# Topic 1. Cytology

## Control questions

1. Cell components.
2. Biological membranes structure.
3. Cell surface. Principle functions of plasma membrane.
4. Receptive function of cell's plasma membrane.
5. Transport function of plasma membrane.
6. Cells cytoplasm. Hyaloplasm.
7. Inclusions.
8. General and special organelles: ribosomes; endoplasmic reticulum; Golgi complex; lysosomes; peroxisomes; mitochondria; centrosome; cytoskeleton (microtubules, microfilaments, intermediate filaments).
9. Nucleus and its components: nuclear envelope; chromatin; nucleolus.
10. Cell cycle.

## Question 1. Cell components.

Cytology is a science about the cell. Cell is the basic and smallest structural and functional unit of the multicellular organisms. Cells perform main functions of organism, such as protection, ingestion, digestion, absorbtion, elimination of wastes, movement, reproduction.

The cell consists of three main components:

1. Cell surface;
2. Cytoplasm;
3. Nucleus.

## Question 2. Biological membranes structure.

In cells, the biological membranes are lipoproteid structures separating cell from outside (plasma membrane) and forming some cells organelles (membranous organelles) and nuclear envelope.

The modern interpretation of the molecular organization of the biological membranes is known as the modified fluid-mosaic model. The biological membranes of cells consists of lipid (phospholipids and cholesterol) and protein molecules [13].

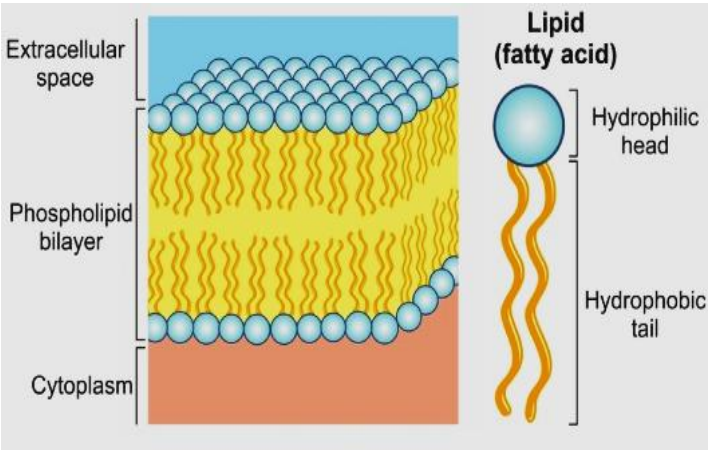



**Figure 1.1. Diagram of plasma membranes lipid bilayer, presenting by the phospholipid molecules.**

Each phospholipid molecule has two parts:

1) a hydrophilic head having no affinity for water;
2) a thin hydrophobic tail (fatty acid chains) having affinity for water.

All biomembranes of cells have a common plan of their organization. They are represented by the phospholipid molecules, forming a lipid bilayer, where hydrophobic tails face each other to form the inner portion of the membrane [5].

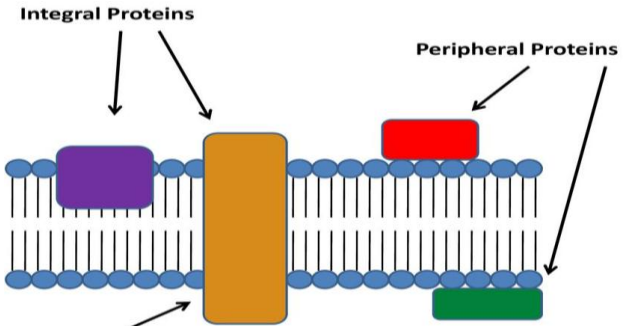



**Figure 1.2. Diagram of integral and peripheral membrane proteins.**

Protein molecules situate in the lipid bilayer by mosaic principle.

In biological membranes of the cells according to localization there are 2 groups of proteins:

1) Integral membrane proteins which are embedded within the lipid bilayer completely and partially;
2) Peripheral membrane proteins which are not embedded within the lipid bilayer, but associated with plasma membrane [13].

