



Cytoplasmic Organelles, Microskeleton, Inclusions

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OUTLINE

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SUMMARY OF ABBREVIATIONS

ATP	Adenosine Triphosphate
Ca ²⁺	Calcium
ECM	Extracellular Matrix
ER	Endoplasmic Reticulum
H ⁺	Hydrogen
H ₂ O ₂	Hydrogen Peroxide
Na ⁺	Sodium
SER	Smooth Endoplasmic Reticulum
RER	Rough Endoplasmic Reticulum
TEM	Transmission Electron Microscope

LEGENDS

Must know	Lecturer	Book	Presentation
!	👤	📖	💻

LEARNING OBJECTIVES

- At the end of the lecture, the student should be able to:
- ✓ Describe the structure, composition, and functions of the plasma membrane
 - ✓ Explain the mechanisms of membrane transport
 - ✓ Discuss the major pathways of cell signalling and the mechanisms of signal reception and transduction
 - ✓ Identify the major cytoplasmic organelles and describe their ultrastructure, functions, and distribution in different cell types
 - ✓ Differentiate the 3 major components of the cytoskeleton - microtubules, microfilaments, and intermediate filaments- with respect to their structure, composition, and cellular functions.
 - ✓ Describe the different types of cytoplasmic inclusions.

INTRODUCTION TO CELL

- **Cell**
 - Basic structural and functional units of the body

Table 1. Cell

Prokaryotic	Eukaryotic
• (+) Cell wall • (-) Nuclei and membranous cytoplasmic structures	• (+) Distinct, membrane-enclosed nucleus • (+) Cytoplasm fluid containing a system of membranous

organelles, non-membranous molecular assemblies, and a cytoskeleton

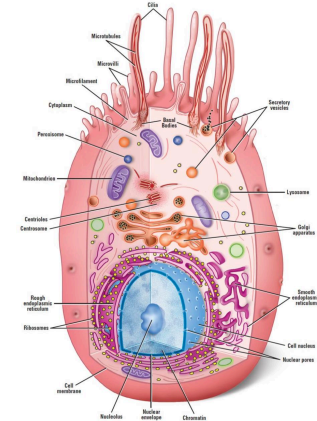


Figure 1. Cell

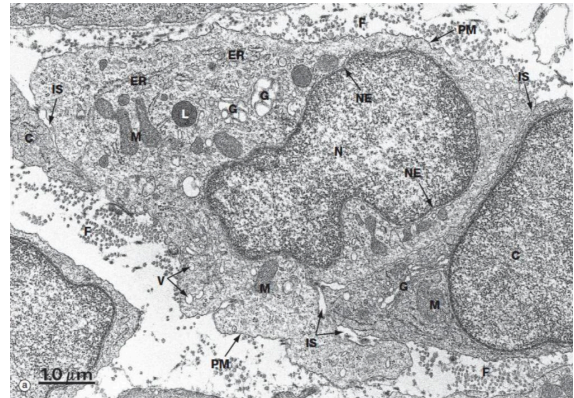


Figure 2. Histology of a cell

CELL DIFFERENTIATION

- The average adult human body consists of nearly 40 trillion cells
- **Zygote**
 - Hundreds of histologically distinct cell types
 - A single cell formed by the merger of a spermatozoon with an oocyte at fertilization
- **Blastomeres**
 - Cells produced by first zygotic cellular division
 - Give rise to all tissue types of the fetus
 - Cells of the inner cell mass are called **embryonic stem cells**

Differentiation

- **Specialization process** - express sets of genes that mediate specific cytoplasmic activities - organized in tissues with specialized functions
 - **Muscle cell precursors**
 - Elongate into long, fiber-like cells containing large arrays of actin and myosin
 - Specialized cells have capacity for one or more of these functions during differentiation

A summarized table of Cell Differentiation is available in the appendix. !

- Cells that appear similar structurally often have different families of receptors for signaling molecules (hormones and ECM components) causing them to behave differently
 - Breast fibroblasts and uterine smooth muscle cells are exceptionally sensitive to female sex hormones, while most others are insensitive

PLASMA MEMBRANE

- AKA **Cell membrane**/plasmalemma
- Envelops every eukaryotic cell
 - Defines the **outer limit** of the cell
- Forms an important barrier or boundary between the internal and external environment
- ~ **7.5 to 10 nm** in thickness
- Consists of:
 - Phospholipids
 - Cholesterol
 - Proteins
- Membrane Phospholipids**
 - Amphipathic
 - Most stable when organized into a bilayer
 - Phospholipids in each half of the bilayer are different
 - Characterized as a **fluid mosaic model**
 - The lipid bilayer of the cell membrane has a **fluid consistency**

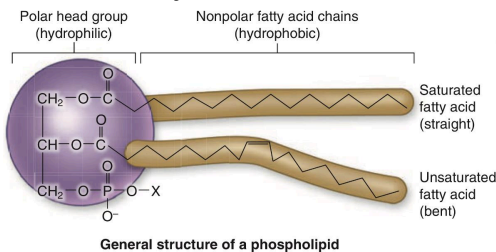
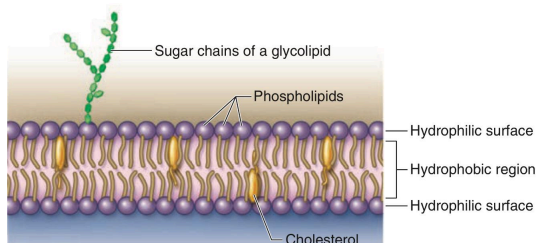


Figure 3. Structure of a Phospholipid



PLASMA MEMBRANE FUNCTIONS

Physical Barrier

- Establishes a flexible boundary, protects cellular contents, and supports cell structure
- Phospholipid bilayer**
 - Separates substances inside and outside the cell

Selective Permeability

- Regulates entry and exit of ions, nutrients, and waste molecules through the membrane

Electrochemical Gradients

- Establishes and maintains an electrical charge difference across the plasma membrane

Communication

- Contains receptors that recognize and respond to molecular signals

CHOLESTEROL

- Insert at varying densities among the closely-packed phospholipid fatty acids
- Restrict movements and modulating the fluidity of all membrane components

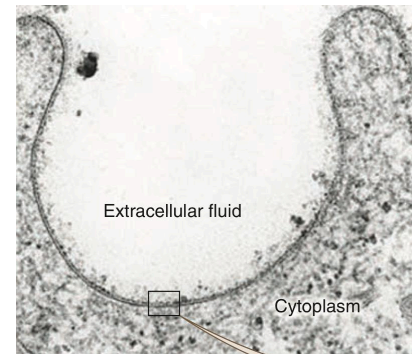


Figure 5. Extracellular fluid; Cytoplasm

MEMBRANE PROTEINS

- Major constituents of membranes (~50% by weight in the plasma membrane)
- Interspersed within and embedded in the phospholipid bilayer
- Integral membrane proteins and peripheral membrane proteins

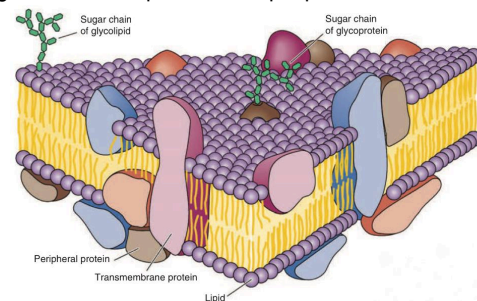


Figure 6. Proteins associated with the membrane lipid bilayer

INTEGRAL MEMBRANE PROTEINS

- Incorporated within the lipid bilayer
- Transmembrane proteins**
 - Span the entire thickness of the cell membrane, and are exposed on the outer and inner surface of the cell membrane
- Participate in transporting molecules across the lipid bilayer
- Serve as membrane receptors for different hormones
- Attach to and support the internal cytoskeleton of the cell membrane
- Possess specific enzyme activity

PERIPHERAL PROTEINS

- Do not protrude into the phospholipid bilayer and are not embedded within the cell membrane.
- Associated with the cell membrane on both its extracellular (outer) and intracellular (inner) surfaces.
- Some of the peripheral proteins are anchored to the network of tiny microfilaments of the cytoskeleton of the cell and are held firmly in place.

