground substance and protein fibers.
- Ground substance is between fibers.
- **Vascularized**: They contain blood vessels, allowing for the delivery of oxygen, nutrients, hormones, and removal of waste.

Major Functions:

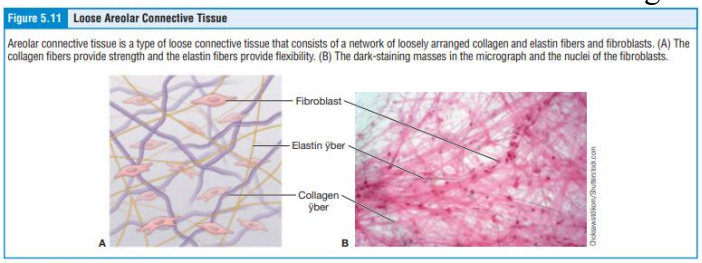
- **Connection:** Attaches tissues and organs (e.g., tendons, ligaments).
- **Support:** Provides a structural framework for the body (e.g., skeleton).
- **Protection:** Fibrous capsules and bones shield delicate organs.
- **Defense:** Specialized immune cells patrol the matrix for microorganisms.
- **Transport:** Fluid tissues (blood/lymph) move nutrients, waste, and messengers.
- **Storage/Insulation:** Adipose cells store energy as fat and provide thermal insulation.

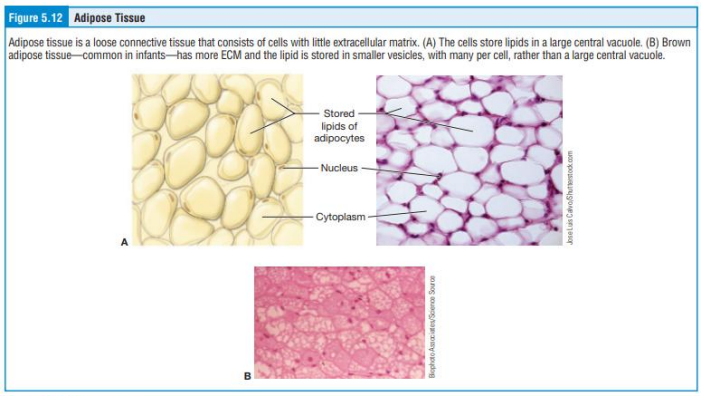
Classification of Connective Tissues

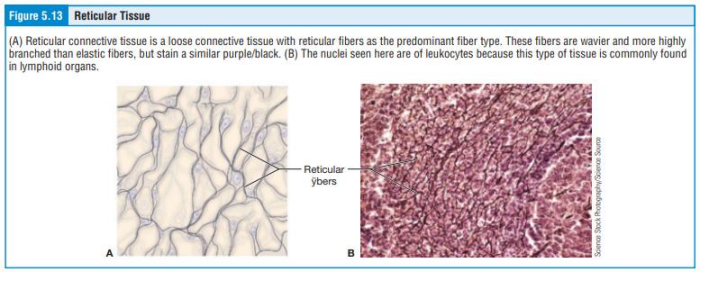
- **Connective Tissue Proper:** Semisolid and flexible; includes loose and dense types.
- **Loose Connective Tissue**



- **Areolar:** Web-like; underlies most epithelia; supports organs and vessels.
- Subcutaneous layer; Supports nearby tissues.
- **Adipose:** Packed with adipocytes; white (energy/insulation) and brown (heat production in infants).
- Subcutaneous layer; Energy storage, cushioning.
- **Reticular:** Mesh-like framework for lymphatic tissue, spleen, and the liver. Framework of internal organs.

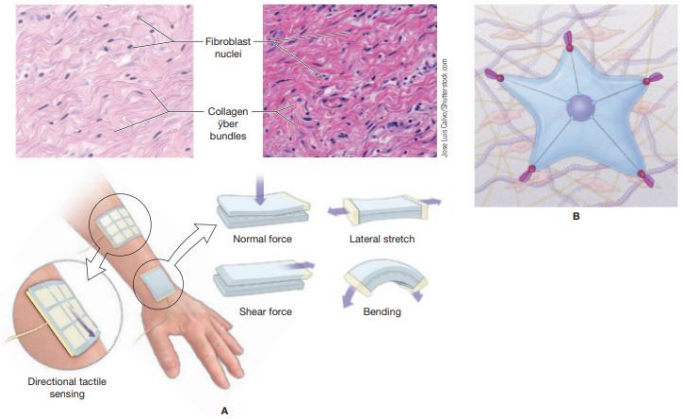






- **Dense Connective Tissue**
- **Dense Irregular:** Fibers in random patterns; resists tension/allows tissue to withstand force in any plane (e.g., dermis of skin).
- Contains a high number of collagen fibers.

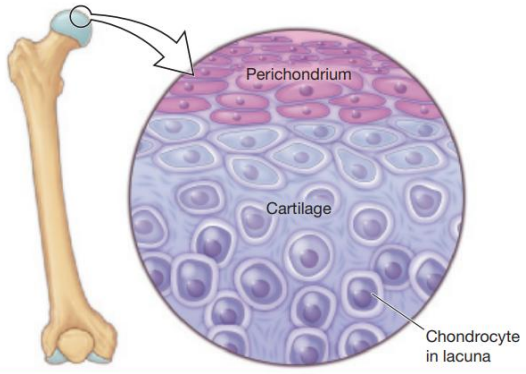
(A) Dense irregular connective tissue consists of closely-woven collagen fibers and fibroblasts. (B) In dense irregular connective tissue, the fibers are oriented in every direction, like a net, so that force can be withstood in any plane.



- **Perichondrium**: Made of dense irregular connective tissue.
- Encapsulates cartilage within the body.

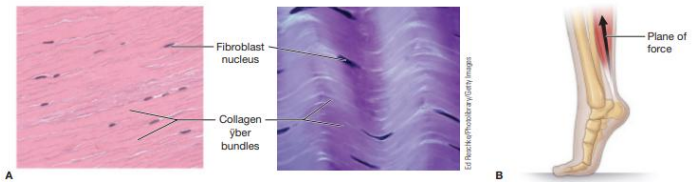
Figure 5.18 Macro and Micro Views of the Perichondrium

The perichondrium is a layer of dense irregular connective tissue that often surrounds a mass of cartilage in the body. This example shows the perichondrium surrounding the articular cartilage that covers the ends of a bone in a joint.

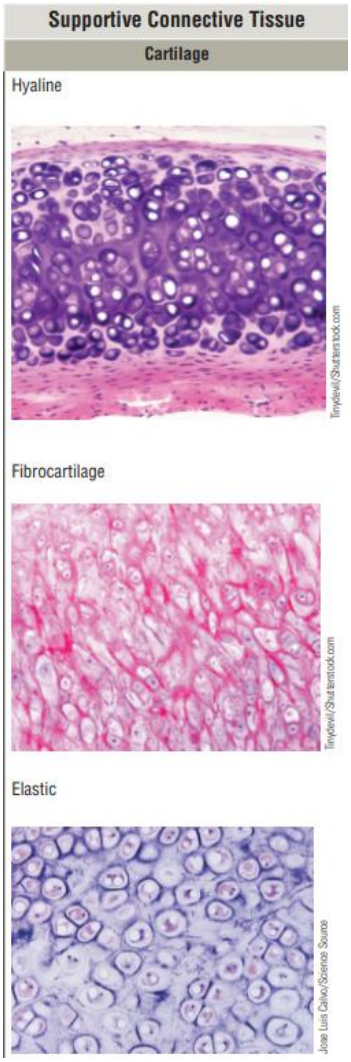


- **Dense Regular:** Collagen fibers oriented parallel to each other; allows tissue to withstand force in the direction of the orientation of the fibers (e.g., tendons, ligaments).
- Contains a high number of collagen fibers.

(A) Dense regular connective tissue consists of closely woven collagen fibers that are oriented in one direction. (B) Because of this, force can be withstood only in one plane.



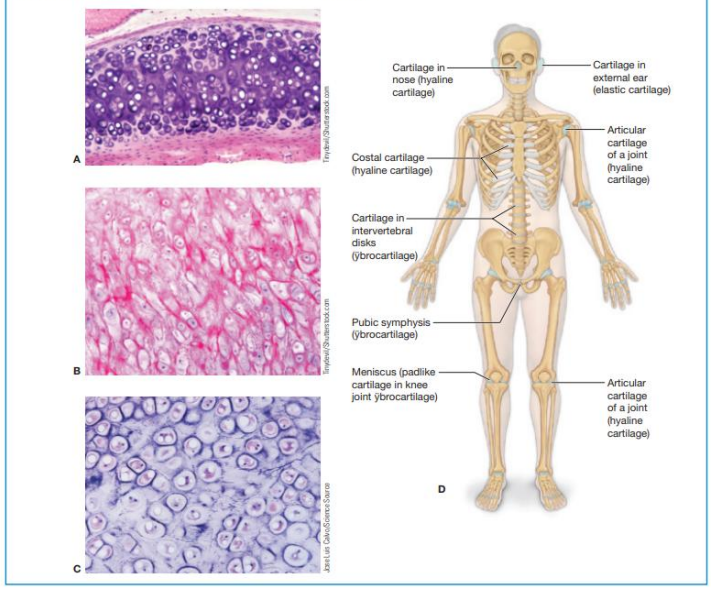
- **Supportive Connective Tissue:** Solid or semisolid; includes bone and cartilage.
- **Cartilage**:
- A supportive connective tissue consisting of collagenous fibers embedded in a semisolid matrix.
- Semisolid matrix containing chondroitin sulfates and cells called chondrocytes.
- **Lacunae**: Small "chambers" in the matrix where chondrocytes reside.
- **Avascular**: Lacks blood vessels; heals slowly as nutrients must diffuse through the matrix.



- **Types of Cartilage**:
- **Hyaline**: Smooth, glassy appearance with no visible fibers; found in ribcage and joint surfaces.
- It is slightly flexible, and comprises the majority of cartilage in the body.
- Most abundant cartilage
- **Fibrocartilage**: Tough and impact-resistant; found in weight-bearing locations due to its ability to absorb pressure. It is commonly found in intervertebral discs and the knees.
- Contains many visible collagen fibers.
- Strongest cartilage.
- **Elastic**: Highly flexible; found in the external ear.
- Notable because of its visible, dark, elastic fibers. It is found in places that require the ability to move or change shape.
- Most flexible type of cartilage.

Figure 5.17 Types of Cartilage

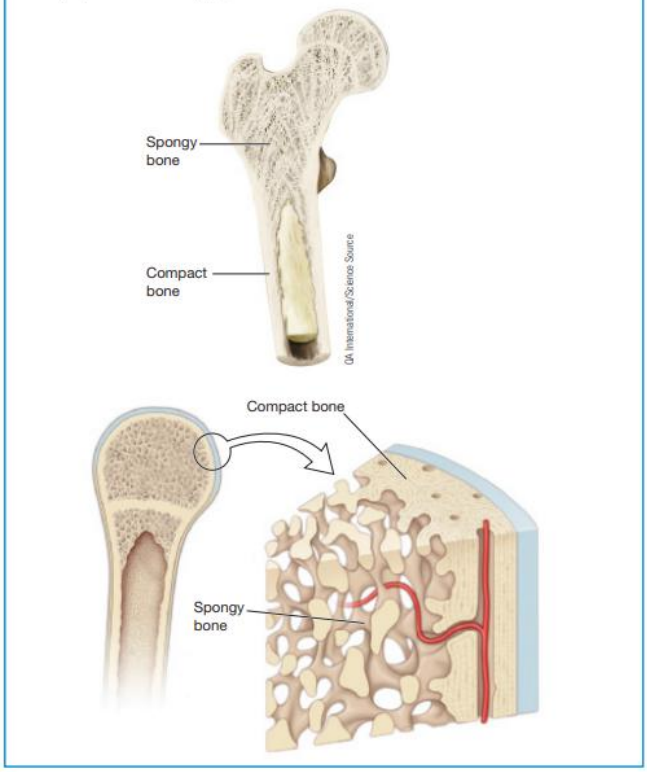
Cartilage is a supportive connective tissue consisting of collagenous fibers embedded in a semisolid matrix. (A) Hyaline cartilage has a smooth appearance with no visible fibers; it is slightly flexible and comprises the majority of cartilage in the body. (B) Fibrocartilage is so named because it has many visible collagen fibers. Fibrocartilage is found in weight-bearing locations because of its ability to absorb pressure. (C) Elastic cartilage is notable because of its visible, dark elastic fibers. It is found in places that require the ability to move or change shape. (D) Hyaline cartilage is the most common type of cartilage in the body, and elastic cartilage is the least common.



- **Bone**:
- The most rigid of the connective tissues.
- Hardest tissue; matrix is mineralized with calcium and phosphorus.
- Provides protection and support for internal organs.
- **Cells**: Osteocytes (in lacunae) and osteoblasts (build the matrix).
- **Vascularity**: Highly vascularized; heals much faster than cartilage.
- **Types of Bone**:
- **Compact Bone**: Solid and structurally strong.
- Solid with greater strength than spongy bone.
- **Spongy Bone**: Network of arches (trabeculae) with empty spaces; lighter weight.
- Empty spaces contain red bone marrow.

Figure 5.19 Bone: the Most Rigid Type of Connective Tissue

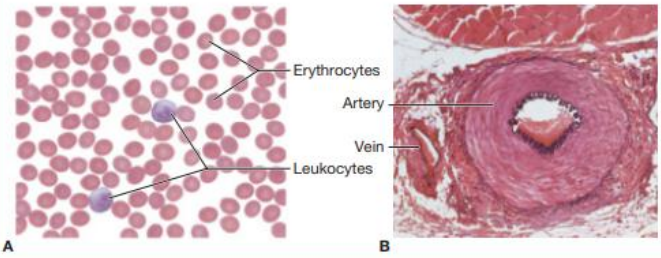
There are two types of bone in the body: compact bone, which forms the periphery of most bones, and spongy bone, which is composed of trabeculae and marrow-filled spaces and forms the deeper portion and the epiphyses of most bones.



- **Fluid Connective Tissue:** Liquid matrix; includes blood and lymph.
- Transport molecules and cells throughout the body.
- Matrix: Called plasma; contains proteins in monomer form (fibers only form during clotting).
- **Blood Components:**
- Erythrocytes (RBCs): Transport oxygen.
- Leukocytes (WBCs): Immune defense.
- Platelets: Cell fragments for blood clotting.

Figure 5.20 Blood: A Fluid Connective Tissue

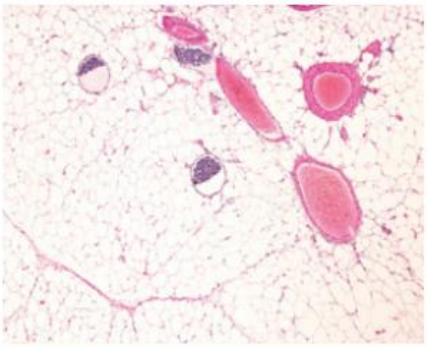
(A) Blood is a fluid connective tissue containing erythrocytes, five types of leukocytes, and platelets that circulate in a liquid extracellular matrix. (B) Two blood vessels in cross section with blood inside.



- Lymph: Collected interstitial fluid; lacks resident cells; drains back into the bloodstream.
- Lymph is primarily acellular

Figure 5.21 Lymph within Lymphatic Vessels

Lymph and blood are the two forms of fluid connective tissue. In contrast to blood, lymph is mostly acellular.



Cells and Fibers of Connective Tissues:

- **Fibroblasts:** The most abundant cells; responsible for secreting protein fibers in the ECM.
- **Fiber Types**
- **Collagen Fibers:** Flexible with high tensile strength; resist stretching (found in tendons).
- **Elastic Fibers:** Contain **elastin**; return to original shape after being stretched (found in skin).
- **Reticular Fibers:** Narrow, branching network; support soft organs like the liver and spleen.
- **Adipocytes:** Fat-storage cells; white adipocytes store one large droplet, brown store many small ones.
- Provide cushioning.
- **White blood cells**: Provide immune function.
- **Red blood cells**: Carry gases such as oxygen and carbon dioxide.
- **Macrophages:** Large immune cells that "scavenge" for debris and bacteria.
- **Mast Cells:** Release chemicals like **histamine** to trigger inflammation and allergic responses.

Introduction to Muscle Tissue: Muscle cells are "excitable," meaning they remain at rest until they respond to a stimulus.

- **Contraction**: The primary response of muscle tissue is to shorten and generate a pulling force.
- **Composition**: Unlike connective tissue, muscle tissue is densely packed with cells and lacks extra-cellular fibers or ground substance.
- **Classification**: Muscle types are differentiated by location, cell shape/size, and whether they are voluntary (conscious control) or involuntary (unconscious control).

- **Skeletal Muscle**
- Most are attached to bones; some attach to skin (facial expressions) or the throat (swallowing).
- Accounts for approximately 40% of total body mass.
- **Thermoregulation**: Generates heat as a byproduct of ATP conversion; shivering is an involuntary contraction used to maintain body temperature homeostasis.
- Allows body movement and maintains posture.

Cellular Characteristics:

- **Skeletal Muscle Fibers**: These are the muscle cells, which remain relatively constant in number throughout life.
- **Growth**: Cells increase in size (hypertrophy) but do not undergo mitosis (cell division).
- **Multinucleated**: Formed by the fusion of multiple myoblasts, resulting in many nuclei per cell.
- **Physical Structure**: Cells are extremely long (can be several inches) and run most of the length of the muscle.
- **Appearance**: Striated (**striped**) due to the organized arrangement of actin and myosin proteins.
- Contains striations—alternating light and dark bands under light microscope
- **Nuclei Placement**: Nuclei are pushed to the periphery (edges) of the cell.
- **Control**: Mostly voluntary.

- **Cardiac Muscle**
- Forms the contractile walls of the heart.
- Pumping Action: Squeezes blood through the heart and pumps it throughout the body.
- Contains striations.
- **Control**: Involuntary (unconscious control).

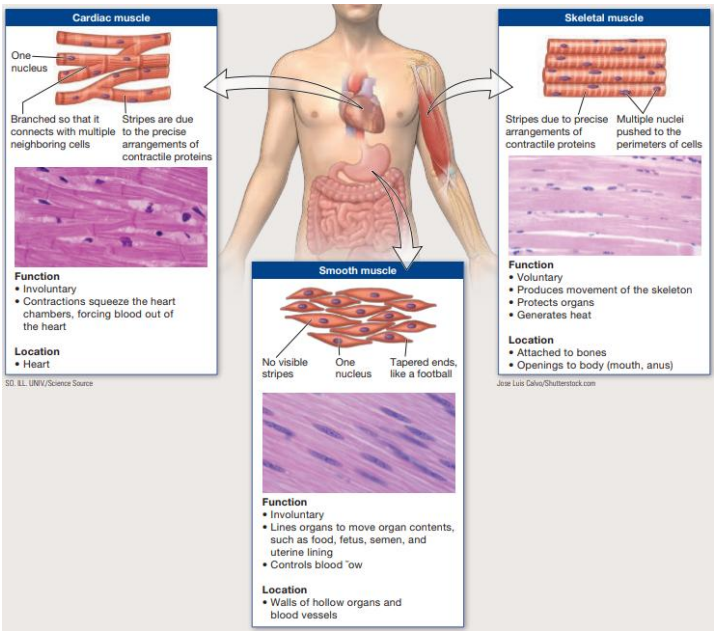
Cellular Characteristics:

- **Cardiomyocytes**: The name for individual cardiac muscle cells.
- **Appearance**: Striated (**striped**), similar to skeletal muscle.
- **Structure**: Cells are smaller than skeletal fibers and typically contain a single, central nucleus.
- Cells attached by **intercalated discs**; specialized junctions that connect cardiomyocytes both physically and electrically.
    - **Desmosomes**: Provide strong physical attachment to withstand forceful contractions.
    - **Gap Junctions**: Allow electrical signals and nutrients to pass seamlessly, ensuring the heart contracts as a single, synchronized unit.

- **Smooth Muscle**
- Found in the walls of the digestive, respiratory, urinary, and reproductive systems.
- Located in the airways and arteries.
- **Control**: Involuntary.

Cellular Characteristics:

- **Shape**: Spindle-shaped or "football-shaped."
- **Nucleus**: Contains a single, centrally located nucleus.
- **Appearance**: Non-striated; lacks the visible striped pattern found in skeletal and cardiac muscle.



Introduction to Nervous Tissue

- **Location**: Comprises the brain, spinal cord, and peripheral nerves.
- **Excitability**: Like muscle tissue, nervous tissue has a resting state and responds to stimulation.
- **Function**: Facilitates rapid communication throughout the body using electrochemical impulses.

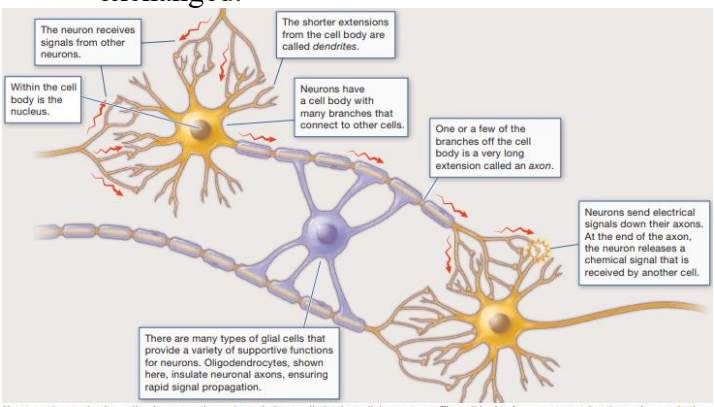
Cell Types of Nervous Tissue

1. Neurons: The primary functional units that respond to stimuli and transmit signals.

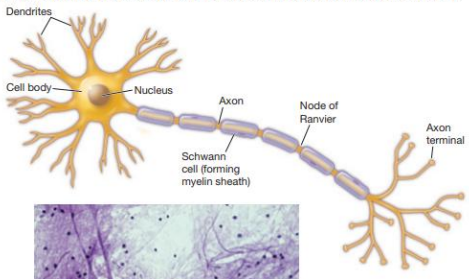
- The electrochemical impulses used by neurons to communicate.
- Neurons generate action potentials.
- Action potentials trigger the release of chemical molecules to bridge gaps between cells.

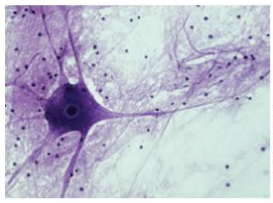
Structure of a Neuron

- **Cell Body (Soma)**: The central part of the cell containing the nucleus, organelles, and most of the cytoplasm.
- **Dendrites**: Short, branching extensions that **receive** incoming signals from neighboring cells.
- **Axon**: A long extension that **sends** signals away from the cell body toward other cells.
- **Synapse**: The microscopic gap between the end of an axon and its target (such as another neuron or a muscle cell) where chemical signals are exchanged.



Neurons, the conducting cells of nervous tissue, have their own distinctive cellular anatomy. The cell body of a neuron contains the nucleus and other organelles. The dendrites are the recipients of signals or other stimuli. The axon carries the action potential to another cell.

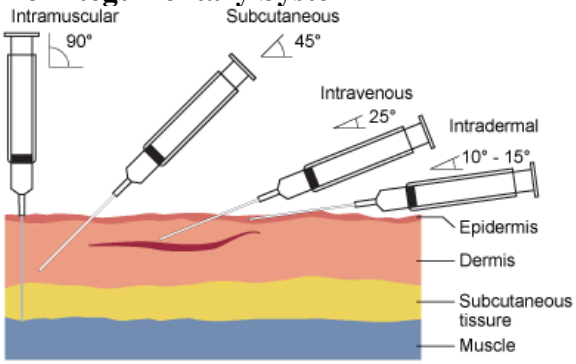


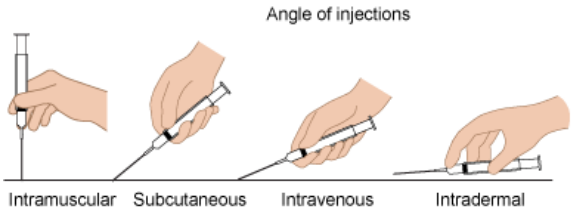


2. Glial Cells (Glia): Essential supportive cells that enable neurons to function properly (neuronal functioning).

- **Ratio**: Outnumber neurons approximately **9 to 1**.
- **Capabilities**: While they cannot send electrical signals themselves, they influence memory, problem-solving, and emotional behavior.
- **Myelin**: A protective, insulating layer formed by glial cells that wraps around axons to speed up signal transmission.

The Integumentary System





Body Membranes:

- Cover body surfaces.
- Line body cavities.
- Form protective sheets around organs.

Classified according to tissue types:

- **Mucous membranes –** Line body cavities that are exposed to the external environment.
- Usually contain goblet cells that secrete mucus.
- They are typically found in the **respiratory tract** (airways), **digestive tract** (mouth to anus), **urinary tract** (urethra), and **reproductive tract**.

