

Epithelial tissue

A diverse group of tissues that lines or cover surfaces of the body, body cavities and ducts

The principal functions:

1. Covering and lining of surfaces (e.g. skin and intestines)
2. Absorption via endocytosis or pinocytosis (e.g. intestines)
3. Secretion via exocytosis (e.g glands)
4. Sensation (e.g gustatory and olfactory neuroepithelium)

Epithelia are avascular, no vessels between epithelia cells (are not penetrated by blood vessels)

Two main groups: covering epithelia and glandular epithelia

Epithelia tissue

1. Cells
 - Closely aggregated cells
 - Arrangement into cohesive sheets (intercellular junction)
2. Extracellular matrix
 - Very little extracellular matrix
 - Basement membrane = basal lamina
 - Basement membrane separates epithelia from underlying supporting tissues
 - Epithelia are dependent on the diffusion of oxygen and metabolites from underlying supporting tissues
 -

The classification of epithelia is based on the morphological characteristics:

According to the cell shape

- Squamous (flat plate – like)
- Cuboidal (height and width similar)
- Columnar (height 2-5 times greater than width)

According to the number of formed cell layers

- Simple epithelium (single layer)
- Stratified epithelium (several layers)

According to the surface specialization, such as cilia

- Pseudostratified ciliated epithelium
- Stratified keratinizing epithelium

Simple epithelium

- All cells contact the basement membrane (the underlying extracellular matrix)

Squamous epithelium

- Flat and plate like cells
- Flattened nuclei
- Specific names (endothelium and mesothelium)

Simple cuboidal epithelium

- Height, width, and depth of the cell are the same
- Centrally located nuclei

Simple columnar epithelium

- Height of the cell is 2-5 times greater than its width
- Elongated nuclei

Pseudostratified simple epithelium

- Appear to be arranged in layers but all cells contact the basement membrane
- Several layers of nuclei suggests several layers of cells
- All cells are in contact with the basement membrane

Stratified epithelium

- Form several layers but only the bottom layer of the cell is in the contact with extracellular matrix
- Name derives from the appearance of cells in the superficial layer (e.g squamous stratified epithelium)
- Cornified or nor cornified

Urothelium – stratified epithelium

- Restricted to the lining of the urinary tract
- Dome shaped superficial cells with specialized membranes for protection
- Allow for stretching and distension

Common types of epithelia

Major Feature	Cell Form	Examples of Distribution	Main Function
Simple (one layer of cells)	Squamous	Lining of vessels (endothelium); Serous lining of cavities: pericardium, pleura, peritoneum (mesothelium)	Facilitates the movement of the viscera (mesothelium), active transport by pinocytosis (mesothelium and endothelium), secretion of biologically active molecules (mesothelium)
	Cuboidal	Covering the ovary, thyroid	Covering, secretion
	Columnar	Lining of intestine, gallbladder	Protection, lubrication, absorption, secretion
Stratified (two or more layers of cells)	Squamous keratinized (dry)	Epidermis	Protection; prevents water loss
	Squamous nonkeratinized (moist)	Mouth, esophagus, larynx, vagina, anal canal	Protection, secretion; prevents water loss
	Cuboidal	Sweat glands, developing ovarian follicles	Protection, secretion
	Transitional	Bladder, ureters, renal calyces	Protection, distensibility
	Columnar	Conjunctiva	Protection
Pseudostratified (layers of cells with nuclei at different levels; not all cells reach surface but all adhere to basal lamina)		Lining of trachea, bronchi, nasal cavity	Protection, secretion; cilia-mediated transport of particles trapped in mucus out of the air passages

Membrane specializations of epithelia

Intercellular surface

- Occluding junction (tight junction)
- Adhering (anchoring junction)
- Communicating junctions (gap= nexus junctions)

Luminal surface

- __Cilia
- __Microvilli
- __Stereocilia

Epithelial cell junctions

- Epithelial cells are extremely cohesive
- Specialized structures which link individual cells together into a functional unit (cells to each other and cells to basement membrane)
- 3 types
-

1. Occluding

- Form an impermeable barrier
- Binds cells together and maintains the integrity of epithelial cells as a barrier
- Is performed by the fusion of the integral membrane proteins
- Located just beneath the surface of epithelial cells
- Proximal renal tubules and urinary bladder

2. Anchoring

- Provide mechanical strength
- Provide mechanical stability to groups of epithelial cells (they can function as a cohesive unit)
- 2 types
- 1. Between adjacent cells
- 2. Between cell and extracellular matrix
- Acts as anchorage sites for cytoskeleton of each cell, so that cytoskeletons of all cells are effectively linked into a single functional unit
- Link cytoskeletal filaments (actin or intermediate) of adjacent cells by transmembrane proteins (cadherins)

- Adherent junction

- ___ Forms a continuous band around the cell
- ___ Links actin filament network to adjacent cells
- ___ Transmembrane proteins : cadherins
- ___ Examples : intestines, epithelium and intercalated disc

Desmosome

- ___ Forms a small, circular spot
- ___ Links intermediate filament network to adjacent cells
- ___ Transmembrane proteins: desmogleins
- ___ Cytokeratin, desmin or vimentin
- ___ Examples: stratum, spinosum, intestines epithelium and intercalated disc

Hemidesmosome

- ___ Links intermediate filament network of cell to extracellular matrix (basal lamina)
- ___ Transmembrane proteins: integrins

3. Communicating

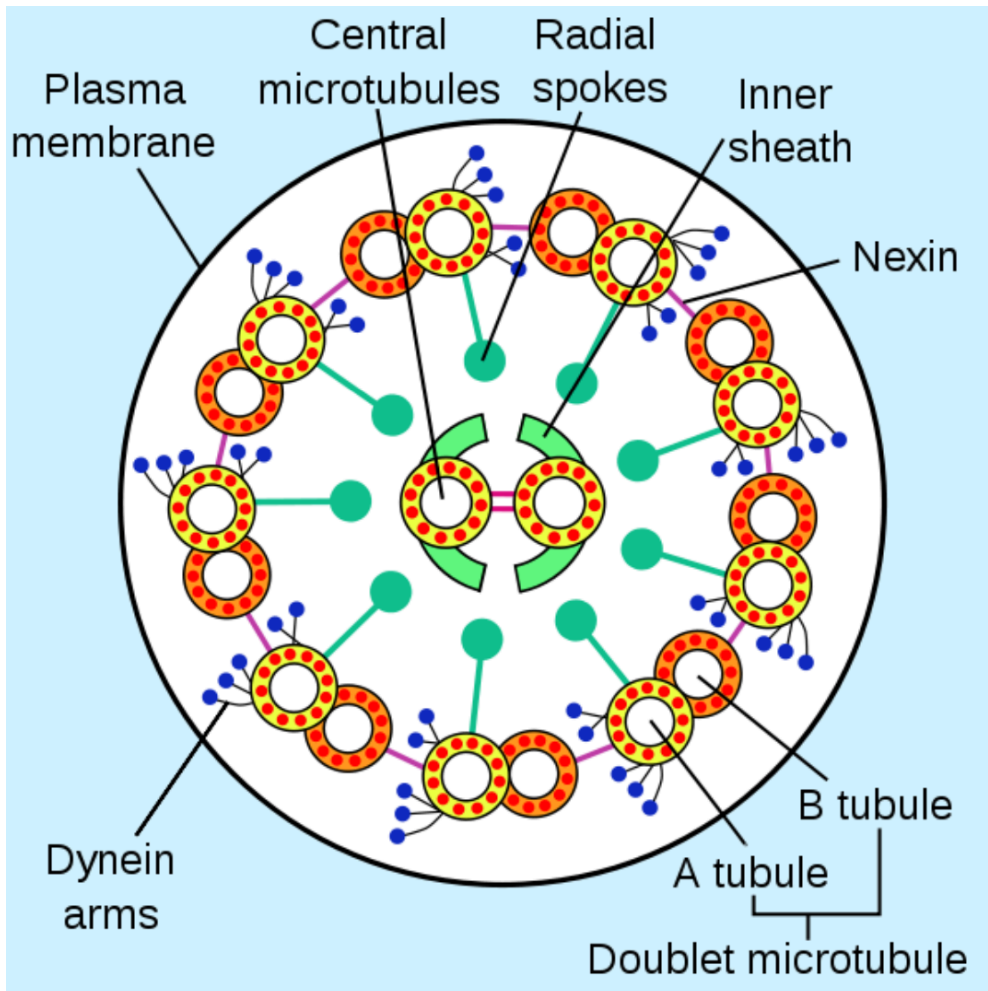
- Gap junction
- Hundreds of tiny pores which permit passage of small molecules between adjacent cells
- Allows direct cell- cell communication (allows selective diffusion of molecules between adjacent cells)
- Present in cardiac and smooth muscle cells (pass ions involved in signals during contraction)

Epithelial cell surface specialization

- The surface of epithelial cells can be adapted to aloe a specialized function
- Increased surface area (e.g microvilli)
- Moving substance over surface of epithelia (cilia)

- Celiac disease, also called gluten- sensitive enteropathy or sprue, is a disorder of the small intestines in which one of the first pathological changes is loss of the microvilli brush border of the absorptive cells
- Kartanger syndrome/ciliary immobility syndrome, genetically determined structural abnormalities in axoneme (eg. the lack of dynein arms)

Arrangement of the microtubules in cilia and flagella

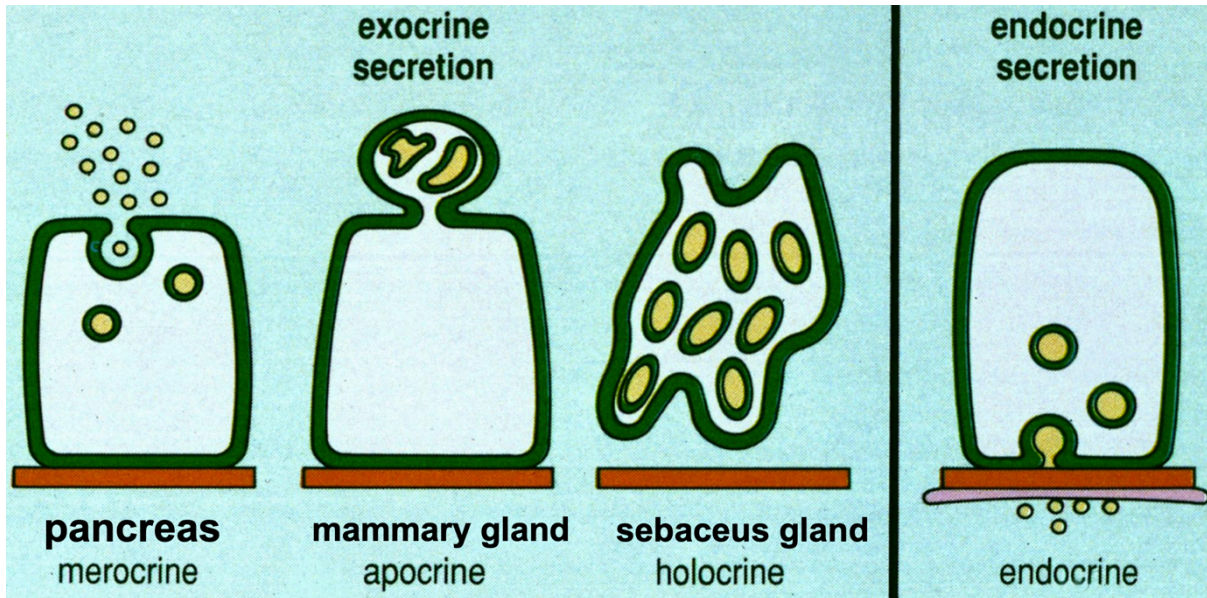


Axonem – an organized set of stable microtubules parallel arranged

Secretory adaption

- Exocytosis of secretory granules

- Product accumulates at the cells apical ends, portions of which are then released together with small amounts of cytoplasm and cell membrane
- Lipid droplets
- Cells with product enlarge and undergo differentiation
- Culminating in cell disruption the product is released into the gland's lumen



Secretory glands formation

Cords: adrenal gland, parathyroid and pituitary

Follicles : thyroid gland

Simple glands – ducts do not branch

Class	Simple Tubular	Branched Tubular	Coiled Tubular	Acinar (or Alveolar)	Branched Acinar
Features	Elongated secretory portion; duct usually short or absent	Several long secretory parts joining to drain into 1 duct	Secretory portion is very long and coiled	Rounded, saclike secretory portion	Multiple saclike secretory parts entering the same duct
Examples	Mucous glands of colon; intestinal glands or crypts (of Lieberkühn)	Glands in the uterus and stomach	Sweat glands	Small mucous glands along the urethra	Sebaceous glands of the skin

Compound glands – ducts from several secretory units converge into larger ducts

Class	Tubular	Acinar (Alveolar)	Tubuloacinar
Features	Several <i>elongated</i> coiled secretory units and their ducts converge to form larger ducts	Several <i>saclike</i> secretory units with small ducts converge at a larger duct	Ducts of both tubular and acinar secretory units converge at larger ducts
Examples	Submucosal mucous glands (of Brunner) in the duodenum	Exocrine pancreas	Salivary glands

TABLE 4-1 Main characteristics of the four basic types of tissues.