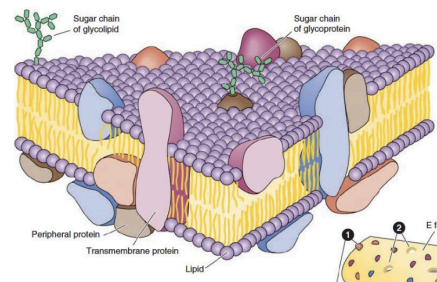


Figure 7. Integral and Peripheral Protein

GLYCOLIPIDS

- The outer layer's lipids
- GLYCOCALYX**
 - Located on the external surface of the cell membrane oligosaccharide chains and contribute to a delicate cell surface coating
 - Composed of carbohydrate molecules that are attached to the integral proteins of the cell membrane and that project from the external cell surface
 - Has important roles in **cell recognition**, **cell-to-cell attachments** or **adhesions**, and as a **receptor** or binding site for different bloodborne hormones.

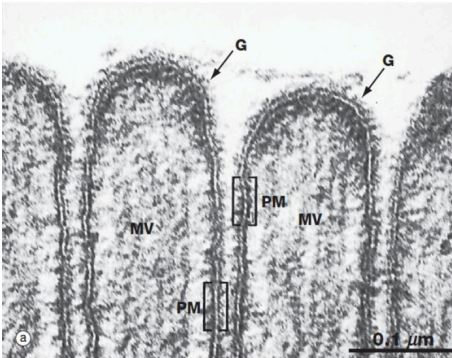


Figure 8. Glycocalyx^[PPT]

TRANSMEMBRANE PROTEINS & MEMBRANE TRANSPORT

- The plasma membrane is the site where materials are exchanged between the cell and its environment.

Table 3. PASSIVE VS ACTIVE PROCESS

PASSIVE PROCESS	ACTIVE PROCESS
Movement of substances <u>down a concentration gradient</u> due to the kinetic energy of the substance; no expenditure of cellular energy is required; continues until equilibrium is reached (if unopposed)	Movement of substances requires expenditure of cellular energy
- Diffusion - Facilitated - Channels, Carriers - Osmosis	ACTIVE TRANSPORT - Primary, secondary, symport, antiport VESICULAR TRANSPORT - Exocytosis, endocytosis, phagocytosis, pinocytosis, receptor-mediated endocytosis

DIFFUSION

- Transports small, nonpolar molecules directly through the lipid bilayer.
- Lipophilic molecules diffuse through membranes readily

CHANNELS

- Are multipass proteins forming transmembrane pores through which ions or small molecules pass selectively.
- Cells open and close specific channels for Na⁺, K⁺, Ca²⁺, and other ions in response to various physiological stimuli.
- Water molecules usually cross the plasma membrane through channel proteins called aquaporins.

Carriers

Are transmembrane proteins that bind small molecules and translocate them across the membrane via conformational changes

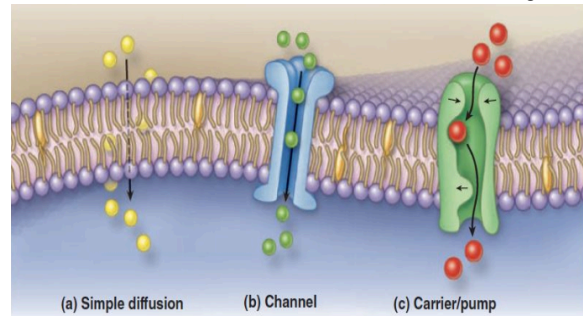


Figure 9. Membrane Transport^[PPT]

TRANSPORT BY VESICLES: ENDOCYTOSIS AND EXOCYTOSIS

ENDOCYTOSIS - Movement of large molecules from outside to inside the cell

- Phagocytosis
- Pinocytosis
- Receptor-mediated endocytosis

EXOCYTOSIS - Movement of large molecules from inside to outside the cell

- Constitutive secretion
- Regulated secretion

ENDOCYTOSIS

Phagocytosis ("cell eating")

- Ingestion / intake of large solid particles, such as bacteria or dead cell remnants.
 - eg. macrophages and neutrophils
- Fusion of the membranous folds encloses the bacterium in an intracellular vacuole called a phagosome

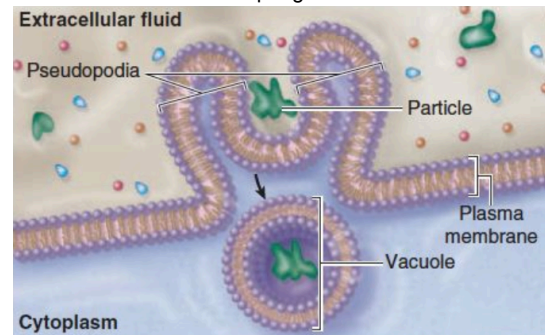


Figure 10. Phagocytosis^[PPT]

Pinocytosis ("cell drinking")

- Cells ingest small molecules of extracellular fluids
- Pinocytotic vesicles (~80 nm in diameter) then pinch off inwardly from the cell surface and either fuse with lysosomes
- Transcytosis** - move to the opposite cell surface where they fuse with the membrane and release their contents outside the cell.

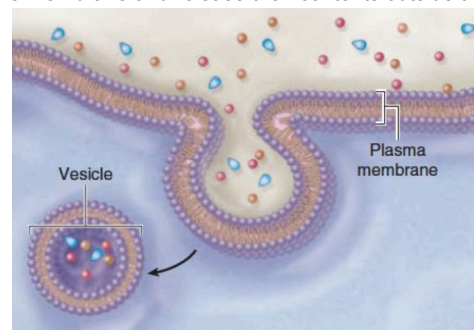


Figure 11. Pinocytosis^[PPT]

Receptor-Mediated Endocytosis

- Highly selective form of pinocytosis, or phagocytosis
 - eg. low-density lipoproteins and protein hormones
- High-affinity binding of such ligands to their receptors causes these proteins to aggregate in special membrane regions that then invaginate and pinch off internally as vesicles.

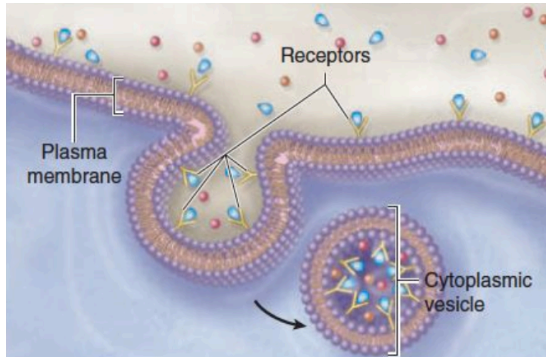


Figure 12. Receptor-Mediated Endocytosis^[PPT]

EXOCYTOSIS

- Triggered in many cells by a transient increase in cytosolic Ca^{2+}
- Highly regulated** with selective interactions between several specific membrane proteins.
 - Occurs via either of two pathways:
 - Constitutive secretion:** used for products that are released from cells continuously, as soon as synthesis is complete.
 - E.g. collagen subunits for the ECM.
 - Regulated secretion:** occurs in response to signals coming to the cells
 - E.g. release of digestive
 - Regulated exocytosis of stored products from epithelial cells usually occurs specifically at the apical domains of cells, constituting a major mechanism of glandular secretion.
- Membrane trafficking:** process of membrane movement and recycling; occurs continuously in most cells.
 - crucial for maintaining the cell and reducing blood lipid levels.
- Multivesicular bodies:** accumulation of small vesicles.
 - may merge with lysosomes for selective degradation of their content
 - may also fuse with the plasma membrane and release the intraluminal vesicle outside the cell.
- Exosomes:** small (<120nm diameter) vesicles which can fuse with other cells transferring their contents and membranes.