Construction:

- Epithelium type depends on site:
  - **Stratified squamous** – mouth and esophagus
  - **Simple columnar** – respiratory tract, rest of the gastrointestinal tract.
- **Loose connective tissue** (lamina propria).

- **Serous membranes** – line closed body cavities and cover internal organs, such as the **pleura** (lungs), **pericardium** (heart), and **peritoneum** (abdominal organs).
- Reduce friction created as organs move.

- **Cutaneous membrane** – is the skin and covers the body.

- Protects body from desiccation and pathogens.
- Made of stratified squamous epithelium and connective tissue
- Keratin provides a thick barrier for protection against pathogens

- **Synovial membranes** – line joints.
- Loose areolar connective tissue only (no epithelial tissue)
- Line fibrous capsules surrounding joints, bursae, tendon sheaths.
- Provide a smooth surface and secrete a lubricating fluid to cushion organs moving against each other during muscle activity.

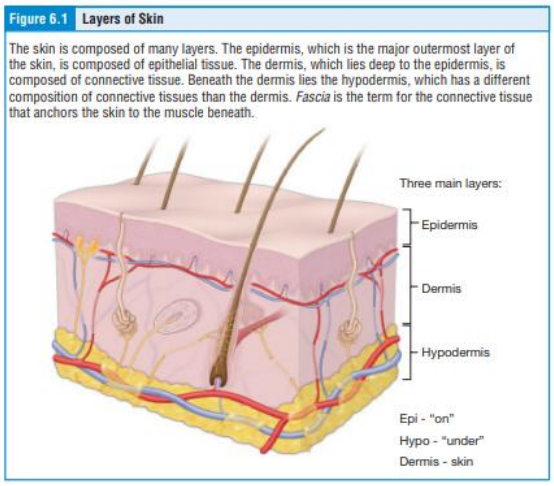
Components of the **Integumentary System**:

- The skin
- Hair
- Nails
- Associated exocrine glands.

Layers of the Skin:

The skin is an organ composed of multiple tissue layers working together to provide protection, sensation, and thermoregulation.

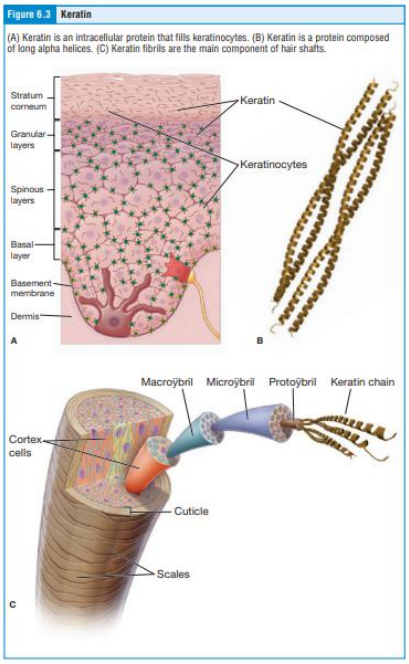
- **Skin Layers**: Consists of three main layers: the epidermis, dermis, and hypodermis (subcutaneous layer).



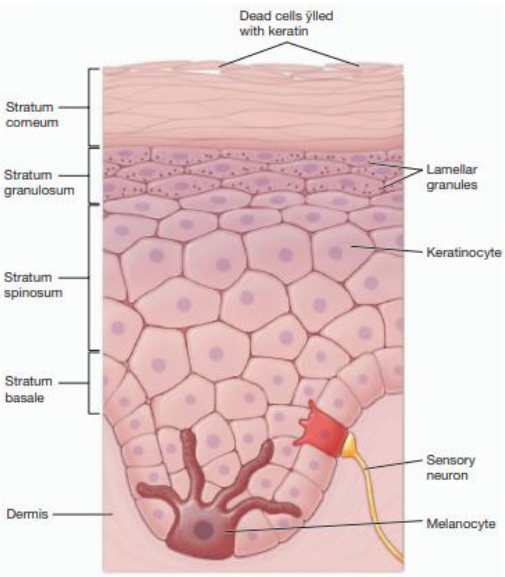
- The deeper layers are highly **vascularized** and **innervated** (rich in nerves).
- Fascia connects skin to the underlying muscle.

The Epidermis: The most superficial layer of the skin

- Tissue Type: **Keratinized stratified squamous epithelium.**
- Vascularity: **Avascular**; relies on the dermis for nutrients.
- **Cell Dynamics**: Cells are "born" in the deepest layer via mitosis and push toward the surface, eventually dying and sloughing off.
- Contains four to five layers depending on location.
  - **Thick skin** (five layers) – found on palms of hands and soles of feet.
  - **Thin skin** (four layers) – found in all other locations.
- **Keratinocytes: T**he primary, mature skin cells; produce **keratin**, a fibrous protein.
  - **Keratin:** is an intracellular fibrous protein made of long alpha helices.



  - Gives hair, nails, and skin hardness and water resistance.
  - Makes up the main component of hair shafts



Layers of the Epidermis (Deep to Superficial)

- **Stratum Basale:** A single layer of stem cells responsible for constant cell production (mitosis).
- The deepest of the epidermal layers.
- Anchored to the basement membrane.

Additional cells found in stratum basale:

- **Merkel cells**: Sensory receptors used for discriminatory touch.
- **Melanocytes**: Melanin-producing cells.
  - **Melanin**: Protects DNA from UV radiation and prevents folic acid breakdown; balanced by the body's need for Vitamin D.
  - Two forms of melanin:
  - Eumelanin – black and brown pigment.
  - Pheomelanin – reddish pigment.
  - All humans have similar concentration of melanocytes. The activity of melanocytes leads to different skin tones.

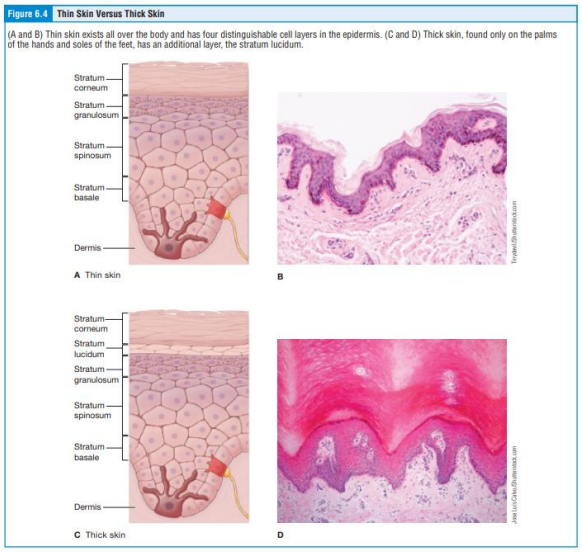
- **Stratum Spinosum**: 8–10 layers of "football-shaped" keratinocytes joined by desmosomes to resist friction.
  - Pointed ends that look like spines give rise to the name "**spinosum**"
  - Contains **Langerhans (dendritic) cells**, which act as macrophages to engulf bacteria and damaged cells (immune protection).
  - Cells are continually pushed toward the stratum granulosum.

- **Stratum Granulosum**: Cells flatten and fill with keratin and keratohyalin (protein granules).
  - Named for its granular appearance (granules = keratohyalin).
  - Melanin (skin pigment) can move into cells here, carried in **melanosomes**.
    - Melanin produced by melanocytes in stratum basale.
    - Long extensions transfer melanin to cells in stratum granulosum.
  - Organelles and nuclei begin to disintegrate as cells start to die.

- ***Stratum Lucidum****: Found only in "thick skin" (palms and soles).*
  - *Made of closely packed, dead skin cells called keratinocytes.*
  - *Appears **translucent** (almost clear) because the cells are flat and filled with **eleidin**, a protein that functions as a water barrier.*
- **Stratum Corneum**: The most superficial layer (15–30 layers of dead keratinocytes).
  - Cells are shed and lost due to mechanical forces.
  - Cells are replaced by cells in deeper layers migrating into the stratum corneum.
  - Provides mechanical protection against microbes, dehydration, and abrasion.

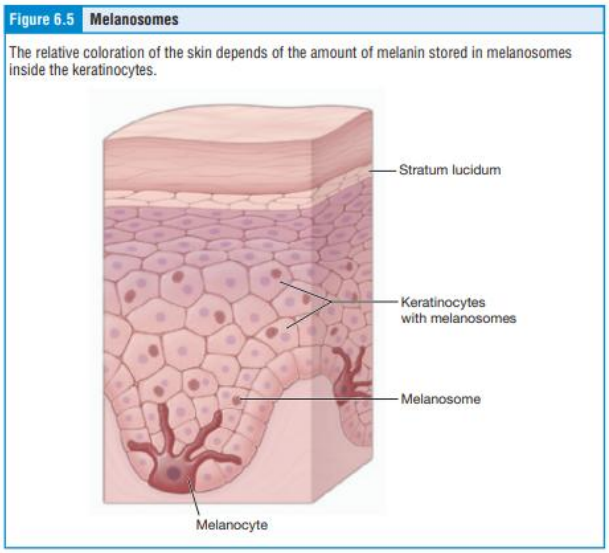
Thin versus Thick Skin:

➢ Thin skin covers most of the body.	➢ Thick skin also has higher number of sensory receptors.



The Dermis: Supports the epidermis with nutrients, strength, and elasticity; houses hair follicles, sweat glands, and blood vessels.

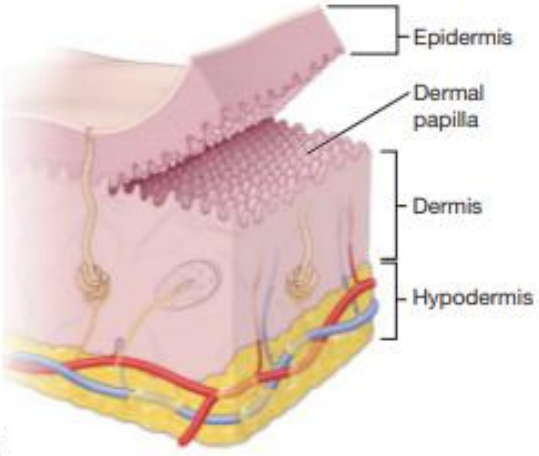
- Lies deep to the epidermis.
- Forms projections that extend into the epidermis (dermal papilla).
- Composed mainly of connective tissue.



- Collagen Fibers: Provides structure and hydration.
- Elastin (**elastic fibers**): Allows skin to stretch and recoil.

Layers of the Dermis:

- **Papillary Layer**: Superficial layer made of loose areolar connective tissue.
  - Features **dermal papillae** (finger-like projections) that interlock with the epidermis to prevent tissue separation and create fingerprints.



  - Contains **Tactile (Meissner) corpuscles**, which detect **light pressure**, as well as **blood vessels and nerve fibers**.
  - Helps to anchor the epidermis to the dermis.

- **Reticular Layer**: Deeper, thicker layer made of dense irregular connective tissue.
  - **Much thicker than papillary layer**
  - Highly vascularized with a rich nerve supply and thick collagen bundles.

The Hypodermis (Subcutaneous Layer):

(Not part of the integumentary system because it's beneath the skin and doesn't directly contribute to the skin's protective functions).

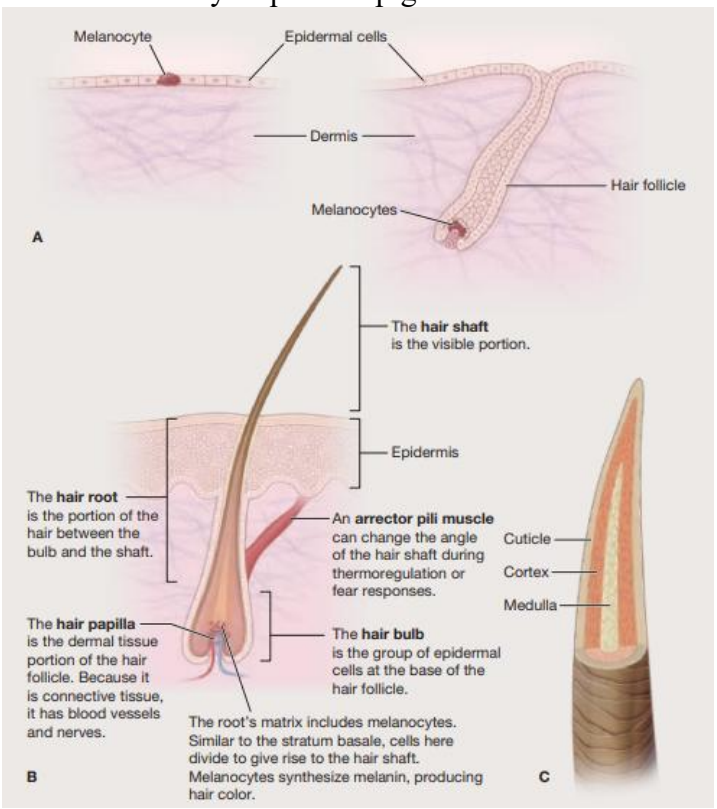
- Directly below the dermis; technically not part of the skin.
- Composition: Loose areolar connective tissue and adipose tissue (fat).
- Functions: Connects skin to underlying fascia (muscle covering), stores fat, provides insulation, and acts as a cushion.
- Contains brown fat in infants.
  - Aids in thermoregulation in infants.

Accessory Structures of the Skin:

Hair: Found on most body surfaces [Exceptions include palms of hands and soles of feet (thick skin)]; Composed of dead, keratinized cells from epidermis.

Structures associated with hair:

- Consists of hard keratinized epithelial cells.
- Melanocytes provide pigment for hair color.



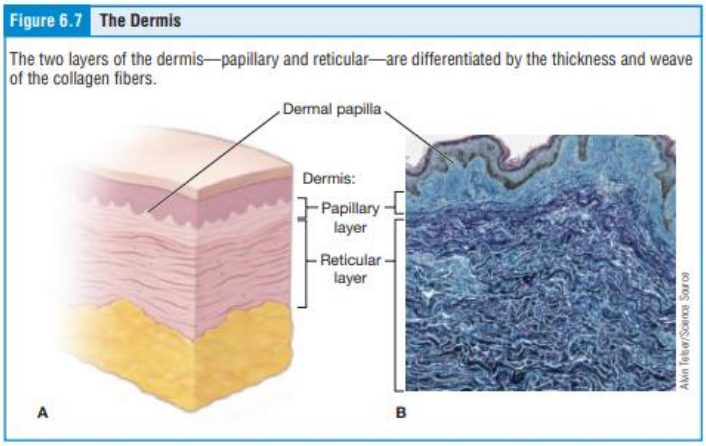
Functions of hair: **Protects against UV** and **particles** (nose/eyes), provides **sensory input** via the hair root plexus, and assists in **thermoregulation.**

Anatomy of Hair:

- **Hair Follicle**: The epidermal tube that anchors and produces the hair.
- Root is enclosed in the follicle.

Composed of an epithelial root sheath and fibrous sheath.

- Contains hair follicles, blood vessels, and nerves.
- Contain **Pacinian corpuscles**, cells that sense **deep pressure**.



- Dermal region provides a blood supply to the hair bulb (deepest part of the follicle).
- The **arrector pili muscle** attaches to the hair follicle and makes hair stand up (goosebumps), helping insulate the body and stimulate hair growth.

Components of hair from deep to superficial:

- **Hair Papilla**: Connective tissue at the base containing blood vessels/nerves to nourish the hair.
- **Hair Bulb**: The base of the follicle where living cells divide.
  - **Hair Matrix**: The matrix is the actively dividing area in the hair bulb. Hair grows here, in the stratum basale.
- **Hair Root**—between bulb and shaft.
- **Hair Shaft**: The dead, visible portion above the skin.

Hair Layers:

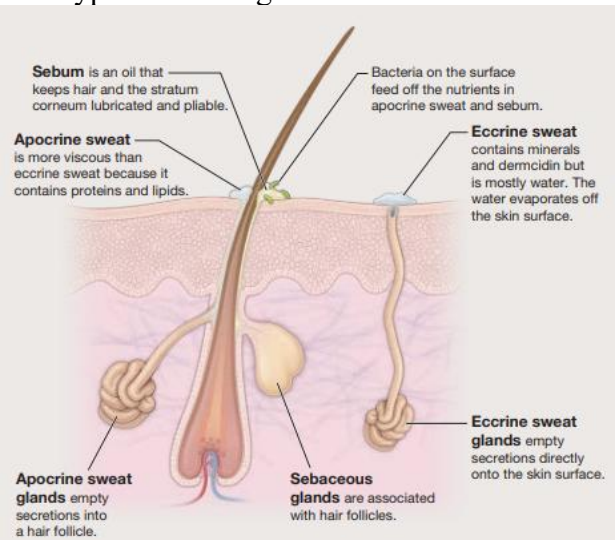
- **Medulla**: Fragile inner core (only in thick hair).
- **Cortex**: Compressed keratinized cells determining hair shape (curly/straight); surrounds medulla.
- **Cuticle**: Hard, outer layer of keratinized cells.

Nails: Composed of keratinized epidermal cells.
Components of Nail:

- **Nail bed**: Living component of nail.
  - Produces nail body.
- **Nail Body**: Hard, keratinized plate protecting fingertips and assisting in picking up objects. The visible hard portion of nail.
- **Nail Root/Matrix**: The proximal region where continuous growth occurs.

Sweat Glands (Sudoriferous glands): Produce sweat (perspiration) to aid in temperature regulation.

Two types of sweat glands:

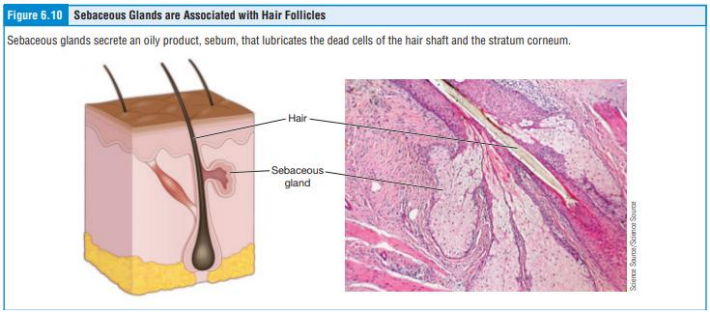


- **Eccrine Glands**:
  - Found all over the body (abundant on palms, soles, forehead).
  - Function: Primary thermoregulation via evaporative cooling.
  - Secretes: Water, salt (electrolytes), and dermcidin (an antimicrobial).
  - Less viscous secretion.

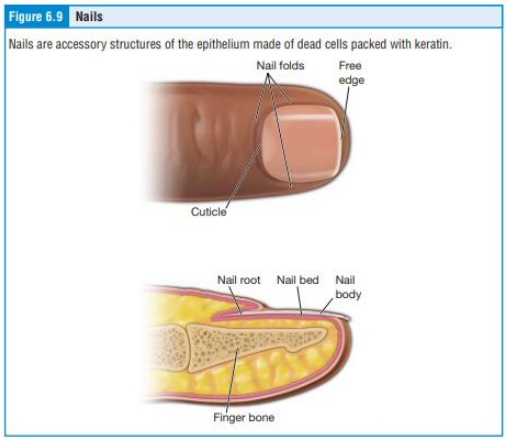
- **Apocrine Glands**:
  - Located in axilla (armpits) and genital regions (groin); empty into hair follicles.
  - Secretes: Thicker/viscous secretion (sweat) containing lipids/proteins; associated with body odor and potential pheromones.
  - Associated with pubic hair.
  - **Not active till puberty.**

Sebaceous (Oil) Glands: produce **sebum** (oily mixture), which lubricates and waterproofs the skin and hair. They are usually associated with hair follicles.

- Mechanism: Uses holocrine secretion (entire cell ruptures to release oil).
- Secretion stimulated by hormones released during puberty.

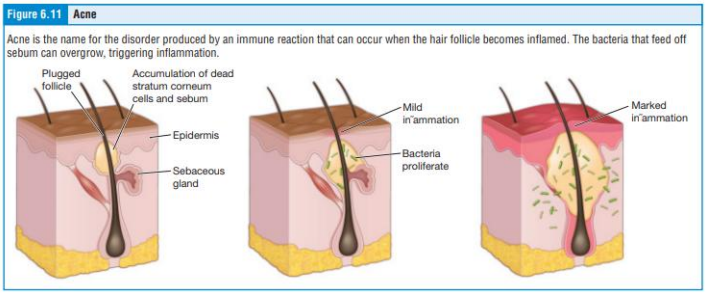


- **Eponychium (Cuticle)**: Thin layer of skin at base of nail. The fold of epidermis meeting the proximal nail body.
- **Lunula**: The crescent-shaped, thick epithelial region at the base.



Acne: Caused by overproduction of sebum, keratin, and dead cells blocking follicles, leading to infection and inflammation.

- Bacteria feed on sebum and sweat to grow



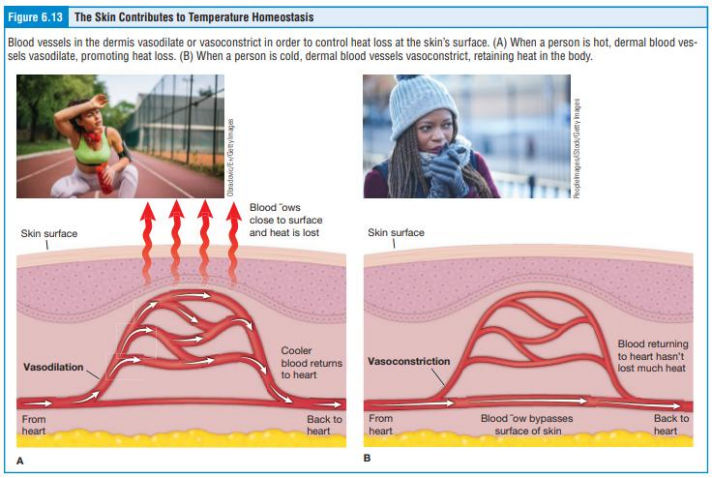
Functions of the Integumentary System:

Protection:

- Keratin, sebum, and glycolipids prevent water loss.
- Dermcidin in sweat and macrophages fight microbes.
- Melanin protects against UV radiation.
- The skin itself shields against mechanical injury.

Sensory Function: The skin contains different types of sensory receptors found in various layers.

- **Tactile (Meissner) corpuscles**: Light touch/pressure.
- **Lamellated (Pacinian) corpuscles**: Deep Pressure and vibration.
- **Nociceptors**: Pain.
- **Thermoreceptors**: Temperature.
- **Vasoconstriction**: Narrowing of blood vessels to conserve heat.

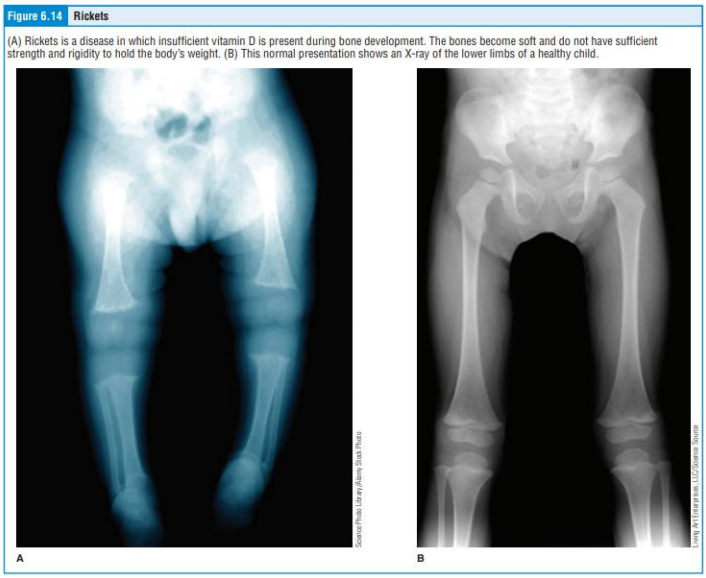


Vitamin D Synthesis: Ultraviolet (UV) rays activate the precursor molecule to initiate vitamin D synthesis

- UV radiation converts cholesterol into a Vitamin D3 precursor.
  - Vitamin D aids in the absorption of calcium from foods in the gastrointestinal tract
  - Necessary for bone growth and immune function.

Deficiency leads to:

- **Rickets** – weak, misshaped bones in children due to **calcium deficiency**.
- Can develop into **osteomalacia** in adults.