Tissue	Cells	Extracellular Matrix	Main Functions
Epithelial	Aggregated polyhedral cells	Small amount	Lining of surface or body cavities; glandular secretion
Connective	Several types of fixed and wandering cells	Abundant amount	Support and protection of tissues/organs
Muscle	Elongated contractile cells	Moderate amount	Strong contraction; body movements
Nervous	Elongated cells with extremely fine processes	Very small amount	Transmission of nerve impulses

Major Feature	Cell Form	Examples of Distribution	Main Function
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Junction	Tight Junction (Zonula Occludens)	Adherens Junction (Zonula Adherens)	Desmosome (Macula Adherens)	Hemidesmosome	Gap Junction (Nexus)
Major transmembrane link proteins	Occludins, claudins, ZO proteins	E-cadherin, catenin complexes	Cadherin family proteins (desmogleins, desmocollin)	Integrins	Connexin
Cytoskeletal components	Actin filaments	Actin filaments	Intermediate filaments (keratins)	Intermediate filaments	None
Major functions	Seals adjacent cells to one another, controlling passage of molecules between them; separates apical and basolateral membrane domains	Provides points linking the cytoskeletons of adjacent cells; strengthens and stabilizes nearby tight junctions	Provides points of strong intermediate filament coupling between adjacent cells, strengthening the tissue	Anchors cytoskeleton to the basal lamina	Allows direct transfer of small molecules and ions from one cell to another
Medical significance	Defects in occludins may compromise the fetal blood-brain barrier, leading to severe neurologic disorders	Loss of E-cadherin in epithelial cell tumors (carcinomas) promotes tumor invasion and the shift to malignancy	Autoimmunity against desmoglein I leads to dyshesive skin disorders characterized by reduced cohesion of epidermal cells	Mutations in the integrin-β4 gene are linked to some types of epidermolysis bullosa, a skin blistering disorder	Mutations in various connexin genes have been linked to certain types of deafness and peripheral neuropathy

Connective tissue

Components of connective tissue

- cells and extracellular matrix (ground substance and fibers)
- Mature connective tissue is referred to as connective tissue proper or specialized connective tissue (cartilage and bone)

Functions of connective tissue

- Structural support
- As a medium of exchange (e.g nutrients, metabolic waste, oxygen etc.)
- Defense and protection (phagocytic cells, immunocompetent cells, inflammation)

COMPONENTS

CELLS

MATRIX

Fixed	Wandering	Ground Substance	Fibers
Fibroblast Adipocyte Persistent Mesenchymal Cells	Macrophage Mast cells Plasma cell Pigment cell Eosinophil Neutrophil	Group 1 Proteoglycans Group 2 GAG/MPS SO ₄ NON SO ₄	Collagen Elastic Fiber

Cellular components

Fixed cells

- Resident population of cells that remain in place in the connective tissue where they perform their function
- Stable and long-lived population that include fibroblasts, adipose cells and mesenchymal cells

Transit cells

- Free or wandering cells
- Derived from the bone marrow and circulate in the bloodstream into connective tissue where they perform their function
- Usually short lived cells, need cell renewal(stem cell)
- Include plasma cells, lymphocytes, neutrophils, macrophages and many others

Mesenchyme cells

- Most abundant in embryonic developing tissue
- Multipotential cells, differentiate into a variety of distinct cell types(e.g. fibroblast, osteoblast ect)
- Pleomorphic shape, with a long oval nucleus hard to find in adult tissue

Fibroblast

- Main cell type in connective tissue
- Produces collagen, reticular and elastic fibers
- Fills in the spaces in the connective tissue and helps to form organ capsules tendons and ligaments
- Two forms of fibroblast

Active fibroblast

- Found in close association with collagen bundles (parallel to these bundles)
- Elongated cells with a pale staining cytoplasm
- Key feature, dark stained, large, granular oval shaped nucleus with a well defined nucleolus
- Extensive RER system and golgi appartures
- Very common cell type

Inactive fibroblasts

- Smaller, oval shaped cell body with an acidophilic cytoplasm
- Nucleus is smaller and elongated compared to the active form
- Contains RER (not as extensive as the active form)
- Contains many ribosomes

Macrophages

- Macrophages residing in connective tissue are called resident macrophages (fixed)
- Phagocytose senescent, damaged, dead cells and debris and digest this material via the action of hydrolytic enzymes from the lysosomes
- Phagocytose microorganisms
- Immune response – “ activated MP” and “antigen presenting cell” to lymphocytes

Mast cell

- Very large (20 to 30 m)
- Ovoid shape, centrally located nucleus
- Numerous granules in the cytoplasm (very large)
- Produce histamin and heparin
- Derived from precursors in the basement membrane
- Play a role in the immune response and inflammation

Transient connective tissue cells

Plasma cells

- Throughout connective tissue esp? in regions of chronic inflammation
- Derived from B cells and produce antibodies
- Large ovoid cells with an eccentric nucleus
- “clock face” nucleus due to the clumps of chromatin
- Basophilic cytoplasm

Leukocytes

- White blood cells may enter the connective tissue via capillaries
- Many types and many function including phagocytosis, esp areas of acute and chronic inflammation

Ground substance

- Hydrated, amorphous gel like substance containing glycosaminoglycans, proteoglycans and glycoproteins
- Functions as transporter/barrier
- Medium for growth and synthesis (e.g fibre formation, in wound repair and in development)

Types of ground substance

Soft ground substance

- Made of glycosaminoglycans (GAGs)
- E.g hyaluronic acid (less sulphated) found in synovial fluid, vitreous humor

Firm ground substance

- Made of glycosaminoglycans
- E.g chondroitin sulfate, found in bone of ground substance

Proteoglycans

- Glycosaminoglycans and protein
- Range in size from 50 Kd to millions – very large molecules
- Aggrecan – macromolecules found in cartilage and connective tissue proper

- Aggrecan and hyaluronic acid, enormous molecule that occupies a very large volume and mass (over 100 megadaltones)
- Responsible for the gelatinous state of the ground substance (ECM)
- Acts as a barrier
- Resists movement of microorganisms and metastatic cells

Fibrous component of connective tissue

- Gives the connective tissue strength and support
- Three types of fibers

Collagen

- Very common and most abundant protein (20% of all proteins in the body)
- Gives connective tissue great tensile strength, no elasticity
- Characteristic banding pattern, 3 helical peptide chains (1000 aa each)
- At least 15 different types of collagen
- Specific collagen molecules are located in specific regions of the body
- We are interested in type 1- 5

Collage types

Collagen type 1

- Most common
- forms thick fibers
- Present in connective tissue proper
- Present in bone and dentin
- Makes up tendons and ligaments
- Found in skin

Collagen type 2

- Found in cartilage

Collagen type 3

- Also called reticular fiber
- Associated with blood vessels
- Lung
- Forms the structural framework for the spleen
- Liver
- Lymph nodes
- Smooth muscle

Collagen type 4

- Not a real fiber
- Forms a meshwork of procollagen molecules
- Found in the basement membrane

collagen type 5

- Usually associated with type 1 collagen

Collagen type 6

- Anchor fibre
- Secures the basement membrane to the underlying connective tissue (via type 1/3 collagen)

Elastic fiber

- Gives the connective tissue its elastic properties (ECM)
- Fibers are long, thin and usually branch in loose connective tissue, but form coarse bundles in ligaments (walls of large blood vessels)
- Produced by fibroblasts in connective tissue by smooth muscle cells in BV
- Composed of elastin, contains the unusual, desmosine and isodesmosine (combo of 4 lysine residues)
- Location, blood vessels, skin, cartilage, lung and urinary bladder

Reticular fibers

- Known as type 3 collagen
- Produced by fibroblasts, smooth muscle cells, hepatocytes, reticular cells
- Usually in the form of a network
- Forms the structural framework of the spleen, liver, lymph node and smooth muscle

Classification of connective tissue

Embryonic

Connective tissue proper

- Loose (areolar) connective tissue
- Dense connective tissue (regular irregular)
- Reticular tissue
- Adipose tissue

Specialized connective tissue

- Cartilage, bone, blood

There are six major types of connective tissue

Loose areolar connective tissue

- Tissue that fills in the spaces of the body
- Characterized by ground substance, fibers and cells
- Contains many transient cells, responsible for inflammation and the immune response
- Ground substance and tissue fluid, housing the fixed connective tissue cells
- Fibrous component (e.g collagen)

- With small nerve fibers and blood vessels supplying the cells with nutrients and oxygen

Dense connective tissue

- Very similar to loose connective tissue
- The major difference is that dense connective tissue has many more fibers and fewer cells
- The orientation and arrangement of collagen make it resistant to stress
- Two subclasses
- Dense irregular connective tissue
- Dense regular connective tissue
- Random arrangement of collagen fibers, fibers are packed tight, little room for ground substance
-

Dense irregular connective tissue

- Dense irregular connective tissue – collagen is arranged randomly
- Location, dermis of skin, sheaths of nerves, capsules of spleen, ovary, kidney and lymph nodes

Dense regular connective tissue

- Dense regular connective tissue collagen is arranged in an organized manner
- Collagenous
- Organized sheets, parallel bundles of type 1 collagen
- Little ground substance and a few fibroblasts (thin)
- Tendon, ligament and the sheaths that bind muscles together

Reticular tissue

- Major component is type 3 collagen
- Forms a meshwork, cell types include fibroblasts, macrophages, and reticular cells

- Form the “architectural” framework of the liver sinusoids, bone marrow, lymph nodes, spleen, smooth muscle and the islets of Langerhans

Adipose tissue

- Fat cells or adipocytes
- Function in the synthesis and storage of triglycerides
- Two major cell types
 1. Single, large lipid droplet, unilobular fat cell
- Forming white adipose tissue
 2. Multiple, small lipid droplets, multilobular fat cells
- Brown adipose tissue

White adipose tissue

- Store fat in the form of a single large droplet
- Usually displaces the cytoplasm and nucleus to the periphery, near the cell membrane
- Septa may divide groups of adipose cells into lobes
- Septa of connective tissue

Brown adipose tissue

- Smaller and more polygonal than WAC?
- Store fat in many small droplets
- Spherical nucleus, not pushed to the periphery cell
- Many mitochondria, associated with body heat production,
- Oxidize fatty acids 20X the rate of WAC, 3 fold increase in the production of heat

Cell Type	Major Product or Activity
Fibroblasts (fibrocytes)	Extracellular fibers and ground substance
Plasma cells	Antibodies
Lymphocytes (several types)	Various immune/defense functions
Eosinophilic leukocytes	Modulate allergic/vasoactive reactions and defense against parasites
Neutrophilic leukocytes	Phagocytosis of bacteria
Macrophages	Phagocytosis of ECM components and debris; antigen processing and presentation to immune cells; secretion of growth factors, cytokines, and other agents
Mast cells and basophilic leukocytes	Pharmacologically active molecules (eg, histamine)
Adipocytes	Storage of neutral fats

