Department of
Cellular and Physiological Sciences

# Cell

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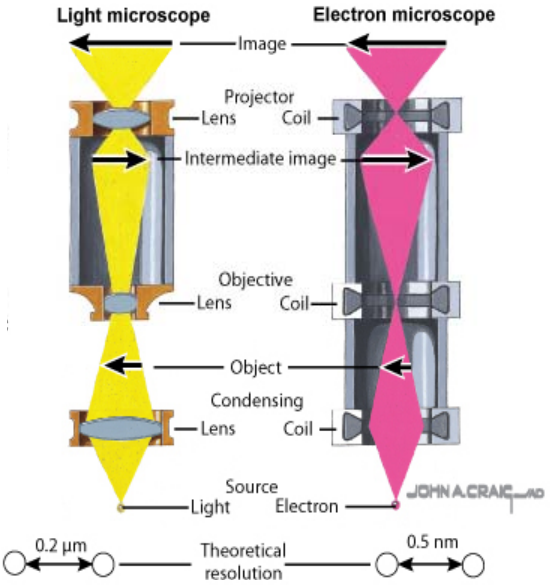
## Cell

- Is the basic functional unit of organism.
- Human body is composed of over 200 different types of cells and 4 major types of tissues.
  - Epithelial tissue
  - Connective tissue
  - Muscular tissue
  - Nervous tissue
- The living substance of the cell is called PROTOPLASM and is subdivided into two compartments:
  - Cytoplasm: extending from the plasma membrane to the nuclear envelope,
  - Karyoplasm: the substance forming the content of the nucleus.

# Microscopes

- In light microscope:
  - Visible light is passed through the specimen
  - Optical lenses are used to focus the light and magnify the image.
  - Resolution is about 0.2 μm.
- In electron microscope:
  - Electron beam is passed through the specimen
  - Magnets are used to focus the electron beam and magnify the image.
  - Resolution is about 0.2 – 0.5 nm.

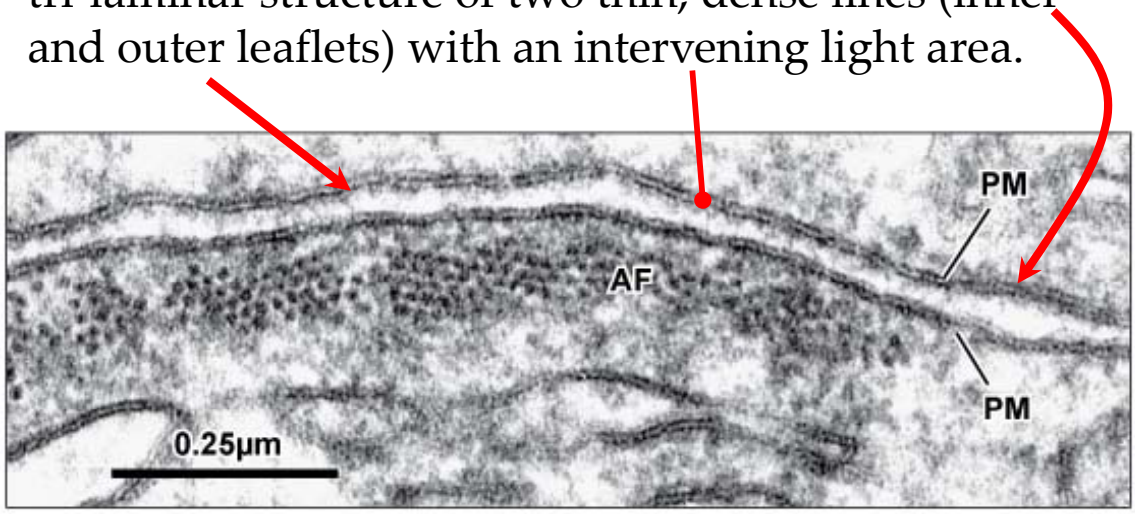



# Cell Membrane

- Forms a selectively barrier between the cytoplasm and the external milieu. The function of which is:
  1. Maintaining the structural integrity of the cell
  2. Controlling movements of substances in and out of the cell.
  3. Regulating cell-cell interaction
  4. Recognition via receptors (antigens, and foreign/altered cells).
  5. Establishing transport systems for specific molecules
  6. Transducing extracellular physical or chemical signals into intracellular events

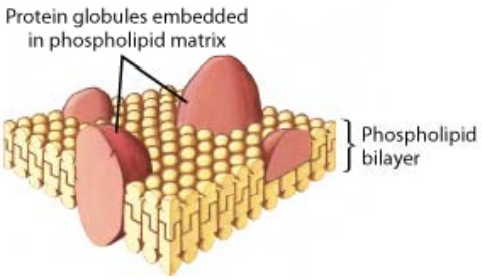
# Plasmalemma Structure

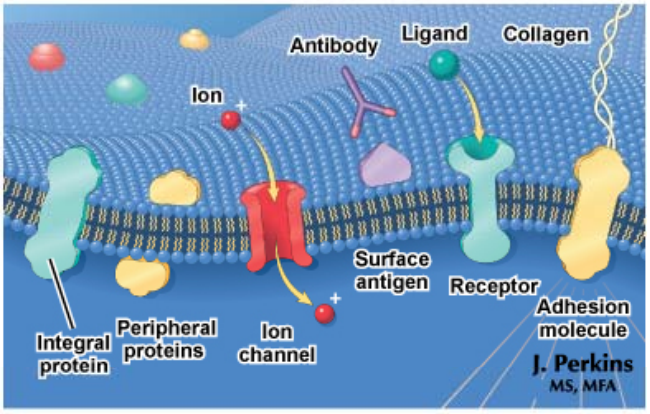
- The cell membrane is 5 – 8 nm thick and appears as a tri-laminar structure of two thin, dense lines (inner and outer leaflets) with an intervening light area.




F. 1.4

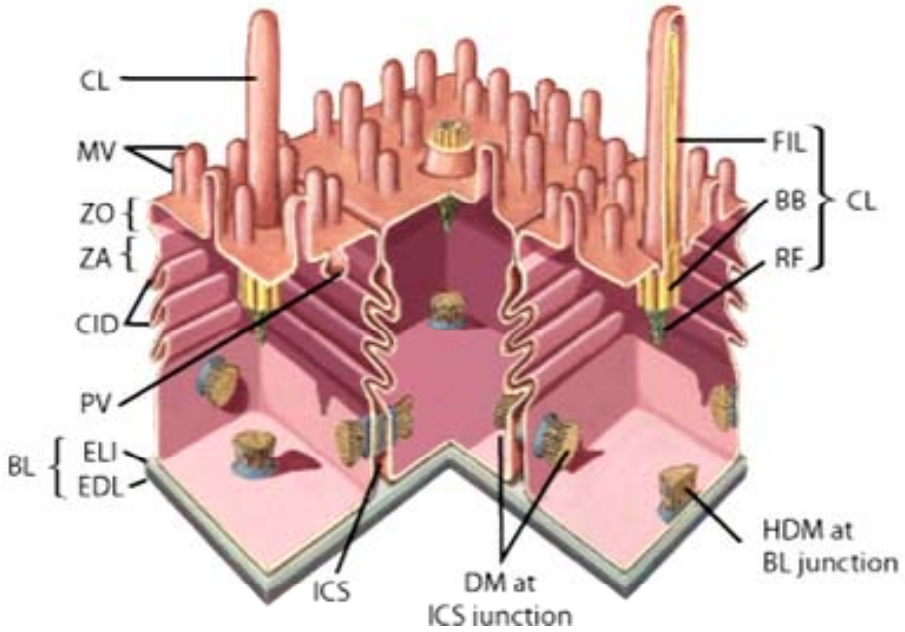
- Each leaflet is composed of a single layer of phospholipids and associated proteins.
  - The phospholipid molecule is amphipathic (has a polar / hydrophilic head and a non-polar / hydrophobic tail).
  - The protein component can be in two forms:
    - Integral proteins; passing through the thickness of the cell membrane (aka trans-membrane).
    - Peripheral proteins; associated with one of the leaflets.