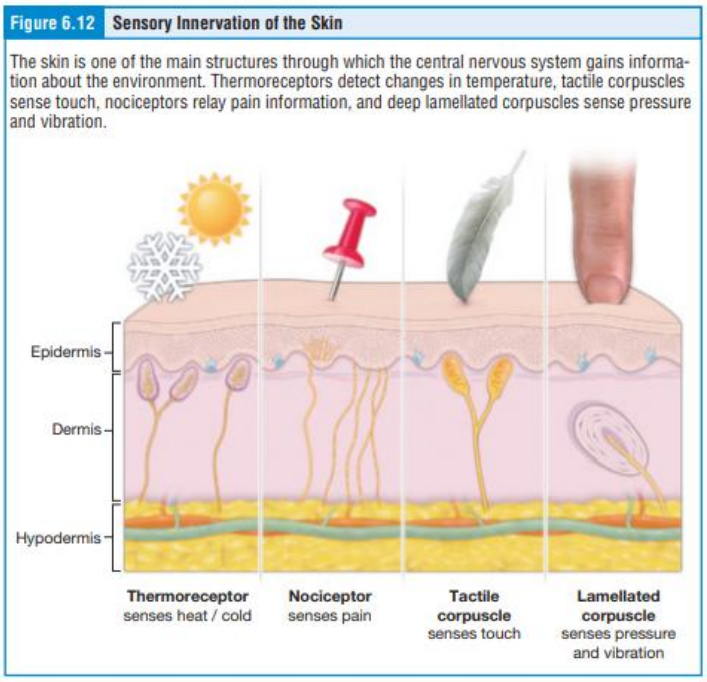
Skin Injury and Repair:

- Skin is highly vulnerable to injury (e.g., abrasions, cuts, burns).
- Skin is highly regenerative

Wound healing can cause scars because:

- Loss of accessory structures (hair, glands).
- Repaired tissue may have a different texture or consistency.

Burns: Occur when damage is caused by heat, radiation, electricity, or chemicals.



Thermoregulation: Sweat helps keep the body cool.
Temperature Homeostasis:

- **Vasodilation**: Widening of blood vessels to release heat.
  - Increased blood flow to the skin cools body.
- Skin cells die and can be replaced.
- Classification:
  - 1st Degree: Epidermis only (e.g., mild sunburn).
  - 2nd Degree: Epidermis and part of dermis (blistering).
  - 3rd Degree: Full thickness (epidermis dermis, and hypodermis destroyed); may not be painful due to nerve damage.
- Size of burn is important in determining treatment.
- Rule of Nines: Method to estimate the total surface area affected by burns.
- Head and neck – 9%; Upper limbs – 9% each; Trunk – 36%; Genitalia – 1%; Lower limbs – 18% each.

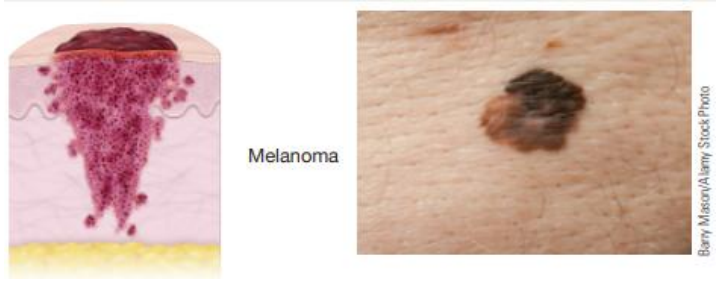
Wound Healing Stages:

- **Blood Clotting**: Formation of a blood clot and scab to stop bleeding.
- Granulation Tissue: **Fibroblasts deposit** collagen to bridge the wound.
- **Regeneration**: Basal stem cells recreate the epidermis.

- **Scars**: Occur when collagen repair is so rapid/fibrous that accessory structures (hair/glands) cannot regenerate.
  - Occurs frequently in areas that are most susceptible to long-term sun exposure

- **Squamous Cell Carcinoma** – caused by **keratinocytes** of stratum spinosum.
  - The second most common type of skin cancer.
  - More aggressive and can metastasize.
  - **Metastasis** is the spread of cancer cells to other parts of the body.

- **Melanoma** – caused by melanocytes.
  - Melanoma usually begins as a mole.
  - A mole becomes **melanoma** when melanocytes **grow uncontrollably**.
  - Appearing as asymmetrical, uneven dark patches.
  - Difficult to detect, highly metastatic and deadly.

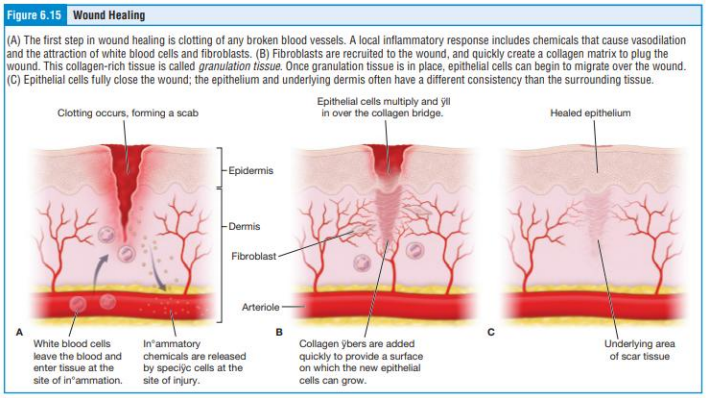


Skin as a Diagnostic Aid:
The color of blood in the dermis contributes to skin color.

- **Hemoglobin** in the red blood cell **which carries O_2** causes the **redness** of the blood.
- A **decrease in blood flow**, as occurs in shock, can make the **skin appear pale**.

Cyanosis is a bluish or purplish color of the skin and mucous membranes caused by low oxygen in the blood (deoxygenated hemoglobin is purple).

- Keloid: A raised scar caused by overproduction of scar tissue.



Skin Cancer:

- Associated with overexposure to UV radiation.
  - UV radiation causes mutations in DNA, leading to increased cancer risk.
  - **Benign** (noncancerous, localized)
  - **Malignant** (cancerous, invasive)

Skin cancers vary depending on the cell where the cancer originated:

- **Basal Cell Carcinoma** – cause by cells of stratum basale.
  - Most common cancer in United States.
- It occurs when there are about **5 g/dL of deoxygenated hemoglobin** in the capillaries.

Central Cyanosis

- Indicates a problem with breathing or blood circulation.

Common signs appear in:

- Tongue (especially the edges and underside)
- Inner lips
- Gums, soft palate, and cheeks
- Lower eyelid (palpebral conjunctiva)

Redness (erythema) – caused by increased blood flow due to embarrassment, inflammation, high blood pressure, fever, or allergies.

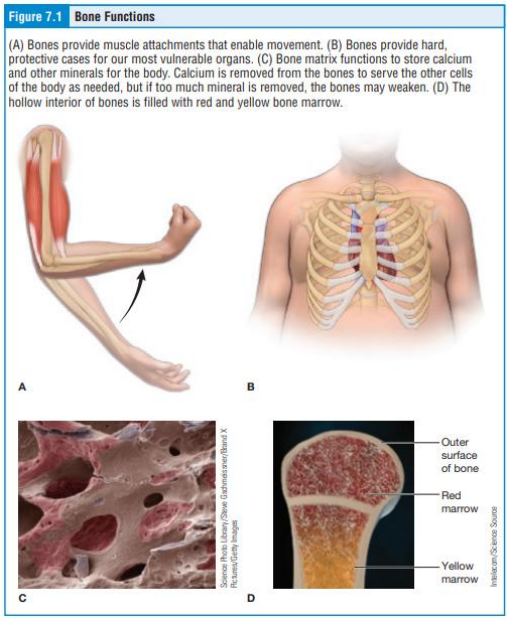
Pallor (blanching) – pale skin caused by emotional stress (fear), anemia, low blood pressure, or reduced blood flow.

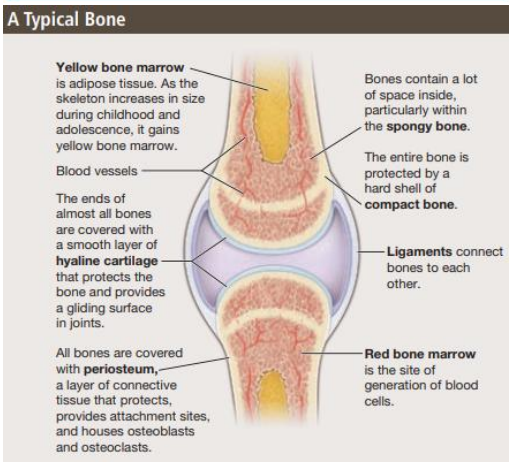
Bruises – black-and-blue marks caused by **hematomas**, which are clotted blood that has leaked into tissues.

Jaundice – yellowing of the skin due to high levels of **bilirubin**, usually linked to liver problems.

The Skeletal System: Human body has 206 bones.
Bone Function:

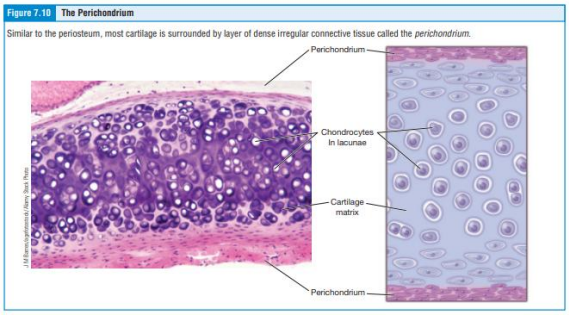
- Attachment sites for muscles.
- Provides a framework for the body.
- Allowing movement as muscles pull on bones
- Shields vital organs (e.g., skull → brain).
- Stores calcium and phosphorus.
- Hematopoiesis: Produces blood cells in red marrow.
- Storing energy in the form of adipose in yellow bone marrow
- Storing minerals in the bone extracellular matrix





Cartilage Tissue:

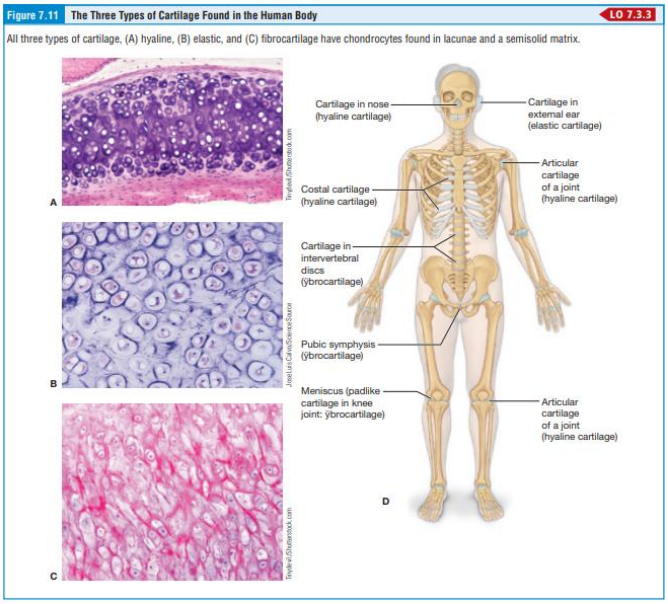
- **Avascular** (no blood vessels) and **aneural** (no nerves); nutrients move via **diffusion**.
- Semi-solid connective tissue
- **Perichondrium**: Dense connective tissue covering cartilage; contains blood vessels and supplies nutrients.



- **Chondroblasts:** Peripheral cells that actively secrete new cartilage matrix.
- **Chondrocytes:** Mature cells located in small spaces called **lacunae**; they maintain the cartilage matrix while being completely surrounded by it.
- **Matrix Composition:** A gel-like substance containing **chondroitin sulfate** and protein fibers (collagen or elastin).

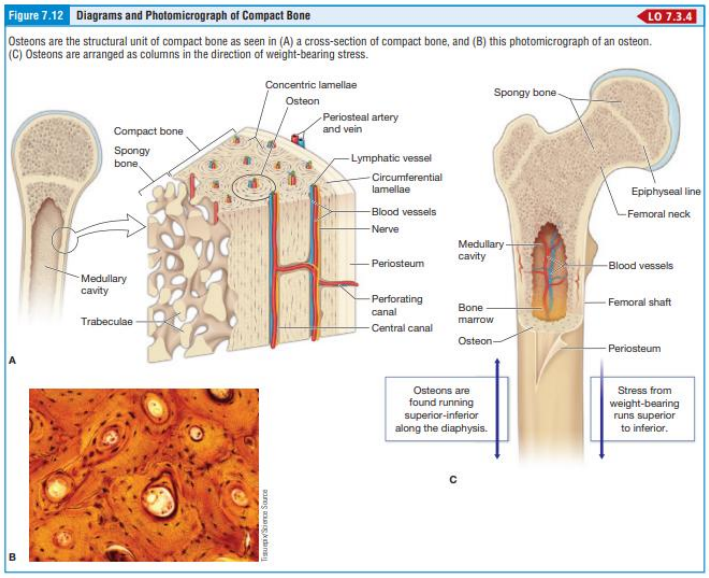
Three Types of Cartilage:

- **Elastic cartilage –** Rare and flexible; found in the external ear, nose tip, and epiglottis.
- **Hyaline cartilage –** Most common; found in joints and growth plates.
  - Found at the ends of bones.
  - Helps bones glide past each other due to its smooth surface, which reduces friction.
  - Loss of hyaline cartilage leads to osteoarthritis.
- **Fibrocartilage –** Rich in collagen; resists heavy pressure; found in knee menisci intervertebral discs, and the pubic symphysis.

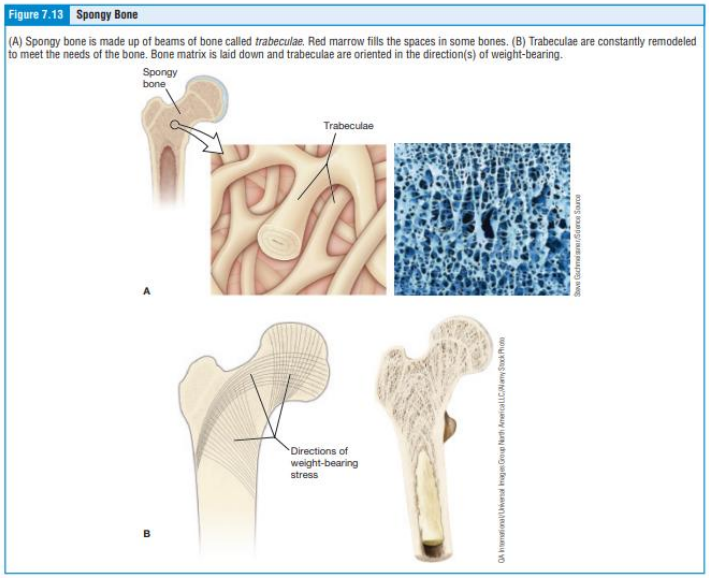


Bone Tissue: Solid connective tissue

- **Compact Bone**: Dense and hard; forms the outer layer of all bones; provides support and protection.
  - **Osteon:** The microscopic structural unit of compact bone; resembles a weight-bearing column.
  - **Central (Haversian) canal:** Runs through the center; contains blood vessels and nerves.
  - **Lamellae:** Concentric rings of calcified matrix surrounding the central canal for strength.
  - **Perforating (Volkmann's) canals:** Horizontal channels that connect blood vessels between osteons and the periosteum.
  - **Canaliculi:** Tiny channels that allow nutrient and waste exchange between osteocytes and blood vessels.



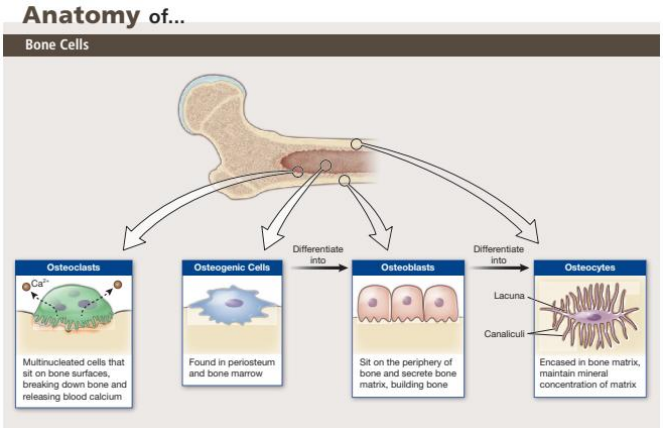
- **Spongy Bone**: Found at the ends of long bones and the center of flat bones; contains red bone marrow and provides strength.
  - Contain osteocytes within trabeculae.
  - **Trabeculae:** Lattice-like network of "beams" that align along stress lines to provide strength.
  - **Function:** Makes bones lighter; protects red bone marrow for hematopoiesis



Red versus Yellow Mallow:

- **Red Marrow:** Site of blood cell production; found in spongy bone.
- **Yellow Marrow:** Site of fat (triglyceride) storage; found in the medullary cavity.

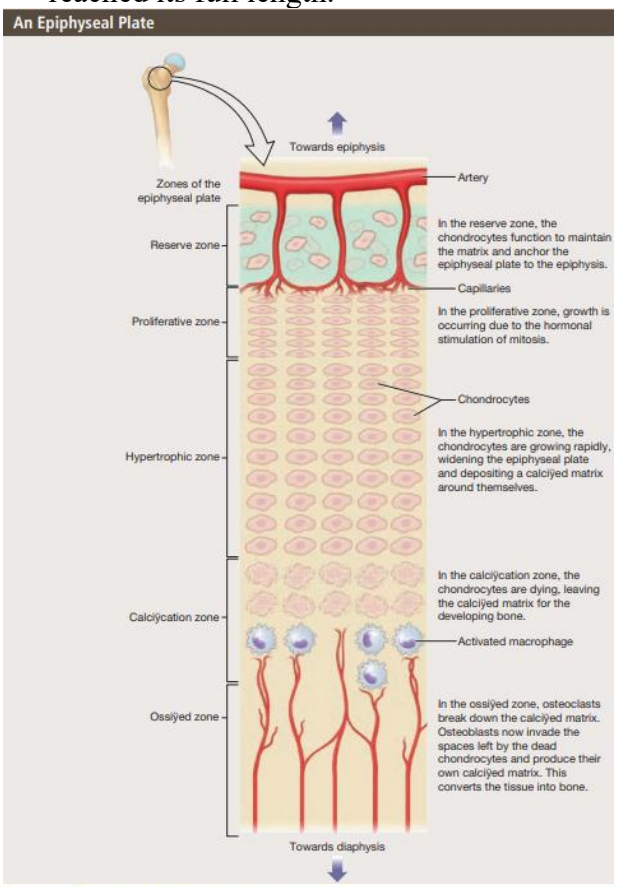
Bone Cells (The Anatomy of Bone Cells)

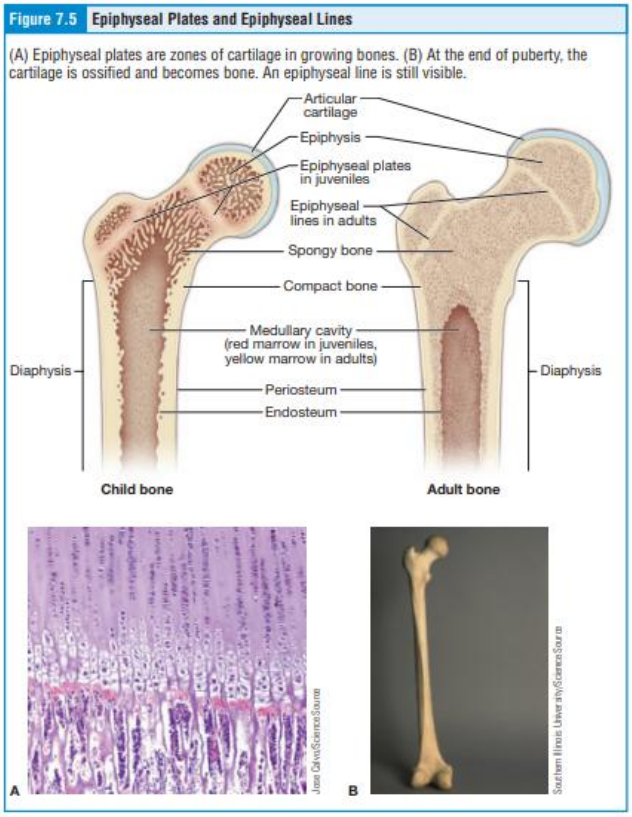


- **Osteogenic Cells:** Stem cells; the only bone cells capable of mitosis; differentiate into osteoblasts; communicate via canaliculi.
- **Osteoblasts:** Bone-building cells; secrete **osteoid** (unmineralized matrix); found in the periosteum and endosteum.
- **Osteocytes:** Mature bone cells trapped in lacunae; maintain bone minerals and communicate via canaliculi; formed when osteoblasts become fully surrounded by matrix.
- **Osteoclasts:** Bone-destroying cells; large and multinucleated; use enzymes to dissolve bone for remodeling or calcium release; aid in bone remodeling.

Anatomy of a Typical Bone:

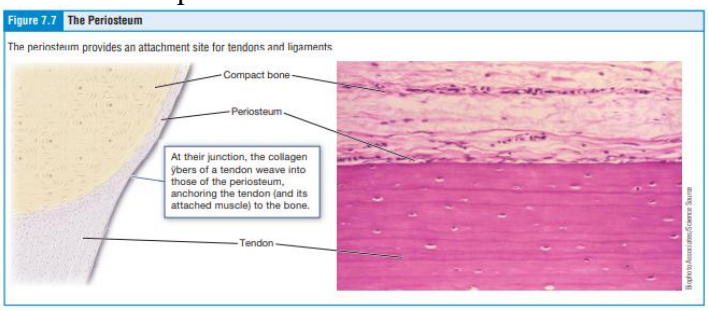
- **Periosteum:** Covers the bone surface.
- **Compact Bone**: Dense and hard; forms the outer layer of all bones.
- **Spongy Bone**: Found in the ends of long bones and center of flat bones; contains **red bone marrow**.
- **Medullary cavity:** Contains **yellow bone marrow**.
- **Articular cartilage:** Made of hyaline cartilage.
  - Found at ends of long bones where joints form.
  - Reduce friction and act as shock absorber.
- **Epiphyseal plate (growth plate):** Hyaline cartilage in children that allows bones to lengthen; becomes the epiphyseal line in adults when ossified.
- **Epiphyseal line:** The remnant of the epiphyseal plate in adults, indicating that the bone has reached its full length.





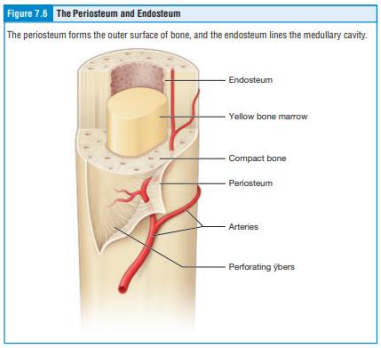
- **Medullary cavity:** Hollow space in diaphysis; contains yellow bone marrow (in adults).
- **Articular cartilage:** Hyaline cartilage at joints.

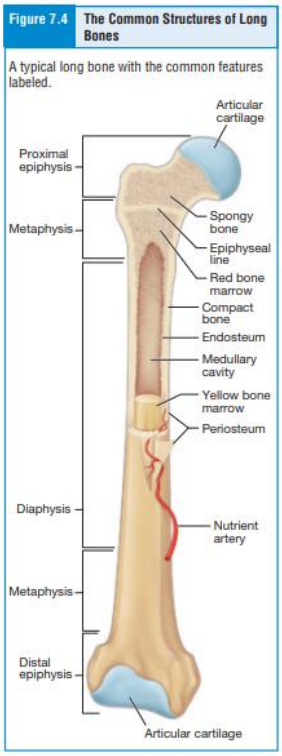
- **Periosteum:** Dense connective tissue covering the bone surface; contains blood vessels, nerves, and lymph vessels. Tendons and ligaments attach via perforating fibers.
  - Collagen fibers of tendon weave into those of periosteum to anchor muscle to bone.



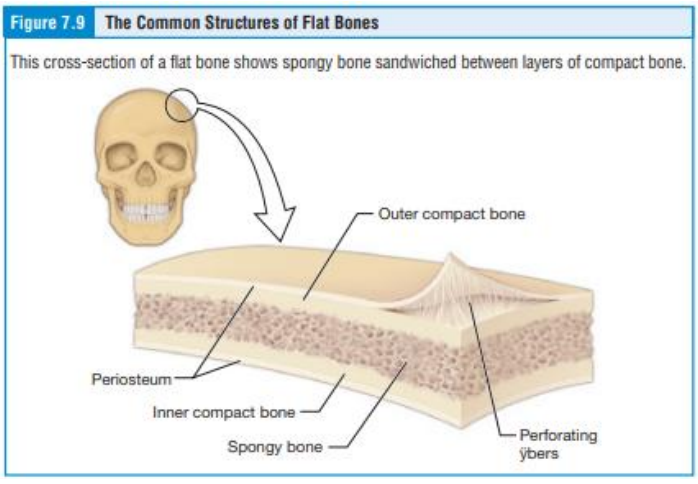
- **Endosteum:** Connective tissue lining the medullary cavity.

Both **periosteum and endosteum** have cells that support bone growth.