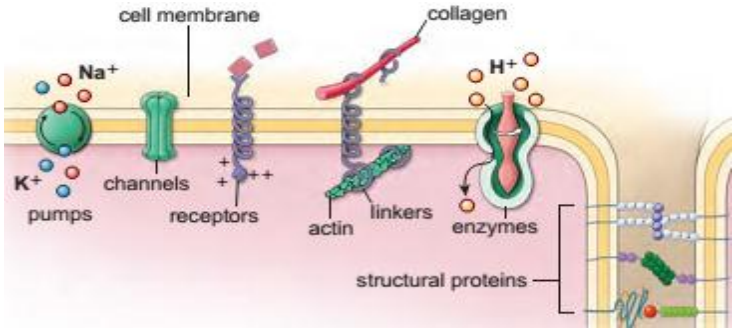



**Figure 1.3. Diagram of different functional types of integral membrane proteins [13].**

According to the function there are 6 types of the membrane proteins:

1) transport (pumps and channels);
2) reseptors;
3) linkers;
4) enzymes;
5) structural.

Pumps serve to transport ions, such as Na, amino acids and sugars across membrane.

Proteins-channels allow the passage of small ions, molecules, and water across the plasma membrane in either directions.

Reseptor proteins allow recognition and binding of ligands.

Linker proteins anchor the intracellular cytoskeleton to the extracellular matrix protein.

Enzymes proteins have a variety of functions.

Structural proteins involved in cell-to-cell junctions [13].

## Question 3. Cell surface. Principle functions of plasma membrane.

Cell surface is represented by the thickest biological membrane of cell called plasma membrane and the extracellular disposed glycocalyx or cell coat.

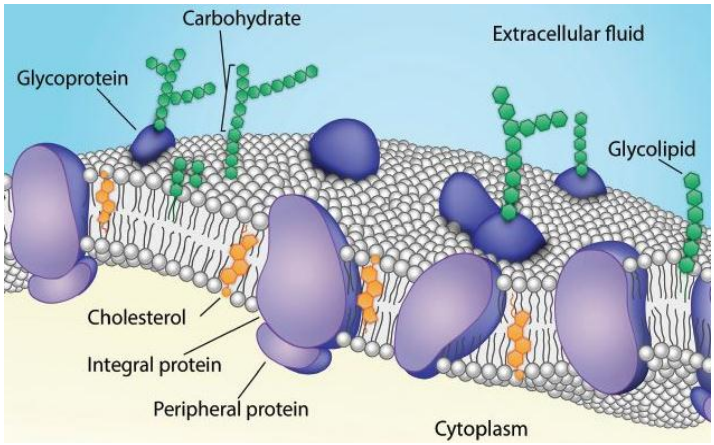



**Figure 1.4. Diagram of glycoproteins and glycolipids of the glycocalyx [2].**

On the extracellular surface of the plasma membrane, there are carbohydrate chains which may be attached to protein molecule, forming a complex called glycoprotein; or to phospholipid molecule forming a complex called glycolipid. These glycoproteins and glycolipids constitute a layer on the surface of cell called the cell coat or glycocalyx [Ross].

Main functions of the glycocalyx are:

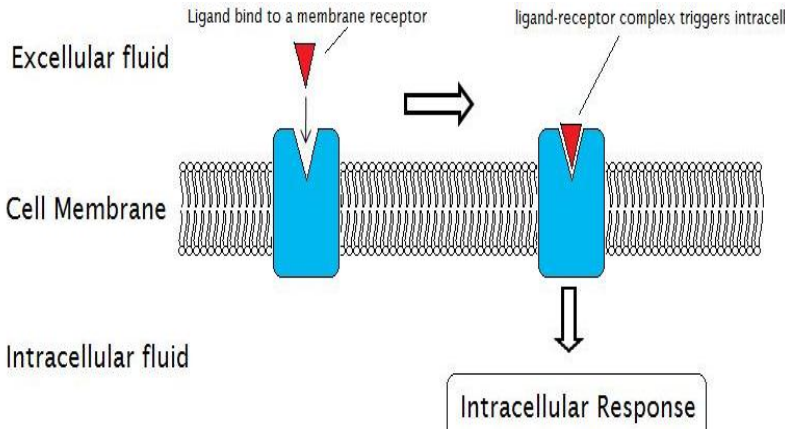
1. Reception and recognition of cells and intercellular substance;
2. Cell association (intercellular contacts);
3. Digestion.

