# ORGANELLES
# AND
# CYTOPLASMIC INCLUSIONS

A- Organelles

B- Cytoplasmic inclusions

A- **ORGANELLES**

a- Membranous organelles

b- Nonmembranous cytoplasmic organelles

**A- MEMBRANOUS ORGANELLES**

**1-Cell membran**

**2-Ergastoplasm: a) free ribosomes**

**b)endoplasmic reticulum**

**3-Golgi apparatus**

**4- Lysosomes**

**5-Microbodies**

**6-Mitochondria**

# Golgi Apparatus

- The Golgi apparatus is well developed in secretory cells and does not stain with hematoxylin or eosin. It is seen with special stains impregnating methods.
- The Golgi complex occupies a characteristic position in the cytoplasm between the nucleus and the apical plasma membrane.
- Secretory cells, plasma cells, osteoblast, cells of the epididymis and goblet cells have a large Golgi apparatus.
- The Golgi complex  is responsible inside the cell for packaging of the protein molecules before they are sent to their destination.
- These organelles helps in processing and packaging the macromolecules like proteins and lipids that are synthesized by the cell.
- The major function of the Golgi apparatus is to modify , sort and package the macromolecules.

# Golgi Apparatus Structure

- The Golgi complex is composed of stacks of membrane-bound structures, these structures are known as the cisterna.
- Each cisterna is a disc enclosed in a membrane, it possesses special enzymes of the Golgi which help to modify and transport of the modified proteins to their destination.
- The flat sacs of the cisternae are stacked and are bent and semicircular in shape.
- Each group of stacks is membrane-bound and its insides are separated from the cytoplasm of the cell.
- The Golgi complex is polar in nature.
- One end of the stack is known as the cis face, or *cis-Golgi network (CGN)*. It is the 'receiving department" while the other end is the trans face or *trans-Golgi network (TGN)* and is the "shipping department".
- The cis face of the Golgi apparatus is closely associated with the

# Golgi Apparatus Structure

- Small vesicles called *transport vesicles* carry newly synthesized proteins from the rER to the cis face (CGN).
- From there, they travel within the transport vesicles from one cisterna to the next.
- The vesicles bud from one cisterna and fuse with the adjacent cisternae.

# Golgi Apparatus Function

- The cell synthesizes a huge amount of variety of macromolecules. The main function of the Golgi apparatus is to modify, sort and package the macromolecules that are synthesized by the cells for secretion purposes or for use within the cell.
- It mainly modifies the proteins that are prepared by the rough endoplasmic reticulum.
- They are also involved in the transport of lipid molecules around the cell.

# Golgi Apparatus
# Function

- The Golgi apparatus also form lysosomes.
- The Golgi complex is thus referred to as post office where the molecules are packaged, labeled and sent to different parts of the cell.
- The enzymes in the cisternae have the ability to modify proteins by the addition of carbohydrates and phosphate by the process of glycosylation and phosphorylation  respectively.

# Golgi Apparatus Function

- The Golgi complex plays an important role in the production of proteoglycans.
- The proteoglycans are molecules that are present in the extracellular matrix of the animal cells.
- It is also a major site of synthesis of carbohydrates.
- These carbohydrates include the synthesis of glycosaminoglycans, Golgi attaches to these polysaccharides which then attaches to a protein produced in the endoplasmic reticulum to form proteoglycans.

## Golgi Apparatus Function

The TEM and cytochemical methods have shown that Golgi saccules contain different enzymes at different *cis-trans levels and that the Golgi apparatus is important for* glycosylation, sulfation, phosphorylation, and limited proteolysis of proteins. Furthermore, the Golgi apparatus initiates packing, concentration, and storage of secretory products.

# Lysosomes

- Lysosomes are sites of intracellular digestion and turnover of cellular components.
- Lysosomes are membrane-limited vesicles that contain a large variety of hydrolytic enzymes (more than 40) whose main function is intracytoplasmic digestion.
- Lysosomes are particularly abundant in cells exhibiting phagocytic activity (eg, macrophages, neutrophilic leukocytes).
- Although the nature and activity of lysosomal enzymes vary depending on the cell type, the most common enzymes are acid phosphatase, ribonuclease, deoxyribonuclease, proteases, sulfatases, lipases, and -glucuronidase.
- As can be seen from this list, lysosomal enzymes are capable of breaking down most biological macromolecules.
- Lysosomal enzymes have optimal activity at an acidic pH.