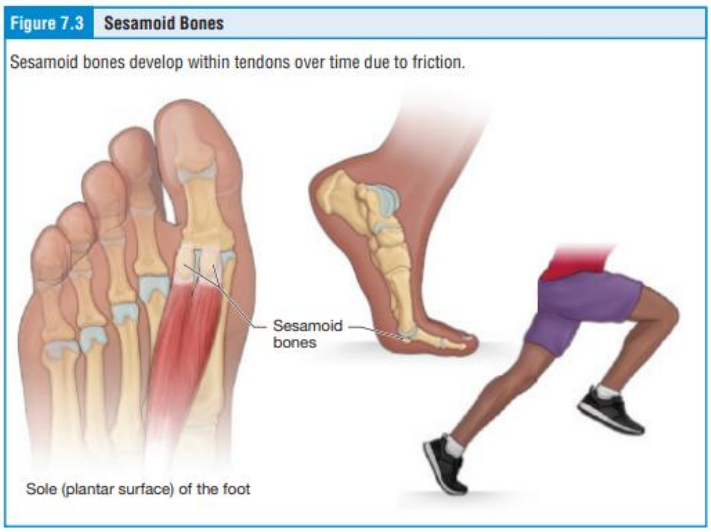


- **Short Bones:** Cube-like; equal length and width; provide stability and support (e.g., carpals in wrist, tarsals in ankle).
- **Flat Bones:** Usually thin, plate like, and often curved; primary for protection and muscle attachment (e.g., skull, ribs, sternum).
  - Composed of a layer of spongy bone between two layers of compact bone.



- **Irregular Bones:** Complex shapes; do not fit other categories; do not have an easily characterized shape (e.g., vertebrae, facial bones).

- **Sesamoid Bones:** Small, round bones formed within tendons to protect them from pressure (e.g., patella/kneecap).



  - Patella is the only common sesamoid bone in every person.
  - Develop over time due to friction.
  - Typically seen in tendons of feet, hands, and knees.

Table 7.1 Bone Classifications

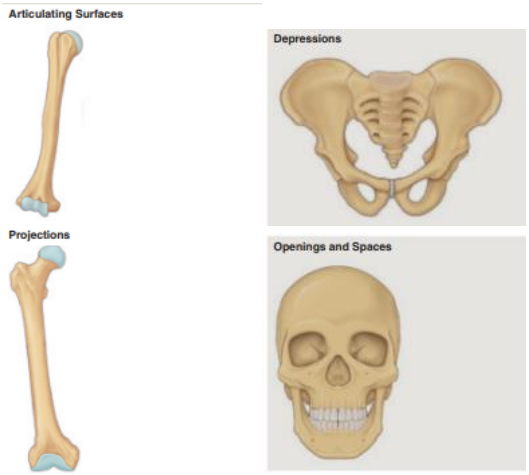
Bone Classification	Features	Function(s)	Examples
Long	Cylinder-like shape, longer than it is wide	Leverage	Femur, tibia, fibula, metatarsals, humerus, ulna, radius, metacarpals, phalanges
Short	Cube-like shape, approximately equal in length, width, and thickness	Provide stability, support, while allowing for some motion	Carpals, tarsals
Flat	Thin and curved	Points of attachment for muscles; protectors of internal organs	Sternum, ribs, scapulae, cranial bones
Irregular	Complex shape	Protect internal organs	Vertebrae, facial bones
Sesamoid	Small and round; embedded in tendons	Protect tendons from compressive forces	Patellae

Bone Markings: The surface features of bones.

- **Articulating surfaces:** Where two bones meet to form a joint.
- **Depressions:** Sunken areas where organs or blood vessels rest.
- **Projections:** Raised areas that serve as attachment points for ligaments and tendons.
- **Holes/Spaces:** Openings (foramina) that allow nerves and blood vessels to pass through bone.

Table 7.2 Bone Markings

Name	Description	Example
Condyle	Rounded surface	Occipital condyles
Facet	Flat surface	Vertebrae
Head	Prominent rounded surface	Head of femur
Trochlea	Rounded articulating surface	Trochlea of humerus
Fossa	Elongated basin	Mandibular fossa
Sulcus	Groove	Sigmoid sulcus of the temporal bones
Crest	Ridge	Iliac crest
Epicondyle	Projection off a condyle	Lateral and medial epicondyles of humerus
Line	Slight, elongated ridge	Temporal lines of the parietal bones
Process	Prominent feature	Transverse process of vertebra
Ramus	Long projection (branch)	Mandibular ramus
Spine	Sharp process	Ischial spine
Trochanter	Rough round projection for muscle attachment	Greater trochanter of femur
Tubercle	Small, rounded process	Tubercle of humerus
Tuberosity	Rough surface	Deltoid tuberosity
Canal	Passage in bone	Auditory canal
Fissure	Slit through bone	Auricular fissure
Foramen	Opening in bone	Foramen magnum in the occipital bone
Meatus	Opening into canal	External auditory meatus
Sinus	Air-filled space in bone	Nasal sinus

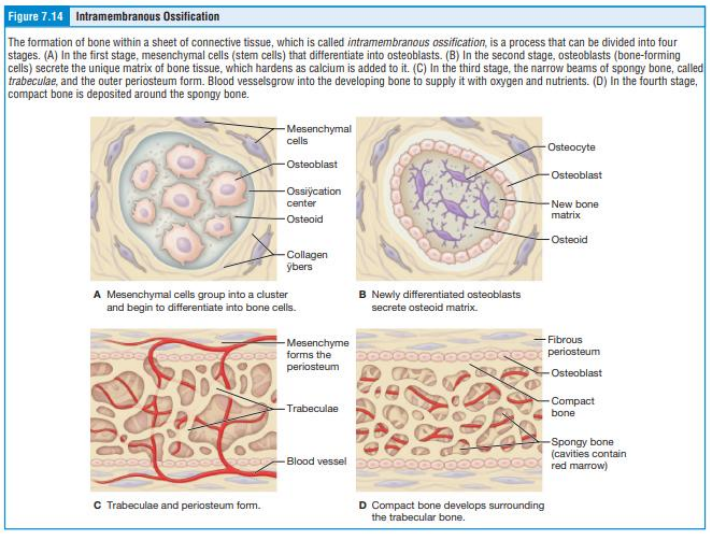


Bone Development (Ossification): bone formation using a cartilage or connective tissue model; new bone tissue replaces or builds on this model.

Type of Ossification:

Intramembranous Ossification: connective tissue membrane is used to make bone

- **Template:** Dense irregular connective tissue (mesenchyme).
- **Result:** Flat bones of the face, skull, and clavicles.

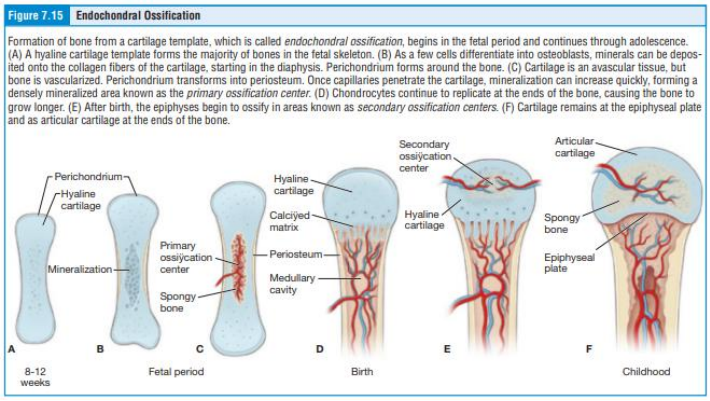


Process:

1. Mesenchymal cells group together and differentiate into osteoblasts forming ossification center.
2. Osteoblasts begin to secret osteoid.
3. Trabeculae and periosteum form.
4. Compact bone surrounds trabecular bone.

Endochondral Ossification:

- **Template:** Hyaline cartilage model.
- **Result:** Most long bones and the rest of the skeleton.

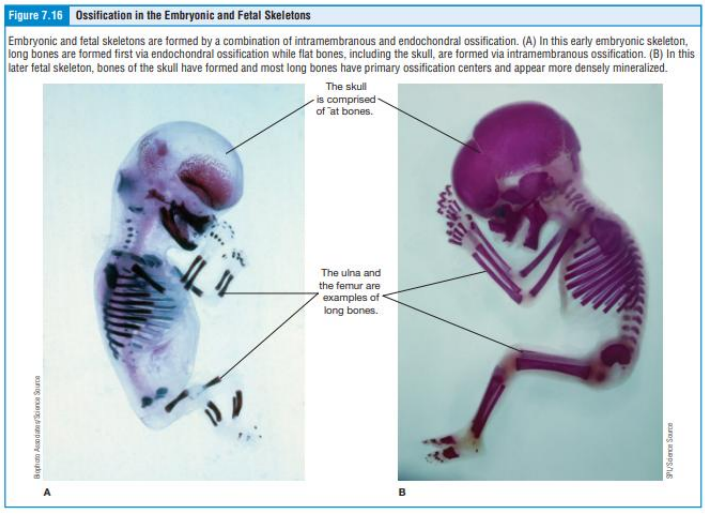


Process:

1. Cells in cartilage differentiate into osteoblasts.
2. Minerals are deposited on collagen fibers in cartilage starting at diaphysis.
3. Perichondrium becomes periosteum.
4. Blood vessels penetrate periosteum forming primary ossification center.
   4.1. Mineralization increases.
5. Cartilage remains at epiphyseal plate to allow bone to grow in length.
6. Epiphyses ossify after birth at secondary ossification centers.

Ossification of Embryonic and Fetal Skeletons: form by combination of intramembranous (formation of long bones) and endochondral ossification (formation of flat bones).

- Mineralization increases during development.

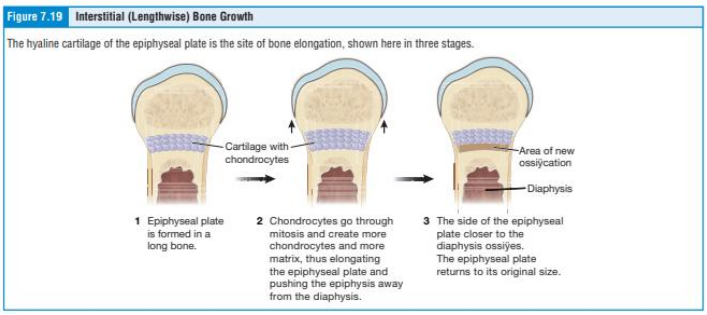


Growth and Remodeling

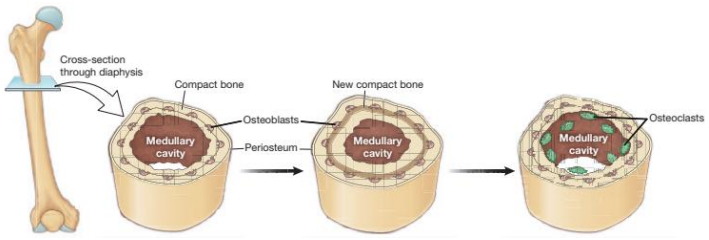
- **Interstitial Growth:** Increases bone **length**; occurs at the epiphyseal plate (growth plate).
- Epiphyseal (growth) plate is firmly attached to the diaphysis.
- The increase in size increases the distance between the epiphysis and diaphysis.
- Cartilage on the diaphysis side of the plate is replaced with bone; bone is longer as a result.

Epiphyseal plates exhibit four zones of activity:

- **Reserve Zone:** Anchors plate to epiphysis.
- **Proliferative Zone:** Rapid mitosis of chondrocytes.
- **Zone of Mature Cartilage:** Cells enlarge and matrix calcifies.
- **Zone of Calcified Matrix:** Chondrocytes die; osteoblasts replace cartilage with bone.



- **Appositional Growth:** Increases bone **diameter**; osteoblasts add bone to the surface while osteoclasts widen the medullary cavity.



1) Osteoblasts are found in a circle around the medullary cavity called a lamella.

2) Osteoblasts lay down new osteoid and build new bone matrix. Compact bone becomes temporarily thicker.

3) Osteoclasts break down compact bone lining the medullary cavity. Compact bone returns to its original thickness but the bone is now wider in diameter.

Bone Remodeling: The changes bones go through on a daily basis.

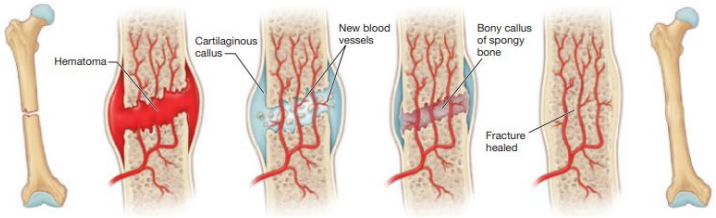
- The ongoing replacement of old bone with new bone (approx. 20% of the skeleton annually).
- Bone is constantly broken down and new bone is formed.
- Aids homeostasis by making minerals available
- Bone remodels to increase strength along line of resistance.
- Bone remodeling happens in response to stress or damage (e.g., injury, exercise, and other activities).

Bone Repair (Fracture Healing)

- A **fracture** is a break in a bone.

Steps in bone repair:

1. **Fracture hematoma:** A blood clot forms within hours to stop bleeding.
2. **Fibrocartilaginous callus:** A cartilage bridge stabilizes the break within 48 hours.
3. **Bony callus:** Osteoblasts replace cartilage with spongy bone over several weeks.
4. **Remodeling:** Osteoclasts and osteoblasts reshape bone into strong compact bone.



Assisting bone repair:

- **Reduction:** Realignment of broken bones for proper healing; done as soon as possible.
- **Stabilization:** Pins, screws, or rods may be surgically added.

Fractures are classified based on complexity, location, and other features.

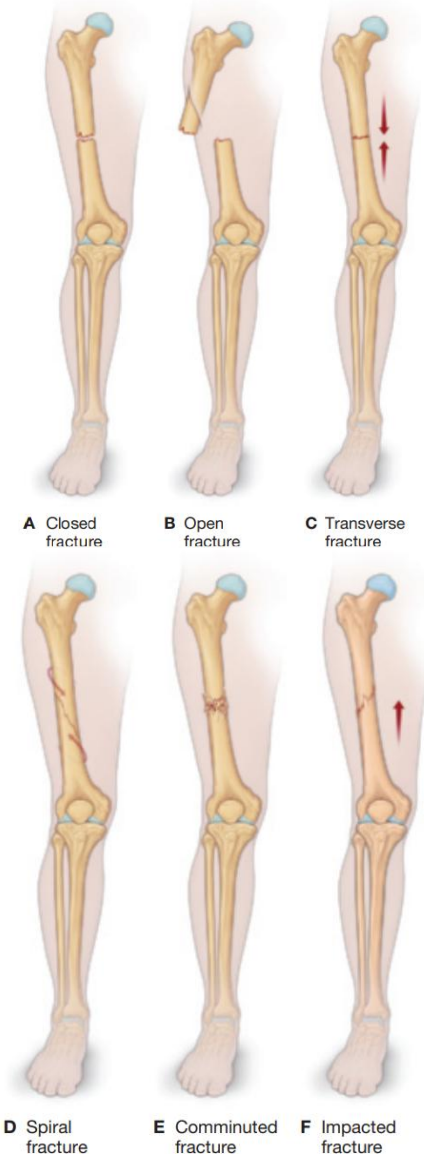


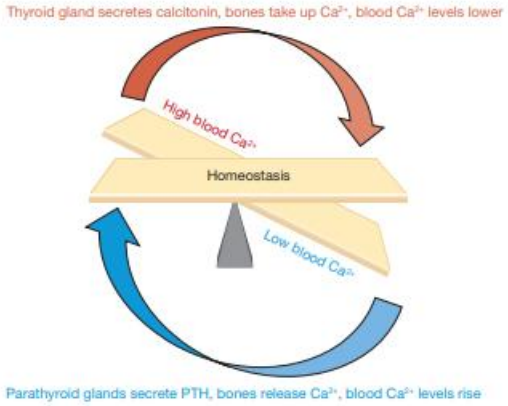
Table 7.3 Hormones That Influence the Skeletal System

Hormone	Action	Example
GH	Promotes mitosis of chondrocytes, resulting in an increase in the length of bones.	
T_3 and T_4	Increase the activity of osteoblasts, resulting in more bone matrix.	
Estrogen and testosterone	Increase the activity of osteoblasts, resulting in more bone matrix; *at high levels convert epiphyseal plate to epiphyseal line.*	
Calcitriol	Increases the absorption of calcium and phosphate from the digestive tract.	Ca^{2+}
PTH	Increases osteoclast proliferation and activity, resulting in less bone matrix.	
Calcitonin	Increases osteoblast activity, which increases deposition of bone matrix. Decreases osteoclast activity, which prevents resorption of bone matrix.	

Hormone	Source	Effect on Bone
Growth Hormone (GH)	Pituitary	Stimulates chondrocyte proliferation and bone density; **promotes bone growth**.

Thyroxine /Sex Hormones	Thyroid/ Gonads	**Stimulate osteoblasts**; promote adolescent growth spurts.
Calcitriol (Vit. D)	Kidneys	Increases calcium absorption from the gut.
Parathyroid Hormone (PTH)	Parathyroids	Stimulating **osteoclasts**.
Calcitonin	Thyroid	Inhibiting osteoclastic activity.

Calcium Homeostasis: When blood calcium is high, calcium is stored in bone; when low, it is released to support nerve and muscle function.



- Calcium is the most abundant mineral in the body, mainly stored in bones.
- **Functions:** Essential for blood clotting, heart rhythm, nerve signaling, and muscle contraction.
- **Normal blood level:** ~10 mg/dL.

Imbalances:

- **Hypocalcemia:** Low blood calcium; causes weak bones and impaired muscle, nerve, and clotting function.
- **Hypercalcemia:** High blood calcium; mainly affects the nervous system.

Hormonal control:

- **Calcitonin:** Promotes calcium storage in bone, lowering blood calcium.
- **Parathyroid hormone (PTH):** Stimulates calcium release from bone, raising blood calcium.

Figure 7.24 Dietary Calcium

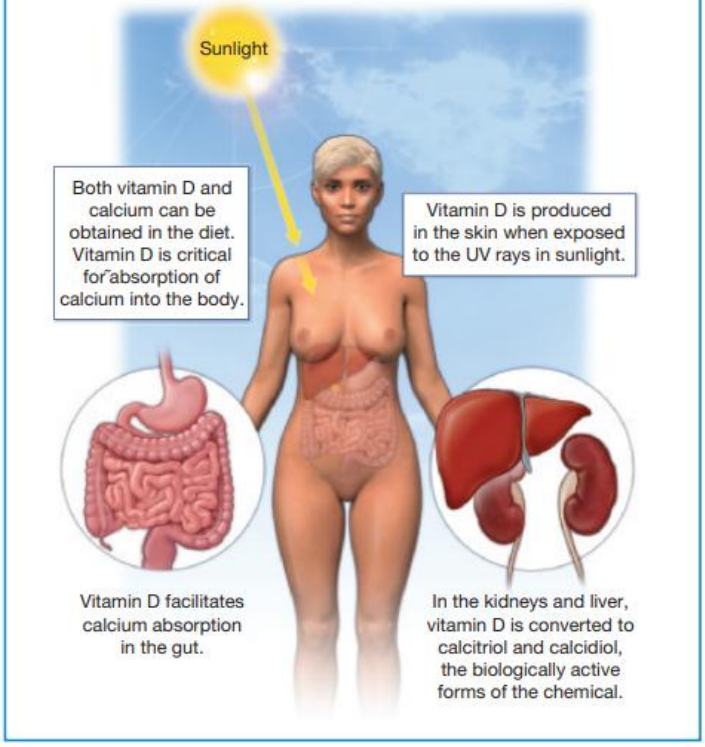
Many different types of foods are good sources of dietary calcium.

Calcium and Vitamin D

- **Dependency:** Calcium cannot be absorbed by the small intestine without the presence of **Vitamin D**.
- **Vitamin D Sources:** Found in fatty fish (salmon/tuna) and fortified foods like milk.
  - **Sunlight:** The skin produces Vitamin D when exposed to UV radiation.
- **Classification:** Though called a "vitamin," it acts as a **hormone** because the body can synthesize it and transport it through the blood.

Figure 7.26 Vitamin D Synthesis

Vitamin D can be synthesized in the skin upon exposure to sunlight. Once in the body, it is converted to active forms and facilitates the uptake of calcium from the gut.



Vitamin D Synthesis

- The body can produce vitamin D with sunlight (UV) exposure.
- Vitamin D is activated by the kidneys into **calcidiol** and **calcitriol**.
- The active form travels through the blood to the small intestine.
- It increases calcium absorption in the small intestine.

Exercise and Bone Density

Figure 7.27 Exercise Is Essential for Skeletal Maintenance

As observed in both sedentary individuals and astronauts in space for prolonged periods, the absence of weight-bearing exercise causes rapid loss of both collagen and mineral matrix from bone.

- Bones adapt to the "load" or weight placed on them; lack of stress leads to mineral and collagen loss.
- **Weight-Bearing Exercise:** Stimulates osteoblasts to deposit mineral salts and collagen fibers, resulting in thicker, stronger bones.
- Lack of exercise leads to weaker, lighter bones; increases risk of fracture.

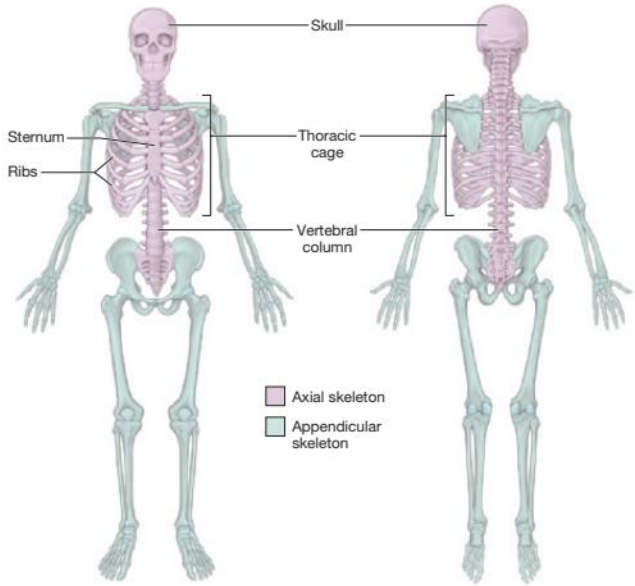
Osteoporosis: Characterized by a decrease in bone mass with age.

- Rate of bone resorption exceeds rate of bone formation.
- Osteoclasts more active than osteoblasts.
- Rapidly declining levels of estradiol in females increases risk.

Skeletal System Overview

- **Composition**: Includes all bones, cartilages, and ligaments.
- **Bone Count**: Adults average 206 bones; children have more because several bones fuse together during growth.
- **Primary Functions**:
  - Acts as a lever system for muscles to produce movement.
  - Assists in calcium homeostasis.
- **Evolutionary Specialization**:
  - **Lower Skeleton**: Specialized for stability (walking/running).
  - **Upper Skeleton**: Specialized for mobility and range of motion (lifting/carrying).

Major Divisions of the Skeleton



The Axial Skeleton (80 bones): The vertical, central axis of the body.

- **Components**: Skull (22 bones), vertebral column (24 vertebrae + sacrum and coccyx), thoracic cage (12 pairs of ribs + sternum), hyoid bone, and ear ossicles.
- **Function**: Protects the brain, spinal cord, heart, and lungs; serves as an attachment site for muscles of the head, neck, and trunk, allowing movement.

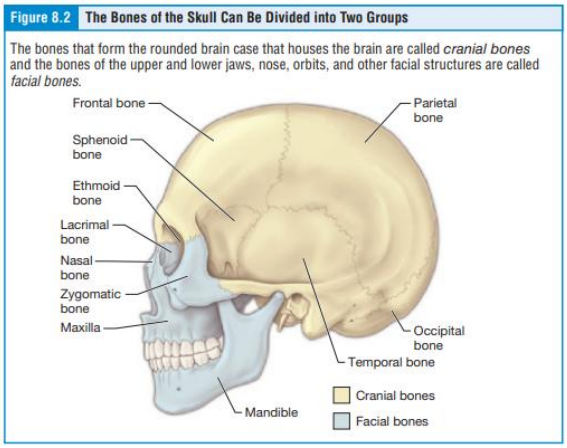
The Appendicular Skeleton (126 bones): Includes all bones of the upper and lower limbs.

- **Girdles**: Includes the scapulae (shoulder) and pelvis, which attach limbs to the axial skeleton.