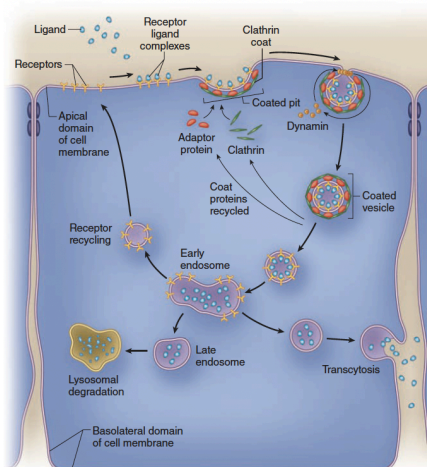


Figure 13. Endocytosis and Exocytosis^[PPT]

SIGNAL RECEPTION AND TRANSDUCTION

- Cells in a multicellular organism communicate with one another to regulate tissue and organ development, to control their growth and division, and to coordinate their functions.
- Routes of signal molecules:
 - Endocrine Signaling:** the signal molecules (**hormones**) are carried in the blood from their source to *target cells throughout the body*.
 - Paracrine Signaling:** the chemical ligand diffuses in extracellular fluid but is rapidly metabolized so that its effect is only local on *target cells near its source*.
 - Synaptic Signaling:** a special kind of paracrine interaction, neurotransmitters *act on adjacent cells* through special contact areas called **synapses**.
 - Autocrine Signaling:** signals bind receptors on *the same cells* that produced the messenger molecule.
 - Juxtacrine Signaling:** important in early embryonic tissue interactions, the signaling molecules are cell membrane-bound proteins which bind surface receptors of the target cells when the two cells make *direct physical contact*.

RECEPTORS FOR HYDROPHILIC SIGNALING

- These are usually transmembrane proteins in the plasmalemma of target cells.
- Three function:
 - Channel-linked receptors
 - Enzymatic receptors
 - G-protein-coupled receptors

Channel-linked Receptors

- Open associated channels upon ligand binding to promote transfer of molecules or ions across the membrane.

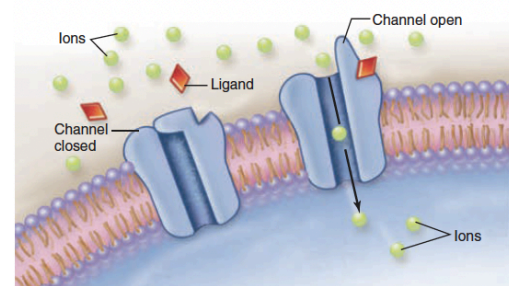


Figure 14. Channel-linked receptors^[PPT]

Enzymatic Receptors

- Ligand binding induces catalytic activity in associated peripheral proteins.

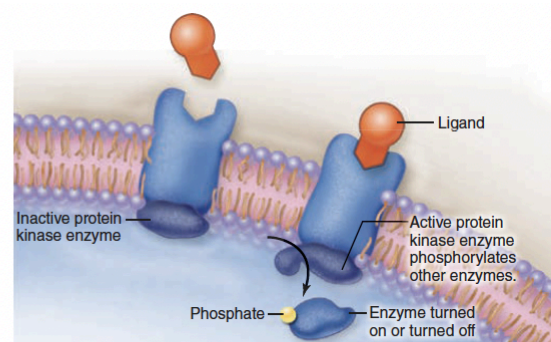


Figure 15. Enzymatic receptors^[PPT]

G-protein-coupled Receptors

- Ligand binding stimulated associated G-protein which then bind the guanine nucleotide GTP and are released to activate other cytoplasmic proteins

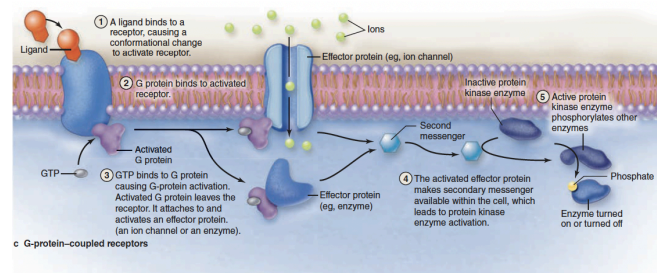


Figure 16. G-protein-coupled receptors

CYTOPLASMIC ORGANELLS

- Performs a specialized metabolic function that is essential for maintaining cellular homeostasis and cell life.
- Most are positioned in the cytoplasm by movements along the polymers of the cytoskeleton
- Most are **Membrane-bound or membranous**, except of course, ribosomes and proteasomes (**non-membranous**) (as learnt from other subjects).

RIBOSOMES

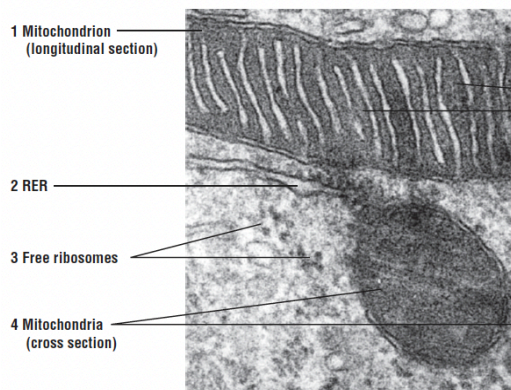


Figure 17. Free ribosomes and attached ribosomes. [PPT]

- ~20 x 30 nm (nanometers) in size,
- Important role in protein synthesis
- Perform essential role in decoding or translating the coded genetic message from the nucleus
- Ribosomal subunits and associated proteins are first synthesized in the nucleolus and then transported to the cytoplasm via the nuclear pores.
- ribosomes are most abundant in the cytoplasm of protein-secreting cells, for the amino acid sequence of proteins that are then synthesized by the cell

Free Ribosomes

- synthesize proteins for use within the cell cytoplasm
- Makes proteins used inside the cell's own cytosol

Attached Ribosomes

- synthesize proteins that are packaged and stored in the cell as lysosomes or are released from the cell as secretory products.
- attached to the membranes of the endoplasmic reticulum.
- Makes proteins used for export out of the cell.
- Example of protein synthesis (bare explanation, translation part)

FIGURE 2-9 Polyribosomes: free or bound to the endoplasmic reticulum.

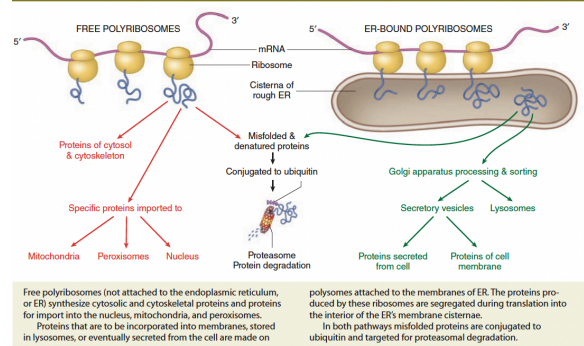


Figure 18. Action of polyribosomes in protein synthesis.