# Lysosomes

- Lysosomes, which are usually spherical, range in diameter from 0.05 to 0.5 µm and present a uniformly granular, electron-dense appearance in electron micrographs.
- In a few cells, such as macrophages and neutrophilic leukocytes, primary lysosomes are larger, up to 0.5 µm in diameter, and thus are just visible with the light microscope.
- The enveloping membrane separates the lytic enzymes from the cytoplasm, preventing the lysosomal enzymes from attacking and digesting cytoplasmic components.
- The fact that the lysosomal enzymes are practically inactive at the pH of the cytosol (7.2) is additional protection of the cell against leakage of lysosomal enzymes.

# Lysosomes

- Lysosomal enzymes are synthesized and segregated in the RER and subsequently transferred to the Golgi complex, where the enzymes are modified and packaged as lysosomes.
- Lysosomes that have not entered into a digestive event are identified as **primary lysosomes.**
- Lysosomes can digest material taken into the cell from its environment. The material is taken into a **phagosome** or **phagocytic vacuole**; primary lysosomes then fuse with the membrane of the phagosome and empty their hydrolytic enzymes into the vacuole. Digestion follows, and the composite structure is now termed a **secondary lysosome.**

# Lysosomes

- Secondary lysosomes are generally 0.2–2 µm in diameter and present a heterogeneous appearance in electron microscopes because of the wide variety of materials they may be digesting.
- After digestion of the contents of the secondary lysosome, nutrients diffuse through the lysosomal-limiting membrane and enter the cytosol.
- Indigestible compounds are retained within the vacuoles, which are now called **residual bodies**. In some long-lived cells (eg, neurons, heart muscle), large quantities of residual bodies accumulate and are referred to as **lipofuscin**, or **age pigment**.

# Lysosomes

- Another function of lysosomes concerns the turnover of cytoplasmic organelles. Under certain conditions, a membrane may enclose organelles or portions of cytoplasm.
- Primary lysosomes fuse with this structure and initiate the lysis of the enclosed cytoplasm.
- The resulting secondary lysosomes are known as **autophagosomes,** indicating that their contents are intracellular in origin.
- Cytoplasmic digestion by autophagosomes is enhanced in secretory cells that have accumulated excess secretory product. The digested products of lysosomal hydrolysis are recycled by the cell to be reutilized by the cytoplasm.

# Lysosomes

- In some cases, primary lysosomes release their contents extracellularly, and their enzymes act in the extracellular milieu.
- An example is the destruction of bone matrix by the collagenases synthesized and released by osteoclasts during normal bone tissue formation.
- Lysosomal enzymes acting in the extracellular milieu also play a significant role in the response to inflammation or injury.

# Peroxisomes or Microbodies

- Peroxisomes are spherical membrane-limited organelles whose diameter ranges from 0.5 to 1.2 µm.
- Like the mitochondria, they utilize oxygen but do not produce ATP and do not participate directly in cellular metabolism.
- Peroxisomes oxidize specific organic substrates by removing hydrogen atoms that are transferred to molecular oxygen ($O_2$).
- This activity produces hydrogen peroxide ($H_2O_2$), a substance that is very damaging to the cell.

# Peroxisomes or Microbodies

- However, $H_2O_2$ is eliminated by the enzyme **catalase,** which is present in peroxisomes.
- Catalase transfers oxygen atoms from $H_2O_2$ to several compounds and also decomposes $H_2O_2$ to $H_2O$ and $O_2$ ($2\ H_2O_2 \rightarrow 2\ H_2O + O_2$).
- Peroxisomes contain enzymes involved in lipid metabolism.
- Thus, the -oxidation of long-chain fatty acids (18 carbons and longer) is preferentially accomplished by peroxisomal enzymes that differ from their mitochondrial counterparts. Certain reactions leading to the formation of bile acids and cholesterol also have been localized in highly purified peroxisomal fractions.