**Functions of the plasma membrane:**

1. Barrier-defense;
2. Transport of the substance into and out of the cell;
3. Formation of intercellular junctions;
4. Formation of projections;
5. Reception.

## Question 4. Receptive function of cell's plasma membrane.

Cell surface receptors (transmembrane receptors) are integral membrane glycoproteins, which act in cell signaling by binding to extracellular signal molecules called ligands. Ligands are chemical substances such as hormones, neurotransmitters, cytokines and so on. They react with the receptor to induce changes in the metabolism and activity of a cell.




Cell surface receptors include three parts:

1. Extracellular (ligand binding) part;
2. Transmembrane part;
3. Intracellular (cytoplasmic) part.

Signal transduction processes trough transmembrane receptors involve the external reactions in that the ligand binds to a receptor and the internal reactions in that the intracellular response is triggered [5].

**Figure 1.5. Diagram of transmembrane receptor.**

There are 4 types of transmembrane receptors according to their structure and function:

1. Enzyme-linked receptors;
2. Ion channel-linked receptors;
3. G-protein receptors;
4. Cell adhesion molecules.

**Enzyme-linked receptors**

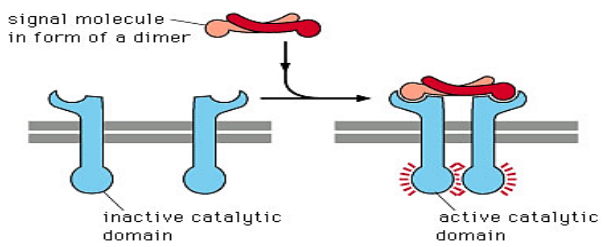



**Figure 1.6. Diagram of enzyme-linked receptor.**

Enzyme-linked (catalytic) receptors are receptors for hormones insulin and growth factors. Their cytoplasmic part is associated with enzyme protein kinase. When a ligand binds to the extracellular part, a signal is transferred through the membrane and activates the enzyme [5].

## Ion channel-linked receptors

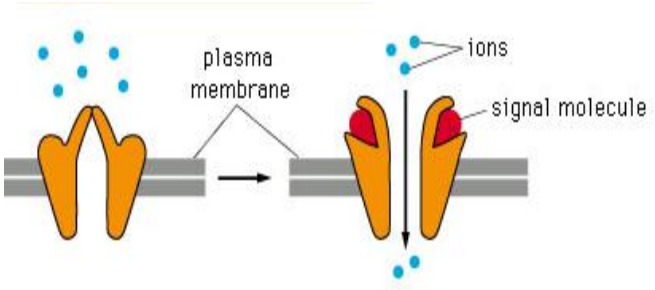



**Figure 1.6. Diagram of ion channel-linked receptor.**

Ion channel-linked receptors are a group of transmembrane ion channels that are opened in response to the binding of ligand, which is a neurotransmitter. As only the neurotransmitter binds to the extracellular part of this receptor, the ion channel is opened to allow the flow ions across the plasma membrane to trigger a nerve impulse [5].