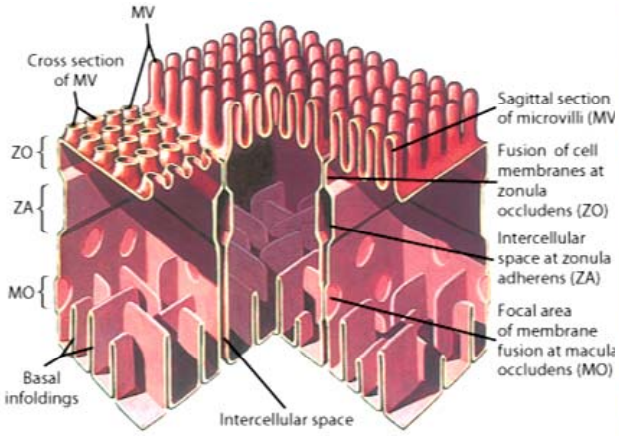
# Intercellular Junctions

- Tight ( Zonula occludens) junctions – belt-like seal / barrier between cells that prevents entry of material.
- Anchoring ( Zonula adherens) junctions -maintain cell-cell contact. Usually found at the sides (desmosome) or base (hemidesmosome) of cells and resist mechanical stresses.
- Communicating (Gap) junctions - movement of substances between cells. Is formed by densely packed intercellular channels.

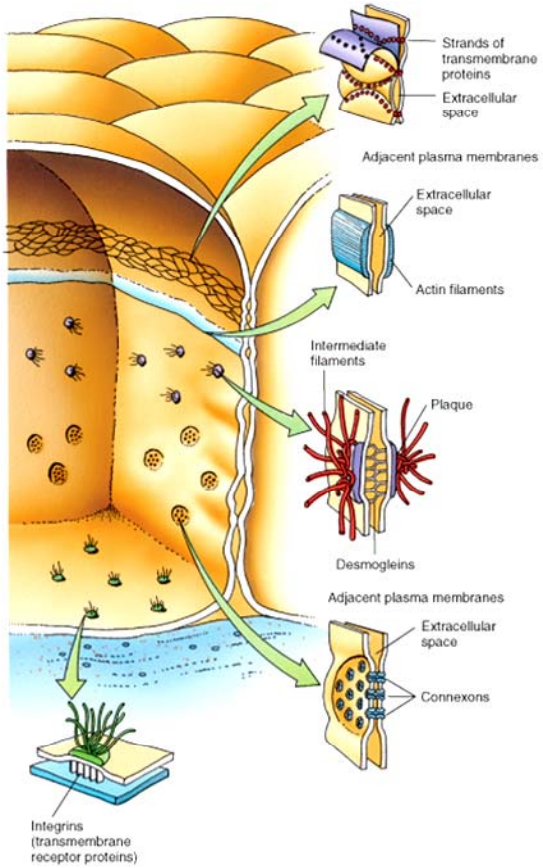



**Detailed section of desmosomes**

BB = Basal body
BL = Basal lamina
CID = Cellular interdigitations
CL = Cilia
DM = Desmosomes
EDL = Electron-dense lamina
ELL = Electron-lucent lamina
FIL = Filaments
HDM = Hemidesmosomes
ICS = Intercellular space
IDP = Intermediate dense plaque
MV = Microvilli
PV = Pinocytic vesicle
RF = Root fibrils
TF = Tonofibrils
ZA = Zonula adherens
ZO = Zonula occludens



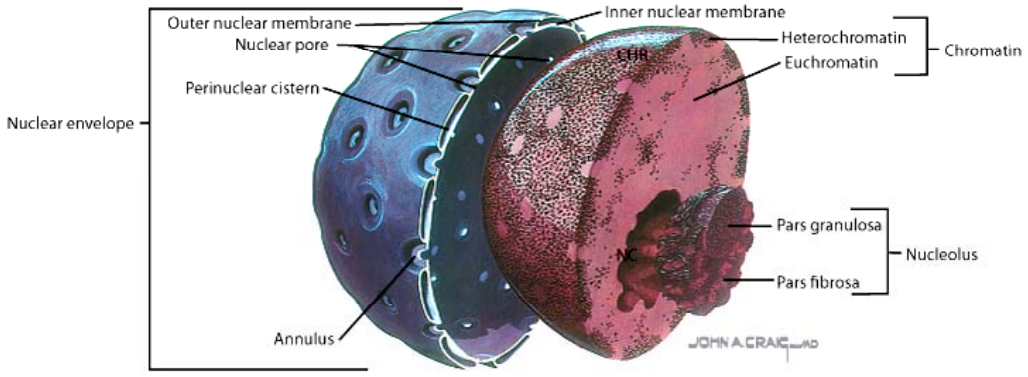

▲ **Parts of three cells with microvilli on apical surfaces and junctional complexes at lateral borders.** A typical junctional complex comprises several types of intercellular junctions, such as tight junctions (zonula and macula occludens) and zonula adherens, seen here.




# Nucleus

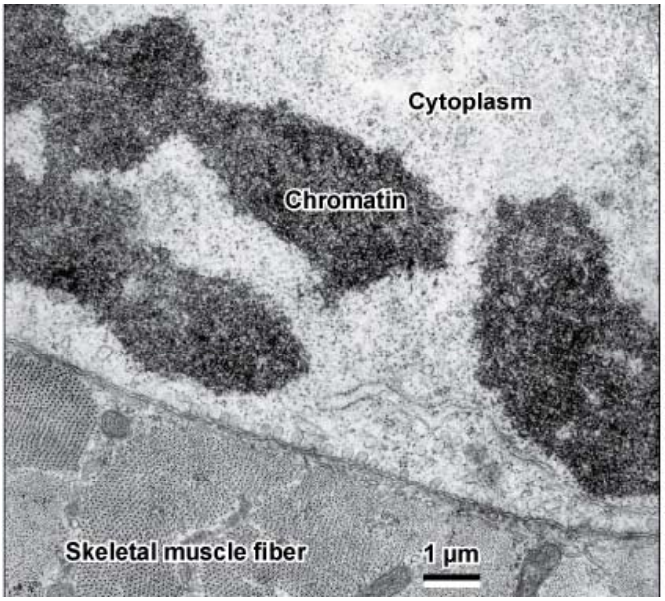
- Houses three major components:
  - Chromatin; the genetic material of the cell
  - Nucleolus; synthesizes rRNA, ans assembles the ribosomal subunits.
  - Nucleoplasm; containing macromolecules and nuclear particles.

▼ **Nuclear components.**



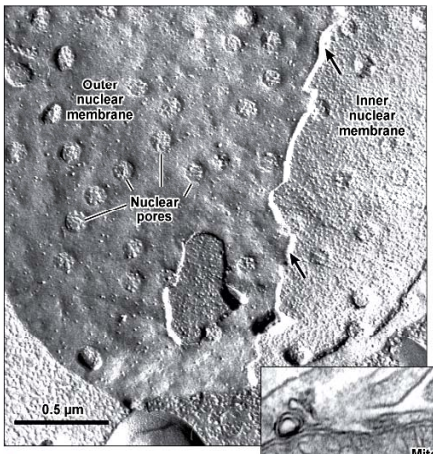
# Chromatin

- A complex of DNA and proteins that represents the relaxed, uncoiled chromosomes of the inter-phase nucleus.
- Based on its transcriptional activity it may be condensed as heterochromatin or extended euchromatin.