Cell Type	Major Location	Main Function
Monocyte	Blood	Precursor of macrophages
Macrophage	Connective tissue, lymphoid organs, lungs, bone marrow, pleural and peritoneal cavities	Production of cytokines, chemotactic factors, and several other molecules that participate in inflammation (defense), antigen processing, and presentation
Kupffer cell	Liver (perisinusoidal)	Same as macrophages
Microglial cell	Central nervous system	Same as macrophages
Langerhans cell	Epidermis of skin	Antigen processing and presentation
Dendritic cell	Lymph nodes, spleen	Antigen processing and presentation
Osteoclast (from fusion of several macrophages)	Bone	Localized digestion of bone matrix
Multinuclear giant cell (several fused macrophages)	In connective tissue under various pathological conditions	Segregation and digestion of foreign bodies

	General Organization	Major Functions	Examples
Connective Tissue Proper			
Loose (areolar) connective tissue	Much ground substance; many cells and little collagen, randomly distributed	Supports microvasculature, nerves, and immune defense cells	Lamina propria beneath epithelial lining of digestive tract
Dense irregular connective tissue	Little ground substance; few cells (mostly fibroblasts); much collagen in randomly arranged fibers	Protects and supports organs; resists tearing	Dermis of skin, organ capsules, submucosa layer of digestive tract
Dense regular connective tissue	Almost completely filled with parallel bundles of collagen; few fibroblasts, aligned with collagen	Provide strong connections within musculoskeletal system; strong resistance to force	Ligaments, tendons, aponeuroses, corneal stroma
Embryonic Connective Tissues			
Mesenchyme	Sparse, undifferentiated cells, uniformly distributed in matrix with sparse collagen fibers	Contains stem/progenitor cells for all adult connective tissue cells	Mesodermal layer of early embryo
Mucoid (mucous) connective tissue	Random fibroblasts and collagen fibers in viscous matrix	Supports and cushions large blood vessels	Matrix of the fetal umbilical cord
Specialized Connective Tissues			
Reticular connective tissue (see Chapter 14)	Delicate network of reticulin/collagen III with attached fibroblasts (reticular cells)	Supports blood-forming cells, many secretory cells, and lymphocytes in most lymphoid organs	Bone marrow, liver, pancreas, adrenal glands, all lymphoid organs except the thymus

Cartilage

General about cartilage

- Connective tissue with very firm extracellular matrix
- Avascular
- No innervations
- No lymphatic
- Forms from embryonic mesenchyme
- Main cells = chondrocytes

Function

- Supports soft tissue
- Work as shock absorber and friction reduction in joints
- Development and growth of long bones

Chondrocytes

- Synthesize and maintain extracellular matrix
- Located in lacunae, surrounded by extracellular matrix
- Have low metabolic activity due to being in avascular tissue

Isogenous aggregates

- Grouping of up to 8 cells that come from the mitotic divisions of a single chondroblast

Matrix

Consists of proteoglycans and glycoproteins and hyaluronic acid

Aggrecan

- Proteoglycan side chains of chondroitin sulfate and keratan sulfate (most abundant in hyaline)

Chondronectin

- Structural multiadhesive glycoprotein
- Binds to glycosaminoglycans, collagen and integrins to mediate the adherence of chondrocytes to the extracellular matrix

Perichondrium

- Sheath of dense irregular connective tissue
- 2 layers
- 1. Outer fibrous layer
- 2. Inner chondrogenic layer
 - Essential for the growth and maintenance of cartilage
 - Vasculature surrounding cartilage
 - Fibrocartilage does not have perichondrium so it is sustained by diffusion of oxygen from synovial fluid

Hyaline cartilage

- Most common type
- Stained as a blue -white color
- Serve as an embryonic skeleton before it is removed to make, acts as a template
- Epiphysial plate in long bone growth

Chondrocytes

Outer – elliptical with long axis parallel to surface

Deeper – round, may be in group of 8 isogenous group

Chondroblasts, at boundary of perichondrium and cartilage proper

Matrix

- Fills spaces between lacunae
- Territorial matrix adjacent to chondrocytes has much glycosaminoglycan and stains darker than non territorial matrix.

Perichondrium

- Found around all hyaline cartilage except joint hyaline cartilage
- Contains many undifferentiated mesenchyme cell that may differentiate into new chondrocytes

Cartilage growth

Interstitial growth

- Mitotic divisions of existing chondrocytes and production of matrix

Appositional growth

- Differentiation of new chondrocytes from stem cells and production of matrix at surface

	Hyaline Cartilage	Elastic Cartilage	Fibrocartilage
Main features of the extracellular matrix	Homogeneous, with type II collagen and aggrecan	Type II collagen, aggrecan, and darker elastic fibers	Type II collagen and large areas of dense connective tissue with type I collagen
Major cells	Chondrocytes, chondroblasts	Chondrocytes, chondroblasts	Chondrocytes, fibroblasts
Typical arrangement of chondrocytes	Isolated or in small isogenous groups	Usually in small isogenous groups	Isolated or in isogenous groups arranged axially
Presence of perichondrium	Yes (except at epiphyses and articular cartilage)	Yes	No
Main locations or examples	Many components of upper respiratory tract; articular ends and epiphyseal plates of long bones; fetal skeleton	External ear, external acoustic meatus, auditory tube; epiglottis and certain other laryngeal cartilages	Intervertebral discs, pubic symphysis, meniscus, and certain other joints; insertions of tendons
Main functions	Provides smooth, low-friction surfaces in joints; structural support for respiratory tract	Provides flexible shape and support of soft tissues	Provides cushioning, tensile strength, and resistance to tearing and compression

Bone

Composed of

Specialized connective tissue composed of calcified extracellular matrix, the bone matrix

Three major cell types

- Osteocytes
- Osteoblasts
- Osteoclasts

Organic phase

- Non mineral matrix about 25%
- Determines structural mechanical and biochemical properties of bone
- Type 1 collagen
- Glycosaminoglycans
- Gaps between the fibers are filled with multiadhesive glycoproteins – osteocalcin, osteonectin and osteopontin

Inorganic phase

- Crystallized mineral salts make up 50%
- Composed of hydroxyapatite, bicarbonate, citrate, magnesium, potassium and sodium ions
- Water makes up 25%
- 4 types of cells

Functions of bone

- Supporting and protecting soft tissues (e.g ribs and skull)
- Attachment site for muscles making movement possible
- Storage of the minerals Ca^{2+} and PO_4^{3-} mineral homeostasis
- Blood cell production occurs in red bone marrow

Bone shape

- Long bones : extremities
- Short bone: cube shaped, wrist and ankle
- Flat bones : skull, sternum, scapula and ribs

- Irregular bones: vertebrae and pelvis

Bone cell types

Osteoprogenitor cells

- Undifferentiated cells
- Derived from mesenchymal stem cells in bone marrow
- Can divide to replace themselves and become osteoblasts
- Found in inner layer of periosteum and endosteum

Osteoblasts

- Bone forming cells
- Form matrix and collagen 1 fibers but can't divide
- Cuboidal or polygonal shaped cells
- Secrete collagen and ground substance (glycosaminoglycans and proteoglycans)
- Basophilic cytoplasm
- Located at the surface of bone tissue

Osteocytes

- Mature cells that no longer secrete matrix
- Flattened and spindle shaped
- Located within lacunae (cavities) in lamellae

Osteoclasts

- Huge cells that form fused monocytes, function in bone resorption at surface such as endosteum
- Large multinucleated cells
- Bone resorbing cells
- Releasing lysosomal hydrolases into extracellular matrix

Periosteum

Outer fibrous layer

- Dense irregular connective tissue of mostly bundled type 1 collagen along with fibers and fibroblasts

Inner cellular layer

- Composed of osteoprogenitor cells
- May differentiate into osteoblasts
- Contain blood vessels, nerve and Sharpey's fibers (bundles of collagen fibers)
- Attachment for tendons

Endosteum

- Inner surface of compact bone
- Composed of single layer of osteoprogenitor cells

- Osteoblasts
- Bone lining cells within a sparse delicate matrix of collagen fibers
- Covers trabeculae

Bone formation

- Formation of bone directly from mesenchymal cells
- Most flat bones begin to form
- Most bone of the skull, jaw, scapula and clavicle
- Mesenchymal cells become osteoblasts
- Osteoblasts form bone
- Mesenchymal cells become osteoprogenitor, the osteoblasts
- Osteoblasts surround with matrix and become osteocyte
- Matrix calcifies into trabeculae with matrix spaces holding red bone marrow
- Mesenchyme condenses as periosteum at the bone surface
- Superficial layers of spongy bone are replaced

Bone formation

Endochondral bone formation

- Formation of bone with hyaline cartilage shaped as a small version of the model of the bone to be formed. Cartilage is replaced by bone (long bone)

Development of primary ossification

- Perichondrium transforms into periosteal bone collar (thin layer of compact bone)
- Nutrient artery penetrates into center of cartilage model
- Periosteal bud brings osteoblasts and osteoclasts to center of cartilage model
- Osteoblasts deposit bone matrix over calcified cartilage forming spongy bone trabeculae
- Osteoclasts form medullary cavity

Secondary ossification:

- Blood vessels enter the epiphyses around time of birth.
- Spongy bone is formed but no medullary cavity

Formation of articular cartilage:

- Cartilage on ends of bone remains as articular cartilage

Bone growth in length

Epiphyseal plate or cartilage growth plate :

- Cartilage are produced by mitosis on epiphyseal side of plate
- Cartilage cells are destroyed and replaced by bone on diaphyseal side of plate
- Between ages 18- 25 epiphyseal plates close

- Cartilage cells stop dividing and bone replaces the cartilage (epiphyseal line)
- Growth in length stops at the age 25

Osteoporosis

- Decreased bone mass resulting in porous bones

Those at risk :

- White, thin menopausal, smoking, drinking, female with family history
- Athletes who are not menstruating due to decreased body fat and decreased estrogen levels
- People with eating disorder whose intake of calcium is too low

Prevention or decrease in severity:

- Adequate diet, weight bearing exercise and estrogen replacement therapy (for menopausal women)
- Behavior when young may be most important factor

Type of Bone	Histological Features	Major Locations	Synonyms
Woven bone , newly calcified	Irregular and random arrangement of cells and collagen; lightly calcified	Developing and growing bones; hard callus of bone fractures	Immature bone; primary bone; bundle bone
Lamellar bone , remodeled from woven bone	Parallel bundles of collagen in thin layers (lamellae), with regularly spaced cells between; heavily calcified	All normal regions of adult bone	Mature bone; secondary bone
Compact bone , ~80% of all lamellar bone	Parallel lamellae or densely packed osteons, with interstitial lamellae	Thick, outer region (beneath periosteum) of bones	Cortical bone
Cancellous bone , ~20% of all lamellar bone	Interconnected thin spicules or trabeculae covered by endosteum	Inner region of bones, adjacent to marrow cavities	Spongy bone; trabecular bone; medullary bone

Bone resorption > bone deposition

↓ Bone mass

↑ Fractures

Related to :

↓ Estrogen after menopause

↓ Exercise

↓ Calcium and protein in diet

Treatment :

↑ Calcium and exercise

↑ Vitamin D

Muscle tissue

The muscle tissue is composed of cells that maintain the contractile function of connective tissue.