# Mitochondria

- Mitochondria are spherical or filamentous organelles 0.5–1 µm wide that can attain a length of up to 10 µm.
- They tend to accumulate in parts of the cytoplasm at which the utilization of energy is more intense, such as the apical ends of ciliated cells, in the middle piece of spermatozoa, or at the base of ion-transferring cells.
- These organelles transform the chemical energy of the metabolites present in cytoplasm into energy that is easily accessible to the cell.
- About 50% of this energy is stored as high-energy phosphate bonds in ATP molecules, and the remaining 50% is dissipated as heat used to maintain body temperature.
- Mitochondria have a characteristic structure under the electron microscope.
- They are composed of an **outer** and an **inner mitochondrial membrane;** the inner membrane projects folds, termed **cristae**, into the interior of the mitochondrion.
- These membranes enclose two compartments. The compartment located between the two membranes is termed the **intermembrane space.**

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# Mitochondria

- The inner membrane encloses the other compartment—the intercristae, or matrix, space.
- Compared with other cell membranes, mitochondrial membranes contain a large number of protein molecules.
- Most mitochondria have flat, shelflike cristae in their interiors, whereas cells that secrete steroids (eg, adrenal gland) frequently contain tubular cisternae.
- The cristae increase the internal surface area of mitochondria and contain enzymes and other components of oxidative phosphorylation and electron transport systems.
- The adenosine diphosphate (ADP) to ATP phosphorylating system is localized in globular structures connected to the inner membrane by cylindrical.

# Mitochondria

- The globular structures are a complex of proteins with ATP synthetase activity that, in the presence of ADP plus inorganic phosphate and energy, forms ATP.
- The number of mitochondria and the number of cristae in each mitochondrion are related to the energetic activity of the cells in which they reside.
- Thus, cells with a high-energy metabolism (eg, cardiac muscle, cells of some kidney tubules) have abundant mitochondria with a large number of closely packed cristae, whereas cells with a low-energy metabolism have few mitochondria with short cristae.
- Between the cristae is an amorphous **matrix,** rich in protein and containing circular molecules of DNA and the three varieties of RNA.
- In a great number of cell types, the mitochondrial matrix also exhibits rounded electron-dense granules rich in $Ca^{2+}$.
- Although the function of this cation in mitochondria is not completely understood, it may be important in regulating the activity of some mitochondrial enzymes; another functional role is related to the necessity of keeping the cytosolic concentration of $Ca^{2+}$ low.

# Mitochondria

- Mitochondria will pump in $Ca^{2+}$ when its concentration in the cytosol is high. Enzymes for the citric acid (Krebs) cycle and fatty acid -oxidation are found to reside within the matrix space.
- The DNA isolated from the mitochondrial matrix is double stranded and has a circular structure, very similar to that of bacterial chromosomes.
- These strands are synthesized within the mitochondrion; their duplication is independent of nuclear DNA replication.
- Mitochondria contain the three types of RNA: ribosomal RNA (rRNA), messenger RNA (mRNA), and transfer RNA (tRNA).
- Mitochondrial ribosomes are smaller than cytosolic ribosomes and are comparable to bacterial ribosomes.

# Mitochondria

- Protein synthesis occurs in mitochondria, but because of the reduced amount of mitochondrial DNA, only a small proportion of the mitochondrial proteins is produced locally.
- Most are encoded by nuclear DNA and synthesized in polyribosomes located in the cytosol. These proteins have a small amino acid sequence that is a signal for their mitochondrial destination, and they are transported into mitochondria by an energy-requiring mechanism.

# Nonmembranous Organelles

- While membranous organelles are involved in metabolic processes, nonmembranous organelles participates in the movement of entire cells.
- Nonmembranous organelles is also called **cytoskeleton.**
- The **cytoskeleton** is a cellular "scaffolding" or "skeleton" contained within the cytoplasm. The cytoskeleton is present in all cells.
- It is a dynamic structure that maintains cell shape, often protects the cell, enables cellular motion (using structures such as flagella), and plays important roles in both intracellular transport (the movement of vesicles and organelles, for example) and cellular division.

# Cytoskeleton

The cytoplasmic cytoskeleton is a complex network of

(1) microtubules,
(2) microfilaments
(actin filaments)
(3) intermediate filaments.

These protein structures determine the shape of cells, play an important role in the movements of organelles and cytoplasmic vesicles, and also allow the movement of entire cells.