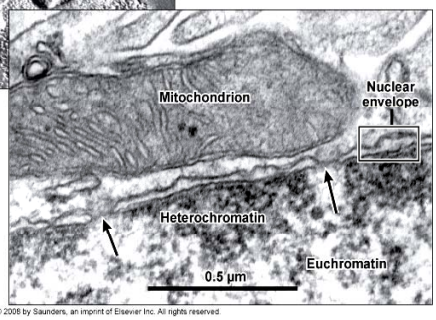



# Nuclear Envelope

- Is a double layer membrane, with a space (10 – 70 nm wide) between them, known as perinuclear cisterna.
- There are some pores (10 nm) in it that provide a passage for bidirectional communication.
- The number of nuclear pores varies due to functional state of the cell. The more active the cell, the more numerous (up to thousands) the pores.




◄ **Freeze-fracture EM replica of the nuclear envelope.** Outer and inner nuclear membranes are seen. The inner membrane has more intramembrane particles, which are integral membrane proteins, than the outer one. Part of the perinuclear space (**arrows**) is seen. Many nuclear pores perforate the envelope. Small spherical granules occupy the center of each pore complex. 50,000×. *(Courtesy of Dr. B. J. Crawford)*




► **EM of the nuclear envelope.** A perinuclear space separates two concentric unit membranes (**box**). The smooth inner membrane directly contacts heterochromatin patches in the nucleus. The outer membrane is usually studded by ribosomes, but they are not seen here. Two nuclear pore complexes (**arrows**) cross the perinuclear space; fibrillar material seems to fill each pore aperture. A mitochondrion is in adjacent cytoplasm. 80,000×. *(Courtesy of Dr. W.A. Webber)*

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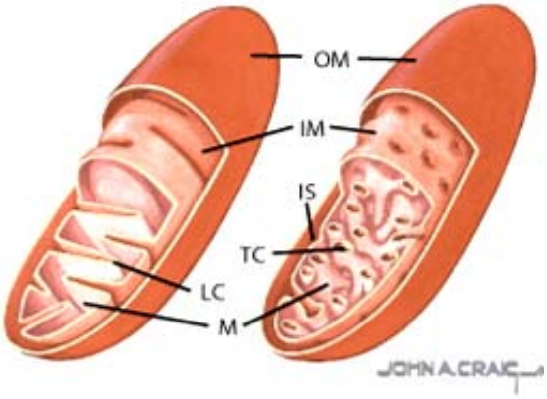
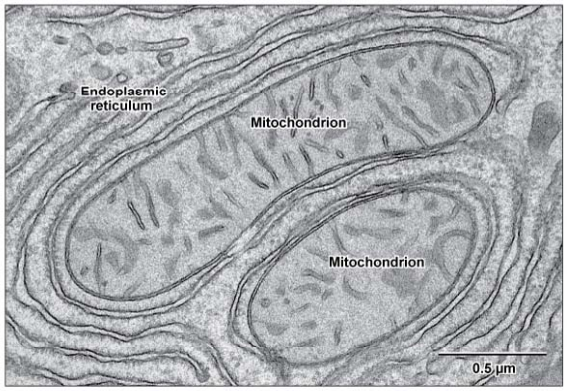
**F. 1.10**

# Mitochondria

- Flexible rod-shaped (1 – 10 μm) organelle.
- Its life span is about 10 days.
- Possesses its own DNA, RNA, even ribosome, and is capable of replication.
- Synthesizes ATP.
- Possesses a smooth outer membrane and a folded (cristae) inner membrane.
- The space between the membranes is called intermembrane space and the one enclosed by the inner membrane is termed the matrix space.




# Mitochondria




▲ **EM of mitochondria in a hepatocyte.** Their shape varies with plane of section and type of cell. Here, one is elongated; the other, more ovoid. Each has thin, shelf-like cristae that project into the mitochondrial matrix. Endoplasmic reticulum cisternae are in the cytoplasm. 54,000×.

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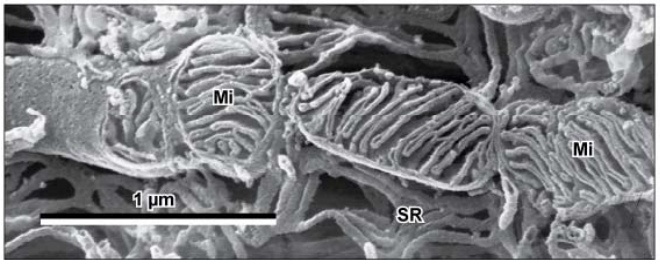


▲ **HRSEM of mitochondria in a diaphragm muscle fiber.** This highly aerobic, skeletal muscle fiber has many large mitochondria (**Mi**). Prominent shelf-like cristae extend across the entire breadth of each organelle and markedly increase surface area for oxidative metabolism. Sarcoplasmic reticulum (**SR**), a form of SER, is also seen. 46,000×.

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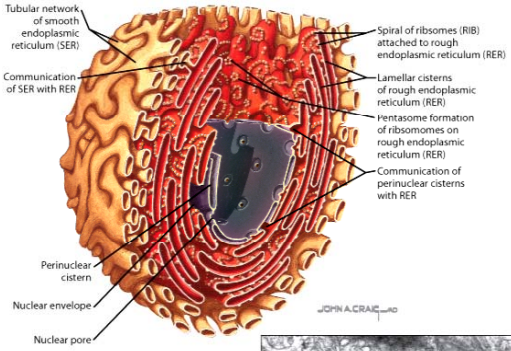
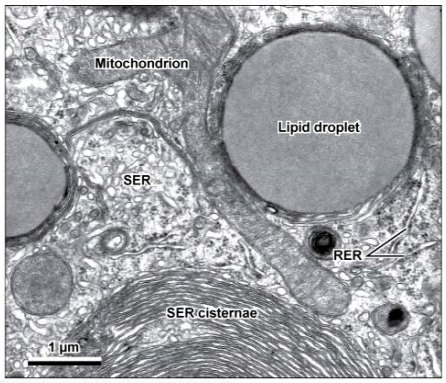
# Smooth Endoplasmic Reticulum

- A system of interconnected tubules ,vesicles and sacs.
- Abundant in cells that produce steroids, cholesterol, and triglycerides (ovary, testicle, and adrenal gland), and cells that function in detoxification of toxic materials (liver).




**Three-dimensional schematic of the ER.** This organelle is a continuous array of membrane-bound tubules, vesicles, and cisternae. A smooth-surfaced membrane encloses a central lumen, which is separated from the cytoplasm. Tubules often have flattened expansions called cisternae. Communications exist between RER and SER. The perinuclear space of the nuclear envelope is also continuous with the RER.




**EM of part of a hepatocyte showing sagittal and cross-sectional SER.** Abundant in hepatocytes, SER exists as small, branching tubules and multiple stacks of flattened cisternae. Here, the SER is closely associated with lipid droplets. A pleomorphic mitochondrion and a few profiles of **RER** also occupy the cytoplasm. 20,000×.

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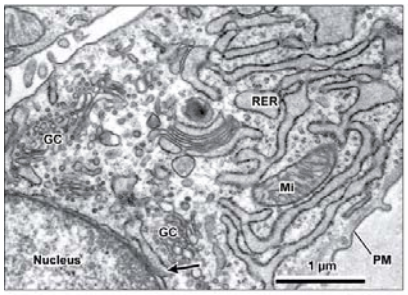
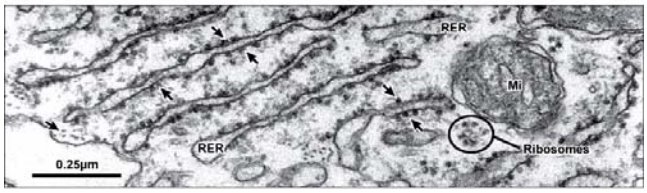
# Rough Endoplasmic Reticulum

- Similar to SER but possesses integral proteins that binds ribosomes to its cytosolic surface.
- Continuous with nuclear envelope.
- Abundant in cells that function in the synthesis of proteins that are to be exported (pancreas). Some of the proteins may also be used as integral proteins of the cell membrane.