Muscle tissue types :

1. **Skeletal muscle tissue** - voluntary control – strong, quick and discontinuous
2. **Cardiac muscle tissue** - involuntary control – strong, quick and continuous
3. **Smooth muscle tissue** – involuntary control – weak and slow

Contractile cells :

Are adapted to generate motile forces necessary for contractions by the sliding interaction of the protein actin and myosin (contractile proteins)

1. **Straited muscle cells**
 - Skeletal muscle cells – voluntary
 - Cardiac muscle cells – involuntary
2. **Smooth muscle cells** - involuntary
3. **Other cells**
 - Myoepithelial cells
 - Myofibroblasts
 - Pericytes

Myoepithelial cells:

- Expel secretion from glands
- Contractile cells
- Move secretory product
- Lie between basal plasma membrane of epithelial cells and basal lamina of epithelium
-

Myofibroblasts:

- Able to contract and secrete collagen role in the formation of the scar
- Are typically activated from fibroblasts
- Can also be derived from other cells types, epithelial cells, endothelial cells and mesothelium cells
- Help in maintain the inflammatory response to injury
- Large cells with a highly endoplasmic reticulum and they can produce and secrete cytokines

Pericyte:

- Surround blood vessels
- Present at intervals along the walls of capillaris
- Control blood flow through blood vessels by extending their long projections

Muscle fibers (muscle cells):

- Muscle fibers develop through the fusion of mesodermal cells called myoblasts

Muscle cell components –

- Sarcoplasma – cytoplasm of muscle cells
- Sarcolemma – muscle cell membrane and its external lamina
- Sarcoplasmic reticulum – smooth endoplasmic reticulum (store ca^+ , needed for contraction)
- In each muscle fiber population of muscle precursor cells (satellite cells)
-

Muscle contraction:

- Shortening of the sarcomere
- During this process neither the thick or thin filaments change their length
- The sliding filament theory proposes that under the influence of energy released from ATP, the thick and thin filaments slide over one another, that cause shortening of the sarcomere
- The repetitive binding and releasing of myosin head along the actin filaments
- Contraction is mediated by a cycle of binding and releasing between actin and myosin and under control by proteins (troponin) and Ca^{2+} ions
- Following a nerve signal membrane excitation of t- tubule system causes Ca^{2+} ions to flood into the sarcoplasm and muscle contraction
 1. The release of acetylcholine in the neurotransmitter junction causes an electrical impulse to be generated in the muscle cell plasma membrane
 2. The electrical impulse is carried to the cell's interior by the T – tubules
 3. Action potential causes depolarization and release of Ca^{2+}
 4. Ca^{2+} exposes myosin binding sites, myosin heads bind to actin
 5. Power stroke, filaments slide past another
 6. ATP binds to myosin, causing it to release actin
 7. ATP is hydrolyzed and myosin heads return to resting position
 8. If Ca^{2+} is returned to sarcoplasmic reticulum, muscle relaxes
 9. If Ca^{2+} remains available the cycle repeats and muscle contraction continues

Sarcomere:

I – band: isotropic in polarized light, light bands, thin filaments = actin filaments

- Diameter – 6- 8 nm, 1 um long

A – band: anisotropic, dark, thin filaments = myosin filaments

- Diameter – 15 nm, 15um

Z – line: disc like zone, thin filaments are attached to z line

- (alpha – actinin with nebulin, titin, telethonin , talin , desmin ,myotilin , filamin C)

M- line: myomesin, M protein, obscurin, creatine kinase

- Filaments are held in place by plates of accessory proteins (lines)
- Regular arrangement of contractile proteins within each sarcomere: each thick filament is surrounded by six thin filaments

Skeletal muscle

Skeletal muscle tissue - voluntary control – strong, quick and discontinuous

Each skeletal muscle fiber/ muscle cell is a multinucleated syncytium formed by fusion of hundreds individual precursors cells (mononucleated myoblasts) in development

Myofiber – skeletal muscle fiber (cell)

Myofibril – the contractile elements of myofiber

Myofilament - the contractile proteins, actin (thin filaments) and myosin (thick filaments) in each myofibril

Skeletal muscle cells (myofibers/muscle fibers) are extremely elongated, unbranched cylindrical cells 50 -60 um in diameter and up to 10 cm long, with numerous flattened nuclei located at periphery just beneath the sarcolemma

Myofibrils lie in the cytoplasm, 1- 2 um diameter, elongated cylindrical structures, arranged parallel to one another and to the long axis of myofiber

Within each myofibril – highly ordered arrangement of the contractile proteins

(myofilaments) give rise to the appearance of cross – striations (striated muscle)

Skeletal muscle striations

- The contractile elements of skeletal muscle – myofibrils composed of assemblies of
 1. Thick filaments – myosin
 2. Thin filaments – actin
- Sarcomere, the skeletal muscle fiber functional unit delineated between two Z – lines
- Myofibrils consist end to end repetitive arrangement sarcomers
- Lateral registration of sarcomers in adjacent myofibrils

Cardiac muscle

Cardiac muscle tissue - involuntary control – strong, quick and continuous

- Cardiac muscle cells develop cell junctions anchoring each cell to its neighbour
- Cardiac muscle cells are faintly striated branching cells which connect by means of intercalated disks to form a functional network. The action potential travels through – all cells are connected together in the syncytium causing them to function as a unit
- Cardiac myocytes are branched mono nucleated cells
- Striated muscle (similar arrangement of actin and myosin filaments like in skeletal muscle)

- Cardiac muscle cells contains one or two nuclei
- Individual cardiac muscle cells are linked into long chains by system of specialized cell junction (termed intercalated disk)
- Stem cells not present = no regeneration

Intercalated disk:

Contains 3 type of cell junction

1. Desmosomal junction

- Tightly links adjacent cells, involving the intermediate filaments

2. Adherent type junction

- Anchors the actin fibers of the sarcomers to end of the cell

3. Gap junction

- Facilitates the passage of membrane excitation = synchronization of muscle contraction

Cardiac muscle contraction

- The molecular basis of the cardiac muscle contraction is very similar to the skeletal muscle contraction
- Contraction of cardiac muscle is regulated. By cytosolic Ca^{2+} ion concentration
- Dyads – terminal cisternae and T – tubule/Z- line
- Contractions are strong and utilize a great deal of energy (like skeletal muscle) but are continuous and initiated by inherent mechanism (like smooth muscle)

Smooth muscle

Smooth muscle tissue – involuntary control – weak and slow

- Smooth muscle cells are the main contractile cells in the walls of the most hollow viscera (gut, urinary, bladder, uterus) and in the blood vessels
- In the wall smooth muscle cells are arranged in sheets aligned circumferentially of longitudinally
- Individual muscle cells are anchored together into functional units by extracellular matrix (linear bundles)
- Each muscle cell is typically spindle shaped and has a single, elongated centrally located nucleus
- Irregularly arranged contractile proteins
- Bundles of contractile proteins criss cross the cell very different to the striated muscle in the skeletal and cardiac muscle
- Calmodulin and myosin light chain kinase (MLCK) instead of troponin and tropomyosin

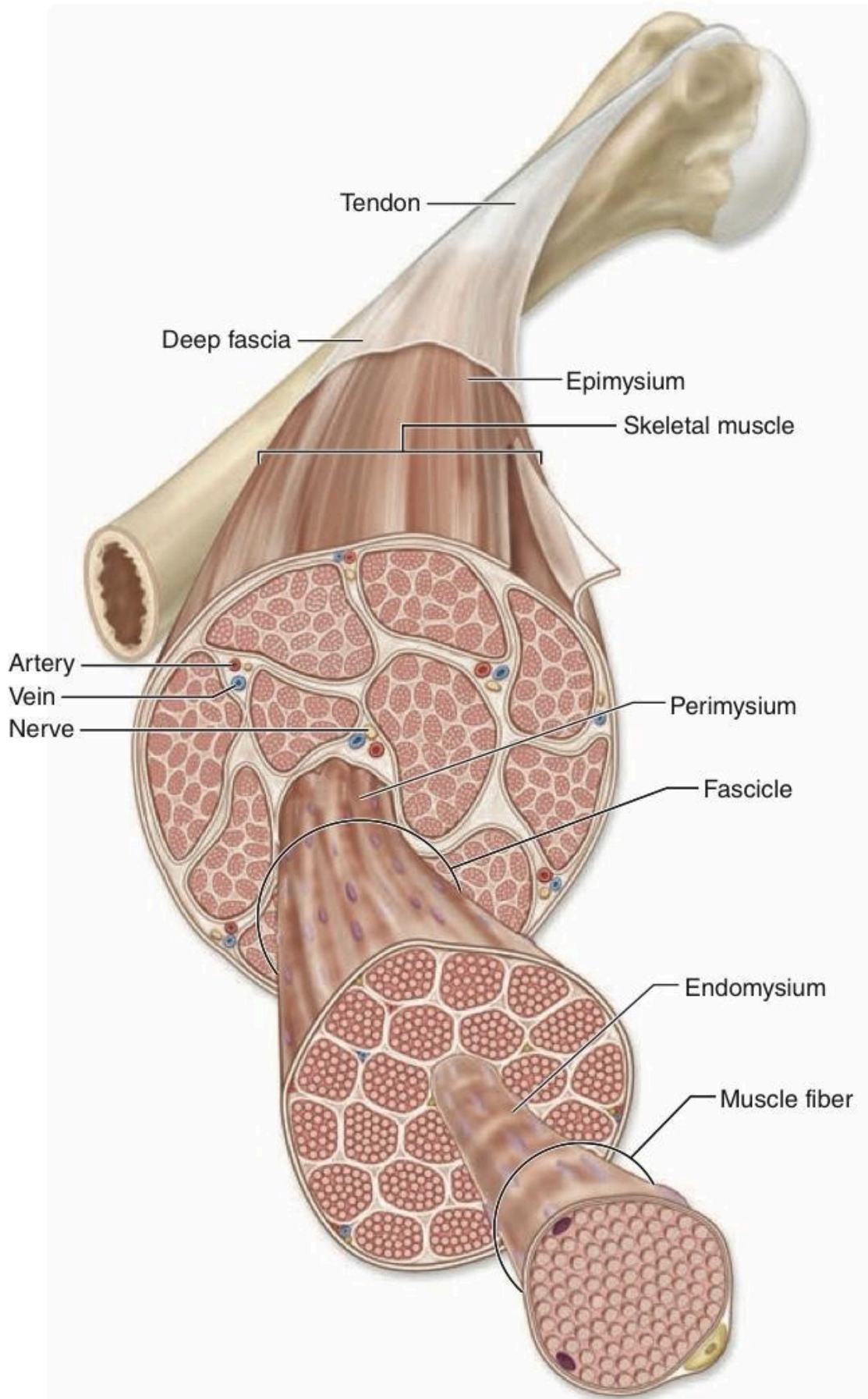
Smooth muscle contraction

- Involuntary muscles – under inherent autonomic and hormonal control
- Relaxed = elongated shape
- Contracted = short, compact, round shape

	Skeletal muscle	Cardiac muscle	Smooth muscle
Fibers	Single multinucleated cells	Aligned cells in branching arrangement	Single small, closely packed fusiform cells
Cell/fiber shape and size	Cylindrical, 10 – 100 um diameter, many cm long	Cylindrical, 10 – 20 um, 50 – 100 um long	Fusiform, diameter 0.2- 10 um, length 50 – 200 um
Striations	Present	Present	Absent
Location of nuclei	Peripheral, adjacent to sarcolemma	Central	Central, at widest part of cell
T- tubules	Center of triads at A-I junctions	In dyads at Z lines	Absent, caveolae may be functionally similar
Sarcoplasmic reticulum (SR)	Well – developed, with two terminal cisterns per sarcomere in triads with T tubule	Less well developed, one small terminal cistern per sarcomere in dyad with T tubule	Irregular smooth endoplasmic reticulum without distinctive organization
Special structural features	Very well organized sarcomers, SR and transverse tubule system	Intercalated discs joining cell, with many adherent and gap junctions	Gap junctions, caveolae, dense bodies
Control of contraction	Troponin C binds Ca^{2+} , moving tropomyosin and exposing actin for myosin binding	Troponin C binds Ca^{2+} , moving tropomyosin and exposing actin for myosin binding	Actin – myosin binding occurs with myosin phosphorylation by MLCK triggered when calmodulin binds Ca^{2+}
Connective tissue organization	Endomysium, perimysium and epimysium	Endomysium, subendocardial and subpericardial CT layers	Endomysium and less organized CT sheaths
Major location	Skeletal muscle, tongue, diaphragm, eyes and upper esophagus	Heart	Blood vessels, digestive and respiratory tract, uterus, bladder and other organs
Key function	Voluntary movements	Autonomic (involuntary) pumping of blood	Involuntary movements
Efferent innervation	Motor	Autonomic	Autonomic
Contractions	All or non, triggered at motor end plates	All or non, intrinsic (beginning at nodes of conducting fibers)	Partial, slow often spontaneous wavelike and rhythmic