## G-protein receptors

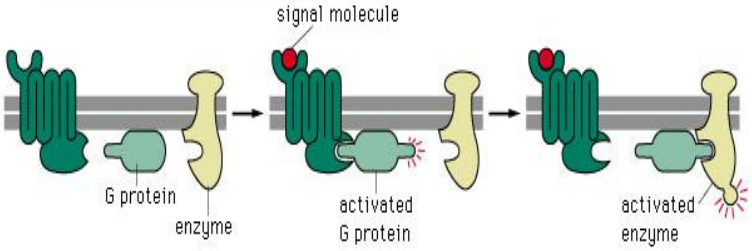



**Figure 1.7. Diagram of G-protein receptor.**

G-protein receptor is a protein consisting of 7 membrane ά-helices. The binding of ligands to it's extracellular part induces a conformational change that allows the cytoplasmic part of the receptor to bind to a G-protein associated with the inner face of the plasma membrane. This interaction activates the G-protein, which then dissociates from the receptor and carries the signal to either intracellular enzyme or an ion channel [5].

## Cell adhesion molecules

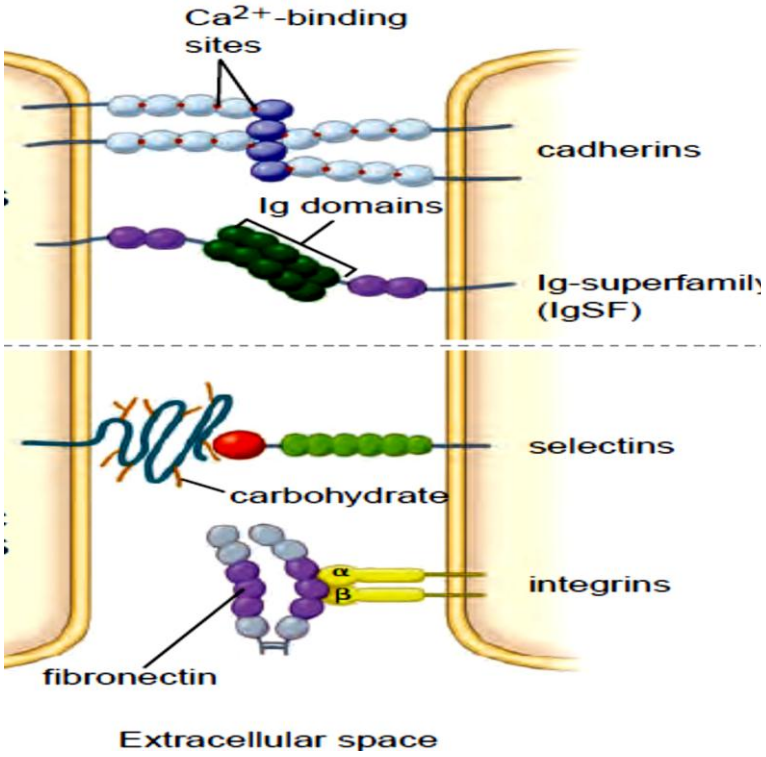



**Figure 1.8. Diagram of Cell adhesion molecules [13].**

Adhesion is a specific interaction between two contacting cells or between cell and extracellular matrix. All molecules of cell adhesion are subdivided into 4 classes:

1) Cadherines that are transmembrane proteins using the calcium ions for adhesion. Cadherines are responsible for cytoskeleton organization and intercellular connection;

2) Integrines that are membrane receptors for extracellular matrix proteins such as fibronectine and laminin. Integrines connect extracellular matrix with cytoskeleton through intracellular proteins - talline, vinkuline and ά-activin. They participate in the cell movement, exocytosis, endocytosis and etc;

3) Selectines. They provide leukocyte adhesion to endothelium of vessels and leukocyte-endothelial interaction, leukocyte migration through vessels wall to a tissue;

4) Immunoglobuline receptors. They play an important role in immune response [13].

## Question 5. Transport function of plasma membrane.

Substances that enter or leave the cell must traverse the plasma membrane by **simple diffusion, membrane transport and vesicular transport.**

### Simple diffusion

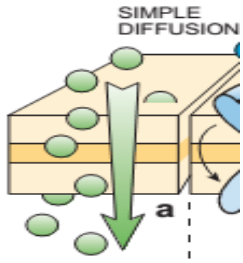



**Figure 1.9. Diagram of simple diffusion [13].**

Simple diffusion is the process, when substances (fat-soluble and small, uncharged molecules) cross the plasma membrane by diffusion down their concentration gradient [13].