**EM of part of a fibroblast in a growing tendon.** The **RER** consists of an extensive network of branching membrane-bound tubules, studded externally with ribosomes. Its luminal contents are moderately electron dense and amorphous. Note the continuity of the RER and perinuclear space (**arrow**). Many free ribosomes are in the cytoplasm. In cells secreting protein for export, abundant RER is usually associated with one or more supranuclear Golgi complexes (**GC**). A mitochondrion (**Mi**) and plasma membrane (**PM**) are also seen. 25,000×.




**Higher magnification EM showing details of the RER.** Association of ribosomes (**arrows**) with RER membranes is clear in this protein-synthesizing fibroblast. Polypeptide chains synthesized on ribosomes are discharged into the RER lumen. The cytoplasm holds several elongated RER cisternae (**RER**), many free ribosomes (**circle**), and a mitochondrion (**Mi**). Many cell types that secrete proteins have this RER arrangement: fibroblasts of connective tissue (secrete collagen), nerve cells (in which RER plus ribosomes are named Nissl substance), pancreatic acinar cells (produce digestive enzymes), pancreatic islet cells (produce the hormone insulin), and plasma cells (produce antibodies called immunoglobulins). 100,000×. *(Courtesy of Dr. B. J. Crawford)*

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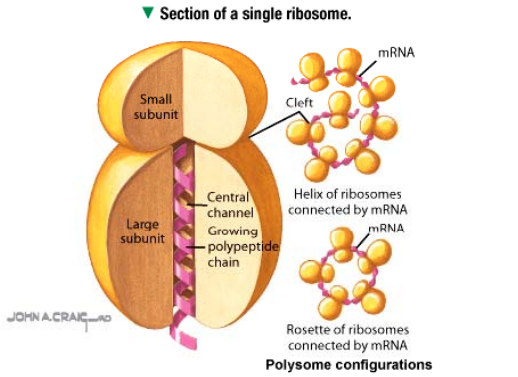
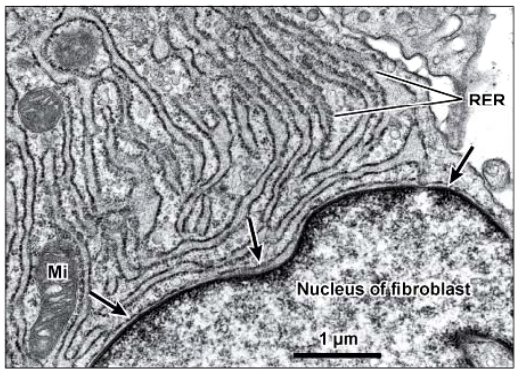
# Ribosome

- Small particles (15 – 20 nm)
- Composed of proteins and rRNA.
- Composed of small (one RNA + 33 proteins) and large (2 RNA + 49 proteins) subunits, both assembled in nucleolus.
- When a group of them attaches to mRNA, the complex is known an poly-ribosome.
- If bound to RER, the protein is destined for export.

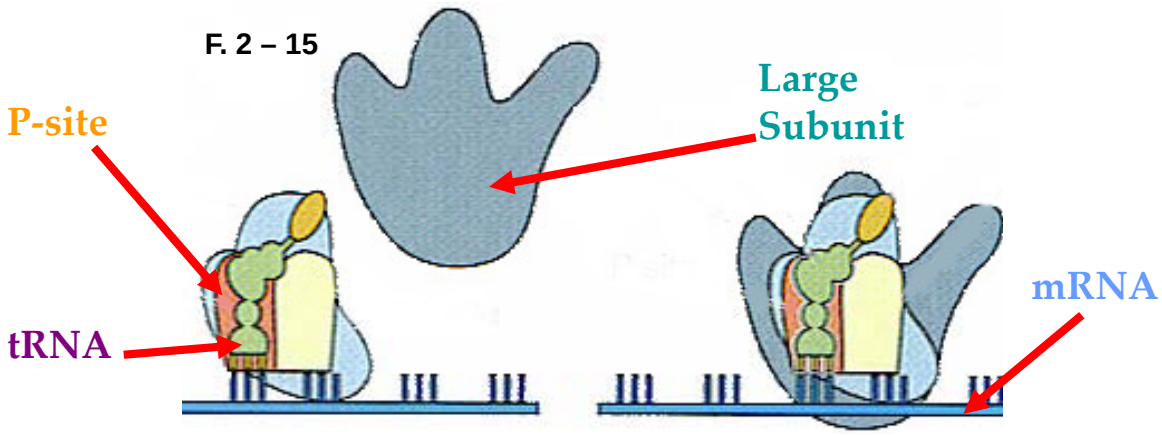



▲ **EM of part of an active fibroblast.** This cell secretes protein for internal use and export. Its cytoplasm contains abundant free ribosomes and ribosomes attached to cisternae of **RER**. Note the outer nuclear envelope (**arrows**) studded with ribosomes around the nucleus. Mitochondria (**Mi**) are also in the cytoplasm. 17,000×.

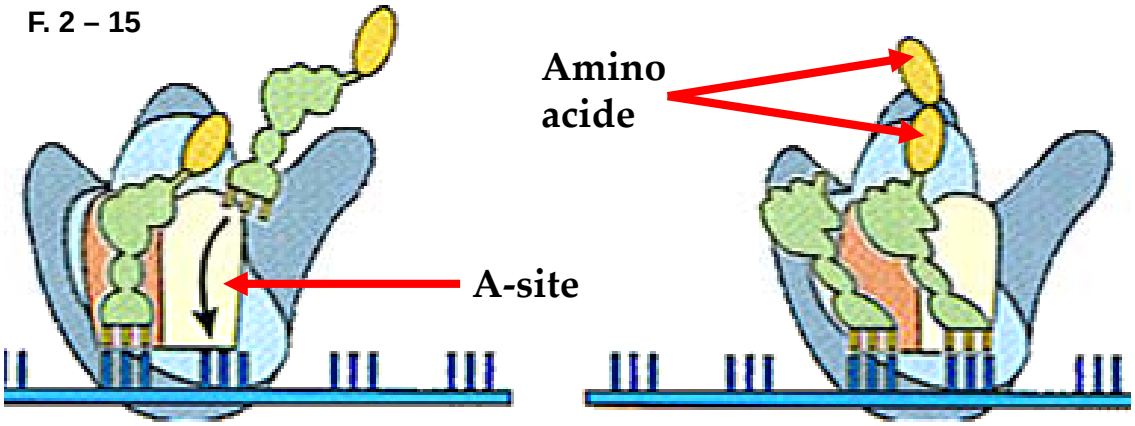
# Protein Synthesis

1. The P-site of the small ribosomal subunit is occupied by an initiator tRNA. Then mRNA binds to the small subunit and finally the anticodon of tRNA recognizes the start codon of mRNA.
2. The large subunit binds to the small subunit and the ribosome moves along the mRNA.



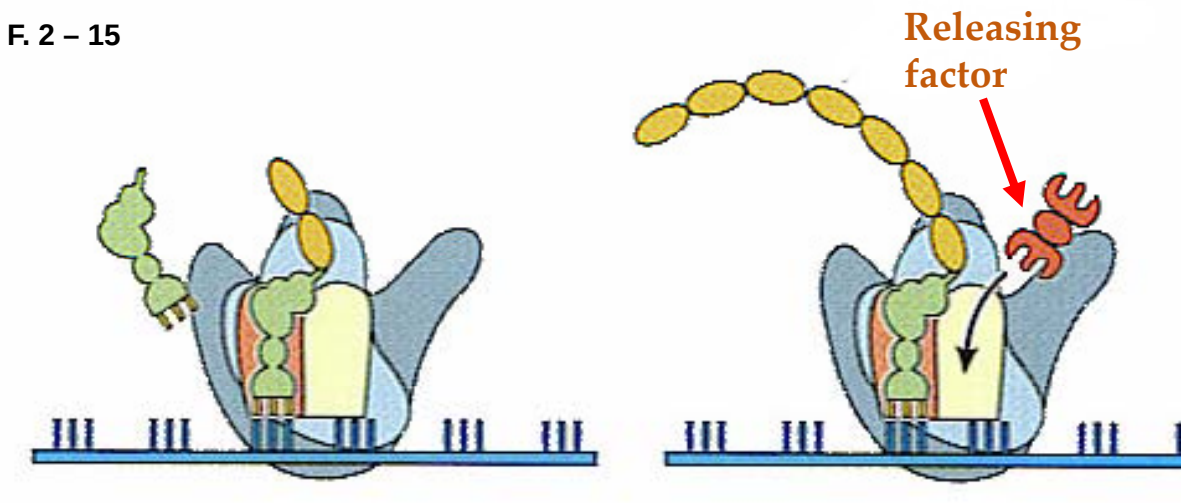
3. A tRNA with matching anticodon with the codon of mRNA binds ti the A-site.
4. The amino acides at the A-site and the P-site form a peptid bond. Then the tRNA on the P-site yields its amino acid to the tRNA at the A-site.