Cell response to increased load	Hypertrophy (increase in fiber size)	Hypertrophy	Hypertrophy and hyperplasia (increase in cell/fiber number)
Capacity for regeneration	Limited, involving satellite cells mainly	Very poor	Good, involving mitotic activity of muscle cells

	Type I: slow oxidative	Type IIA: fast oxidative/glycolytic	Type IIB:fast glycolytic
Twitch speed	Slow	Fast	Fast
Twitch force	small	Medium	Large
Resistance to fatigue	High	High	Low



Nervous tissue and system

Functions

- Sensory, recognize changes in environment
- Integrations, analysis of sensory information, storage of information, decisions
- Motor, initiates impulses to effectors (muscles or glands) that do work)

Cells

- Neurons and supporting cells
- Neurons – produce impulses to transfer information
- Supporting cells – support, protect, nourish and neurons
- Neuroglia (glia cells), astrocytes, oligodendrocytes, ependymocytes, microglia, satellite cells, schwann cells (neurolemmocytes)
- In CNS, tumors arise from abnormal divisions of glial cells

Neuroglia cells

- Found in CNS and PNS
- Perform a supporting function for neurons

CNS	PNS
<ul style="list-style-type: none">- Oligodendrocyte- Astrocytes- Ependymal cells- Microglia	<ul style="list-style-type: none">- Schwann cells- Satellite cells

Classifications of neurons

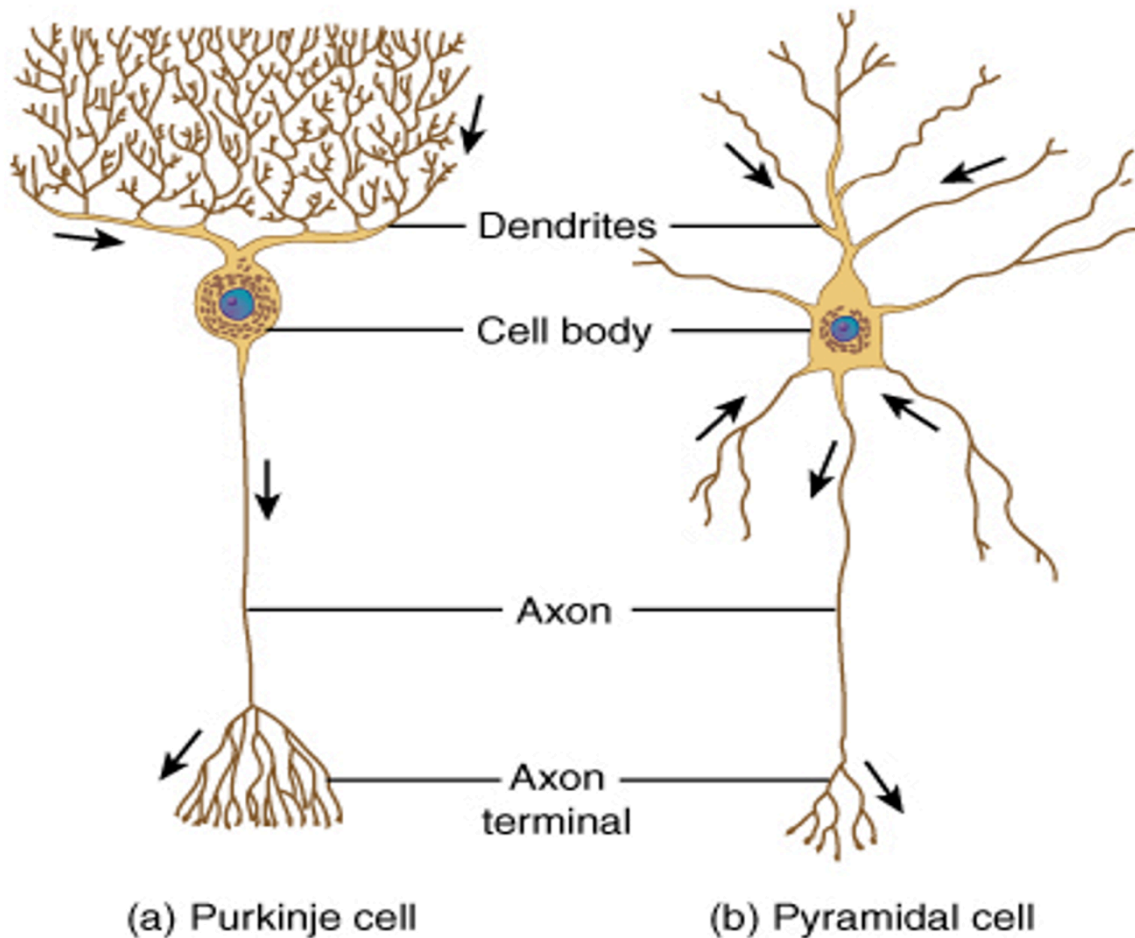
Based on structure – number of processes extending from cell body

- Unipolar
- Pseudounipolar (spinal ganglia)
- Bipolar (retina, olfactory mucosa)
- Multipolar

Based on function – type and direction of information

- Sensory (afferent)
- Motor (efferent)
- Association (interneurons)

Types of interneurons



Neuron

- Cell body (perikaryon)
- contains nucleus
- rich in ribosomes and rough endoplasmic reticulum (nissl bodies)
- produces proteins for export to axon or dendrite
- lots of mitochondria
- neurofilaments (neurofibrils)- intermediate filaments

Structure of neuron

Dendrites

- carry nerve impulses toward cell body
- receive stimuli from synapses or sensory receptors

Cell body

- contains nucleus and nissl bodies
- a form of rough endoplasmic reticulum

Axon

- carry nerve impulses away from the cell bodies
- interact with muscle, glands or other neurons

Neuron processes

Dendrites

- bring depolarization toward cell body
- no myelin

Axon

- generally take action potential (impulse) away from cell body
- myelinated or unmyelinated
- axon hillock
- telodendria, synaptic end bulb

Myelination (myelin sheath)

- formed by oligodendrocytes (CNS), schwann cells (PNS)
- composed of lipids and proteins (neurolemma = cell membrane of schwann cell in PNS)
- nodes of ranvier = spaces between sheath cells

Myelin sheath

- increase speed of impulses conduction
- decrease energy required (Na^+/K^+ pump only active at nodes)

Multiple sclerosis – destruction of myelin sheath in

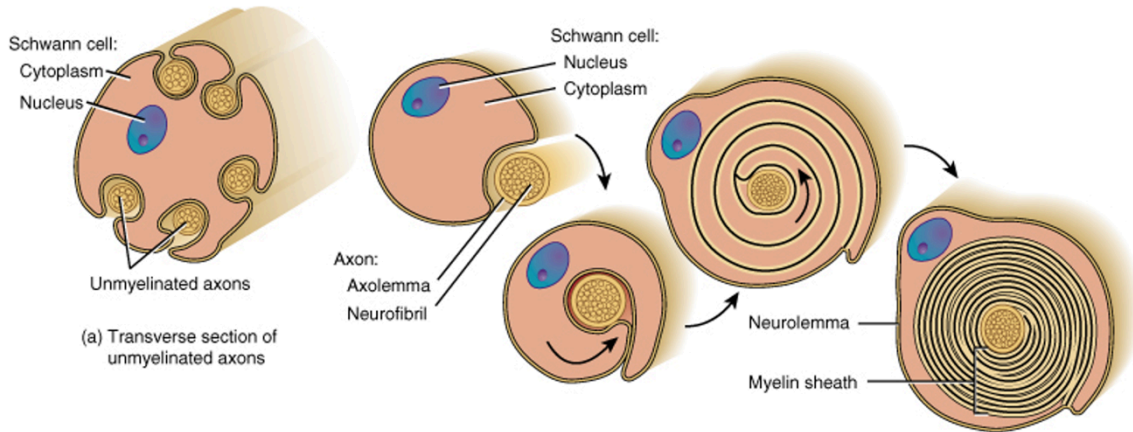
CNS – diminishes impulses conduction

Development of myelin sheath

- myelination begins with the invagination of a single axon into support cell
- oligodendrocytes or schwann cells wrapping spiral layers of cell membrane around axon

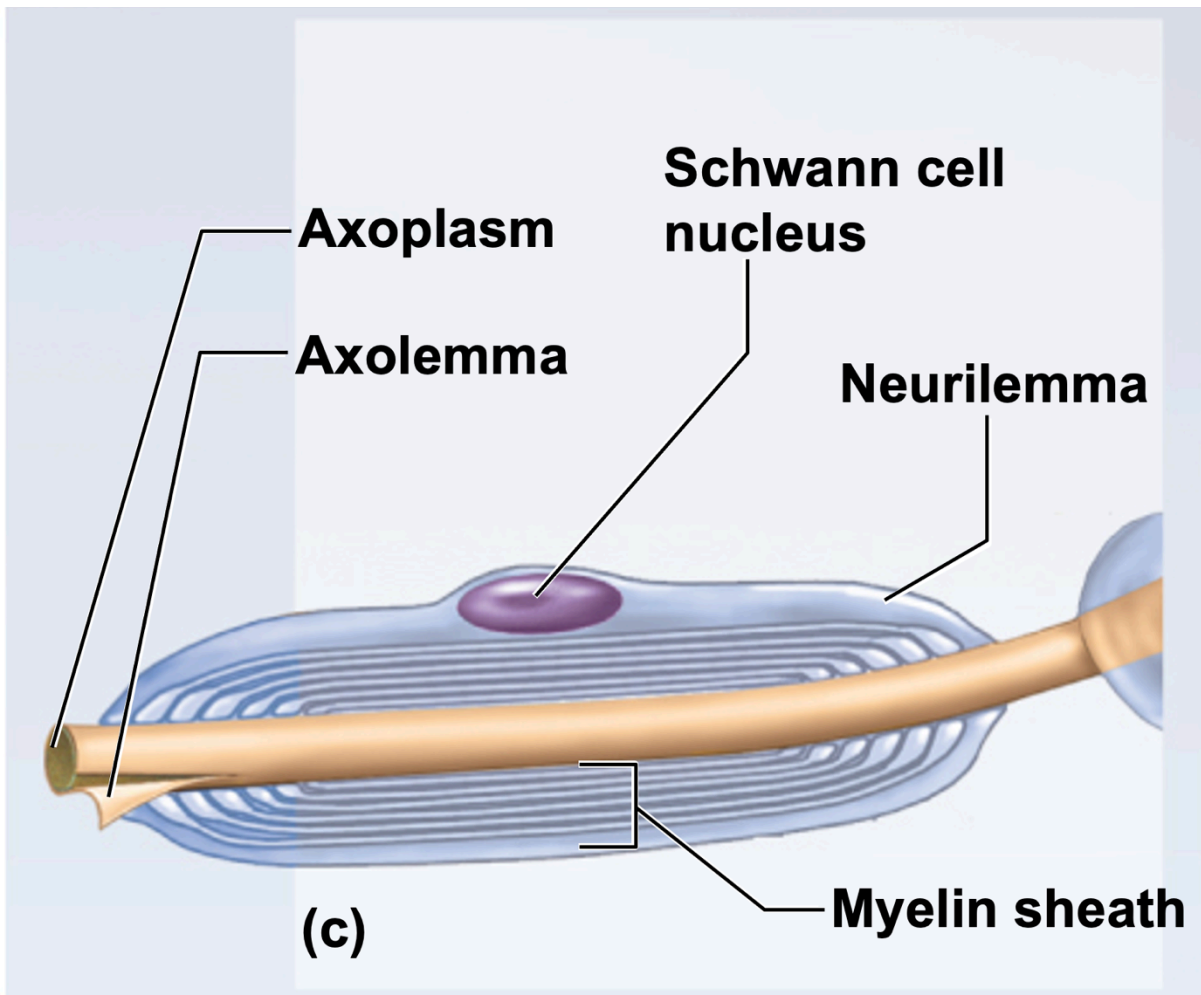
Schwann cells – PNS

- from myelin sheath around peripheral axons
- look like jelly with neurolemma cover
- node of ranvier separates each schwann cells