- Ribosomes are attached to mRNA
- Translation occurs and then an amino acid chain is released (blue wrinkly chain attached to ribosome)
- free ribosomes produce proteins used only inside the cytosol, to mitochondria, peroxisomes, nucleus
- attached ribosomes produce proteins meant for export and secreted outside the cell
- Misfolded, misarranged or miscoded proteins are conjugated to **ubiquitin** (be familiarized with the spelling)

ENDOPLASMIC RETICULUM

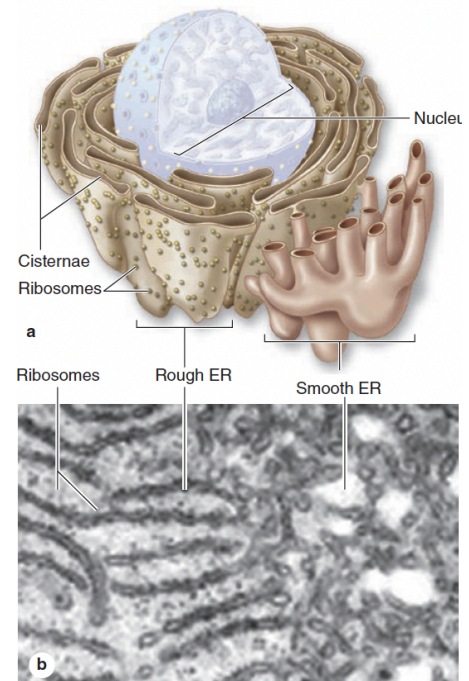


Figure 19. Endoplasmic reticulum.

- Extensive network of sacs, vesicles, and interconnected cisternae.
- Surrounds the Nucleus
- Main Functions:**
 - Synthesis:** Provides a place for chemical reactions
 - Lipid synthesis and carbohydrate metabolism
 - synthesizes proteins for secretion, incorporation into the plasma membrane, and as enzymes within lysosomes
 - Transport:** Moves molecules through the cisternal space from one part of the cell to another, sequestered away from the cytoplasm
 - Storage:** Stores newly synthesized molecules
 - Detoxification:** Smooth ER detoxifies both drugs and alcohol

Rough Endoplasmic Reticulum

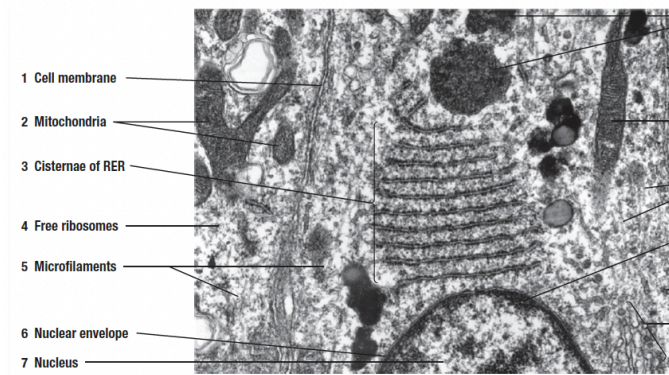


Figure 20. Rough endoplasmic reticulum.

- 🧐 when seen in electron microscope, dark staining due to the presence of ribosomes
- Characterized by numerous flattened interconnected cisternae whose cytoplasmic surfaces are covered with ribosomes
- Extends from the outer membrane of the nuclear envelope to sites throughout the cytoplasm
- **Major Functions:**
 - production of membrane-associated proteins
 - proteins of many membranous organelles
 - proteins to be secreted by exocytosis
- Production includes the initial glycosylation of glycoproteins, certain other posttranslational modifications of newly formed polypeptides, and the assembly of multichain proteins.

Smooth Endoplasmic Reticulum

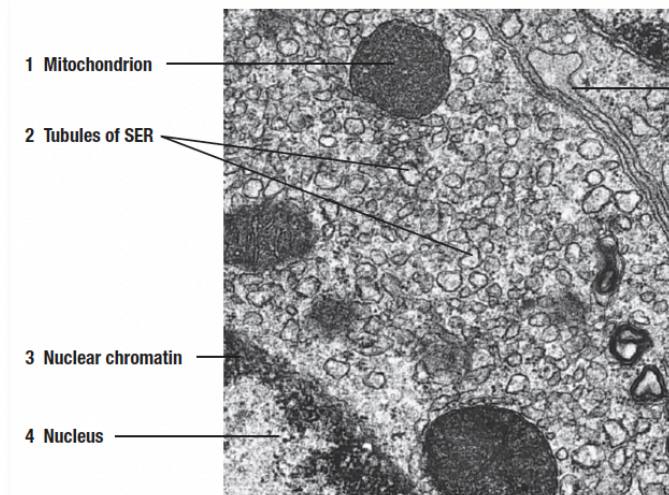


Figure 21. Smooth endoplasmic reticulum.^[PPT]

- Consists primarily of anastomosing or connecting tubules, devoid of ribosomes (absent)
- Is less abundant and continuous with the Rough ER
- NOT BASOPHILIC, best seen with the TEM.
 - Cisternae - more tubular or saclike, with interconnected channels of various shapes and sizes.
- **3 Main Functions:**
 - Synthesis of Phospholipids and steroids
 - Detoxification of potentially harmful exogenous molecules (eg. alcohol, barbiturates, and other drugs)
 - Sequestration and controlled release of Ca^{2+}

MITOCHONDRIA



Figure 22. Mitochondria.

- Round, oval, or elongated structures whose variability and number depend on cell function.
- Diameters of 0.5-1.0 μm (micrometer) and lengths up to 10x greater
- 🧐 Membranous, with outer and inner membrane.
- 🧐 With cristae, inner folds
- 🧐 Involved in the production of ATP

GOLGI APPARATUS

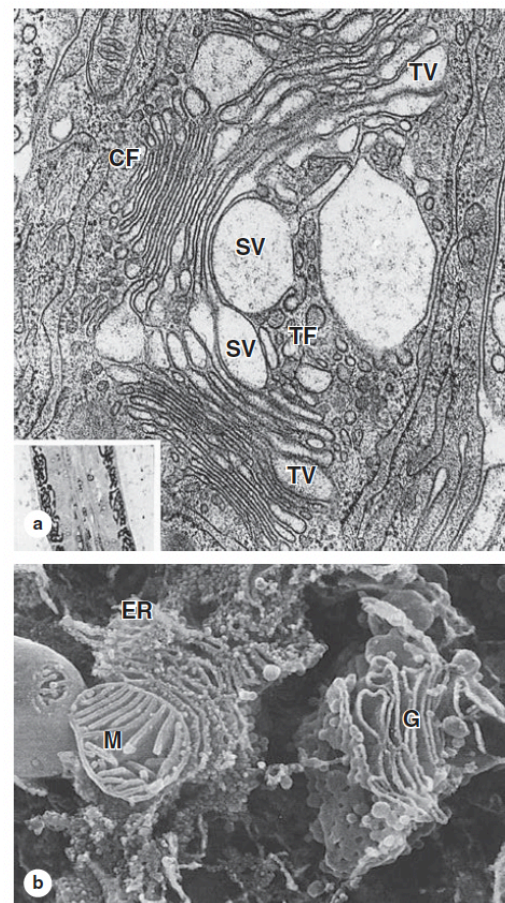


Figure 23. A. Cis face (CF) and trans face (TF) of Golgi apparatus, B. Golgi apparatus seen under SEM.^[PPT]

- Composed of a system of membrane-bound, smooth, flattened, stacked, and slightly curved cisternae.
- Completes posttranslational modifications of proteins produced in the Rough ER and then packages and addresses these proteins to their proper destinations.
- Small vesicles with newly synthesized proteins bud off from the Rough ER, and move to the golgi apparatus for further processing.
- Golgi Cisternae nearest budding vesicles are the **forming, convex/cis-face** of the golgi apparatus (facing the ER),

WHILE the opposite side is the **maturing, inner concave side/ trans-face**

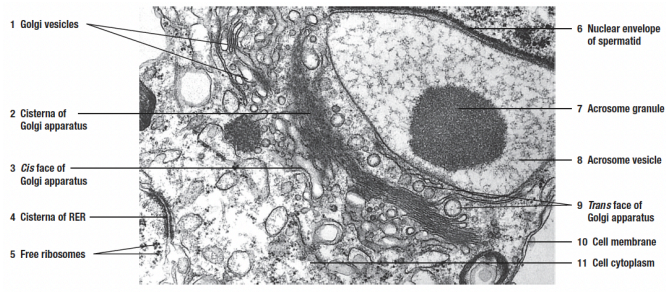


Figure 24. Golgi apparatus.^[PPT]

- 🧑‍🔬 Vesicles from the ER move through the cytoplasm to the cis side of the GA and bud off from the trans side
- 🧑‍🔬 All modifications the proteins need in order for them to be of “quality-control” along with packing them, is done by the Golgi apparatus.