F. 2 – 15



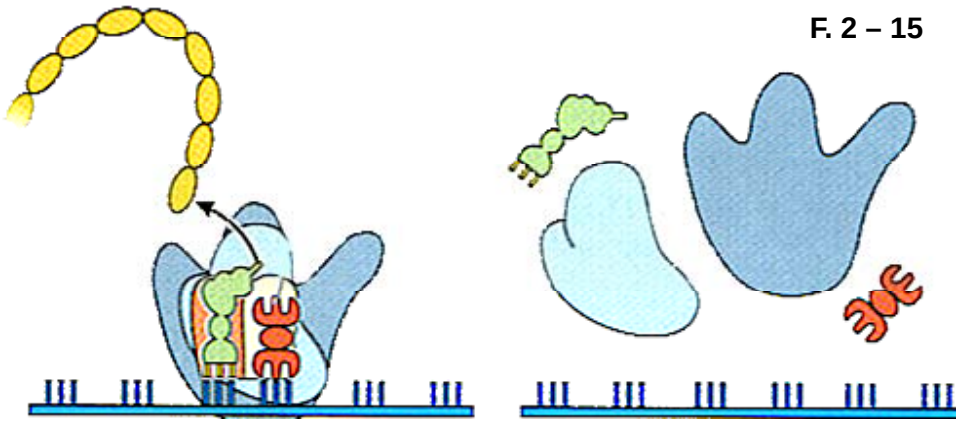

5. The deaminated tRNA leaves the P-site and the tRNA with two amino acides moves to the P-site. Then the next codon lines up with the A-site.
6. Steps 3 – 5 are repeated.

F. 2 – 15



7. When the A-site reaches a stop codon, a release factor binds to the A-site and releases the polypeptide chain from tRNA of the P-site.
8. tRNA is released from the P-site, the release factor is released from the A-site, and the small and large subunits leave the mRNA.

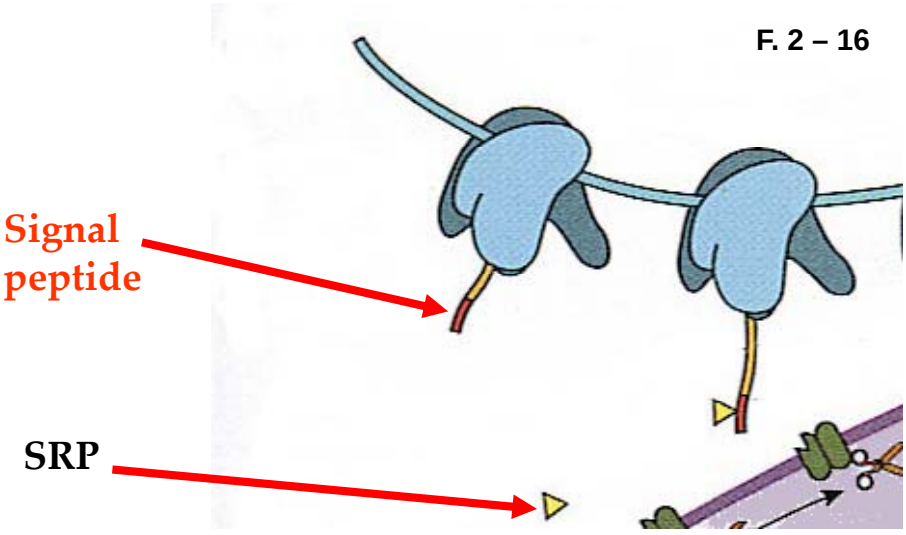
F. 2 – 15



## Protein Synthesis on RER

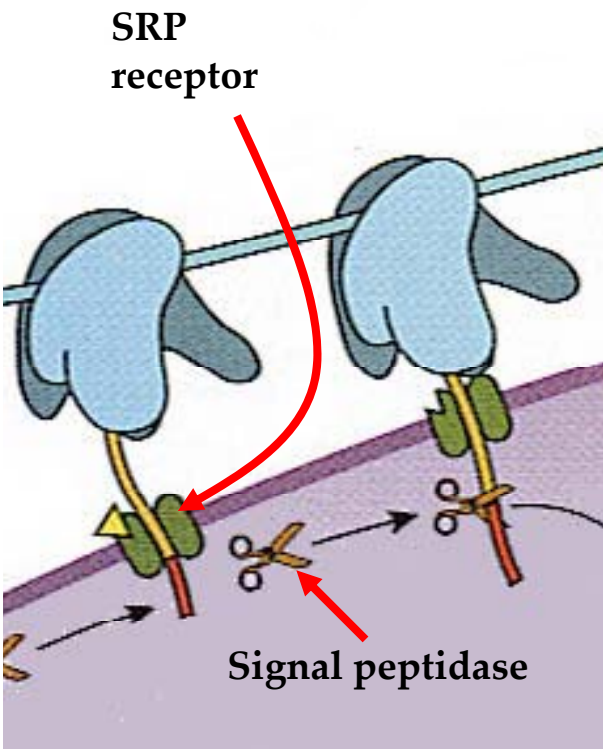
- Right after the start codon there is a small segment of mRNA that codes for a signal peptide.
- Signal peptide is recognized by SRP which inhibits further translation of mRNA.

F. 2 – 16



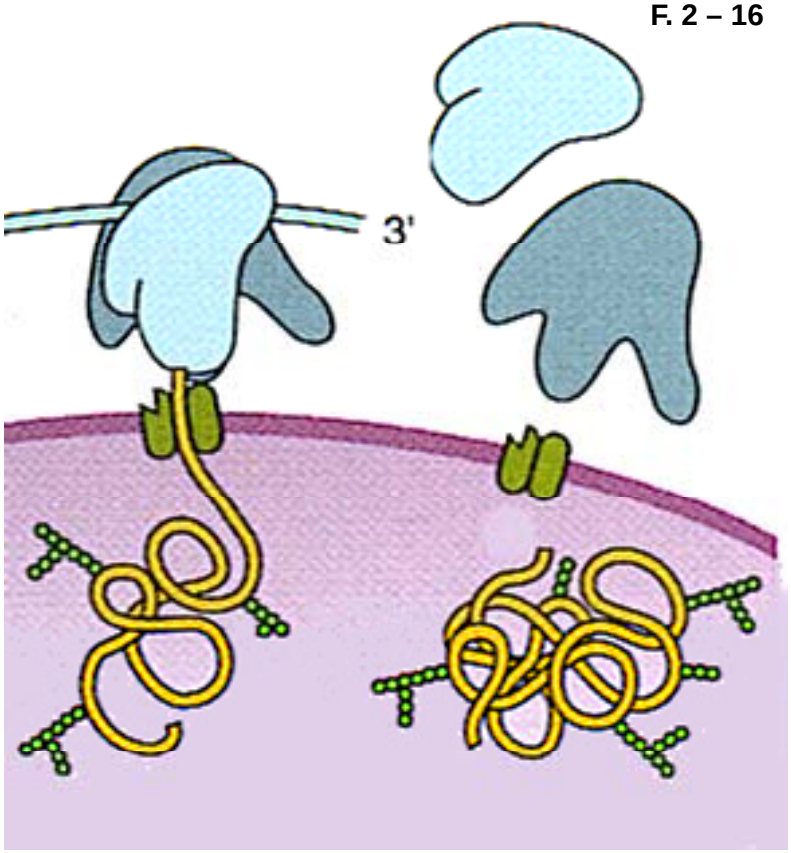
- The SRP receptor in the RER contacts the SRP and the polysome attaches to the RER.
- A pore is formed through the lipid bilayer of RER.
- The signal peptide is translocated into the cistern of RER.
- The SRP is dislodged and frees the P-site of the small subunit.
- An enzyme within the RER known as signal peptidase, cleaves the signal peptide.