### Membrane transport

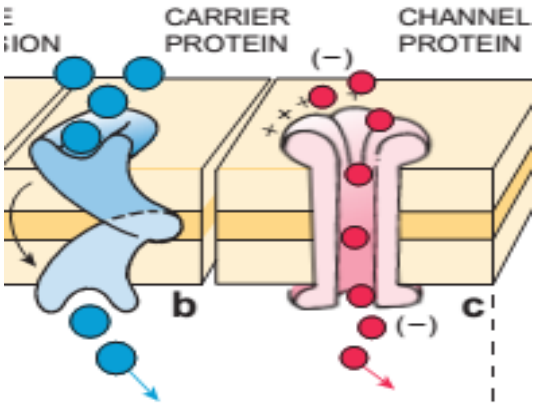



**Figure 1.10. Diagram of membrane transport [13].**

Membrane transport is a mechanism providing by proteins of 2 types: carrier proteins and channel proteins.

Carrier protein transfer small, water-soluble molecules. After binding with a molecule, the carrier protein undergoes of conformational changes and releases the molecule on the other side of the membrane. If this process is not require energy, it is called passive transport (e.g., glucose transport). If this process requires energy for active transport of molecules against their concentration gradient, it is called active transport (e.g., Na/K pump or H pump).

Channel proteins are transmembrane proteins that create hydrophilic channels through the plasma membrane. Ions and other small charged molecules are transported through the plasma membrane by ion-selective channel proteins [13].

### Vesicular transport

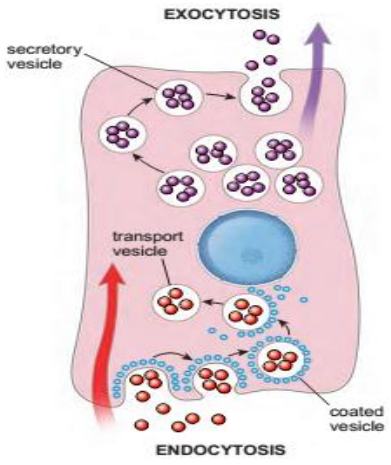



**Figure 1.11. Diagram of endocytosis and exocytosis [13].**

Some substances enter and leave cells by vesicular transport. The vesicular transport is subdivided into endocytosis and exocytosis.

Endocytosis is the processes of vesicular transport in which substances enter the cell.

Exocytosis is the processes of vesicular transport in which substances leave the cell.

Both these processes involve configurational changes in the plasma membrane and formation of membrane coated vesicles from the plasma membrane for endocytosis or fusion of membrane coated vesicles with the plasma membrane for exocytosis [13].

### Endocytosis

There are 3 main mechanisms of endocytosis: pinocytosis, phagocytosis and receptor-mediated endocytosis.

Phagocytosis or "cell eating" is the ingestion of large particles such as cell debris, bacteria, and other foreign materials. In this process, plasma membrane forms projections called pseudopodia to engulf phagocytosed particles into large vesicles called phagosomes.

Pinocytosis or "cell drinking" is the ingestion of fluid and small soluble protein molecules via small vesicles called pinocytotic vesicles that are pinched off from the plasma membrane.

Receptor-mediated endocytosis allows entry of specific molecules into the cell [13].

## Question 6. Cells cytoplasm. Hyaloplasm.

Cytoplasm of cell consist of:

1. Hyaloplasm;
2. Organelles;
3. Inclusions.

### Hyaloplasm

The hyaloplasm or cytoplasmic matrix is a colloid system, which may change it's aggregative state: from liquid sol to more viscous gel. The cytoplasmic matrix consists of a variety of solutes, including inorganic ions (Na, K, Ca) and organic molecules such as metabolites, carbohydrates, lipids, proteins, and RNAs. The cell controls the concentration of solutes within the matrix, which influences the rate of metabolic activity within the cytoplasmic compartment.