(b) Transverse sections of stages in the formation of a myelin sheath

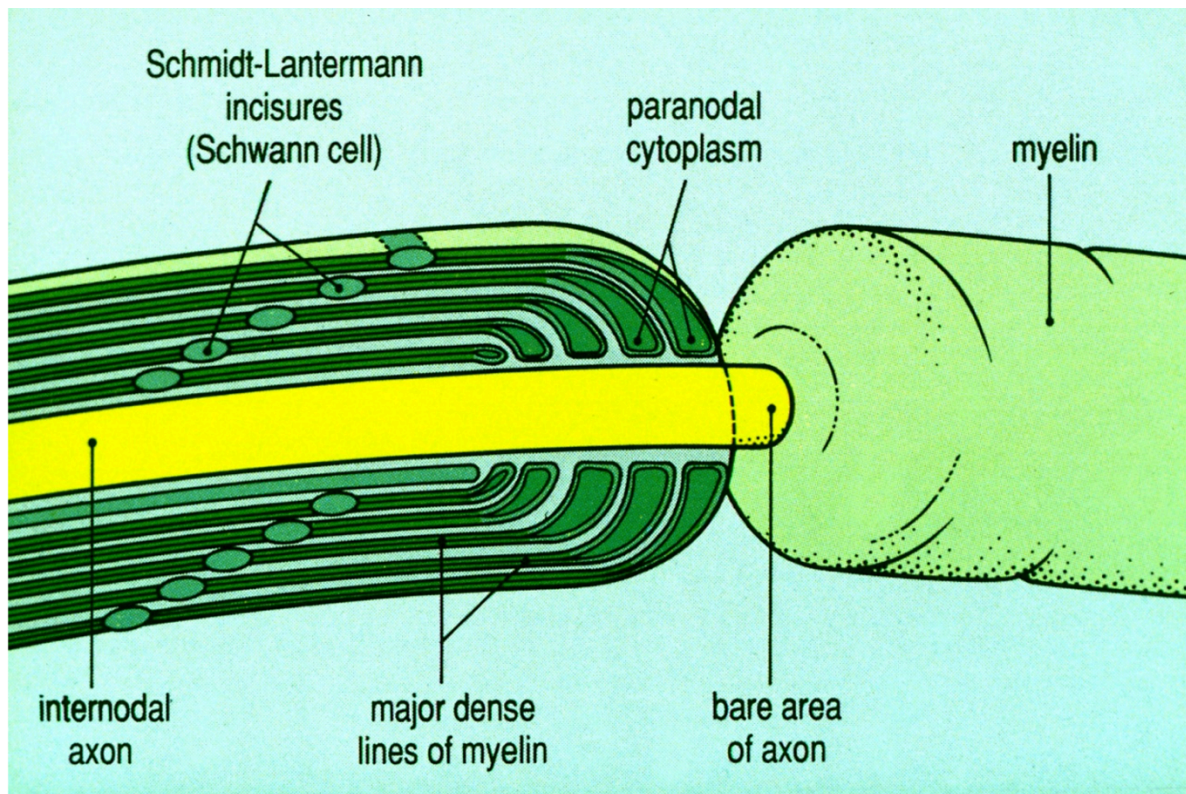
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Node of Ranvier

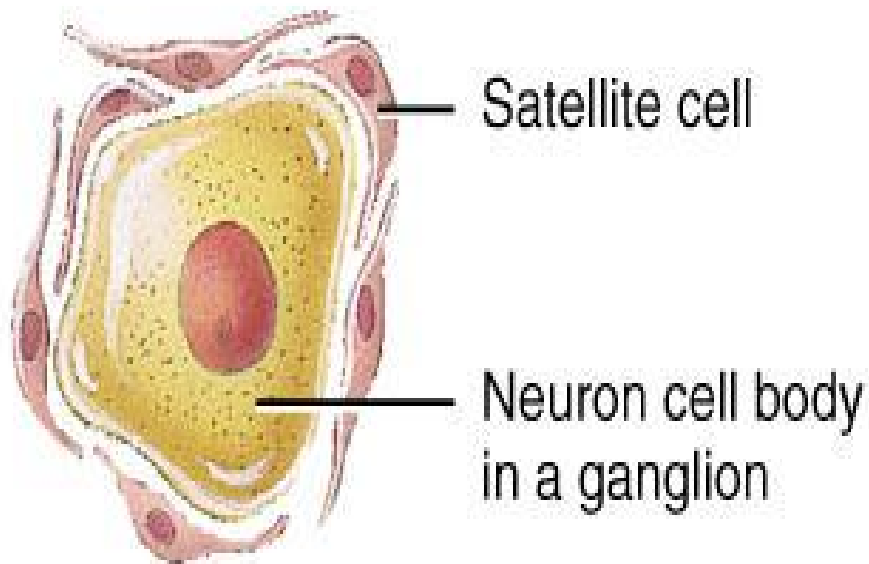
- in CNS axons in the nodes are bare

- in PNS are partly covered by tongues of cytoplasm from schwann cells



Synapses

- Formed by interaction of axon terminal and cell membrane of target cell (axsomatic, axodendritic, axoaxonic)
- components: bouton, presynaptic membrane, synaptic cleft, postsynaptic memb., neurosecretory vesicles



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Schwann cells

- surround all axons of neurons in the PNS creating a *neurilemma* around them. Neurilemma allows for potential regeneration of damaged axons
- creates *myelin sheath* around most axons of PNS

Satellite cells

- support groups of cell bodies of neurons within *ganglia* of the PNS

Astrocytes

- connect neurons to blood supply
- scaffolding for other cells
- blood-brain barrier
- 2 types:
 - fibrous – abundant in white matter
 - protoplasmic – gray matter

- ncreate supportive framework for neurons
- create “blood-brain barrier”
- monitor & regulate interstitial fluid surrounding neurons
- secrete chemicals for embryological neuron formation
- stimulate the formation of scar tissue secondary to CNS injury

Microgli

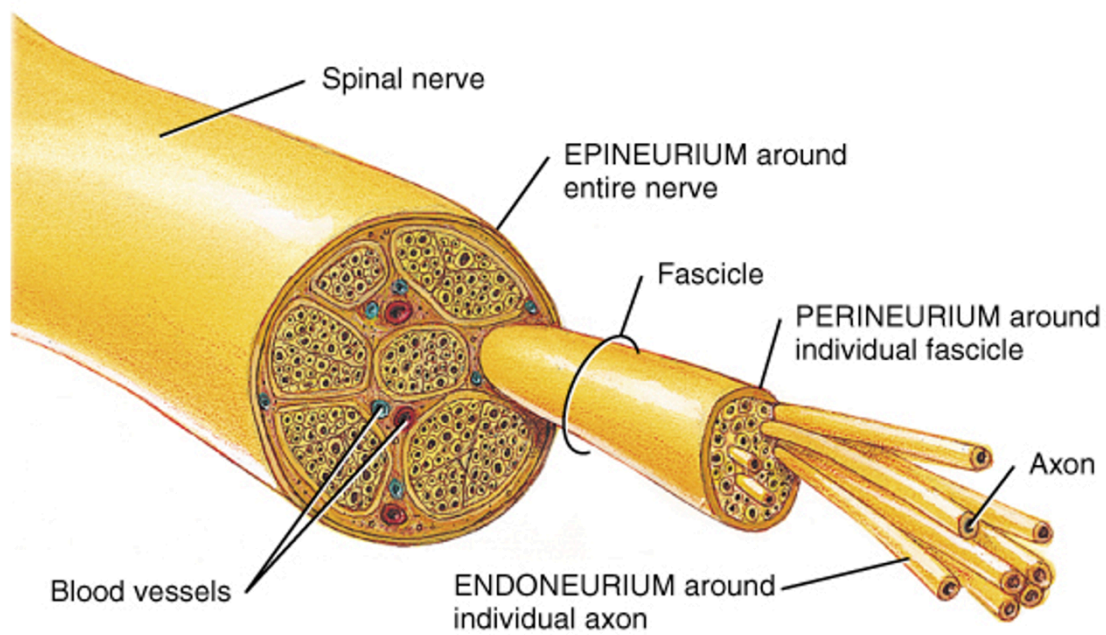
- specialized macrophages of CNS
- form network of cells throughout brain
- Similar to dendritic antigen-presenting cells

Oligodendrocytes

- produce myelin sheath in CNS

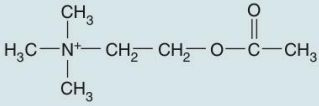
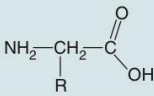
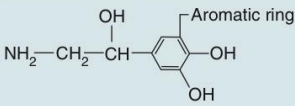

Epedymal cells

- epithelial lining of brain ventricles and central canal of spinal cord
- produce cerebrospinal fluid



(a) Transverse sections showing the coverings of a spinal nerve

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Neurotransmitter	Description/Action
ACETYLCHOLINE (ACh)	
	Chemical structure significantly different from that of other neurotransmitters; active in CNS and in both somatic and autonomic parts of PNS; binds to ACh receptors (cholinergic receptors) in PNS to open ion channels in postsynaptic membrane and stimulate muscle contraction
AMINO ACIDS	
	Molecules with both carboxyl (—COOH) and amine (—NH ₂) groups and various R groups; act as important transmitters in the CNS
Glutamate	Excites activity in neurons to promote cognitive function in the brain (learning and memory); most common neurotransmitter in the brain; opens Na ⁺ channels
Gamma-aminobutyric acid (GABA)	Synthesized from glutamate; primary inhibitory neurotransmitter in the brain; also influences muscle tone; opens or closes various ion channels
Glycine	Inhibits activity between neurons in the CNS, including retina; opens Cl ⁻ channels
MONOAMINES	
	Molecules synthesized from an amino acid by removing the carboxyl group and retaining the single amine group; also called biogenic amines
Serotonin or 5-hydroxytryptamine (5-HT)	Has various functions in the brain related to sleep, appetite, cognition (learning, memory), and mood; modulates actions of other neurotransmitters
Catecholamines	A distinct group of monoamines
Dopamine	Produces inhibitory activity in the brain; important roles in cognition (learning, memory), motivation, behavior, and mood; opens K ⁺ channels, closes Ca ²⁺ channels
Norepinephrine (noradrenaline)	Neurotransmitter of PNS (sympathetic division of autonomic nervous system) and specific CNS regions
Epinephrine (adrenaline)	Has various effects in the CNS, especially the spinal cord, thalamus, and hypothalamus
NEUROPEPTIDES	
	Small polypeptides act as signals to assist in and modulate communication among neurons in the CNS
Enkephalin	Helps regulate response to noxious and potentially harmful stimuli
Neuropeptide Y	Involved in memory regulation and energy balance (increased food intake and decreased physical activity)
Somatostatin	Inhibits activities of neurons in specific brain areas
Substance P	Assists with pain information transmission into the brain
Cholecystokinin (CCK)	Stimulates neurons in the brain to help mediate satiation (fullness) and repress hunger
Beta-endorphin	Prevents release of pain signals from neurons and fosters a feeling of well-being
Neurotensin	Helps control and moderate the effects of dopamine
OTHERS	
Adenosine	Also part of a nucleotide, inhibits activities in certain CNS neurons
Nitric oxide	Involved in learning and memory; relaxes muscle in the digestive tract; important for relaxation of smooth muscle in blood vessels (vasodilation)