F. 2 – 16



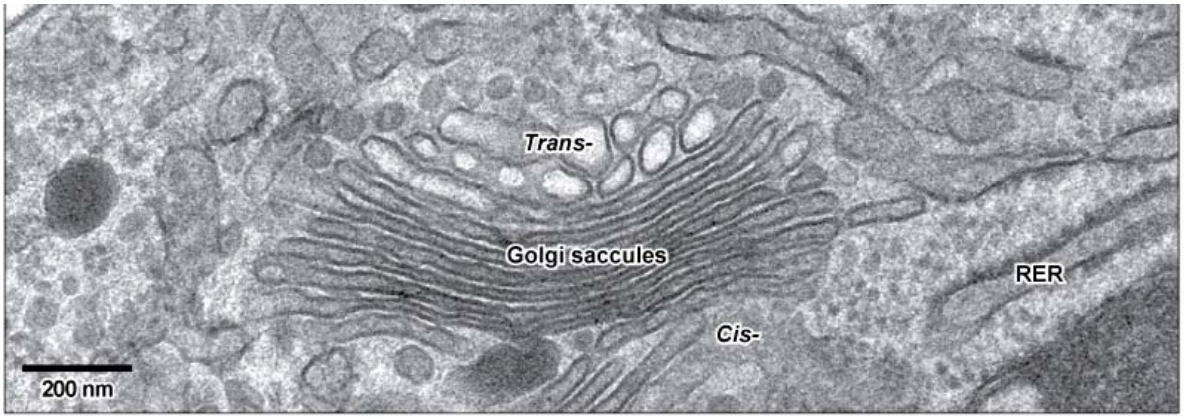

- Protein synthesis continues.
- Additional modifications are done on the newly formed protein.

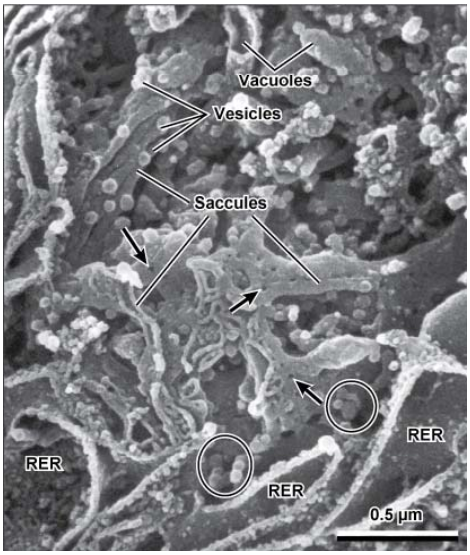
F. 2 – 16

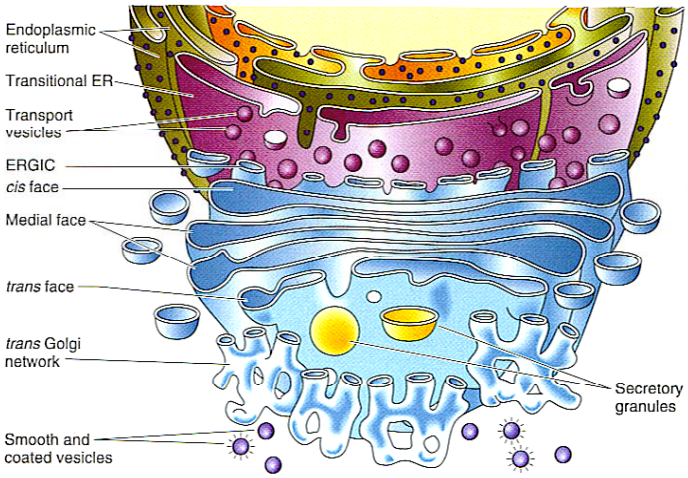


# Golgi Complex

- Is composed of series of flattened, slightly curved membrane bounded cisternae.
- The golgi complex functions in the synthesis of carbohydrates and proteins (cis) and in the modification (medial) and sorting (trans) of proteins manufactured on the RER. It also produces lipids and lysosomes

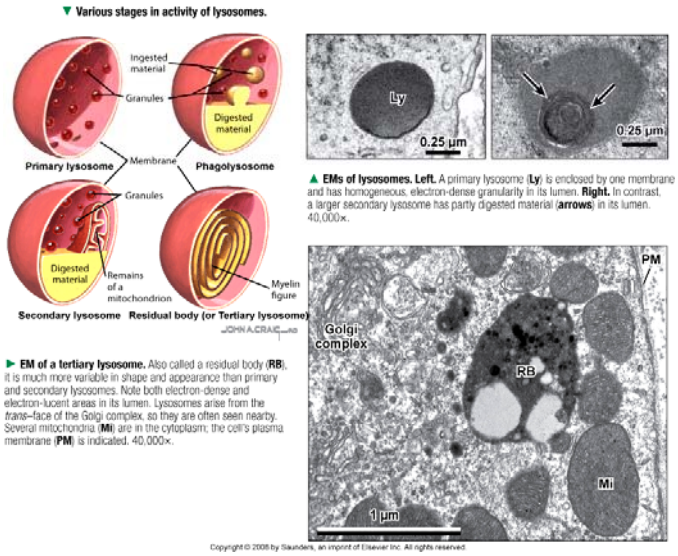


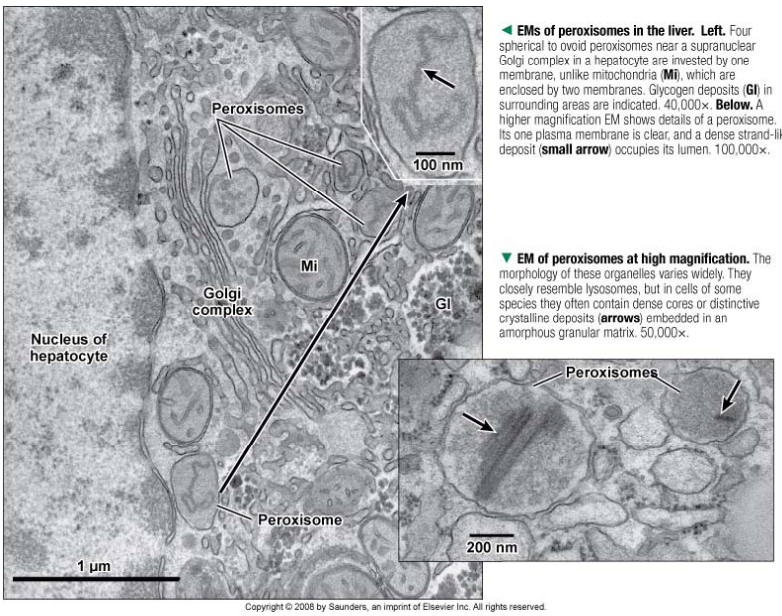
# Lysosome

- Membrane bounded vesicles ( 0.25 – 0.8 μm) arising from golgi complex and loaded with hydrolytic enzymes.
- They are responsible for enzymatic digestion of the contents of endosomes, cellular debris, or excess organelles.
- Primary lysosomes are newly formed and not involved in digestion yet. Secondary lysosomes contain some debries and tertiary lysosomes are filled with debries.