LYSOSOMES

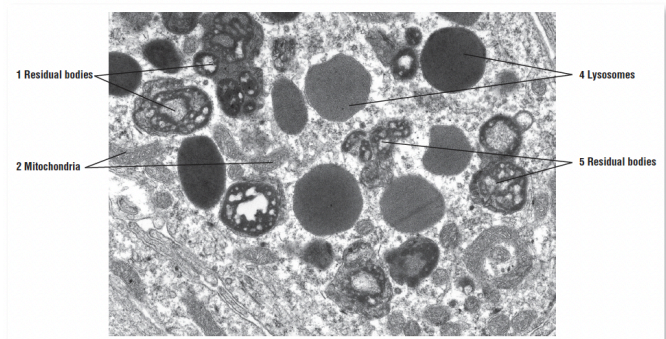


Figure 25. Lysosomes.^[PPT]

- Spherical, range in diameter from 0.05 - 0.5 μm
- Presents a uniformly granular, electron-dense appearance in the TEM.
- Cytoplasmic organelles that contain hydrolyzing or digestive enzymes called **acid hydrolases**.
- **membranous / membrane-bound**
- The membrane separates enzymes in the lysosomes from the cell cytoplasm to PREVENT the lysosomes from digesting the cytoplasm and cell contents.
- **Main Function:** intracellular digestion or phagocytosis of substances taken into the cells
 - Eg. microorganisms, cell debris, cells, and damaged, worn-out, or excessive cell organelles, such as Rough ER or mitochondria

SECRETORY GRANULES

- Originate as condensing vesicles in the Golgi apparatus
- Found in cells that store a product until its release by exocytosis is signaled by a metabolic, hormonal, or neural message (regulated secretion)
- Granules are surrounded by the membrane and contain a concentrated form of the secretory product
- Contents of some secretory granules may be up to >200x concentrated than those in the cisternae of the RER
- **Zymogen granules** - Secretory granules with dense contents of digestive enzymes are also referred to as storage granules

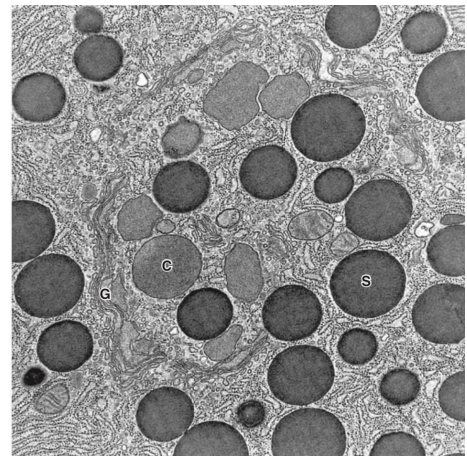


Figure 26. Secretory Granules^[PPT]

PROTEASOMES

- Very small abundant protein complexes that are not associated with membrane
- Function:
 - To degrade denatured or otherwise nonfunctional polypeptides
 - Remove proteins no longer needed by the cell
- A cylindrical structure made of four stacked rings, each composed of seven proteins including proteases and a regulatory particle that contains ATPase and recognizes proteins with attached molecules of **ubiquitin**
- Ubiquitinated proteins are recognized by the regulatory particles of proteasomes, unfolded by the ATPase, and then translocated into the core of the cylindrical structure and degraded by endopeptidases
 - Ubiquitin molecules are released for reuse and the peptides produced may be broken down further to amino acids or they may have other specialized destinations

PEROXISOMES

- Contain several types of **oxidases**, enzymes that oxidize various organic substances to form H_2O_2
 - Contain **catalase** - eliminates excess $\text{H}_2\text{O}_2} \gg \text{H}_2\text{O}$ and O_2 molecules
- Abundant in the cells of the liver and kidney
 - Detoxify, degrade alcohol, oxidize fatty acids, and metabolize various compounds.
- Form in 2 ways:
 - Budding of precursor vesicles from the ER
 - growth and division of preexisting peroxisomes

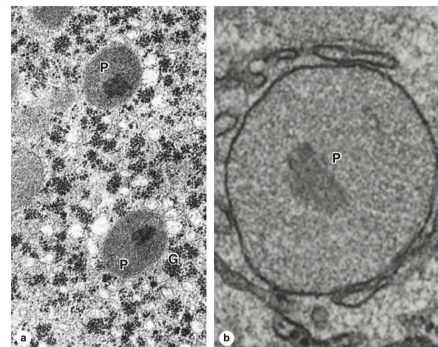


Figure 27. Peroxisomes^[PPT]

CYTOSKELETON

- Serves as the cell's structural framework
- General Function:
 - Structural:
 - Provides structural support to cell
 - Stabilizes junction between cells
 - Movement:
 - Assists with cytosol streaming and cell motility
 - Helps move organelles and materials throughout the cell
 - Helps move chromosome during cell division

MICROTUBULES

- Found in almost all cell types except red blood cells
 - 👤 - mainly found in the plasma membrane of the cell wall
- Largest elements of the cytoskeleton
- Originate from the microtubule organizing center, the centrosome in the cytoplasm, which contains a pair of centrioles
 - In the centrosome, the tubulin subunits polymerize and radiate from the centrioles in a starlike pattern from the center
- Organized into larger, more stable arrays called axonemes in the cytoplasmic extensions
- The centrosome - area of the cytoplasm located near the nucleus
- It is the major microtubule forming the center and the site for generating new microtubules and mitotic spindles
- Consists of 2 small cylindrical structures called centrioles and the surrounding matrix;
 - oriented at right angles at each other
 - consists of 9 evenly spaced clusters of 3 sets of fused microtubules arranged in a circle or a ring
- The microtubules exhibit longitudinal orientation and are parallel to each other
- Before mitosis:
 - The centrioles replicate and form 2 pairs
- During mitosis
 - Each pair moves to the opposite poles of the cell
 - Becoming microtubule-organizing centers for mitotic spindles that control the distribution of chromosomes to the daughter cells
- Beneath the cell membrane, the centrioles induce the formation of basal bodies and organize the development of the microtubules in cilia and flagella

CHARACTERISTICS OF MICROTUBULES

Polymer	Protofilament
Subunit	Heterodimers of $\alpha\beta$ -tubulin
Overall Structure	Hollow tube with a wall of 13 parallel protofilaments
Diameter	25 nm
Monomeric protein	α and β tubulin (54kDa)
Polarity	+ and - ends
Relative stability	Dynamic in cytoplasm; stable in axonemes
General location	Radiating through cytoplasm from concentration at centrosomes; axonemes
Key function	Maintain cell's shape and polarity; Provide tracks for organelle and chromosome movement; Move cilia and flagella