Glial Cell Type	Origin	Location	Main Functions
Oligodendrocyte	Neural tube	CNS	Myelin production, electrical insulation
Astrocyte	Neural tube	CNS	Structural and metabolic support of neurons, especially at synapses; repair processes
Ependymal cell	Neural tube	Line ventricles and central canal of CNS	Aid production and movement of CSF
Microglia	Bone marrow (monocytes)	CNS	Defense and immune-related activities
Schwann cell	Neural crest	Peripheral nerves	Myelin production, electrical insulation
Satellite cells (of ganglia)	Neural crest	Peripheral ganglia	Structural and metabolic support for neuronal cell bodies

Blood

Specialized connective tissue = mixture of cellular elements, fluid, proteins, metabolites

The cellular elements (formed elements) of the blood are formed in the bone marrow

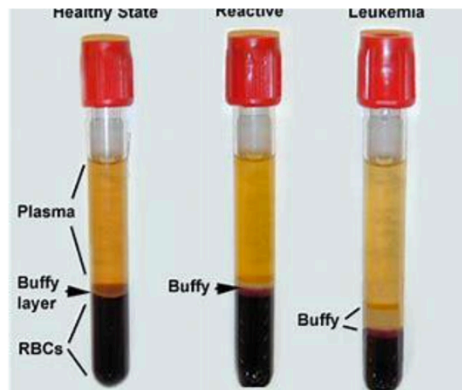
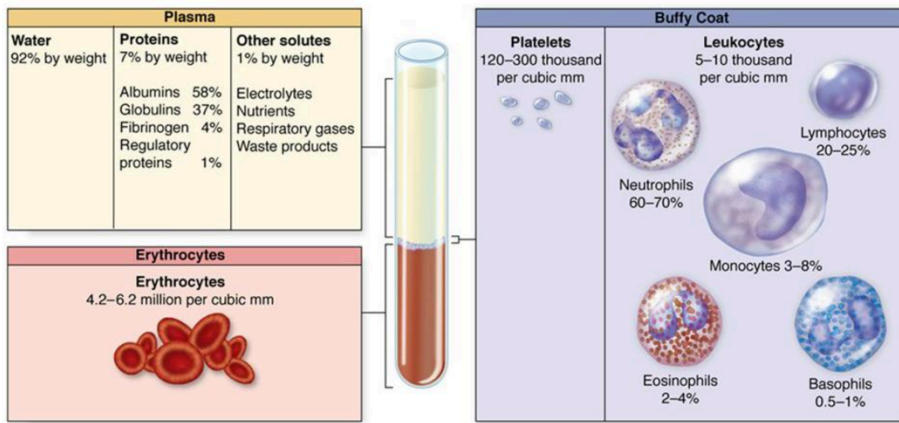
Most of proteins of the plasma are made by the liver.

Plasma: solutions of proteins, the cells circulate, carries nutrients metabolites, antibodies, hormones, proteins throughout the body

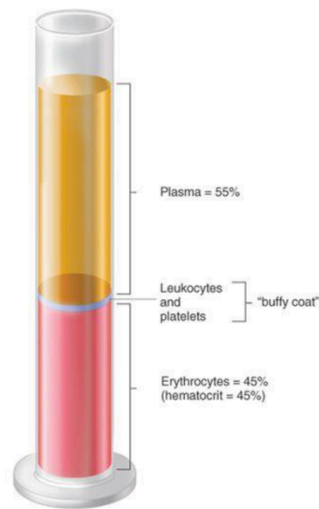
White blood cells(leukocytes) = a defensive role (destroying infecting organisms and removal of dead or damaged tissues)

Platelets (thrombocytes) = essential in hemostasis (aggregate and degranulate in hemostasis)

Red blood cells (erythrocyte) = transport oxygen from the lungs to the peripheral tissues and carbon dioxide from the peripheral tissues to the lungs.



Hematocrit, plasma & serum



Hematocrit = volume of red cells (~45%)

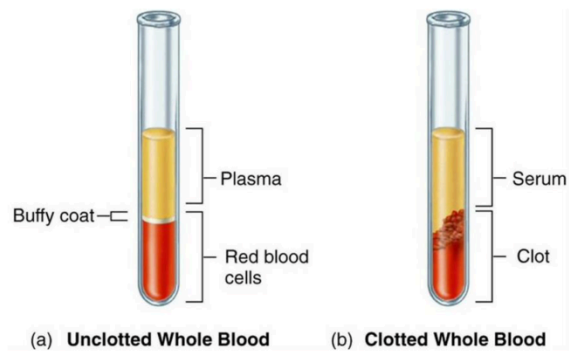
Plasma = fluid in fresh blood

Serum = fluid after blood has clotted

Plasma = serum + fibrinogen (& other clotting factors)

Normal volumes:

blood ~5.5L, plasma ~3L, rbc's ~2.5L



with anticoagulants
eg, heparin, citrate

Blood smear (Film)

Anucleated red blood cells

Nucleated white blood cells (five types)

1. Neutrophils 40-75%
2. Eosinophils 5%
3. Basophils 0.5%
4. Lymphocytes 20 – 50%
5. Monocytes 1-5%

Red blood cells (erythrocytes)

- function exclusively within the vascular system

Primary function

- Transport of O₂ and CO₂

Structure of red blood cells

- Shaped like a double concaved disk (for high surface area/ volum ratio)
- Very flexible cell and can change shape. Takes about 30 second to make a single trip around circulation
- During their formation, loose nucleus and organelles only keeping cytoskeleton
- Limited lifespan of about 120 days

Hemoglobin

- makes up 95% of red blood cells content
- Made of four protein subunits each containing heme. Heme contains iron and combines with oxygen but the oxygen is easily released. CO₂ binds and releases from heme just as easily

Sickle cell anemia

- Mutation in hemoglobin gene causing red blood cells to become stiff and sickle shaped when they release O₂ can transport O₂ and CO₂, but they have a much shorter lifespan and are removed prematurely

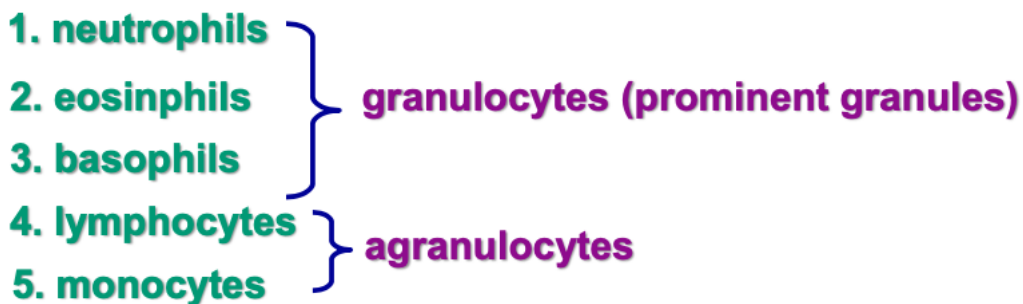
Blood types

- Have specific surface proteins that are exposed to plasma. These proteins are genetically determined
- Three proteins (agglutinogens) are important in blood capability between people.

- They are type A, type B and type D
1. Person can have different combinations (eks, Type A, Type B, Type AB or neither one- Type O)
 2. Rh factor – can have it or not
Usually referred to as being Rh(negative) if you don't have the Rh- (negative) if you don't have the Rh factor
Rh(positive) if you do

White blood cells

- Function within the vascular system and tissues



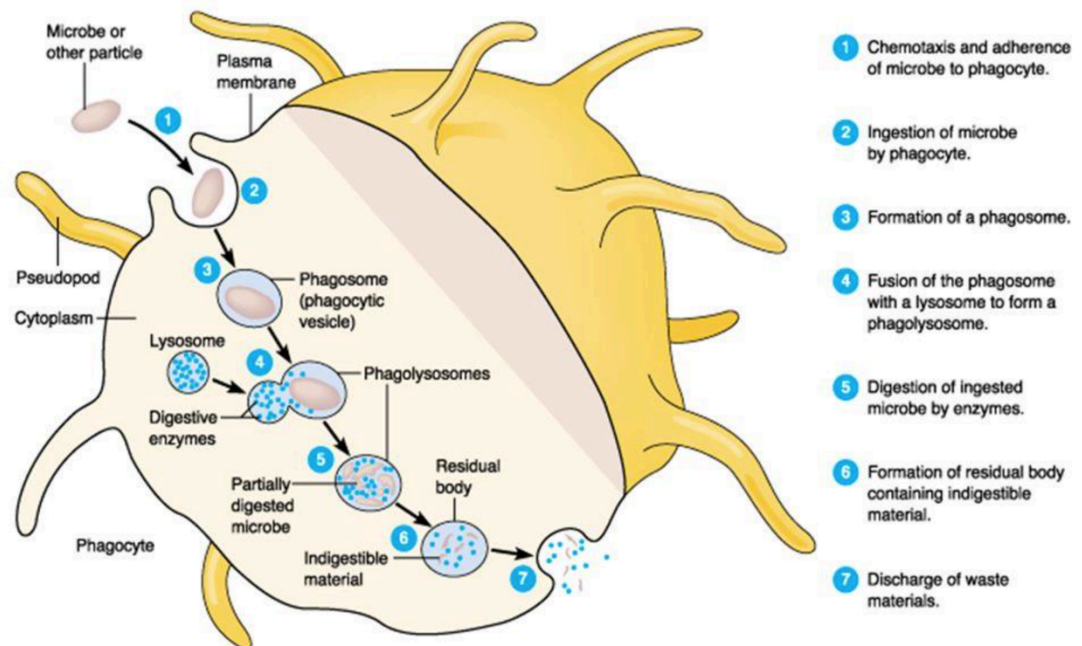
- Originate from bone marrow – use the blood for transport form the bone marrow to their major sites of activity
- The majority of the function – when they leave the circulation to enter tissues
- Lymphocytes in lymph nodes and spleen
- In tissues: monocytes transform into macrophages basophils become mast cells

White blood cells – neutrophils (polymorphonuclear leukocytes)

1. the most common type 40 – 75%of WBSs; lifespan 1-4 days

2. a DEFENSIVE ROLE migrate into areas of tissue damage & phagocytose bacteria and dead cells (in the early stage of acute inflammatory response to tissue injury - the major constituent of pus)
3. increase in number in blood in BACTERIAL INFECTION AND INFLAMMATION (neutrophilia)
4. multilobed nucleus and granules (azurophilic granules with myeloperoxidase, lysozyme, defensins; specific granules with ECM – degrading enzymes)

Phagocytosis: It's enhanced in neutrophils and macrophage by opsonization (phagocyte adhesion to antibodies and/or complement protein C3b bound to microbe).