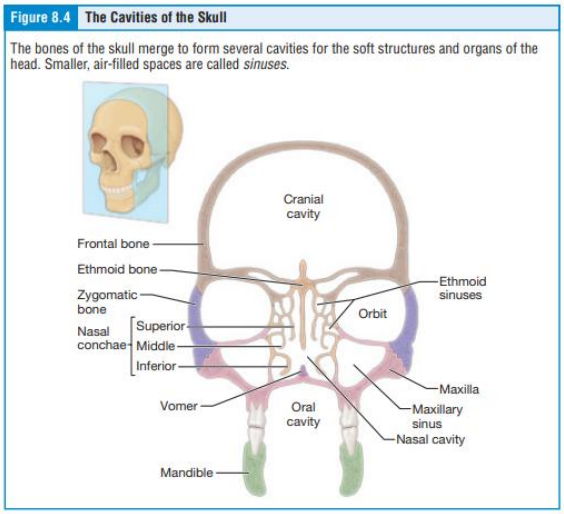
The Skull: Structure and Cavities

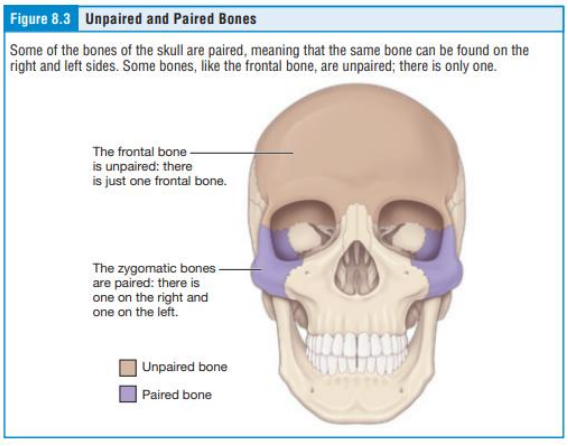
- Consists of 22 bones; 21 are immobile (joined by **sutures**), while the **mandible** is the only moveable bone.
- **Major Subdivisions**:
  - **Cranium** (Cranial bones): **Protects the brain** and houses ear structures.

- **Facial Bones**: Form the face, nasal cavity, mouth, and eye orbits.



❖ **Cavities**: They are hollow spaces that house soft organs and reduce the weight of the skull; includes the cranial cavity, orbits (eye sockets), nasal cavity, paranasal sinuses, and oral cavity.





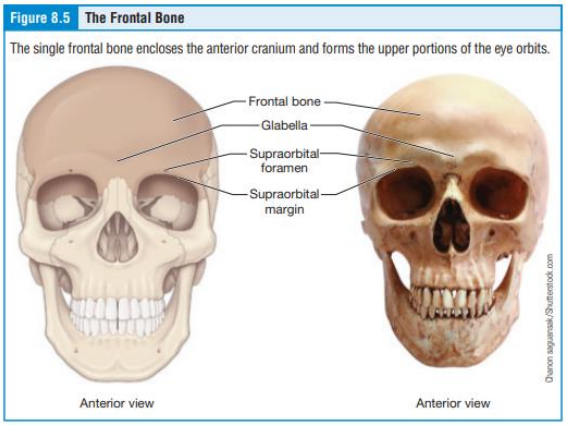
Bones of the Skull

Cranial Bones:

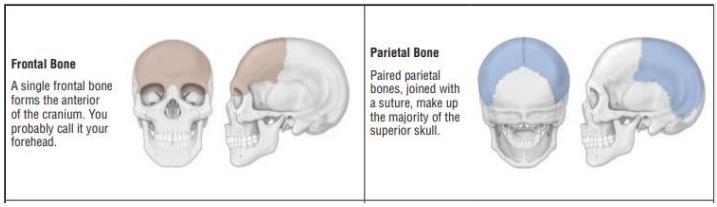
❖ **Frontal Bone** (1): Forms the forehead.

Bony marking

❖ Supraorbital margin, glabella, and Supraorbital foramen.



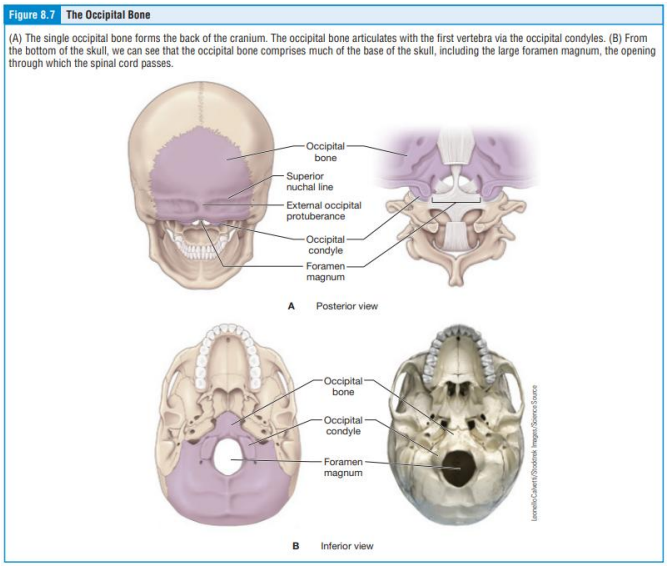
❖ **Parietal Bones** (2): Paired bones forming the superior lateral sides of the skull; articulate with *(forms a joint)* frontal, temporal, and occipital bones



❖ **Occipital Bone** (1): Forms the posterior skull and posterior base; contains the **foramen magnum** (passage for the spinal cord) and **occipital condyles** (joins with the first vertebra).

Bony markings (less critical to remember):

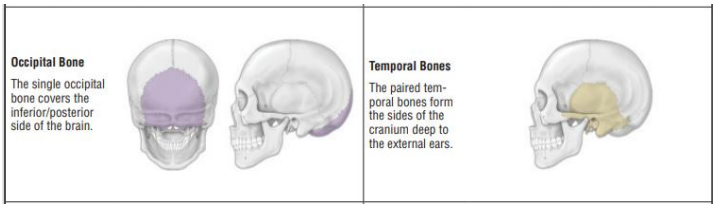
❖ Superior nuchal line, External occipital protuberance.



❖ **Temporal Bones** (2): Form the lower lateral sides of skull; features include the **external acoustic meatus** (ear canal), **mastoid process** (muscle attachment), and **mandibular fossa** (part of the jaw joint).

Bony markings (less critical to remember):

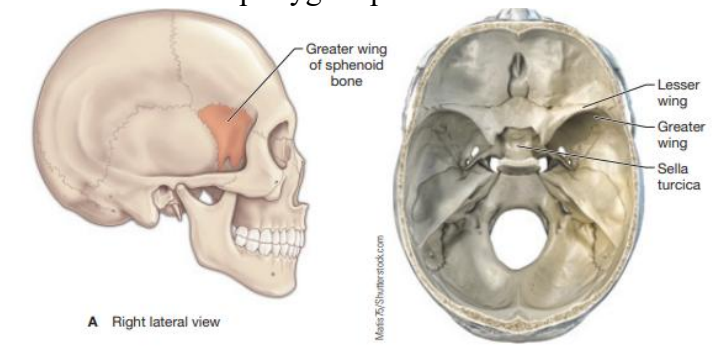
❖ Squamous portion, zygomatic process, articular tubercle, and styloid process.



- **Sphenoid Bone** (1): A single central "butterfly-shaped" bone that articulates with almost every other skull bone (the base of central skull); houses the **sella turcica** which protects the pituitary gland.

Bony markings (less critical to remember):

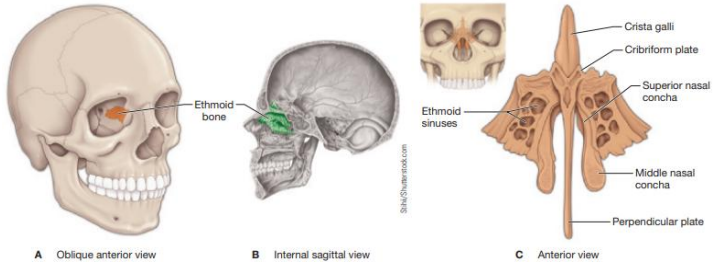
- Greater and lesser wings, pituitary fossa, medial and lateral pterygoid processes.

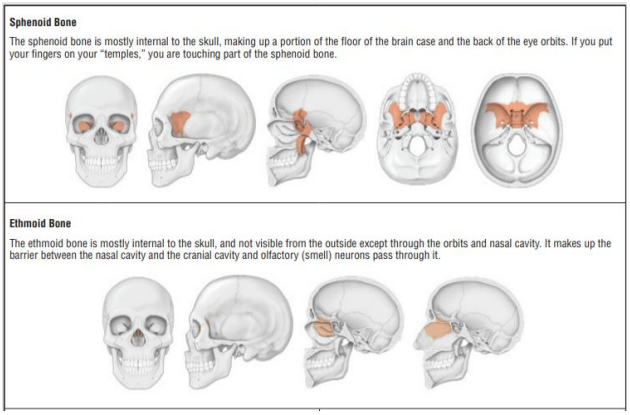


- **Ethmoid Bone** (1): Centrally located between orbits; forms the **nasal septum** (perpendicular plate) and the **crista galli** (brain attachment point). **Cribriform** (olfactory nerve passage)

Bony markings (less critical to remember):

- Superior and middle nasal conchae and Olfactory foramina.



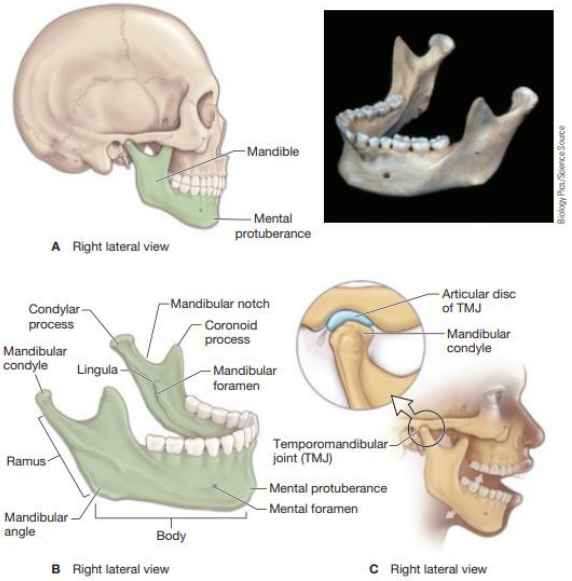


Facial Bones

- **Mandible** (1): The lower jaw; consists of a **body** (horizontal) and **ramus** (vertical); features the **condylar process** which forms the temporomandibular joint (TMJ).

Bony markings (less critical to remember):

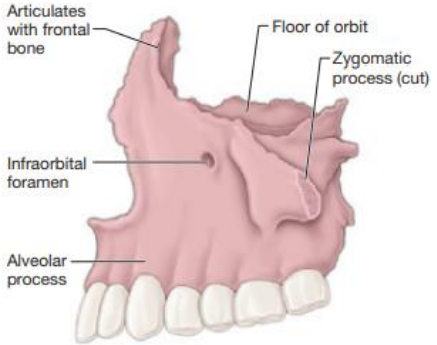
- Angle of Mandible (Jaw corner), coronoid process, mandibular notch, mental foramina, mental protuberance.

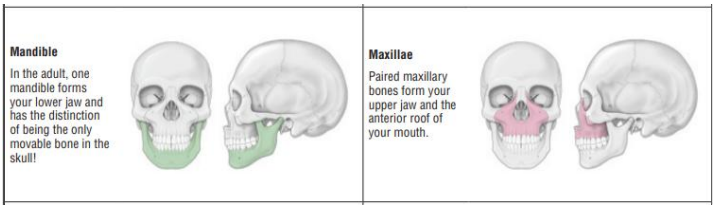


- **Maxillary Bone (Maxilla) (2)**: Forms the upper jaw, hard palate, most of the roof of the mouth, the lateral base of the nose, and floor of the orbit; contains the **alveolar process** (tooth sockets).

Bony markings (less critical to remember):

- Infraorbital foramen.



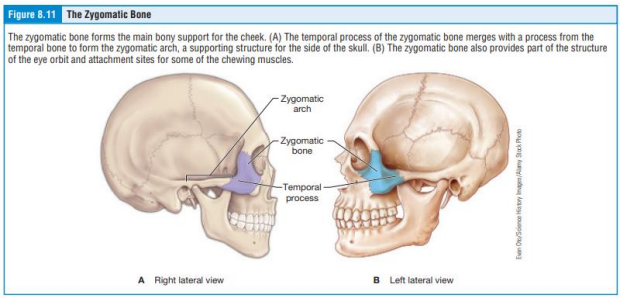


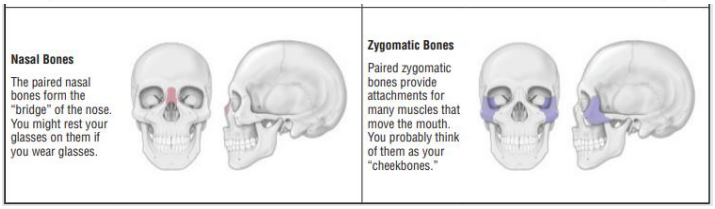
- **Nasal Bones** (2): Paired bones forming the bridge (bony base) and lateral walls of the nose.

- **Zygomatic Bone (2)**: The cheekbone; joins with the temporal bone to form the **zygomatic arch**; forms much of the lateral part of orbit.

Bony markings (less critical to remember):

- Temporal process.

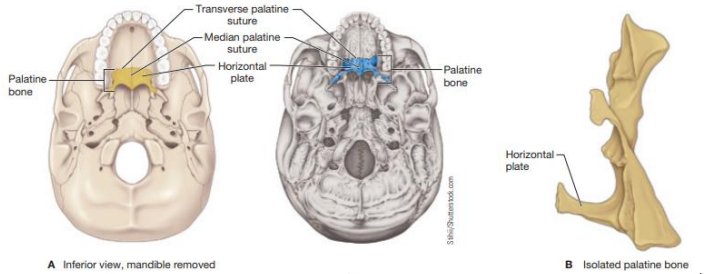


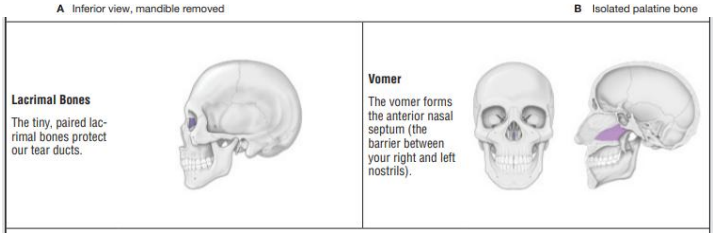


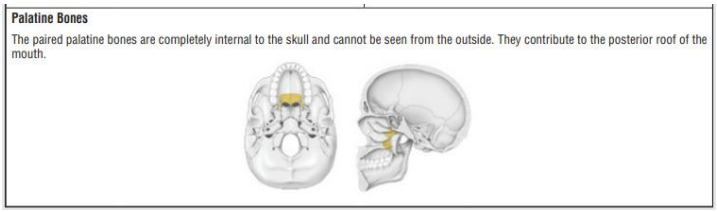
- **Lacrimal Bones (2)**: Small bones in the medial orbit (part of orbit) containing a duct for tears (**lacrimal glands**) to drain into the nasal cavity.

- **Vomer Bone** (1): Triangular bone forming the lower/posterior portion of the nasal septum.

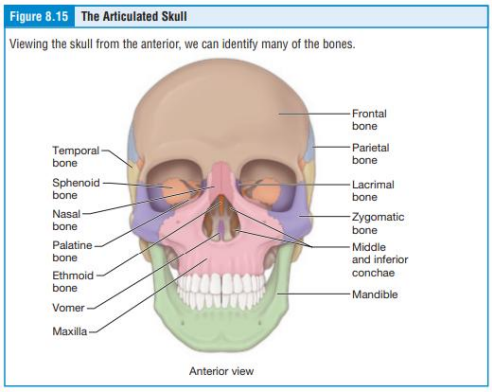
- **Palatine Bones (2)**: L-shaped bones forming the posterior portion of hard palate (roof of the mouth), medial part of orbit, and contributes to vertical section of nasal cavity.







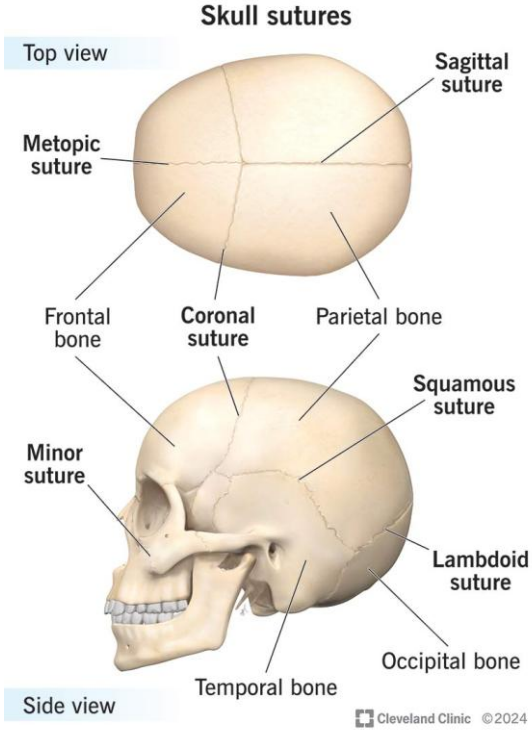
- **Inferior Nasal Conchae** (2): Part of the nasal cavity walls; project into nasal cavity; direct and condition airflow.



Sutures:

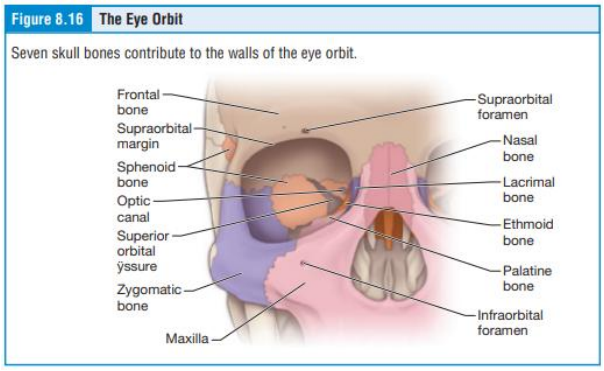
- **Sagittal Suture**: Joins the two parietal bones at the superior midline.
- **Coronal Suture**: connects frontal bone to parietal bones
- **Lambdoid Suture**: An inverted V-shaped joint connecting the parietal bones to the **occipital bone**.
- **Squamous Suture**: The joint connecting the parietal and temporal bones.

Specialized Features of the Skull



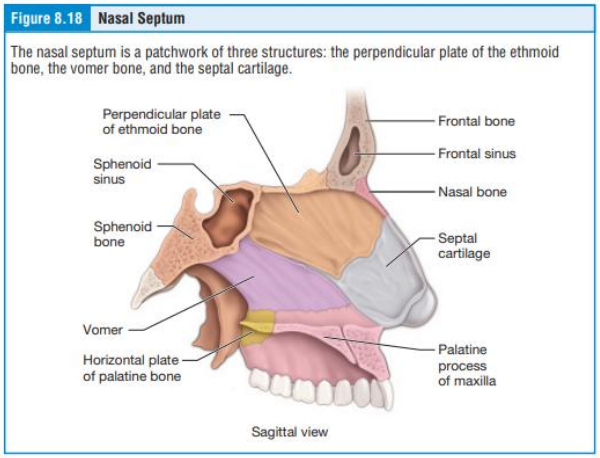
The Orbit (Eye Socket):

- Formed by **seven bones**: Frontal, zygomatic, maxilla, ethmoid, lacrimal, palatine, and sphenoid.
- Protects the eyeball and muscles that move it.
- **Optic Canal**: Opening at the posterior apex for the entry of optic nerve.
- Superior orbital fissure allows entry of blood supply.

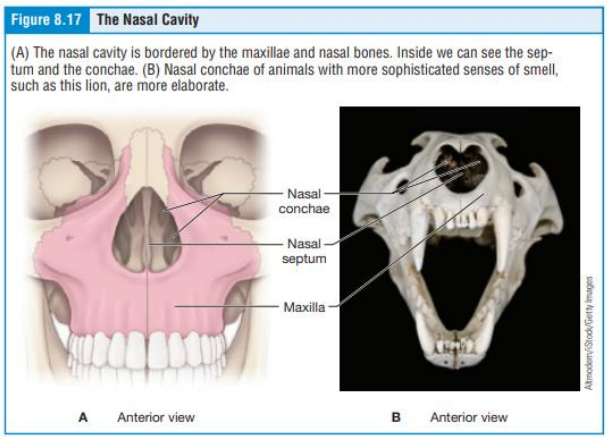


The Nasal Cavity and Conchae: Nasal cavity is bordered by maxillae and nasal bones.

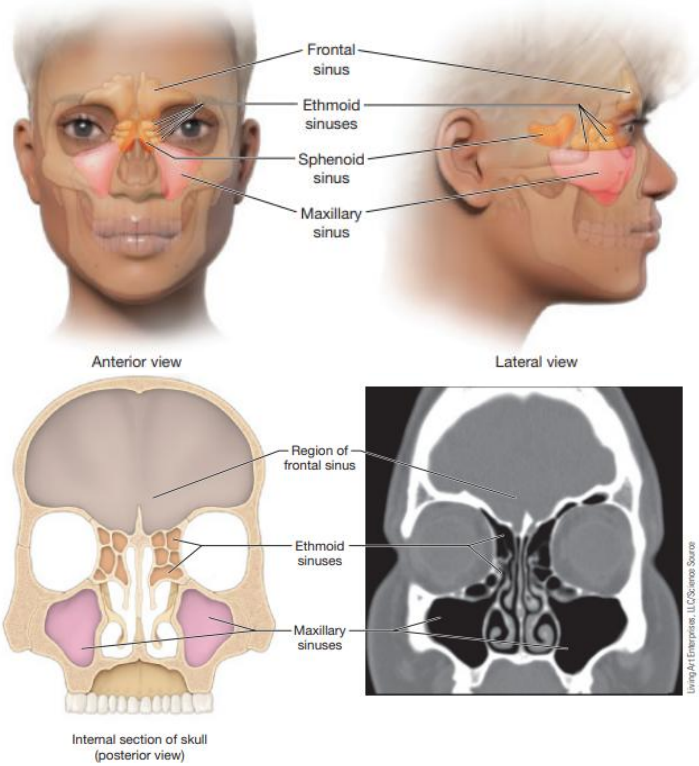
- **Nasal Septum**: Composed of the perpendicular plate (ethmoid), vomer, and septal cartilage; divides nasal cavity.



- **Nasal Conchae**: Bony ridges (superior, middle, inferior) that swirl inhaled air to warm, moisten, and filter it; covered by mucous membranes.

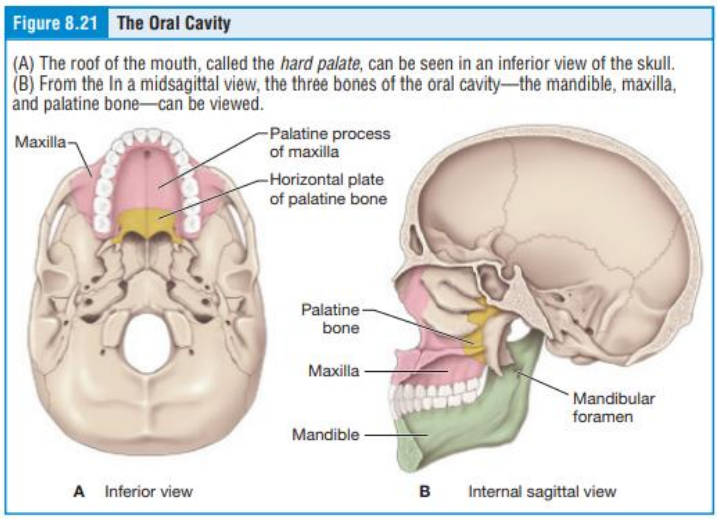


- **Paranasal Sinuses**: Hollow, air-filled spaces in the frontal sinus, maxillary sinuses, sphenoid sinus, and ethmoid sinus.
  - **Functions**: Add volume to skull without adding weight and adds resonance to the voice.
  - Connect to nasal cavity



The Oral Cavity (Mouth): Formed by maxillae, mandible, and palatine bones.

- Teeth are embedded in alveolar processes.
- **Hard Palate**: Formed by the palatine processes of the maxillae (anterior) and horizontal plates of the palatine bones (posterior).
- **Mandibular** (mental) **Foramen**: Opening on the inside of the jaw for nerves supplying the lower teeth (site for dental anesthesia).



Lateral View of the Skull

- **Zygomatic Arch**: The bony bridge spanning from the cheek to the ear; formed by the temporal process of the zygomatic bone and the zygomatic process of the temporal bone.
- **Temporal Fossa**: The shallow space above the zygomatic arch (the "temple").
- **Squamous Suture**.

Posterior View of the Skull

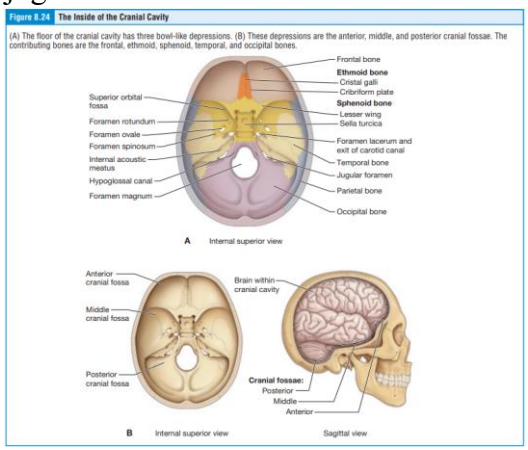
- Sagittal Suture.
- Lambdoid Suture.