# Microtubules

- Microtubules are cylindrical tubes, 20-25 nm in diameter. They are composed of subunits of the protein tubulin--these subunits are termed **alpha** and **beta**.
- Microtubules act as a scaffold to determine cell shape, and provide a set of "tracks" for cell organelles and vesicles to move on.
- Microtubules also form the spindle fibers for separating chromosomes during mitosis. When arranged in geometric patterns inside flagella and cilia, they are used for locomotion.

# Microfilaments

•Microfilaments are fine, thread-like protein fibers, 3-6 nm in diameter. They are composed predominantly of a contractile protein called **actin**, which is the most abundant cellular protein.

•Microfilaments' association with the protein myosin is responsible for muscle contraction.

•Microfilaments can also carry out cellular movements including gliding, contraction, and cytokinesis.

# Intermediate Filaments

- Intermediate filaments have a diameter of about 10 nm, which is intermediate between the diameters of the two other principal elements of the cytoskeleton, actin filaments (about 7 nm) and microtubules (about 25 nm).
- In contrast to actin filaments and microtubules, the intermediate filaments are not directly involved in cell movements. Instead, they appear to play basically a structural role by providing mechanical strength to cells and tissues.

## Examples of the cytoskeleton in epithelial cells :

- In the epithelial cells of the intestine, all three types of fibers are present.
- **Microtubules** grow out of the centrosome to the cell periphery.
- **Microfilaments** project into the villi, giving shape to the cell surface.
- **Intermediate** filaments connect adjacent cells through desmosomes.

# Centrosome

- The centrosome is the microtubule-organizing center for the mitotic spindle and consists of paired centrioles.
- Centrosome environment is more intense. This is called centroplasm.
- The TEM reveals that the two centrioles in a centrosome exist at right angles to one another in a dense matrix of free tubulin subunits and other proteins.

# Centrosome

- Close to the nucleus of nondividing cells is a centrosome made of a pair of centrioles surrounded by a granular material.
- In each pair, the long axes of the centrioles are at right angles to each other.
- Each centriole consists of nine microtubular triplets.

In a poorly understood process, the centrosome duplicates itself and is divided equally during a cell's interphase, each half having a duplicated centriole pair.

At the onset of mitosis, the two daughter centrosomes move to opposite sides of the nucleus and become the two poles of the mitotic spindle of microtubules attaching to chromosomes.

# Cytoplasmic inclusion

- Cytoplasmic **inclusions** are non-living substances that are not able to carry out any metabolic activity and are not bound by membranes.
- Inclusions are stored nutrients, secretory products, and pigment granules.
- Examples of inclusions are glycogen granules in the liver and muscle cells, lipid droplets in fat cells, pigment granules in certain cells of skin and hair, water containing vacuoles, and crystals of various types.

**Glycogen:** Glycogen is the most common form of glucose in animals and is especially abundant in cells of muscles, and liver. It appears in electron micrograph as clusters, or rosette of beta particles that resemble ribosomes, located near the smooth endoplasmic reticulum.

Glycogen is an important energy source of the cell; therefore, it will be available on demand. The enzymes responsible for glycogenolysis degrade glycogen into individual molecules of glucose and can be utilized by multiple organs of the body.

**Lipids:** Lipids are triglycerides in storage form is the common form of inclusions, not only are stored in specialized cells (adipocytes) but also are located as individuals droplets in various cell type especially hepatocytes.

These are fluid at body temperature and appear in living cells as refractile spherical droplets. Lipid yields more than twice as many calories per gram as does carbohydrate.

On demand, they serve as a local store of energy and a potential source of short carbon chains that are used by the cell in its synthesis of membranes and other lipid-containing structural components or secretory products.

**Crystals:** Crystalline inclusions have long been recognized as normal constituents of certain cell types such as Sertoli cells and Leydig cells of the testis, and occasionally in macrophages.

It is believed that these structures are crystalline forms of certain proteins which is located everywhere in the cell such as in nucleus, mitochondria, endoplasmic reticulum, Golgi body, and free in cytoplasmic matrix.

**Pigments:** The most common pigment in the body, besides hemoglobin of red blood cells is melanin, manufactured by melanocytes of the skin and hair, pigments cells of the retina and specialized nerve cells in the substantia nigra of the brain.

These pigments have protective functions in skin and aid in the sense of sight in the retina but their functions in neurons is not understood completely.

Furthermore, cardiac tissue and central nervous system neurons shows yellow to brown pigment called lipofuscin, some believed that they have lysosoma

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