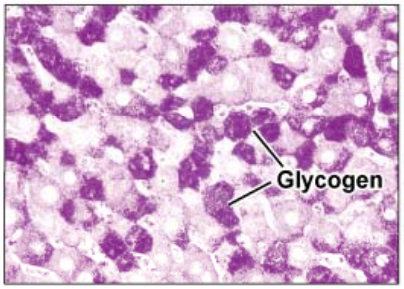

# Peroxisome

- These are usually spherical (0.1 – 0.5 μm) self – replicating organelles that contain oxidative enzymes for catabolism of long chained fatty acids, bile acids, detoxifying noxious agents, and killing micro-organisms.

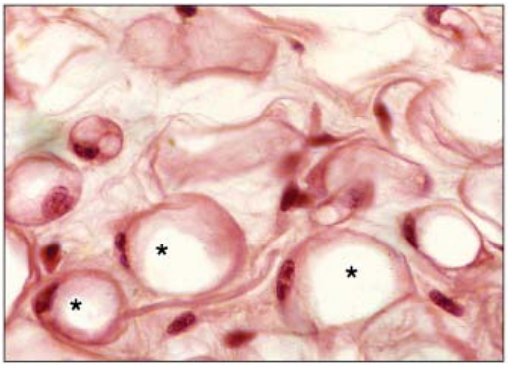


# Inclusions

- Are considered to be non-living components of the cell that do not possess metabolic activity and are not bounded by membranes.
- The most common inclusions are glycogen, lipid droplets, pigments, and crystals.



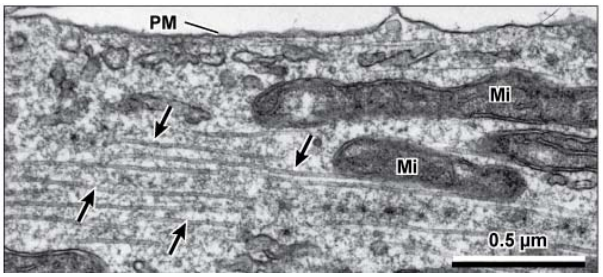

▲ **LM of the liver stained to show glycogen in hepatocytes.** Large amounts of glycogen in many cells impart a magenta color with the PAS stain.

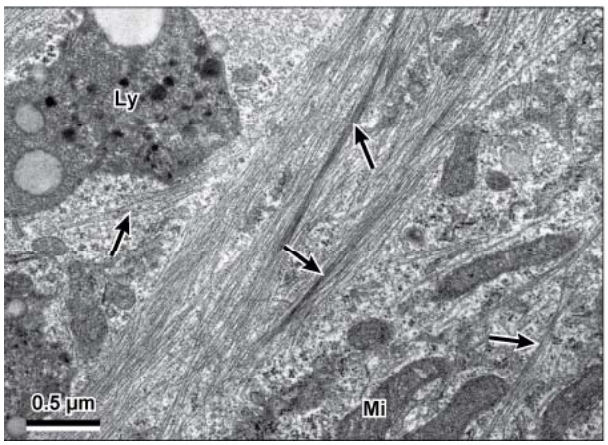


▲ **LM of fat cells in adipose tissue.** Lipid is not well preserved in routine sections and looks washed out. Here, several fat cells (adipocytes) contain lipid (*), which pushes nuclei to the periphery. Cells thus have a signet ring appearance in transverse section.

# Cytoskeleton

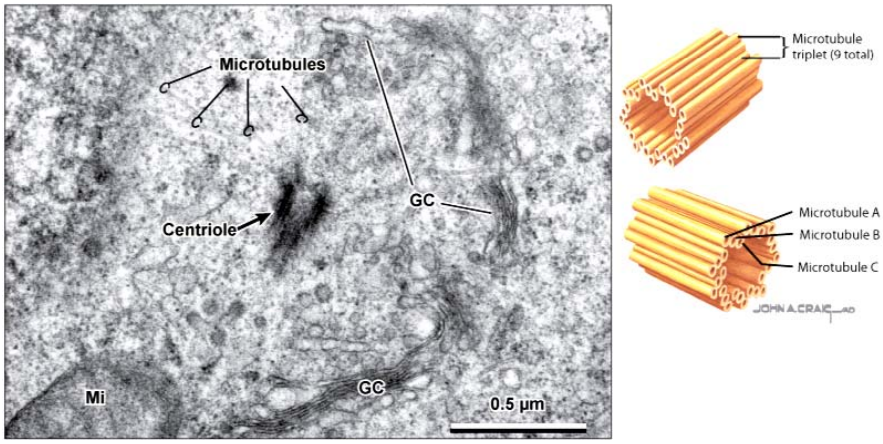
- Has three major components:
  1. Microtubules (25 nm)
  2. Thin filaments (6 nm)
  3. Intermediate (8-12 nm) filaments
- Is responsible for the maintenance of cellular morphology, cellular motion and intracellular transport system.



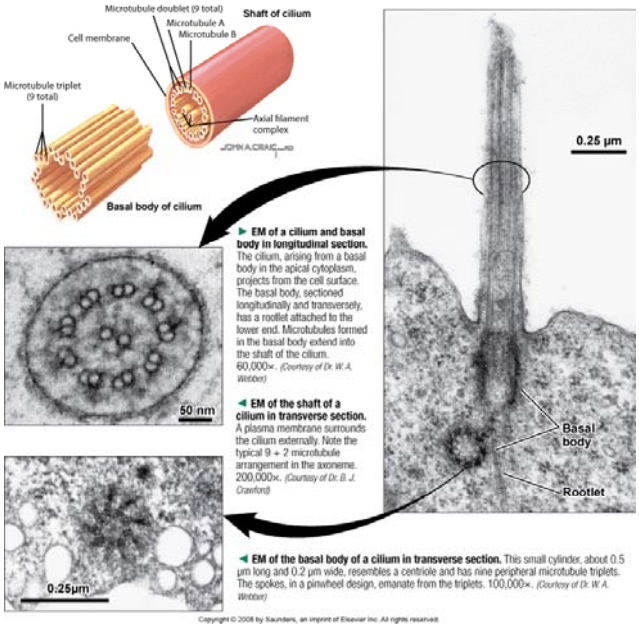
# Centrosome

- Is comprised of a pair of centrioles surrounded by pericentriolar matrix and located near the nucleus.
- Each centriole (200 nm in diameter and 500 – 700 nm long) consists of nine sets of microtubule triplets.
- This organell is responsible for generation of new micritubules and mitotic spindle.




# Cilia

- Are mobile extensions of cells (10 – 12 µm long and 0.2 µm in diameter).the organizing center for cilia is known as basal bodies that are found close to the surface and underneath the cilia. Basal bodies in turn arise from centrioles.
- Cilia consists of a nine sets of microtubule triplets surrounding a pair of central microtubules. The whole structure referred to as AXONEME.



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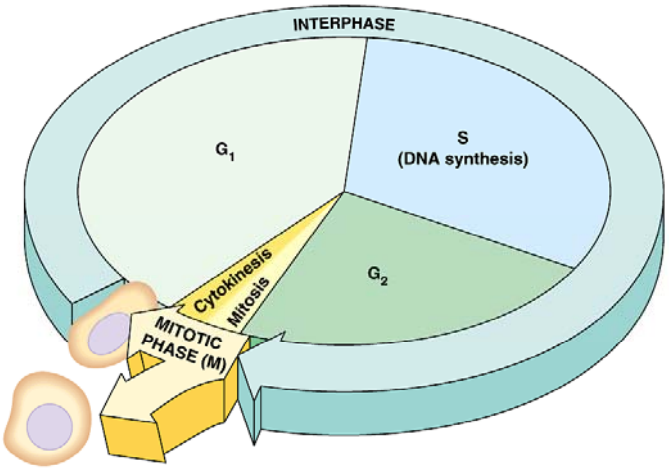
# The cell cycle multiplies cells

- The cell cycle consists of two major phases:
  - Interphase, when:
  1. cell organells are made (G1)
  2. chromosomes duplicate (S)
  3. Energy is stored (G2)

  - The mitotic phase, when cell division occurs.