The Brain Case (Cranial Cavity)

- Mostly occupied by the brain.
- **Calvaria**: The removable "skull cap" or rounded top of the skull.
- **Base of the Skull**: The complex floor of the brain case, divided into three descending levels (fossae).

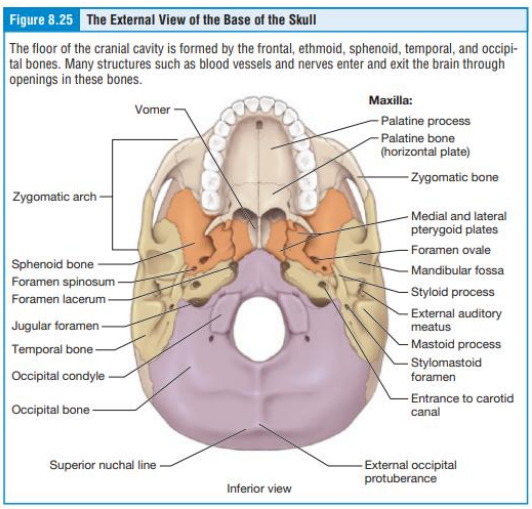
The Three Cranial Fossae

- **Anterior Cranial Fossa**: The shallowest level; overlies the orbits and houses the frontal lobes; contains crista galli and cribriform plates.
- **Middle Cranial Fossa**: Houses the temporal lobes; divided at the midline by the **sella turcica**; contains openings for blood vessels and nerves.
- **Posterior Cranial Fossa**: The deepest level; contains the cerebellum and the **foramen magnum** (exit for the spinal cord); contains internal acoustic meatus, hypoglossal canal, and jugular foramen.



Hormone	Source	Effect on Bone
Optic Canal (M)	Sphenoid	Optic nerve to the eye
Superior Orbital Fissure (M)	Sphenoid	Nerves for eye movement and forehead sensation
Foramen Rotundum (M)	Sphenoid	Sensory nerve to the cheek, nose, and upper teeth
Foramen Ovale (M)	Sphenoid	Sensory nerve to the lower teeth and chin
Foramen Spinosum (M)	Sphenoid	Entry for middle meningeal artery (brain covering)
Carotid Canal (M)	Temporal	Main artery to the brain (Internal Carotid)
Jugular Foramen (P)	Occipital/ Temporal	Jugular vein (blood leaving brain) and several nerves
Internal Acoustic Meatus (P)	Temporal	Nerves for hearing, equilibrium, and facial muscles
Stylomastoid Foramen (M)	Temporal	The exit of nerve to muscles of the face
Foramen Lacerum (M)	Base of the skull	No structures pass through here
Hypoglossal Canal (P)	Occipital	Nerve to the tongue

(M) - Middle Cranial Fossa (P) Posterior Cranial Fossa



Midsagittal Section of Skull:

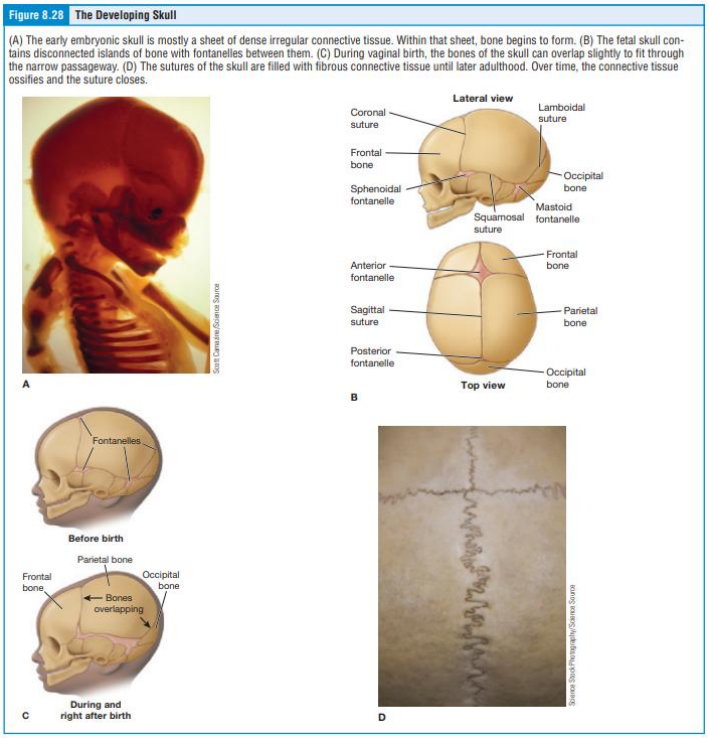
- Coronal Suture.
- Internal acoustic meatus.
- Sphenoid sinus.
- Nasal septum.

Brain-to-Body Size Ratio: Compared to other primates, humans have a high head-to-body ratio, which means the fetal skull must be more flexible during birth.

- Human neonate head – Nearly the same size as the pelvic outlet, making childbirth more difficult.

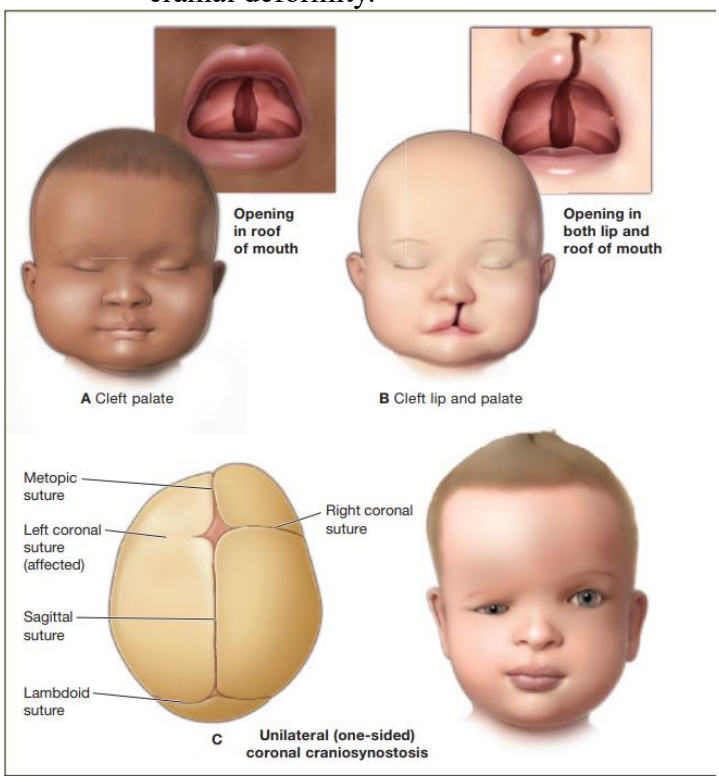
Skull Development and Aging of the Skull:

- **Fontanelles**: "Soft spots" of dense connective tissue between fetal cranial bones; allow the skull to compress in the birth canal and expand as the brain grows; bones are not fully fused until adulthood.
- Early embryonic skull is mainly sheets of connective tissue.
- **Ossification Timing**:
  - Fontanelles typically close by **age 2**.
  - Sutures remain flexible during childhood but eventually ossify in adulthood.
  - **Forensic Use**: Suture ossification patterns help estimate the age of skeletal remains.

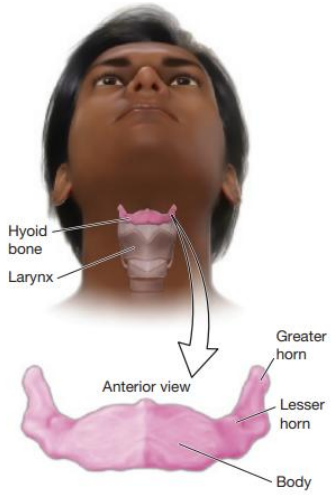


Application: Fusion Disorders:

- **Cleft lip**: Results from partial or complete failure of upper lip to fuse together.
- **Cleft palate**: Results from failure of the hard palate to fuse completely
- **Craniosynostosis** is the premature fusion of a suture line.
  - Results in abnormal growth of skull and cranial deformity.



- ***Auditory Ossicles**: Three tiny bones in the middle ear (**malleus, incus, and stapes**) located within the temporal bone.*
- **Hyoid Bone**: A U-shaped bone in the upper neck that anchors the tongue; used primarily for muscle attachment
  - The hyoid is the **only bone** in the body that does not articulate (contact) with any other bone.
  - **Forensic Significance**: A broken hyoid bone is often a clinical indicator of strangulation.



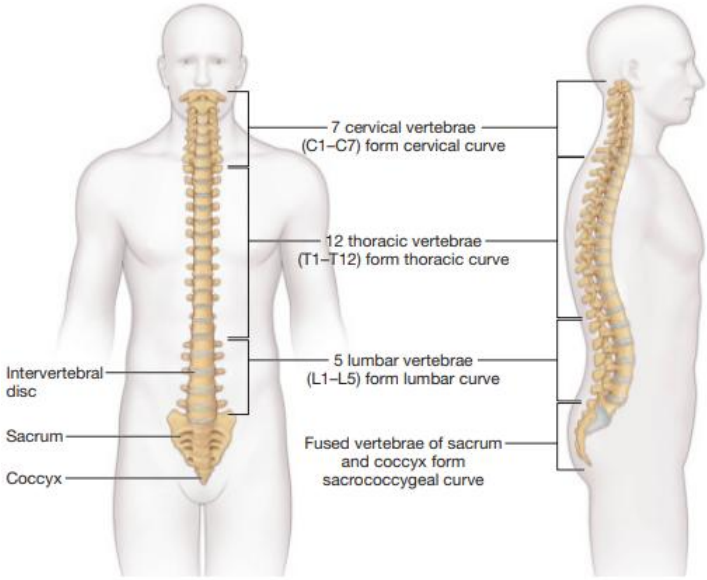
The Vertebral Column (Spine): A flexible column of vertebrae separated by intervertebral discs.

Functions:

- Supports the head, neck, and upper body.
- Protects the spinal cord via the vertebral canal.
- Allows for trunk movements and shock absorption.
- **Total Count**: 24 individual vertebrae + 1 sacrum (5 fused) + 1 coccyx (4 fused).

Regions of the Vertebral Column

- **Cervical (C1–C7):** The neck region; almost all mammals have seven cervical vertebrae.
- **Thoracic (T1–T12):** The mid-back; each vertebra articulates with a pair of ribs.
- **Lumbar (L1–L5):** The lower back; characterized by large, thick bodies to support maximum weight.
- **Sacrum**: 5 vertebrae fused into one triangular bone; part of the pelvis.
- **Coccyx**: 4 small fused vertebrae forming the "tailbone."



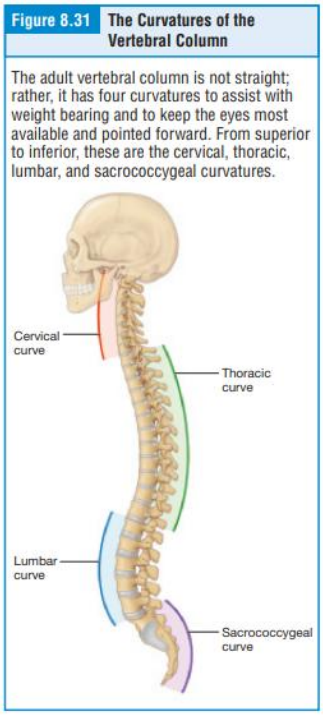
Curvatures and Disorders

Primary vs. Secondary Curves

- Primary Curves: Retained from the fetal position (anteriorly concave); include Thoracic and Sacrococcygeal curves.
- Secondary Curves: Develop after birth; Cervical curve (holding head up) and Lumbar curve (standing/walking).

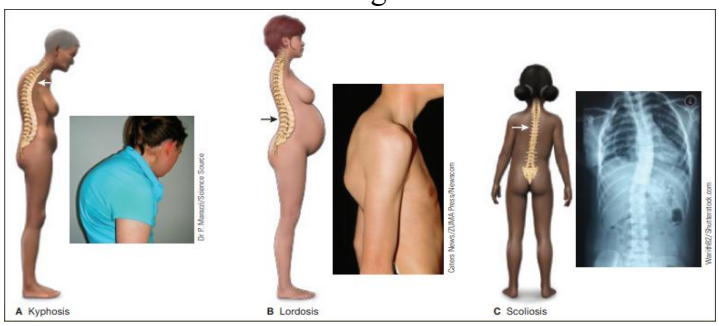
Four curvatures increase strength, flexibility, and shock absorption.

- **Cervical curve** (posteriorly oriented).
- **Thoracic curve** (anteriorly oriented).
- **Lumbar curve** (posteriorly oriented).
- **Sacrococcygeal curve** (anteriorly oriented)



Spinal Disorders

- **Kyphosis**: Excessive posterior curvature of the thoracic region ("**hunchback**").
- **Lordosis**: Excessive anterior curvature of the lumbar region ("**swayback**").
- **Scoliosis**: Abnormal lateral (side-to-side) curvature and twisting.

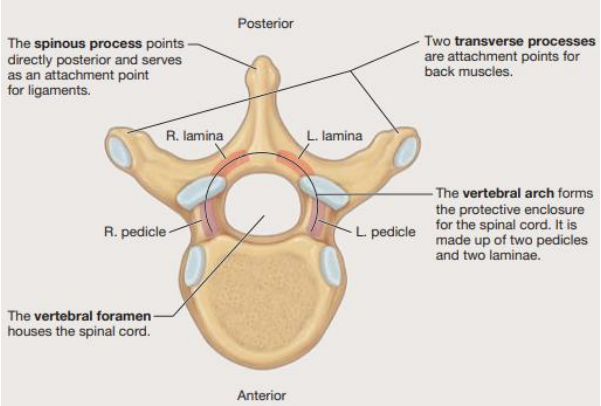


General Structure of a Vertebra

- **Vertebral Body**: The bulky anterior part that supports weight; size increases descending the spine.
- **Vertebral Arch**: Forms the posterior portion; consists of **pedicles** (sides) and **laminae** (roof).
- **Vertebral Foramen**: The large opening in the center for the spinal cord.
- Processes:
  - **Spinous Process**: Single posterior projection (felt as bumps on the back).
  - **Transverse Processes**: Paired lateral projections for muscle/rib attachment.

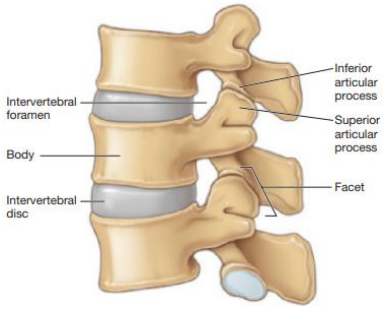
- **Articular Processes**: Superior and inferior projections that form joints with adjacent vertebrae.

❖ **Intervertebral Foramen**: Lateral opening between vertebrae where spinal nerves exit.



Articulated Vertebrae: Intervertebral discs are between the bodies of each vertebrae.

- Superior and inferior articular processes unite the vertebrae posteriorly.
- Intervertebral foramen allow spinal nerves to exit.



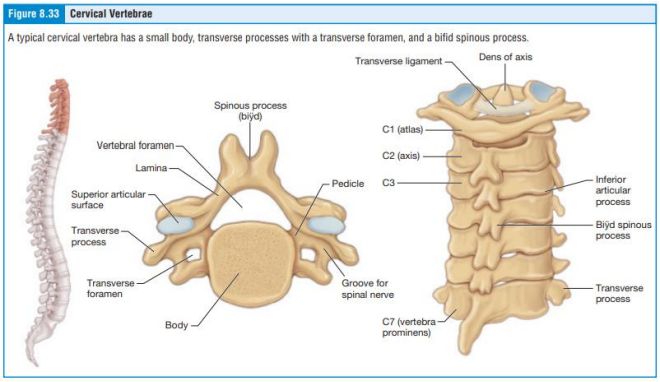
Regional Characteristics

Cervical Vertebrae (C1–C7):

❖ Features: **Small** bodies, **bifid (Y-shaped) spinous processes**, and **transverse foramina** (holes for brain-bound arteries).

❖ **Atlas (C1)**: Ring-shaped; lacks a body and spinous process; supports the skull; allows head to move in a "**yes**" motion

❖ **Axis (C2)**: Features the dens (odontoid process), which acts as a pivot for head rotation; allows head to move in a "**no**" motion

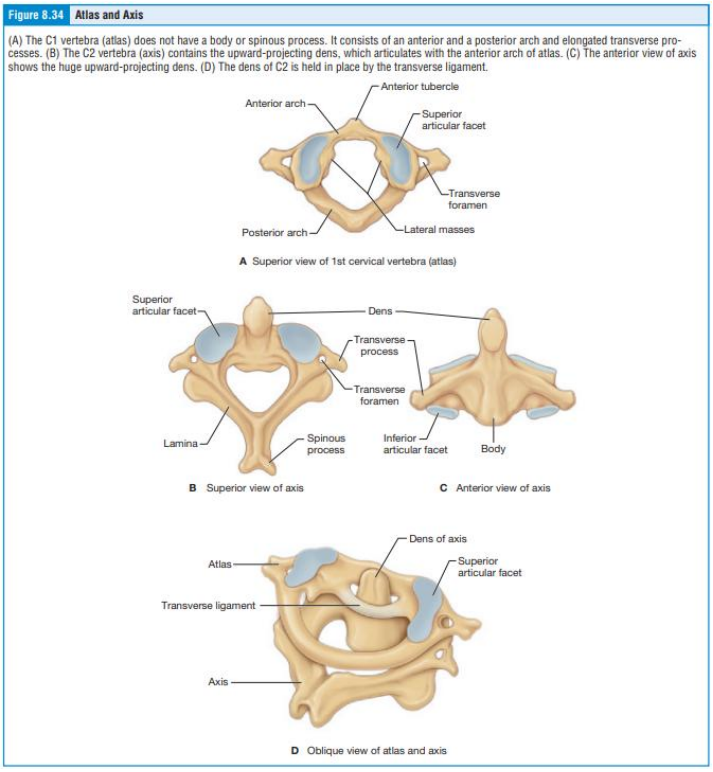


Thoracic Vertebrae (T1–T12):

❖ Vertebral bodies increase in size as you descend the spinal column

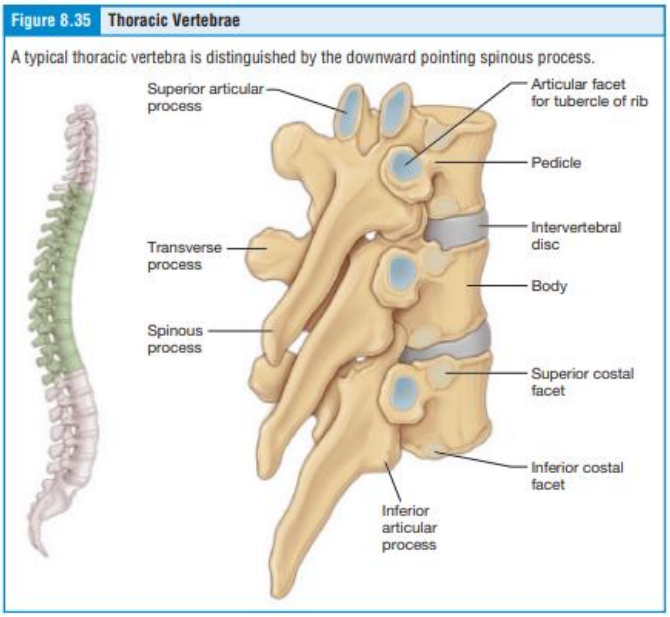
❖ Features: **Long**, downward-pointing spinous processes.

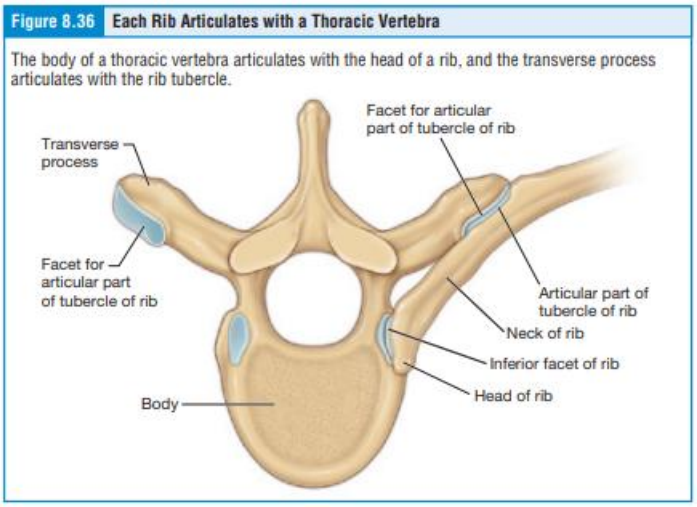
❖ Facets: Specialized surfaces on the body and transverse processes for rib articulation.



Ribs Articulate with Thoracic Vertebrae: Bodies of thoracic vertebrae articulate with heads of ribs.

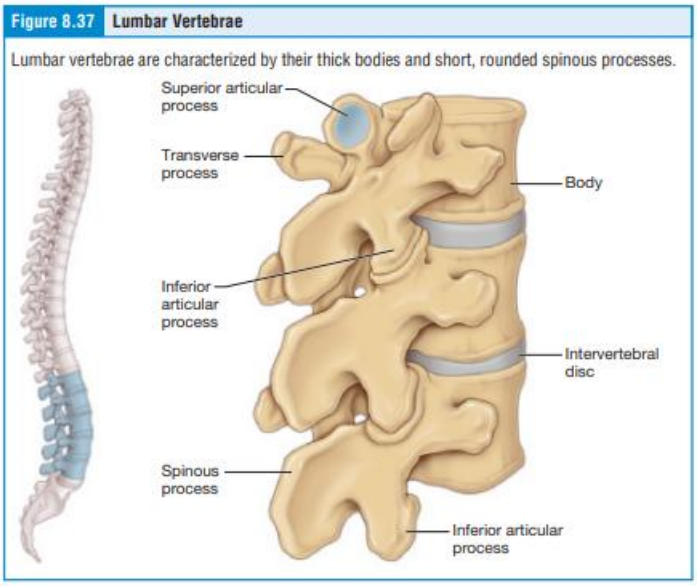
- Transverse processes of thoracic vertebrae articulate with rib tubercles.





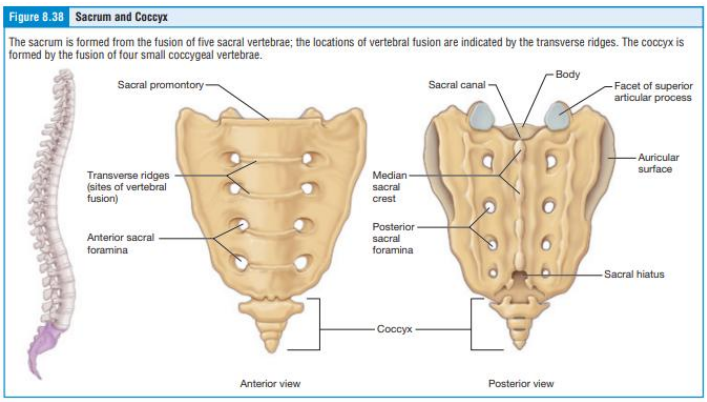
Lumbar Vertebrae (L1–L5):

- Features: **Largest**, thickest bodies; short, blunt spinous processes.



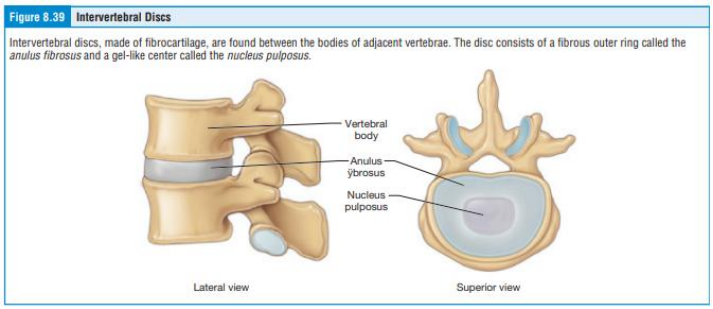
Sacrum and Coccyx

- Sacrum: Median sacral crest; openings are called sacral foramina.
- Sacral Promontory: The anterior lip of the base (top) of the sacrum; superior portion of sacrum.
- Auricular Surface: Roughened area that joins the hipbone to form the sacroiliac joint.