Eosinophils

1. 5% of wbc's; lifespan `1-2 wk.
2. PHAGOCYtic CELLS – remove foreign compounds that have reacted with antibodies (particular affinity for antigen-antibody complexes)

3. Rapid increase in numbers in circulation in an ALLERGIC REACTION (hay fever, asthma) or PARASITIC INFECTION
4. Bilobed nucleus & strongly eosinophilic granules (major basic proteins (MBS), eosinophilic peroxidase)

Basophils

1. 0.5% of wbcs; lifespan several months
2. Reside in support tissues beneath epithelia, around blood vessels, lining serous cavities
3. Large, intensely basophilic granules (contain heparin, histamine, leukotrienes, eosinophil chemotactic factor and other vasoactive mediators)
4. Receptors for immunoglobulin E (ige)

An IMMEDIATE HYPERSENSITIVITY (ANAPHYLACTOID) reaction (i.g. Hay fever, asthma, urticaria, anaphylaxis)

Monocytes

1. 1-5% of wbcs
2. Remain in circulation a few days, then enter tissues (called macrophages) = PRECURSORS OF MACROPHAGES, OSTEOCLASTS, MICROGLIA; arrive at injury site; while engulfing foreign material they release chemicals attracting and stimulating other macrophages, fibroblasts to help repair the injury
3. Non-segmented, kidney-shaped nucleus
4. Antigen-presenting cells

Lymphocytes

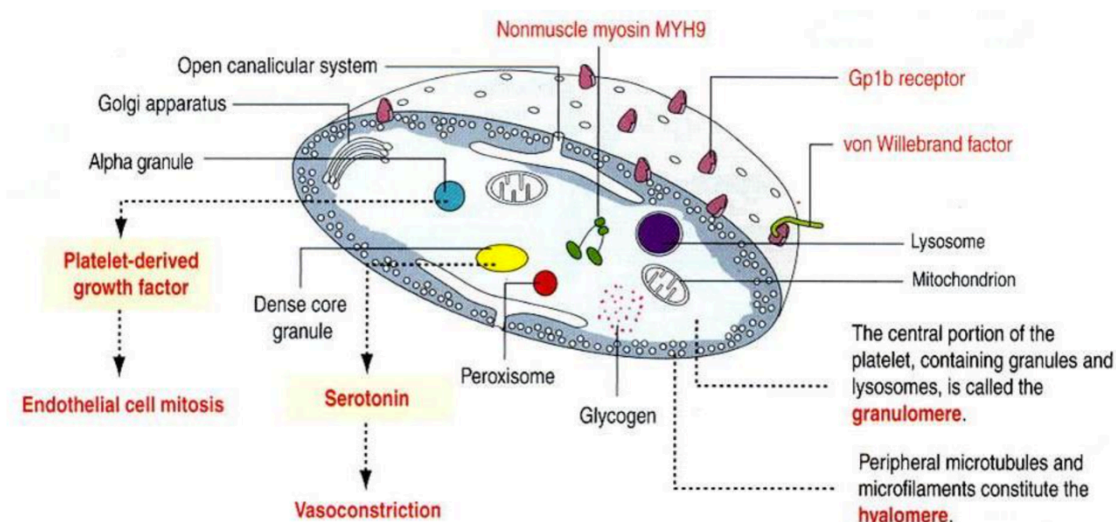
1. 20-50% of wbcs
2. Most circulating are LYMPHOCYTES (only 3% are LARGE) migrate into tissues & into special organs of the immune system (mediate the immune responses)
3. Their number increase in response to INFECTIONS

4. B and T cells, natural killer cells (NK) (different roles: responsible for generating specific immune responses)

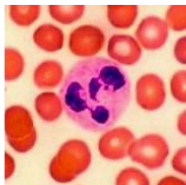
Palates – thrombocytes

1. Are small cell fragments, anuclear, derived from megakaryocytes (huge precursor cells in the bone marrow)
2. Are important in HEMOSTASIS (promote blood clotting)
3. Aggregate together and degranulate in hemostasis
4. Severe reduction in the number (THROMBOCYTOPENIA) spontaneous bleeding
5. 2–4 μ m diameter
6. Life span: 10 days

PLATELETS (thrombocytes)

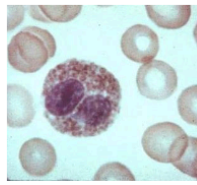


WHITE BLOOD CELLS



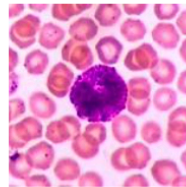
NEUTROPHIL

- 12-14 μ m in diameter
- multilobed nucleus
- pale-staining cytoplasm



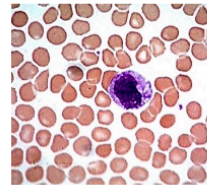
EOSINOPHIL

- 12-17 μ m in diameter
- bilobed nucleus
- strongly eosinophilic granules



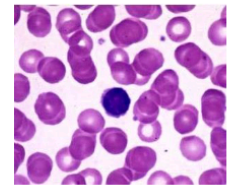
BASOPHIL

- 14-16 μ m in diameter
- non-segmented or bilobed nucleus
- large, intensely basophilic granules



MONOCYTE

- 20 μ m in diameter
- kidney-shaped nucleus
- pale-staining cytoplasm



LYMPHOCYTE

- 6-9 μ m in diameter
- condensed nucleus occupies 90% of the cell

Blood circulatory system

- mediates the continuous movement of all body fluids
- the main way of transporting oxygen, carbon dioxide, nutrients and metabolic breakdown (waste) products, cells of the immune and other defense systems, chemical messengers (hormones)
- involved in temperature regulation

3 MAIN BLOOD CIRCULATORY SYSTEMS:

1. **SYSTEMIC**, transfers oxygenated blood from a central pump (the heart) to all of the body tissue (systemic arterial system) and returns deoxygenated blood (with high CO₂ content from the tissue to the central pump (systemic venous system)

2. **PULMONARY**, transfers deoxygenated blood from the heart to the lungs (pulmonary arterial system) and reoxygenated blood from the lungs back to the central pump (pulmonary venous system)

3. **PORTAL**, vascular channels that do not depend on a central pump (carry substances from one site to another) i.g. hepatic portal venous run between the intestines and the liver

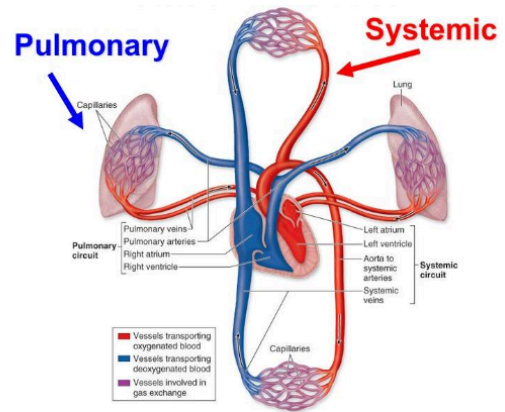
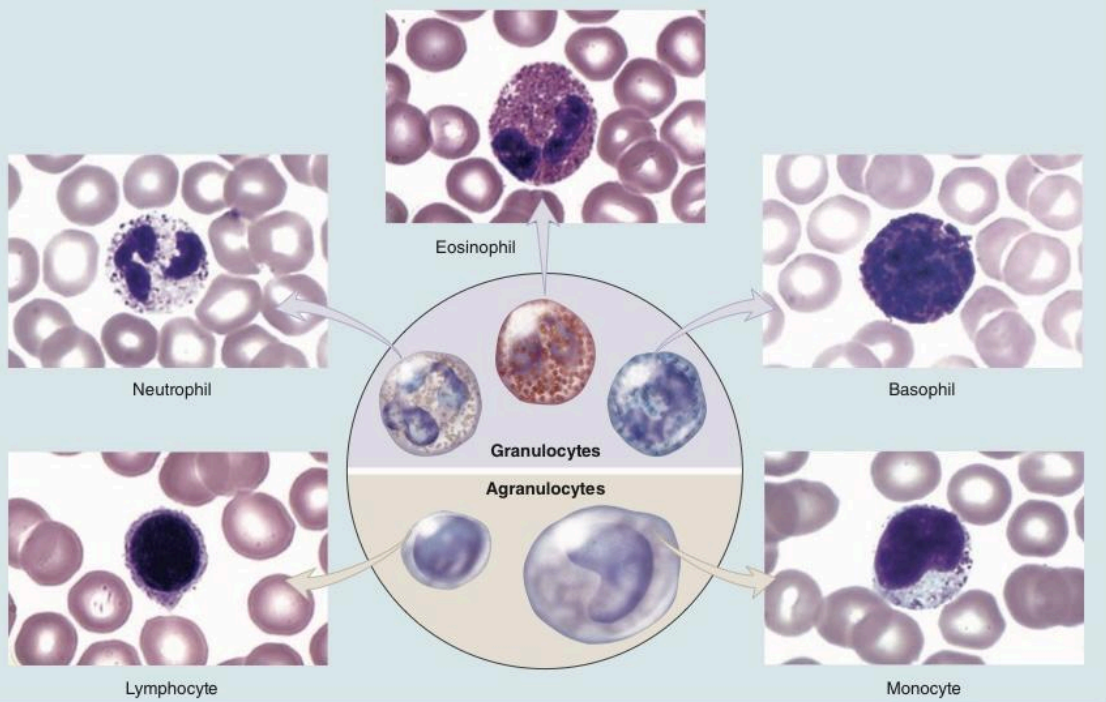


TABLE 12-2 Leukocytes: Numbers, structural features, and major functions.



Type	Nucleus	Specific Granules ^a	Differential Count ^b (%)	Life Span	Major Functions
Granulocytes					
Neutrophils	3-5 lobes	Faint/light pink	50-70	1-4 d	Kill and phagocytose bacteria
Eosinophils	Bilobed	Red/dark pink	1-4	1-2 wk	Kill helminthic and other parasites; modulate local inflammation
Basophils	Bilobed or S-shaped	Dark blue/purple	0.5-1	Several months	Modulate inflammation, release histamine during allergy
Agranulocytes					
Lymphocytes	Rather spherical	(none)	20-40	Hours to many years	Effector and regulatory cells for adaptive immunity
Monocytes	Indented or C-shaped	(none)	2-8	Hours to years	Precursors of macrophages and other mononuclear phagocytic cells

TABLE 12-1

The composition of blood plasma.

Plasma Component (Percentage of Plasma)	Functions
Water (~92% of plasma)	Is the solvent in which formed elements are suspended and proteins and solutes are dissolved
Plasma proteins (~7% of plasma)	All proteins serve to buffer against pH changes
Albumin (~58% of plasma proteins)	Exerts osmotic force to retain fluid within the microvasculature Contributes to blood's viscosity Binds and transports some fatty acids, electrolytes, hormones, and drugs
Globulins (~37% of plasma proteins)	α -Globulins transport lipids and some metal ions β -Globulins transport iron ions and lipids in bloodstream γ -Globulins are antibodies with various immune functions
Fibrinogen (~4% of plasma proteins)	Participates in blood coagulation (clotting); precursor of fibrin
Regulatory proteins (>1% of plasma proteins)	Consists of enzymes, proenzymes, hormones, and the complement system
Other Solutes (~1% of Blood Plasma)	
Electrolytes (eg, sodium, potassium, calcium, chloride, iron, bicarbonate, and hydrogen)	Help establish and maintain membrane potentials, maintain pH balance, and regulate osmosis (control of the percentages of water and salt in the blood)
Nutrients (eg, amino acids, glucose, cholesterol, vitamins, fatty acids)	Energy source; precursor for synthesizing other molecules
Respiratory gases (eg, oxygen: > 2% dissolved in plasma, 98% bound to hemoglobin within erythrocytes; and carbon dioxide: ~7% dissolved in plasma, ~27% bound to hemoglobin within erythrocytes, ~66% converted to HCO_3^-)	Oxygen is needed for aerobic cellular respiration; carbon dioxide is a waste product produced by cells during this process
Wastes (breakdown products of metabolism) (eg, lactic acid, creatinine, urea, bilirubin, ammonia)	Waste products serve no function in the blood plasma; they are merely being transported to the liver and kidneys where they can be removed from the blood

The lymphatic system

Responsible for the protection against external environment composed of foreign substances and organisms – antigens

Specific cells – immunocompetent cells inactive or destroy invasive, foreign substances and organisms

Entire system – immune system

Lymphoid tissue consist of :

- Reticular cells
- Reticular fibres
- Lymphocytes – B,T
- Macrophages
- Antigen- presenting cells (APCs)
- Plasma cells

Immune system

- Recognition of exogenous agents by antigen- presenting cells (APCs) and breaking down into key components (antigens)
- Presenting to effector cells
- Lymphocytes proliferation

Immune response

- Cell – mediated immunity – action of lymphocytes and macrophages to destroy or neutralize the foreign agent

- Humoral immunity – secretion of proteins (antibodies) by one type of lymphocyte

Antibodies

Synthesized by B lymphocytes and bind to specific antigens

Known as immunoglobulins (IgG, IgA, IgD, IgE, IgM)

Consist of light and heavy chains