Table 4. Characteristics of Microtubules

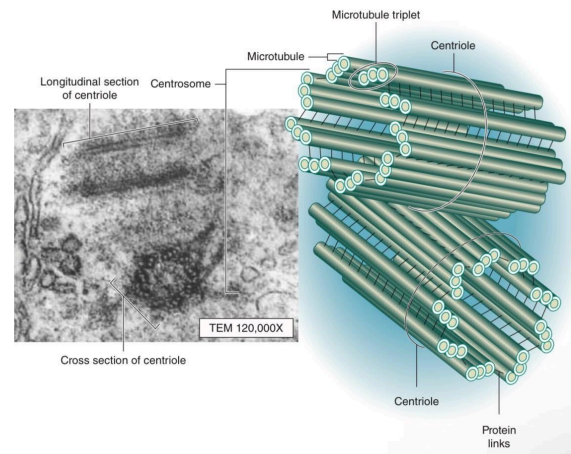


Figure 28. Microtubule

- 👤 - Formation is 9 microtubule triplets stacked together forms a centriole. The centriole multiplies which forms axonemes which then forms the formation of cilia and flagella which aids in the movement of cells

MICROFILAMENTS (ACTIN FILAMENTS)

- The **thinnest**.
- Most prevalent on the peripheral regions of the cell membrane.
- Composed of the protein actin
- These structural proteins shape the cells and contribute to cell movement and movement of the cytoplasmic organelles.
- Used as anchors at cell junctions.
 - actin microfilaments also form the
 - structural core of microvilli and terminal web just inferior to the plasma membrane.
 - In muscle tissues, fill the cells and are associated with myosin proteins to induce muscle contractions.

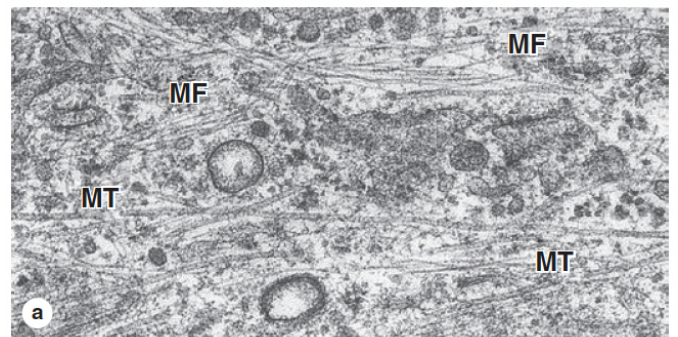
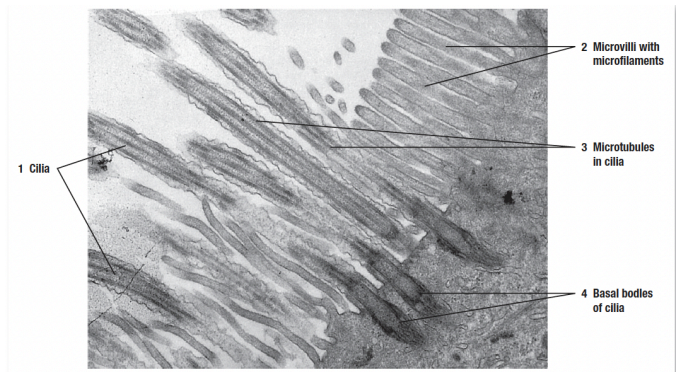


Figure 29. Structure of Microfilaments [PPT]

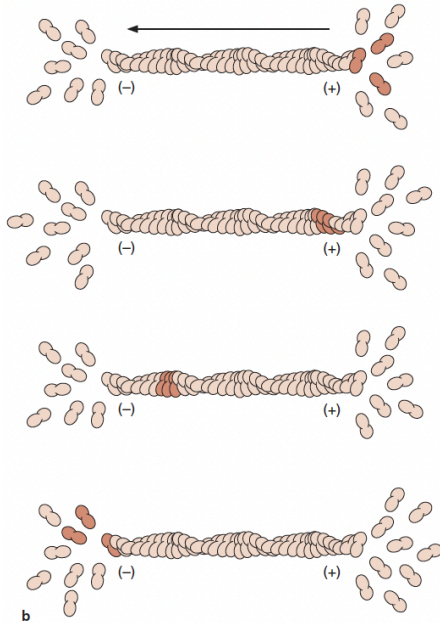
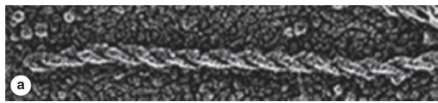
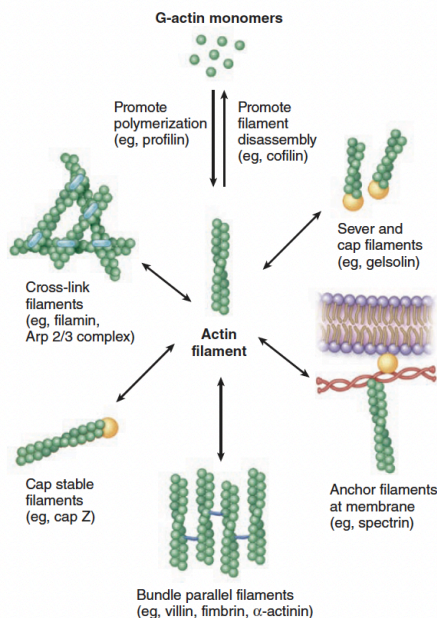


Figure 30. Actin filament treadmilling



A large number of proteins regulate the assembly of microfilaments and the interactions of these filaments with one another. By altering microfilament length and cross-linking, such proteins greatly influence physical properties of the local cytoplasm.

Figure 31. Roles of major actin-binding proteins in regulating the organization of microfilaments

Microfilaments

- **Composed of:** actin subunits
- **Function:** allow motility and most contractile activity in cells using reversible assembly of actin filaments and interactions with myosin family proteins.

Actin Filaments

- Thin: 5–7 nm diameter
- Polarized polymers

- Shorter and more flexible than microtubules
- Composed of **globular G-actin monomers**
- In the presence of **K⁺ and Mg²⁺**, G-actin assembles into a **double-stranded helix of filamentous F-actin**

Formation of New Filaments

- G-actin is generally added to preexisting filaments.
- New filaments are formed from a pool of G-actin by **formin**.
- **Arp2/3 complex**
 - Binds to the side of preexisting actin filaments.
 - Induces a new F-actin branch.
 - Can lead to formation of a microfilament network.

Dynamics

- Highly dynamic.
- Monomers are added rapidly at the **(+) or barbed end** with **ATP hydrolysis** at each addition.
- Monomers dissociate at the **(-) or pointed end**.
- Migration of subunits through the polymer is called **treadmilling**.
- In cells:
 - **Profilin** promotes assembly of subunits from F-actin.
 - **Cofilin** promotes disassembly of subunits from F-actin.

Cell Cortex

- Actin is very abundant in all cells.
- Concentrated in:
 - Networks of actin filaments.
 - Free G-actin subunits near the cell membrane (**cell cortex**).
- **Arp2/3** produces an important branched network of microfilaments in this region.

Microfilament-Rich Cellular Extensions

- Surface folds or ruffles
 - Important for **endocytosis**.
- Microfilaments of the cortex
 - Underlie **endosomal trafficking**.
- **Lamellipodia**
 - Sheet-like protrusions involved in cell movements on firm substrates.
 - Concentrated actin filaments are continuous with deeper parallel F-actin bundles called **stress fibers**.

Actin-Binding Proteins

- Formin and other actin-binding proteins change:
 - Dynamic physical properties.
 - Lengths.
 - Interactions with other structures.
- Determines:
 - Viscosity.
 - Other mechanical properties of the local cytoplasm.
- **Cross-linking** within networks of F-actin
 - Increases cytoplasmic viscosity.
- **Severing (and capping)** filaments
 - Decreases viscosity.
- Lengths and other physical properties are controlled by various actin-binding proteins.