Intervertebral Discs

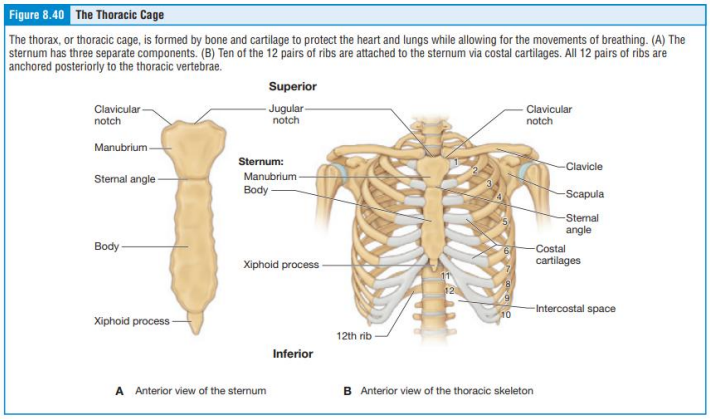
- Function: **Provide padding/cushion** between vertebrae, allow movement, and account for 25% of body height.
- Anchor vertebrae to each other.
- Structure:
  - **Anulus Fibrosus**: The tough, fibrous **outer ring/layer**.
  - **Nucleus Pulposus**: The **soft**, **gel-like** inner core with high water content; resists compression.
- Clinical Note: Discs compress throughout the day (making you shorter at night) and thin with age as water content decreases.



The Sternum (Breastbone)

Parts of the Sternum

- **Manubrium**: The wide, superior portion.
  - **Suprasternal Notch**: U-shaped border felt at the base of the neck.
  - **Clavicular Notch**: Points of articulation for the clavicles (collarbones).
- **Body**: The elongated central portion.
  - **Sternal Angle**: The "bump" where the manubrium and body meet; serves as a landmark for the **second rib**.
- **Xiphoid Process**: The inferior tip; starts as cartilage and ossifies during middle age.

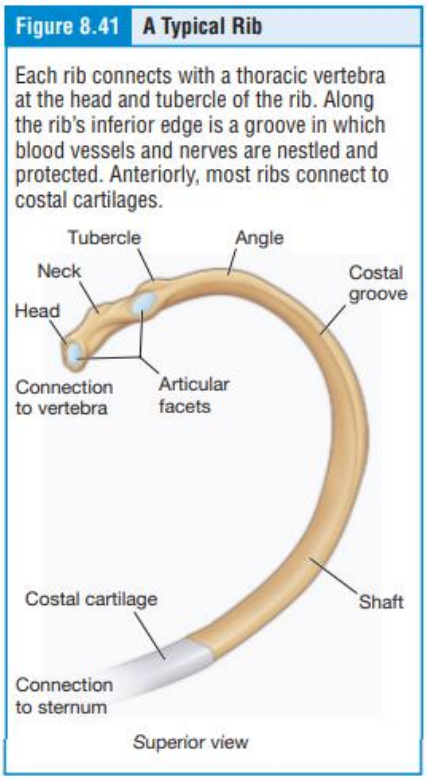


The Thoracic Cage (Rib Cage): The bony and cartilaginous structure forming the thorax (chest).

- **Composition**: 12 pairs of ribs, their associated **costal cartilages**, and the **sternum**.
- **Primary Function**: Protects the heart and lungs while providing flexibility for respiration.

The Ribs: 12 pairs of curved, flat bones that articulate posteriorly with thoracic vertebrae.

- **Costal Cartilages**: Hyaline cartilage strips that connect ribs to the sternum (either directly or indirectly).



Structure of a Typical Rib

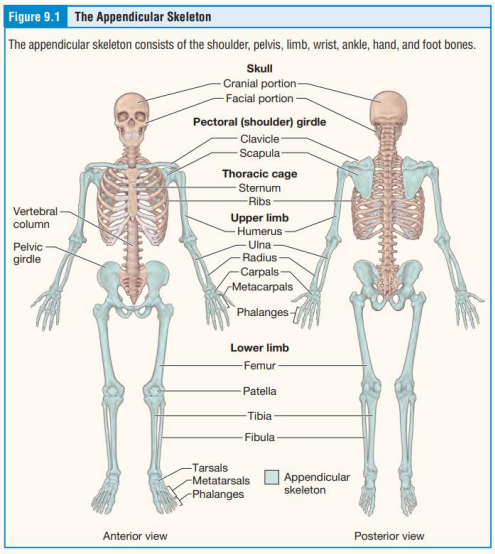
- **Head**: The posterior end that articulates with the body of the thoracic vertebra.
- **Neck**: The narrowed region lateral to the head.
- **Tubercle**: A small bump on the posterior neck that articulates with the **transverse process** of the vertebra.
- **Angle**: The point where the rib curves dramatically toward the anterior body.
- **Body (Shaft)**: The main, curved portion of the rib.
- **Costal Groove**: A shallow groove on the inferior margin that houses blood vessels and nerves.

Classification of Ribs

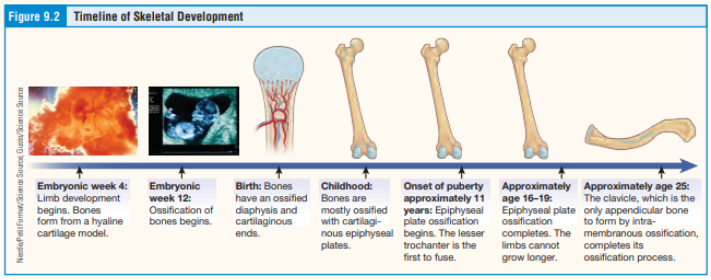
- **True Ribs (1–7)**: Costal cartilages attach **directly** to the sternum.
- **False Ribs (8–12)**: Do not attach directly to the sternum.
  - **Ribs 8–10**: Cartilage attaches to the cartilage of the rib above it.
  - **Floating Ribs (11–12)**: A subset of false ribs that have no costal cartilage and do not articulate with the sternum at all.

The Appendicular Skeleton:

- Bones found in the upper and lower limbs.
- Bones that attach the limbs to axial skeleton.

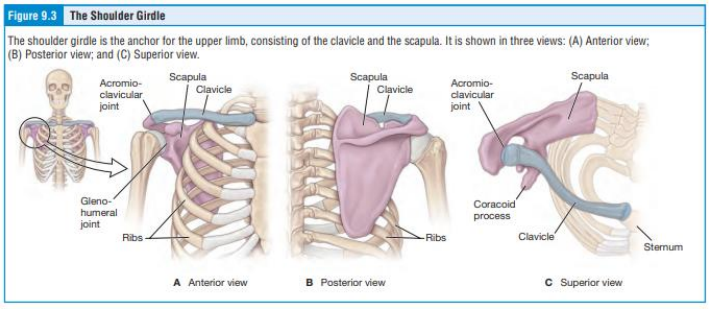


- Appendicular skeleton development begins before birth.
- Continues through early adulthood.
- Completion occurs around age 25.



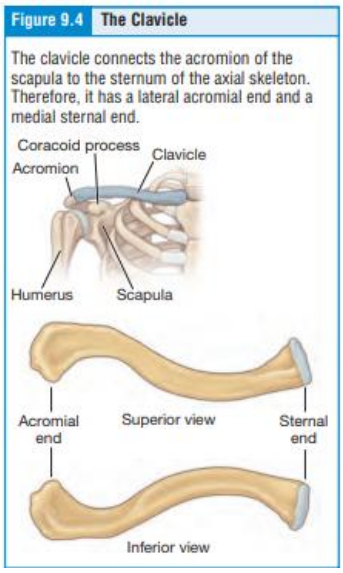
The Pectoral (Shoulder) Girdle: the set of bones that attaches the upper limbs to the axial skeleton.

- **Components**: Consists of two bones—the **clavicle** (anterior) and the **scapula** (posterior).
- **Function**: Supports the upper limb and provides maximal range of motion by holding the shoulder joint away from the rib cage.
- Serve as attachment sites for muscles that move shoulder and arm.



The Clavicle (Collarbone): S-shaped long bone; the only horizontal long bone in the body; loosely-anchored

- **Sternal End**: The medial, triangular end that forms the **sternoclavicular joint** with the manubrium.
- **Acromial End**: The lateral, flattened end that forms the **acromioclavicular joint** with the scapula.



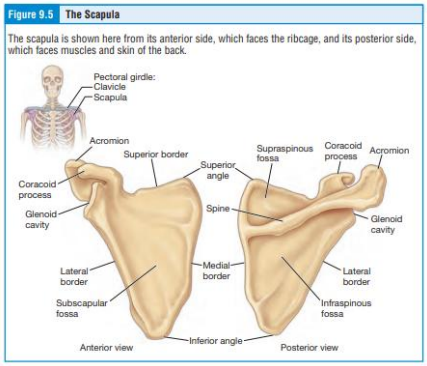
❖ *Key Functions:*

- *Acts as a strut to push the shoulder laterally, preventing anterior collapse.*
- *Protects underlying neurovascular structures passing from the trunk to the arm.*

❖ *Forensics: Generally longer, more curved, and rougher in biological males; thinner and smoother in biological females.*

The Scapula (Shoulder Blade): Flat, triangular bone located on the posterior shoulder; does not articulate directly with the ribs.

- ❖ **Borders & Angles**: Features superior, medial, and lateral borders; and superior and inferior angles.
- ❖ **Glenoid Cavity**: A shallow depression that articulates with the humerus to form the **glenohumeral (shoulder) joint**.



❖ *Projections:*

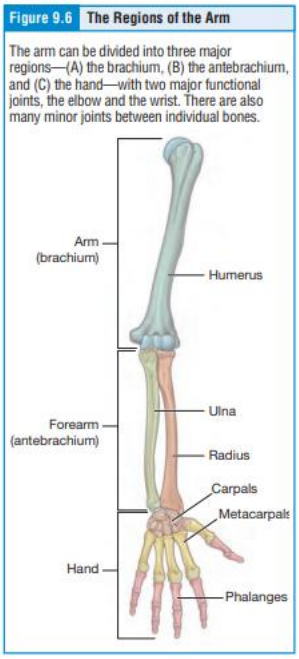
- *Spine: A prominent ridge on the posterior surface.*
- *Acromion: The flattened lateral end of the spine; forms the bony tip of the shoulder.*
- *Coracoid Process: An anterior, hook-like projection for muscle attachment.*

❖ *Fossae (Depressions):*

- *Supraspinous Fossa: Above the spine (posterior).*
- *Infraspinous Fossa: Below the spine (posterior).*
- *Subscapular Fossa: The broad anterior surface (deep).*

The Upper Limb: Brachium (Arm)

- ❖ **Proximal-to-Distal Rule**: Fewer, larger bones proximally (stability); more, smaller bones distally (dexterity).



❖ **Regions**:

- **Brachium**: Shoulder to elbow (Humerus).
- **Antebrachium**: Elbow to wrist (Ulna and Radius).
- **Hand**: Carpal bones, metacarpals, and phalanges.

The Humerus

❖ **Proximal Features**:

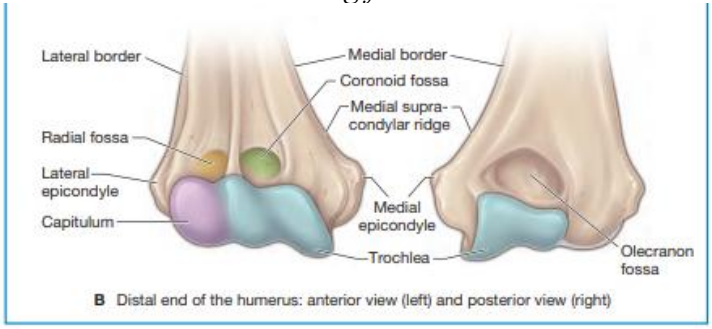
- **Head**: Smooth, rounded part that fits into the glenoid cavity.
- **Anatomical Neck**: The line marking the edge of the articular cartilage.
- **Greater & Lesser Tubercles**: Roughened projections for rotator cuff muscle attachment.
- **Surgical Neck**: The narrowed region below the tubercles; a frequent site for fractures.
- **Deltoid Tuberosity**: A rough V-shaped area on the lateral shaft for the deltoid muscle.

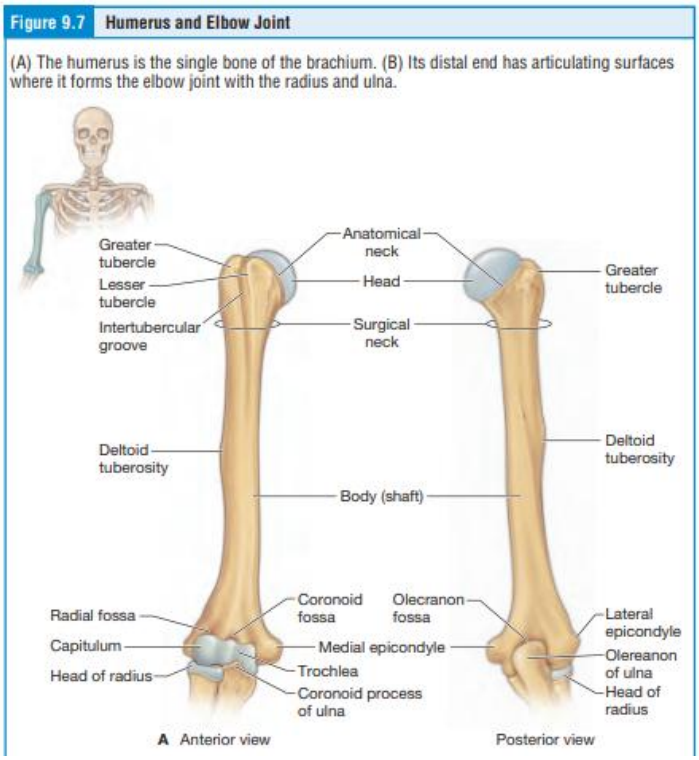
❖ **Distal Features (The Elbow Joint)**:

- **Medial & Lateral Epicondyles**: Bony bumps for forearm muscle attachment; the medial is larger.
- **Trochlea**: Pulley-shaped medial surface that articulates with the **ulna**.
- **Capitulum**: Knob-like lateral surface that articulates with the **radius**.

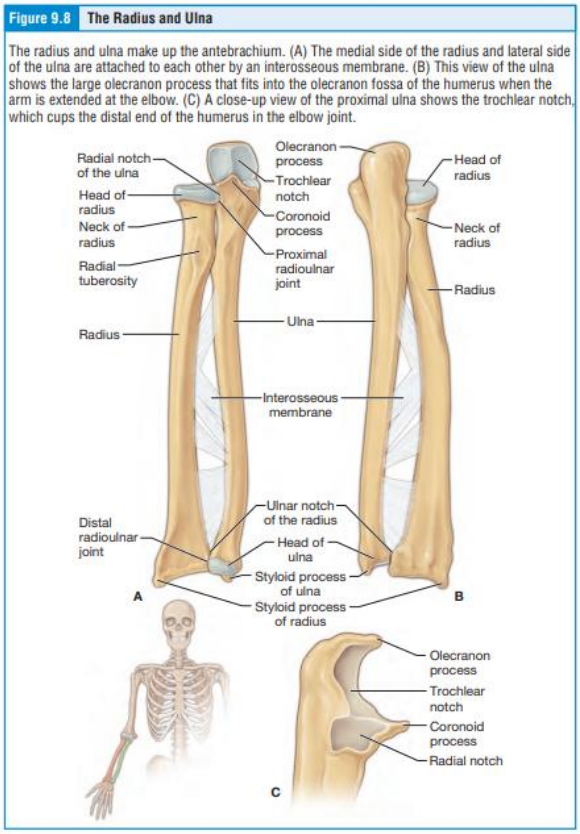
❖ *Depressions (Fossae):*

- *Coronoid Fossa: Anterior; receives the ulna when the elbow is flexed.*
- *Olecranon Fossa: Posterior; receives the "elbow bone" (ulna) when the arm is straight.*
- *Radial Fossa: Anterior; receives the head of the radius during flexion.*



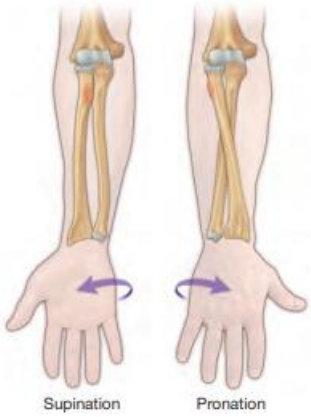


Bones of the Forearm: Radius and Ulna



- ❖ **The Ulna (Medial)**: The bone on the "pinky side" of the forearm.
  - Medial bone of antebrachial region.
  - Allows hinge-like motion of forearm.
  - **Trochlear Notch**: Large C-shaped depression that fits around the humerus to form the elbow hinge.
  - **Olecranon Process**: The bony tip of the elbow (posterior).
  - **Coronoid Process**: The anterior lip of the trochlear notch.
  - Olecranon and coronoid processes form trochlear notch.
    - Articulates with trochlea of humerus at elbow.
  - **Styloid Process of the Ulna**: Small distal projection for connective tissue attachment.

- ❖ **The Radius (Lateral)**: The bone on the "thumb side" of the forearm.
  - Lateral bone of antebrachial region.
  - Head articulates with capitulum of humerus at elbow.
  - Rotates around ulna to allow pronation and supination of forearm.
  - **Interosseous Membrane**: A tough, fibrous sheet connecting the shafts of the radius and ulna Distal end articulates with carpal bones.
  - *Radial Tuberosity: Rough area for biceps attachment.*
  - *Styloid Process of the Radius: Distal projection that limits wrist movement.*
- ❖ *Radioulnar Joints:*
  - *Proximal: Where the radial head rotates against the ulna.*
  - *Distal: Where the ulnar head fits into the ulnar notch of the radius.*
- ❖ **Pronation and Supination**: Movement where the radius rotates over the ulna to turn the palm down/inferior (pronation) or up/superior (supination).



Bones of the Wrist and Hand

The Carpal Bones (Wrist)

- ❖ Consists of **8 bones** arranged in two rows (Lateral to Medial):

- **Proximal Row**: Scaphoid, Lunate, Triquetrum, Pisiform (the "bony bump" at the medial base).
- **Distal Row**: Trapezium, Trapezoid, Capitate, Hamate (features a "hook").

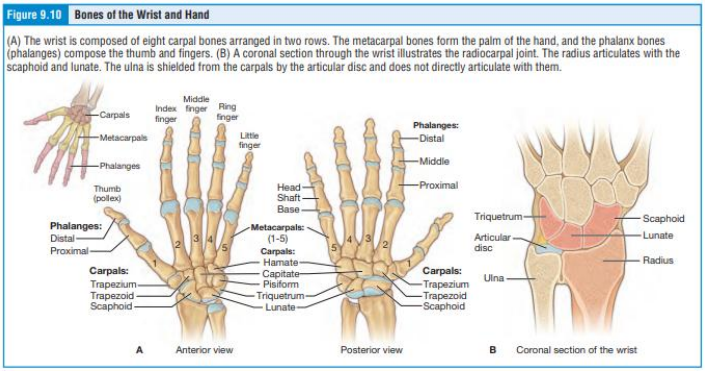
❖ *Wrist Joint: Formed specifically by the radius articulating with carpal bones; the ulna is separated from the joint by a fibrocartilage disc.*

The Metacarpals and Phalanges

❖ **Metacarpals (1–5)**: Five bones forming the palm, numbered starting from the thumb.

❖ **Phalanges (Fingers)**: 14 total bones.

- **Thumb (Pollex)**: 2 phalanges (proximal, distal).
- **Digits 2–5**: 3 phalanges each (proximal, middle, distal).
  - ➢ Named according to relative position.
  - ➢ Proximal, middle, and distal phalanges.
  - ➢ Thumb only has proximal and distal phalanges.



Fractures of Upper Limb Bones:

❖ Usually occur as a result of breaking a fall.

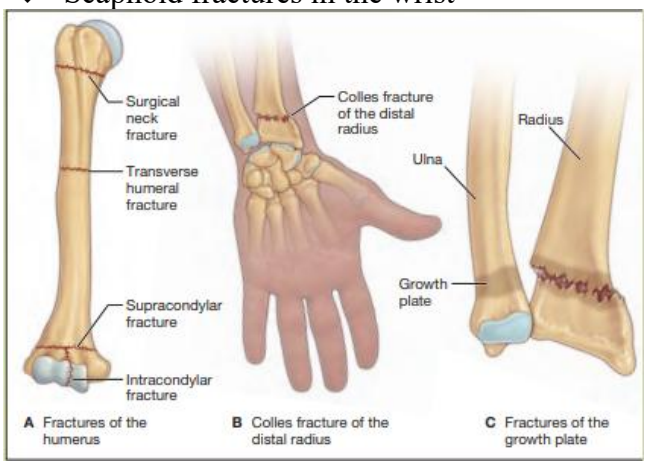
❖ Outstretched hand sends force through upper limb.

- ➢ Force may result in fracture.

❖ Surgical neck, transverse, supracondylar, and intracondylar fractures of the humerus.

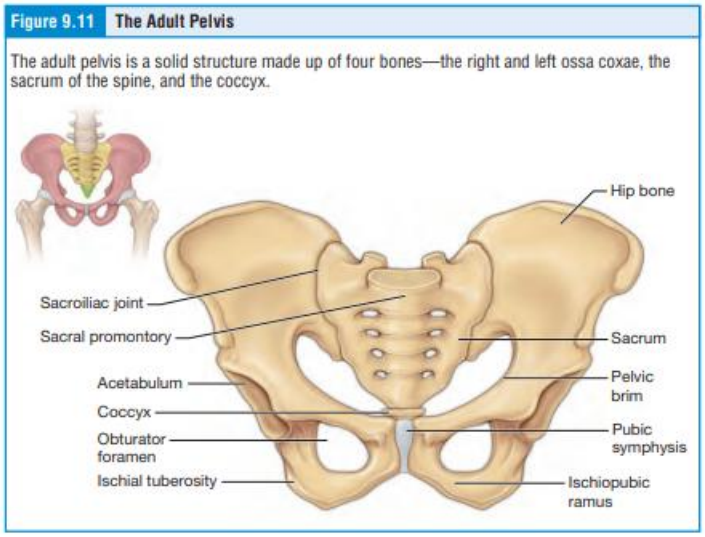
❖ Colles' fracture of the radium.

❖ Scaphoid fractures in the wrist



Pelvic Girdle (Pelvis): Formed by two Os Coxae (hip bones), the sacrum (fused bone), and the coccyx.

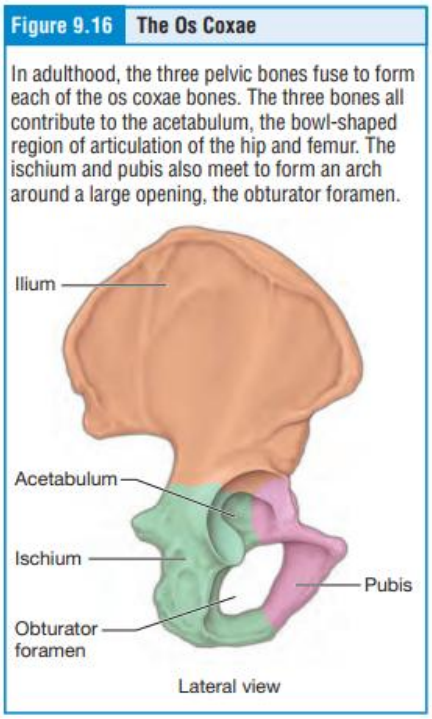
❖ **Function**: A largely immobile, weight-bearing structure specialized for stability.



The Os Coxae (Hip Bone)

❖ Anchored anteriorly by the pubic symphysis.

❖ Anchored posteriorly to the sacrum.

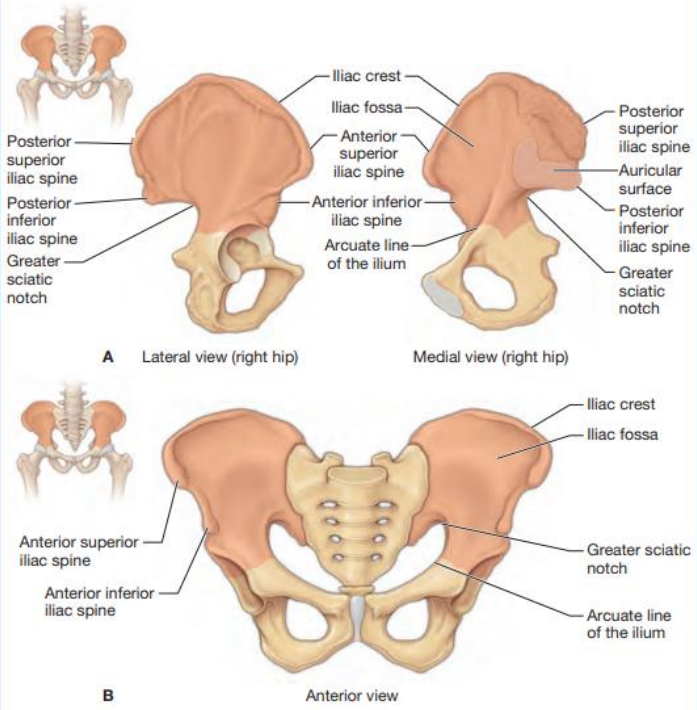


❖ Composed of three bones that fuse in the late teens:

- **Ilium**: The superior, fan-shaped, largest portion. Features the **iliac crest** (hip ridge) and **greater sciatic notch** (for the sciatic nerve).
  - ▪ Site of large muscle attachments.
  - ▪ Move lower extremity.
  - ▪ Bony markings: Iliac spines, Iliac fossa, Iliac spines.