# Cell division

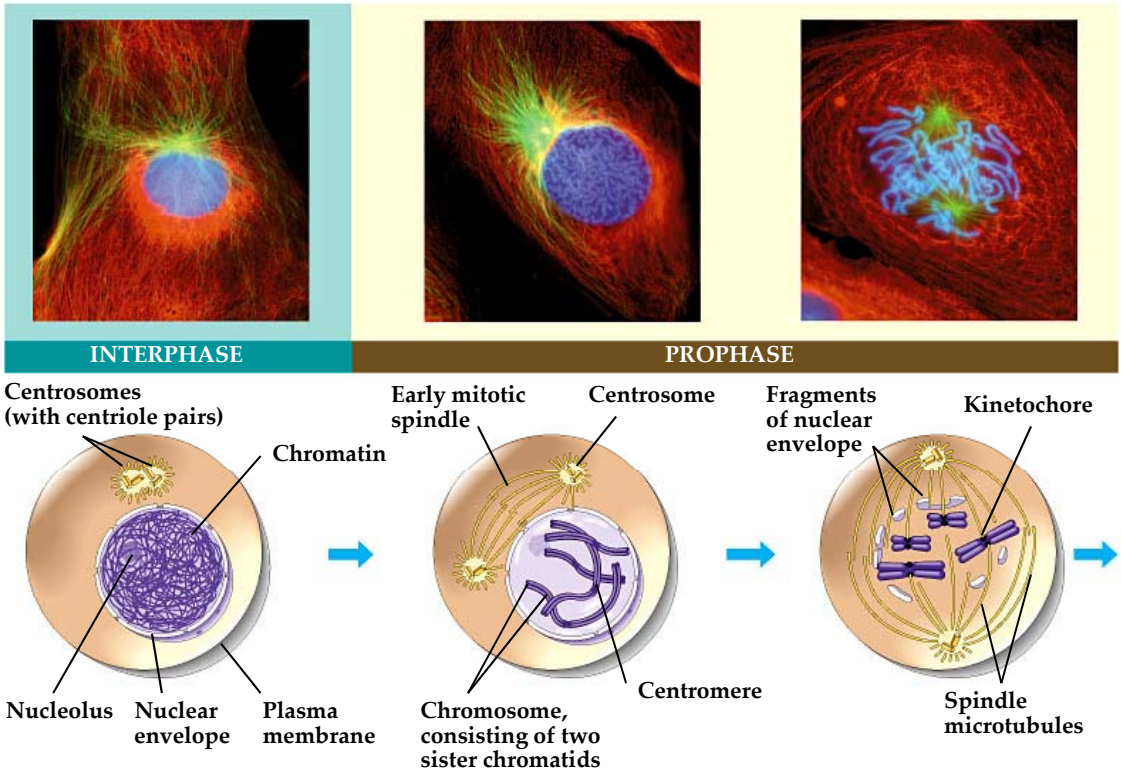
- Cell division consists of two stages:
  - Mitosis
  - Cytokinesis

- In mitosis, the duplicated chromosomes are distributed into two daughter nuclei.

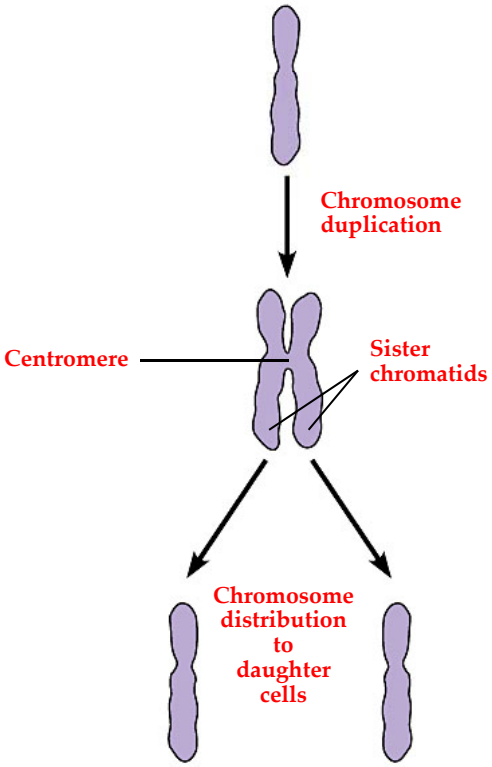
1. After the chromosomes coil up, a mitotic spindle moves them to the middle of the cell (Prophase & Metaphase).

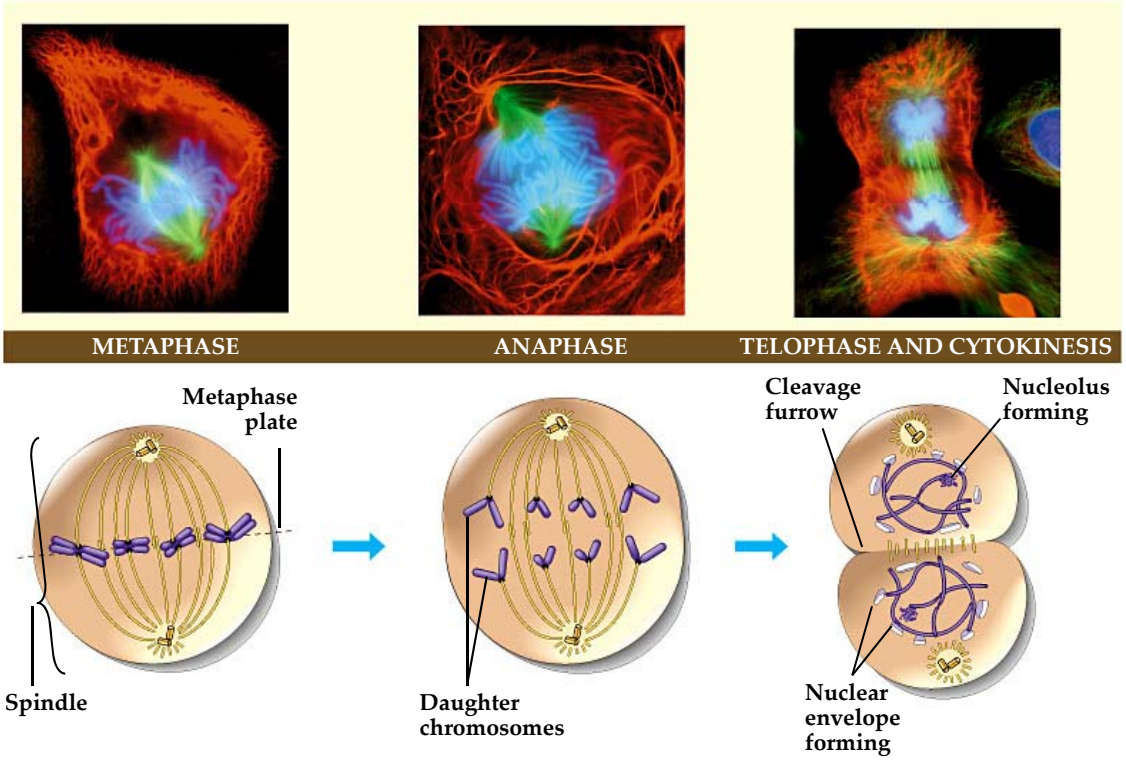
2. The sister chromatids then separate and move to the opposite poles of the cell (Anaphase & Telophase).

3. The process of cytokinesis divides the cell into two genetically identical cells




- When the cell divides, the sister chromatids separate
  - Two daughter cells are produced
  - Each daughter cell has a complete and identical set of chromosomes




METAPHASE
ANAPHASE
TELOPHASE AND CYTOKINESIS
Metaphase plate
Spindle
Daughter chromosomes
Cleavage furrow
Nucleolus forming
Nuclear envelope forming