Myosin Motors

- Use **ATP** to transport cargo along F-actin.
- Movement is usually toward the **barbed (+) end**.

- **Myosin VI** moves toward the opposite direction.

F-actin and Myosin Interactions

- Transport of organelles, vesicles, and granules during **cytoplasmic streaming**.
- **Contractile rings** of microfilaments with **myosin II**
 - Constrict to produce two cells by **cytokinesis** during **mitosis**.
- **Myosin I**
 - Membrane-associated.
 - Movements along microfilaments produce cell surface changes during **endocytosis**.

Muscle Contraction

- Stabilized arrays of actin filaments integrated with arrays of thicker **16 nm myosin filaments** permit very forceful contractions in specialized cells such as **muscle**.

Feature	Actin Filaments (Microfilaments)
Polymer	
Subunit	G-actin monomers
Overall structure	Two intertwined filaments of F-actin
Diameter	5–7 nm
Monomeric protein	Globular G-actin (42 kDa)
Polarity	+ and - ends
Relative stability	Dynamic
General location	Concentrated beneath cell membrane; in cell extensions like microvilli
Key function	Contract and move cells; change cell shape; cytokinesis; cytoplasmic transport and streaming

Table 5. Characteristics of Actin Filaments

INTERMEDIATE FILAMENTS

General Characteristics

- **Thicker than microfilaments.**
- **More stable.**
- Vary among cell types.
- Have specific distribution in different cell types.

Types and Distribution

- **Keratin / Cytokeratin** – Epithelial cells
- **Desmosomes and Hemidesmosomes** – Skin cells
- **Vimentin filaments** – Mesenchymal cells
- **Desmin filaments** – Smooth and striated muscles
- **Neurofilament proteins** – Nerve cells and their processes
- **Glial filaments** – Astrocytic glial cells of the nervous system
- **Nuclear lamin intermediate filaments** – Inner layer of the nuclear membrane

Cytokeratins

- Accumulate in **skin epidermal cells** during differentiation in the process of **keratinization**.
- Produce an outer layer of **nonliving cells** that reduces dehydration.
- Keratinization:
 - Made **terrestrial life** possible during evolution.
 - Provides protection from **minor abrasions**.

- Produces hard protective structures:
 - Nails
 - Feathers
 - Beaks
 - Horns
 - Scales of reptiles

Vimentin (Class III Intermediate Filament)

- Most common **class III intermediate filament protein**.
- Found in most cells derived from **embryonic mesenchyme**.

Vimentin-like Proteins

- **Desmin**
 - Found in almost all **muscle cells**.
- **Glial fibrillar acidic protein (GFAP)**
 - Found especially in **astrocytes**.
 - Supporting cells of **central nervous system tissue**.

Neurofilament Proteins

- Three distinct sizes.
- Form **heterodimers**.
- Heterodimers form the subunits of the major intermediate filaments of **neurons**.

Lamins

- Family of **seven isoforms**.
- Present in the **cell nucleus**.
- Form the structural framework called the **nuclear lamina**.
- Located **just inside the nuclear envelope**.

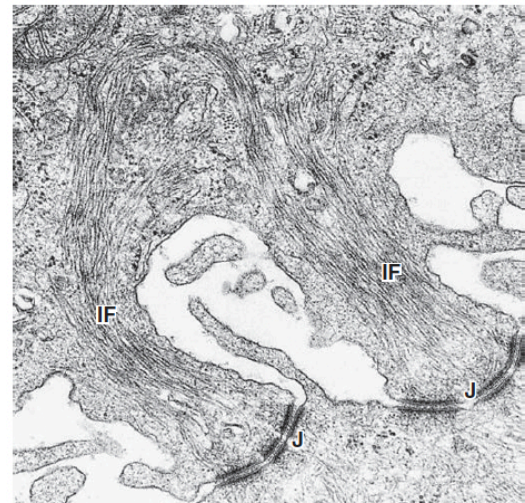


Figure 32. Intermediate filaments of keratin^[PPT]

Feature	Intermediate Filaments
Polymer	Protofibril
Subunit	Antiparallel tetramers of two rod-like dimers
Overall structure	Cable of four intertwined protofibrils, each consisting of bundled tetramers associated end-to-end
Diameter	8–10 nm
Monomeric protein	Various α -helical rod-like proteins (~55 kDa, Table 2–5)
Polarity	No apparent polarity
Relative stability	Stable
General location	Arrayed throughout cytoplasm; at desmosomes; inside nuclear envelope
Key function	Strengthen cell and tissue structure; maintain cell shape; maintain nuclear shape (lamins)

Table 6. Characteristics of Intermediate Filaments

CYTOPLASMIC INCLUSIONS

General Characteristics

- Contain accumulated **metabolites** or other substances.
- Have little or no metabolic activity themselves.
- Most inclusions are **transitory structures** not enclosed by a membrane.

Types of Cell Inclusions

- Lipid droplets
- Glycogen granules
- Pigmented deposits
 - Melanin
 - Lipofuscin
 - Hemosiderin

Lipid Droplets

- Accumulations of lipid.
- Fill **adipocytes (fat cells)**.
- Present in various other cells.

Glycogen Granules

- Aggregates of the carbohydrate polymer in which **glucose is stored**.
- Visible as irregular clumps of:
 - Periodic acid–Schiff (PAS)-positive** material.
 - Electron-dense** material.
- Found in several cell types, notably **liver cells**.

Pigmented Deposits

Melanin

- Dark brown granules.
- Skin serves to protect cells from **ultraviolet radiation**.

Lipofuscin

- Pale brown granule.
- Found in many cells, especially **stable nondividing cells**:
 - Neurons
 - Cardiac muscle
- Contains a complex mix of material partly derived from **residual bodies after lysosomal digestion**.
- Hemosiderin**
- Dense brown aggregate of **denatured ferritin proteins** with many atoms of bound iron.
- Prominent in **phagocytic cells** of the:

- Liver
- Spleen

- Results from **phagocytosis of red blood cells**.

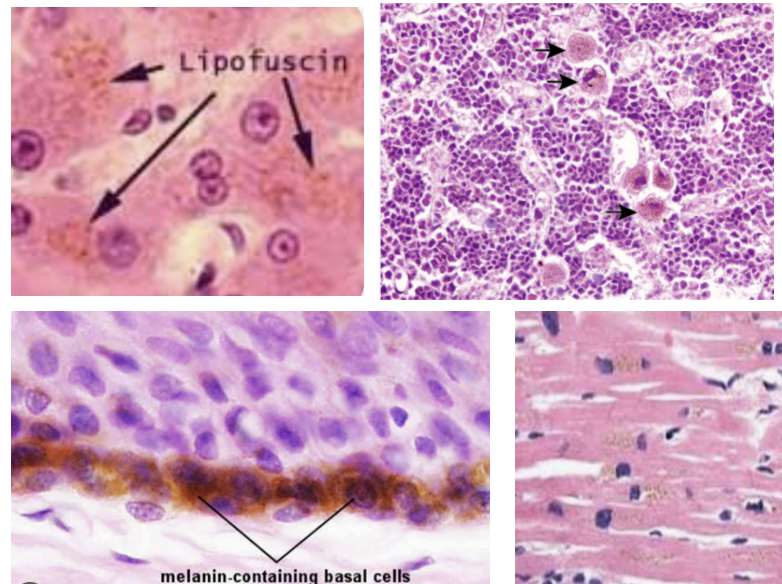


Figure 32. Cytoplasmic Inclusion

REFERENCES

- Mescher, A. L. (2024). *Junqueira's basic histology: Text and atlas* (17th ed.) McGraw Hill.
- Powerpoint: Ilagan-Guinto, M.E. (2026). Cytoplasmic Organelles, Microskeleton, Inclusions
- Previous Trans : 2025