Figure 9.13 The Ilium

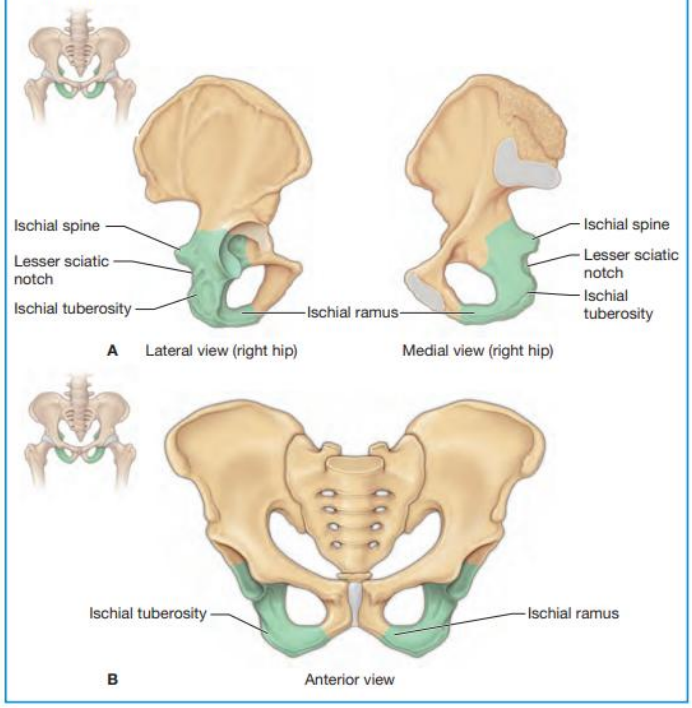
The ilium forms the large fan-shaped superior portion of the hip bone. (A) Lateral and medial views. (B) Anterior view.



- **Ischium**: The posteroinferior portion. Site where large muscles attach. Features the **ischial tuberosity** ("sit bones") which supports weight while seated.
  - Bony markings: Ischial ramus, Lesser sciatic notch, Ischial spine.

Figure 9.14 The Ischium

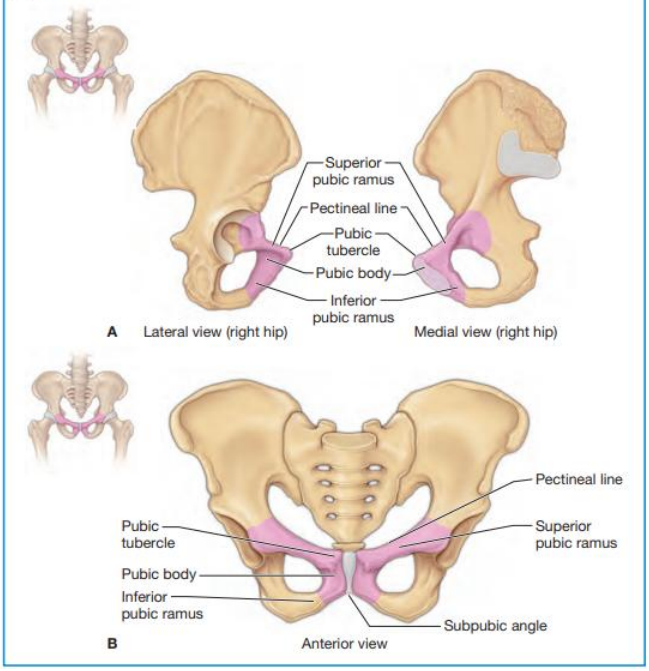
The ischium forms the posteroinferior portion of the hip bone. (A) Lateral and medial views. (B) Anterior view.



- **Pubis**: The anterior portion. Joins the opposite hip bone at the **pubic symphysis**.
  - Bony markings: Pubic body, Pubic tubercle, Superior and inferior rami, Pectineal line, Inferior pubic ramus.

Figure 9.15 The Pubis

The pubis forms the anteromedial portion of the hip bone. (A) Lateral and medial views. (B) Anterior view.



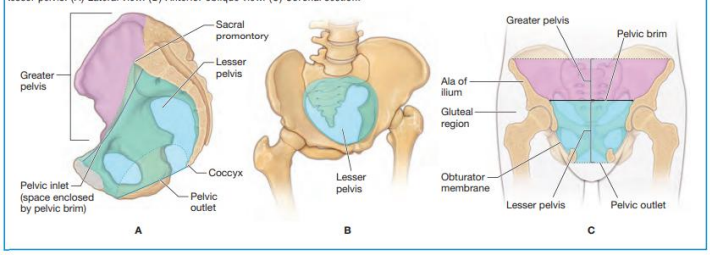
- ❖ **Acetabulum**: The deep, cup-shaped socket where the ilium, ischium, and pubis meet (fusion site); head of femur articulates here to form hip joint.
- ❖ **Obturator Foramen**: Large opening between the pubis and ischium for nerve passage to reach anterior leg.

Boundaries of the Pelvis

- ❖ **Pelvic Brim**: The dividing line between the upper and lower pelvis.
- ❖ **Greater (False) Pelvis**: Superior to the brim; houses intestines.
- ❖ **Lesser (True) Pelvis**: Inferior to the brim; contains reproductive organs, bladder, and rectum.
- ❖ **Pelvic Inlet** (roof)/**Outlet** (floor): The narrow openings the fetus must pass through during childbirth.

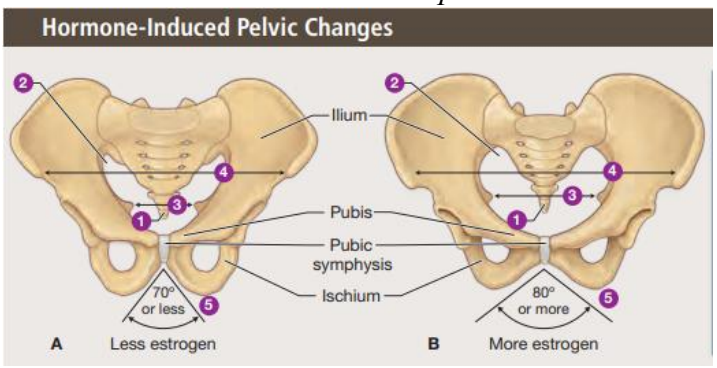
Figure 9.17 The Pelvic Inlet and Outlet

The passageway through the pelvis narrows in two places—the pelvic inlet and the pelvic outlet. These landmarks form the borders of the greater and lesser pelvis. (A) Lateral view. (B) Anterior oblique view. (C) Coronal section.

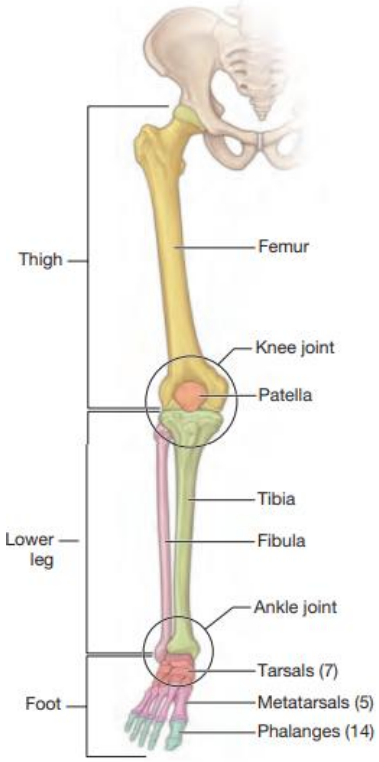


Biological Sex Differences

- **Female Pelvis (High Estrogen Influence)**:
  - Wider and shallower for childbirth.
  - Subpubic angle: Usually (wider) greater than 80 degrees.
  - **Pelvic Inlet**: Rounded or oval-shaped.
  - **Sciatic Notch**: Narrower.
  - Greater distance between ischial tuberosities in female pelvis.
  - Greater distance between anterior iliac spines in female pelvis.
- **Male Pelvis**:
  - Narrower, taller, and more robust.
  - Larger and heavier.
  - *Subpubic angle: Usually less than 70 degrees.*
  - *Pelvic Inlet: Heart-shaped.*



The Lower Limb: Specialized for weight-bearing and stability, featuring the strongest bones in the human body.

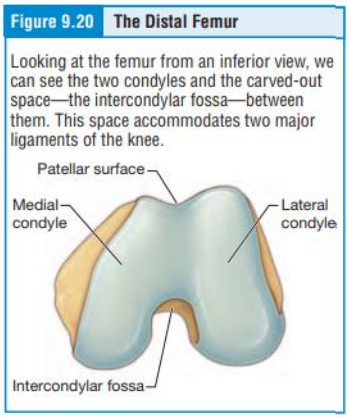


The Thigh Region:

The Femur (Thigh Bone): The longest, heaviest, and strongest bone in the body; accounts for 25% of total height.

- Head articulates with acetabulum of os coxae to form hip joint.
- Multiple markings for muscle attachment.

Distal Femur:



- **Medial and Lateral Condyles**: Smooth surfaces that articulate with the tibia to form the knee joint.
- Intercondylar fossa accommodates ligaments of the knee; anterior and posterior cruciate ligaments.
- Patellar surface articulates with patella
- *Medial and Lateral Epicondyles: Roughened areas above the condyles for ligament and muscle attachment.*
- *Patellar Surface: Anterior U-shaped groove where the kneecap slides.*

Proximal Femur:

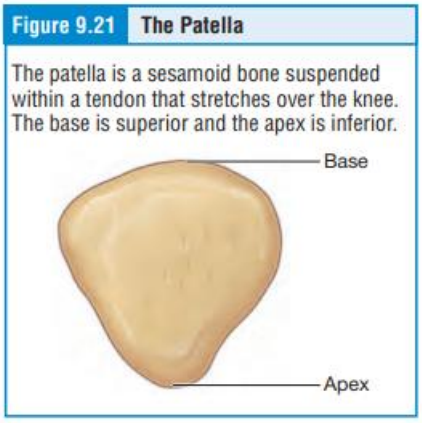
- *Head: Rounded end that fits into the acetabulum; contains the fovea capitis (a small pit for a ligament and artery).*
- *Neck: Narrow region between head and trochanters; common fracture site.*
- *Greater Trochanter: Large lateral projection for hip muscle attachment.*
- *Lesser Trochanter: Medial projection for a powerful hip flexor muscle.*

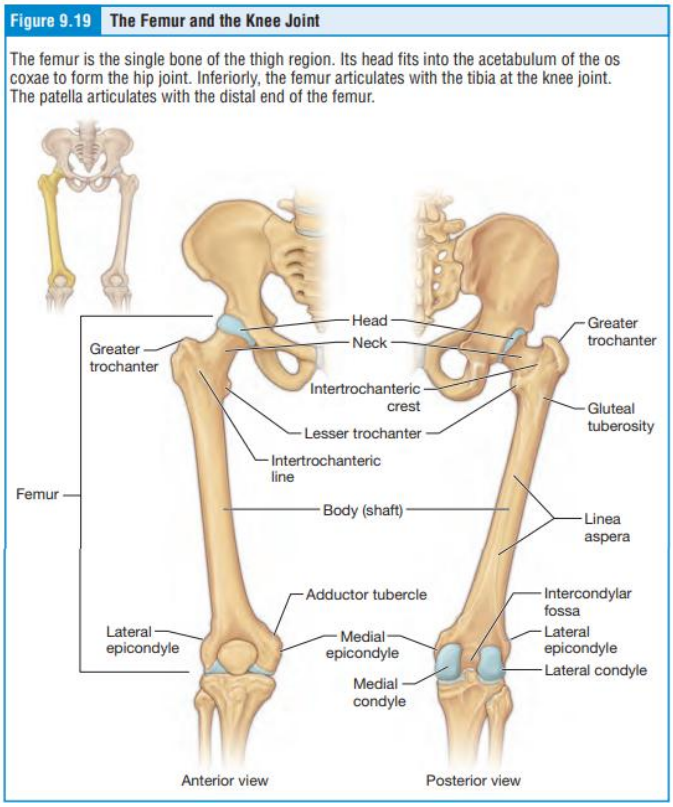
Shaft:

- *Linea Aspera: A prominent "rough line" on the posterior shaft for multiple muscle attachments.*
- *Gluteal Tuberosity: Roughened area leading into the linea aspera.*

The Patella (Kneecap): The largest **sesamoid bone** (bone embedded in a tendon).

- **Function**: Protects the knee joint and increases the leverage of the quadriceps muscle.
- **Articulation**: Articulates only with the **femur**, not the tibia.





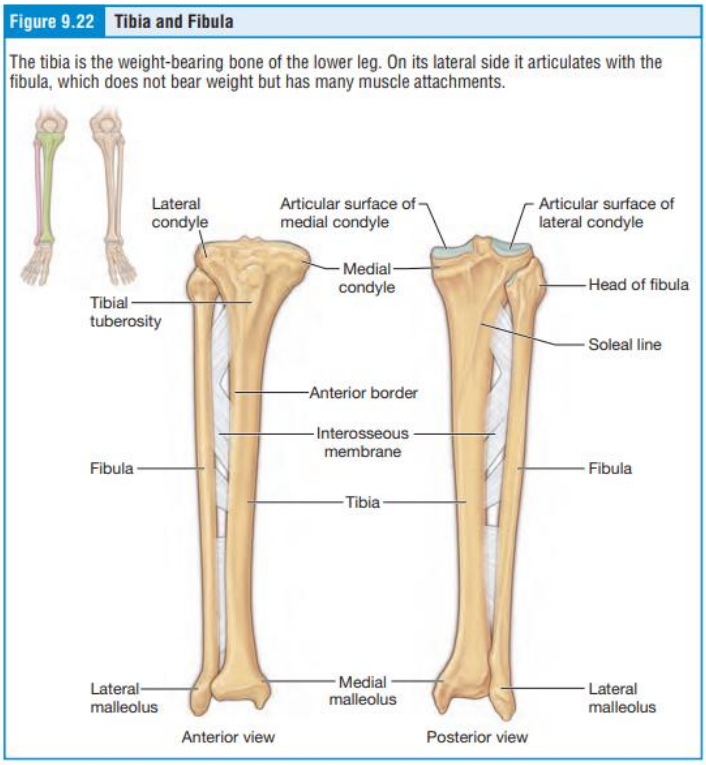
The Lower Leg Region:

The Tibia (Shin Bone): The medial, weight-bearing bone; the second longest bone in the body.

- **Proximal Features**:
  - **Medial and Lateral Condyles**: Flat surfaces that articulate with the femur to form knee joint.
  - *Intercondylar Eminence: Elevated area between condyles for knee ligament attachment.*
  - **Tibial Tuberosity**: Bump on the anterior surface where the patellar tendon attaches.
- **Distal Feature**:
  - **Medial Malleolus**: The bony bump on the inside of the ankle.

The Fibula: The slender, lateral bone; **non-weight-bearing**; used for muscle attachment

- **Head**: Proximal end that articulates only with the tibia (not the femur).
- **Distal Feature**:
  - **Lateral Malleolus**: The bony bump on the outside of the ankle.
- *Interosseous Membrane: Connects the shafts of the tibia and fibula.*



Bones of the Foot: Tarsal Bones (7 Bones)

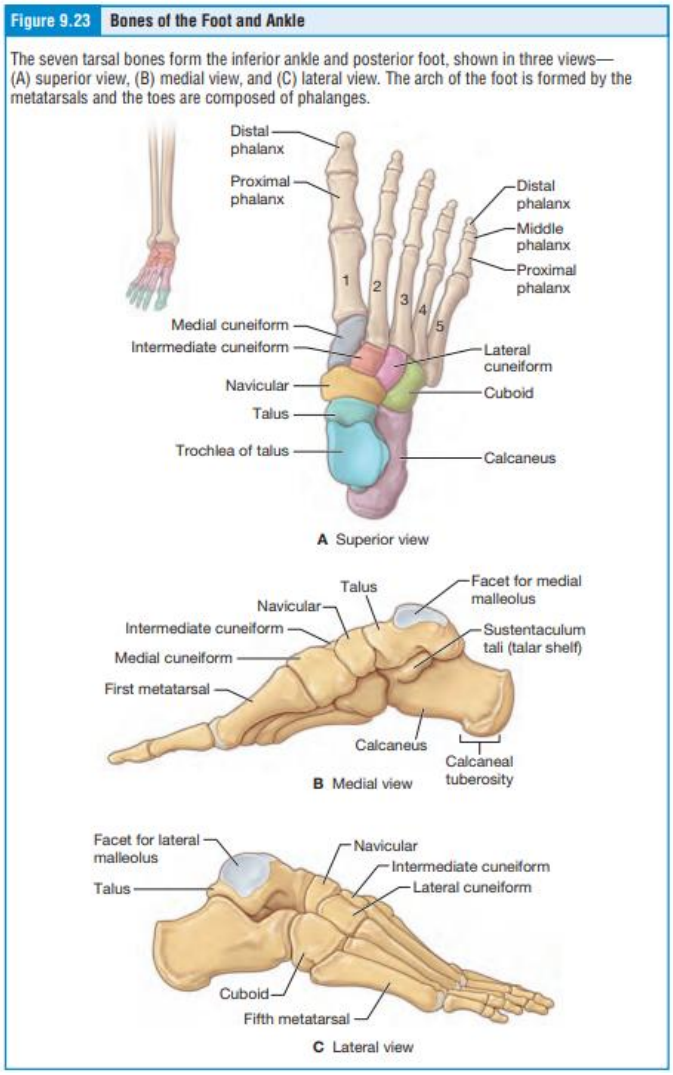
Proximal row of tarsals

- **Talus**: The most superior bone; articulates with the tibia and fibula to form the **ankle joint**.
- **Calcaneus**: The heel bone; the largest tarsal bone.
- **Navicular**: Boat-shaped bone in the proximal row.

Distal Row: Includes the **Cuboid** and three **Cuneiforms** (Medial, Intermediate, Lateral).

Metatarsals and Phalanges

- **Metatarsals (1–5)**: Five long bones forming the mid-foot/arch, numbered from the medial (big toe) side.
- **Phalanges (14 Bones)**:
  - **Big Toe (Hallux)**: Has 2 bones (proximal and distal).
  - **Toes 2–5**: Each has 3 bones (proximal, middle, and distal).
  - Named proximal, middle, and distal according to relative position.



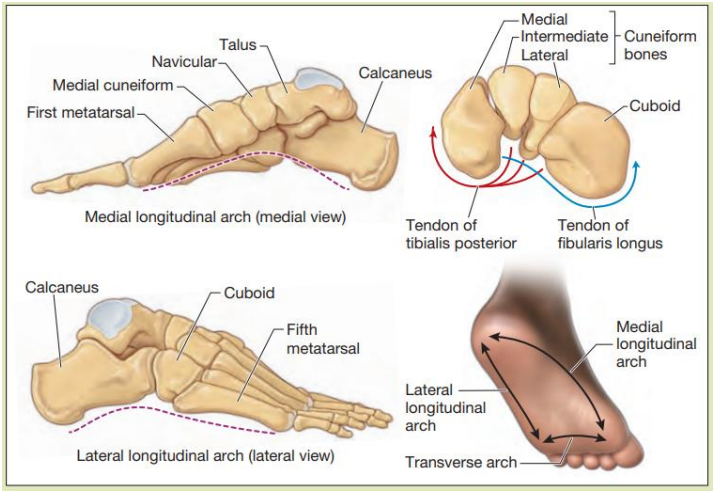
Arches of the Foot:

- Help the bones of the foot distribute and absorb the force of impact (Flatten upon impact).

Medial longitudinal arch: Primary shock absorber; stays elevated off the ground.

Lateral longitudinal arch: Provides stability and bears weight during standing and walking.

Transverse arch: Forms a half-dome shape to distribute weight and support the longitudinal arches.



Synovial Joint Movements

Synovial joints are categorized by the specific types of motion they allow, ranging from simple hinges to complex circular rotations.

Flexion, Extension, and Hyperextension

- **Flexion**: Decreases the angle of the joint from resting position (e.g., bending the elbow or bending the neck forward).
- **Extension**: Increases the angle to return to anatomical position/resting position (e.g., straightening the arm).
- **Hyperextension**: Extending a joint beyond 180 degrees (e.g., looking up at the ceiling).
- **Lateral Flexion**: Bending the neck or trunk toward the right or left side.

Abduction, Adduction, and Circumduction

- **Abduction**: Moving a limb or digit away from the midline of the body (e.g., raising arms to a "T" shape).
- **Adduction**: Moving a limb or digit toward or across the midline.
- **Circumduction**: Moving a limb in a circular motion; a combination of flexion, abduction, extension, and adduction.

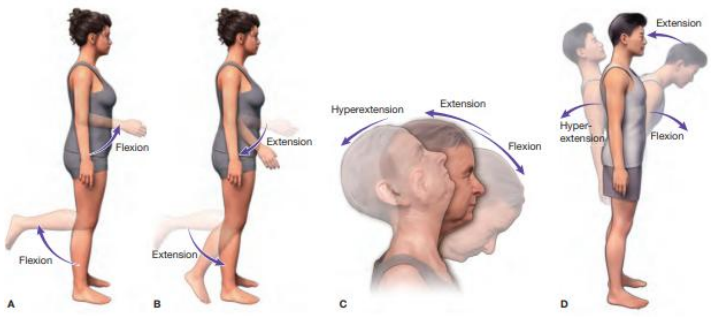
Rotation: twisting movement.

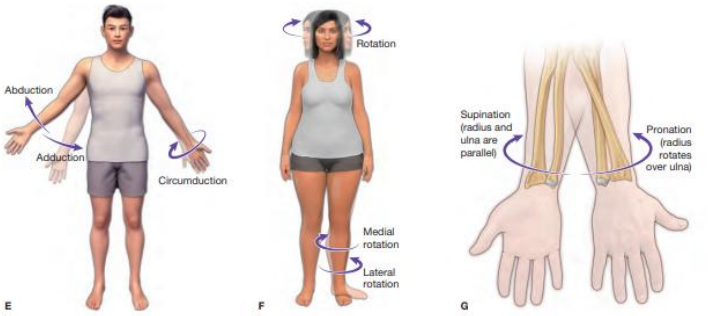
- **Medial (Internal) Rotation**: Turning the anterior surface of a limb toward the midline.
- **Lateral (External) Rotation**: Turning the anterior surface of a limb away from the midline.

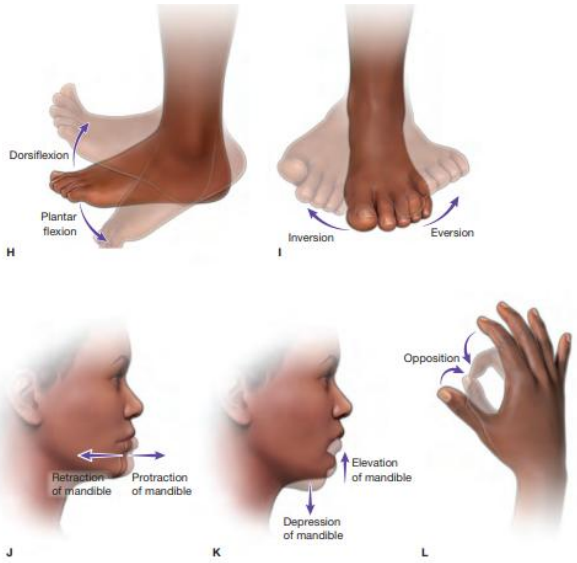
Specialized Movements by Region

Forearm (Radius and Ulna)

- **Supination**: Turning the palm forward (anatomical position); radius and ulna are parallel.
- **Pronation**: Turning the palm backward; the radius crosses over the ulna in an X-shape.







Foot and Ankle

- **Dorsiflexion**: Lifting the front of the foot toward the shin.
- **Plantar Flexion**: Pointing the toes downward or lifting the heel.
- **Inversion**: Turning the sole of the foot toward the midline.
- **Eversion**: Turning the sole of the foot away from the midline.

Mandible (Jaw) and Scapula (Shoulder Blade)

- **Protraction**: Moving a structure anteriorly (pushing the jaw out or shoulders forward).
- **Retraction**: Moving a structure posteriorly (pulling the jaw back or shoulders together).
- **Elevation**: Moving a structure upward (shrugging shoulders or closing the mouth).
- **Depression**: Moving a structure downward (opening the mouth).
- **Excursion**: Side-to-side movement of the mandible (**Lateral** = away from midline; **Medial** = back to center).

The Thumb

- **Opposition**: Bringing the tip of the thumb to touch the tip of a finger (enables grasping).
- **Reposition**: Returning the thumb to the anatomical position next to the index finger.