REVIEW QUESTIONS

- Which of the following is a function of the plasma membrane?
 - Synthesizing ATP
 - Housing chromatin
 - Maintaining ion composition distinct from the extracellular environment
 - Directing posttranslational modification
- Which structure is primarily responsible for intracellular digestion and turnover of cellular components?
 - Golgi Apparatus
 - Lysosome
 - Peroxisome
 - Smooth Endoplasmic Reticulum
- What best describes integral proteins?
 - Loosely attached to one surface of the membrane
 - Enzymes involved in lipid metabolism
 - Span the membrane and often act as carrier proteins
 - Located only in the mitochondrial membrane
- The nucleolus is primarily involved in:
 - DNA replication and protein glycosylation
 - mRNA export and protein folding
 - RNA synthesis and

Answers: 5D, 4C, 3C, 2B, 1C

Appendix A: Mechanism of Transport Along the Plasma Membrane

PROCESS	TYPE OF MOVEMENT	EXAMPLE
PASSIVE PROCESSES	Movement of substances down a concentration gradient due to the kinetic energy of the substance; no expenditure of cellular energy is required; continues until equilibrium is reached (if unopposed)	
Simple diffusion	Unassisted net movement of small, nonpolar substances down their concentration gradient across a selectively permeable membrane	Exchange of oxygen and carbon dioxide between blood and body tissues
Facilitated diffusion	Movement of ions and small, polar molecules down their concentration gradient; assisted across a selectively permeable membrane by a transport protein	
Channel- mediated	Movement of ion down its concentration gradient through a protein channel	Na ⁺ moves through Na ⁺ channel into cell
Carrier- mediated	Movement of small, polar molecule down its concentration gradient by a carrier protein	Transport of glucose into cells by glucose carrier
Osmosis	Diffusion of water across a selectively permeable membrane; direction is determined by relative solute concentrations; continues until equilibrium is reached	Solutes in blood in systemic capillaries "pulls" fluid from interstitial space back into the blood

PROCESS	TYPE OF MOVEMENT	EXAMPLE
ACTIVE PROCESSES	Movement of substances requires expenditure of cellular energy	
Active transport	Transport of ions or small molecules across the membrane against a concentration gradient by transmembrane protein pumps	
• Primary	Unassisted net movement of small, nonpolar substances down their concentration gradient across a selectively permeable membrane	Exchange of oxygen and carbon dioxide between blood and body tissues
• Secondary	Movement of a substance up its concentration gradient is powered by harnessing the movement of a second substance (eg, Na ⁺) down its concentration gradient	
• Symport	Movement of substance up its concentration gradient in the same direction as Na ⁺	Na ⁺ /glucose transport
• Antiport	Movement of substance up its concentration gradient in the opposite direction from Na ⁺	Na ⁺ /H ⁺ transport
Vesicular transport	Vesicle formed or lost as material is brought into a cell or released from a cell	
• Exocytosis	Bulk movement of substance out of the cell by fusion of secretory vesicles with the plasma membrane	Release of neurotransmitter by nerve cells
• Endocytosis	Bulk movement of substances into the cell by vesicles forming at the plasma membrane	
• Phagocytosis	Type of endocytosis in which vesicles are formed as particulate materials external to the cell are engulfed by pseudopodia	White blood cell engulfing a bacterium
• Pinocytosis	Type of endocytosis in which vesicles are formed as interstitial fluid is taken up by the cell	Formation of small vesicles in capillary wall to move substances
• Receptor- mediated endocytosis	Type of endocytosis in which plasma membrane receptors first bind specific substances; receptor and bound substance then taken up by the cell	Uptake of cholesterol into cells

Appendix B: Organelles

Component	Structure	Major Function
Plasma membrane	Phospholipid bilayer containing cholesterol and proteins (integral and peripheral) and some carbohydrates (externally); forms a selectively permeable boundary of the cell	Acts as a physical barrier to enclose cell contents; regulates material movement into and out of the cell; establishes and maintains an electrical charge difference across the plasma membrane; functions in cell communication
Cilia	Short, numerous membrane extensions supported by microtubules, which occur on exposed membrane surfaces of some cells	Move substances (eg, mucus and dissolved materials) over the cell surface
Flagellum	Long, singular membrane extension supported by microtubules found on sperm cells	Propels sperm
Microvilli	Numerous thin membrane folds projecting from the free cell surface; supported by microfilaments	Increase membrane surface area for greater absorption
Cytoplasm	Contents of cells between the plasma membrane and nuclear envelope	Responsible for many cellular processes
Cytosol	Viscous fluid medium with dissolved solutes (eg, ions, proteins, carbohydrates, lipids)	Provides support for organelles; serves as the viscous fluid medium through which diffusion occurs
Organelles	Membrane-bound and nonmembrane-bound	Carry out specific metabolic activities of the cell

	structures	
Rough endoplasmic reticulum (rough ER)	Extensive interconnected membrane network that varies in shape (eg, cisternae, tubules); ribosomes attached on cytoplasmic surface	Modifies, transports, and stores proteins produced by attached ribosomes; these proteins are secreted, become components of the plasma membrane, or serve as enzymes of lysosomes
Smooth endoplasmic reticulum (smooth ER)	Extensive interconnected membrane network lacking ribosomes	Synthesizes, transports, and stores lipids (eg, steroids); metabolizes carbohydrates; detoxifies drugs, alcohol, and poisons; forms vesicles and peroxisomes
Golgi apparatus	Series of several elongated, flattened saclike membranous structures	Modifies, packages, and sorts materials that arrive from the ER in transport vesicles; forms secretory vesicles and lysosomes
Vesicles	Spherical-shaped membrane-bound sacs; contain various types of materials to be transported through the cell	Transport cellular material
Lysosomes	Spherical-shaped membrane-bound organelles formed from the Golgi apparatus; contain digestive enzymes	Digest microbes or materials (eg, ingested by the cell, worn-out cellular components, foreign to the entire cell)
Peroxisomes	Smaller, spherical-shaped membrane-bound organelles formed from the ER through fission; contain oxidative enzymes	Detoxify specific harmful substances either produced by the cell or taken into the cell; engage in beta oxidation of fatty acids to acetyl CoA
Mitochondria	Double membrane-bound organelles containing a circular strand of DNA (genes for producing ATP)	Synthesize most ATP during aerobic cellular respiration by digestion of fuel molecules (eg, glucose) in the presence of oxygen
Ribosomes	Organelles composed of both protein and ribosomal RNA (rRNA) that are organized into both large and small subunits; may be free in the membrane or bound to the rough ER	Engage in protein synthesis: Bound ribosomes produce proteins that are secreted, incorporated into plasma membrane, or which lysosomes have enzymes produced; proteins used within the cell
Cytoskeleton	Organized network of protein filaments and hollow tubes including microfilaments, intermediate filaments, and microtubules	Maintains intracellular structural support and organization of cell; participates in cell division; facilitates movement
Microfilaments	Actin protein monomers organized into thin, intertwined protein strands	Maintain cell shape; support microvilli; generate force for cell division (cytokinesis in a process to cells during cytokinesis); change cell shape; participate in muscle contraction
Intermediate Filaments	Various protein components	Provide structural support; stabilize junctions between cells
Microtubules	Hollow cylinders composed of tubulin protein	Maintain cell shape and rigidity; organize and move organelles; support internal flagella; participate in vesicular transport; separate chromosomes during the process of cell division
Centrosome	Amorphous region adjacent to the nucleus; contains a pair of centrioles	Organizes microtubules; participates in mitotic spindle formation during cell division
Proteasomes	Large, barrel-shaped protein complexes located in both the cytosol and nucleus	Degrade old digest damaged or unneeded proteins; ensure quality of exported proteins