## Question 7. Inclusions.

Inclusions are temporary structural components of the cell cytoplasm. They are classified into:

1. Trophic (glycogen, lipid droplets);
2. Pigment (melanin in pigment cells, hemoglobin in erythrocytes, lipofuscin, which is aging pigment);
3. Secretory. They contain the products secreting by cell;
4. Excretory. They contain substances, which are needed to be evacuated from cell (urea inclusions in kidney cells).

### Inclusions of glycogen in hepatocytes (slide)

**Stain: Carmine**

***Using this slide you must perform the exercise 19 of album (topic "Cytology")***

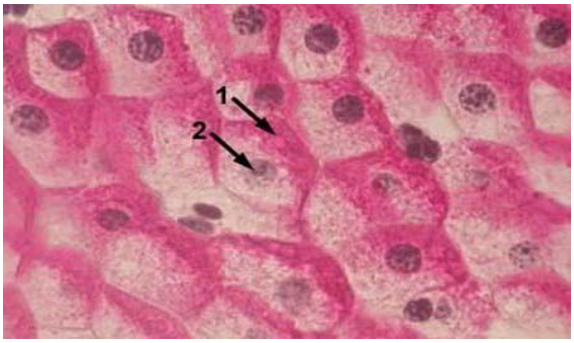



**Figure 1.12. Photomicrograph of the liver.**

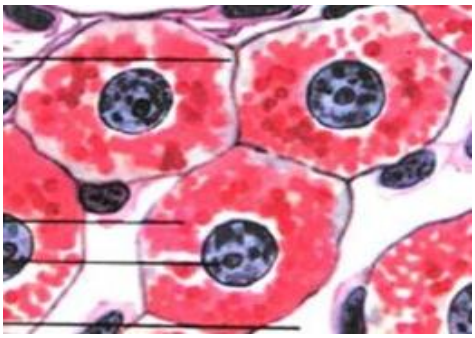


**Figure 1.13. Diagram of inclusions of glycogen in the liver cells hepatocytes** [15].

1. hepatocyte
2. nucleus
3. glycogen granules

## Lipid droplets in hepatocytes (slide)

**Stain: Osmic dye**

***Using this slide you must perform the exercise 20 of album (topic "Cytology")***

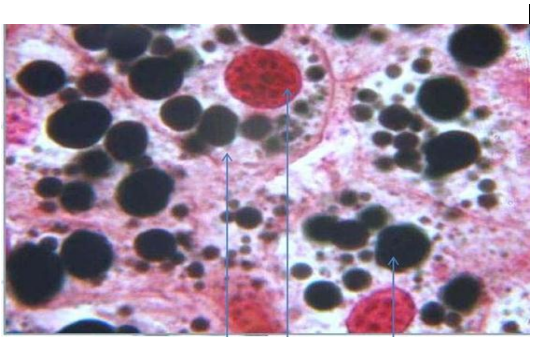


**Figure 1.14. Photomicrograph of the liver.**

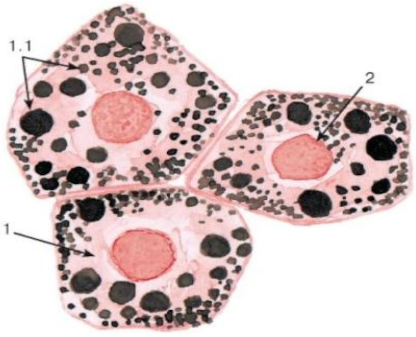



**Figure 1.15. Diagram of lipid droplets in the liver cells hepatocytes** [18].

1. hepatocyte
2. nucleus

1.1. lipid droplets

## Pigment cells of the skin (slide)

***Using this slide you must perform the exercise 21 of album (topic "Cytology")***

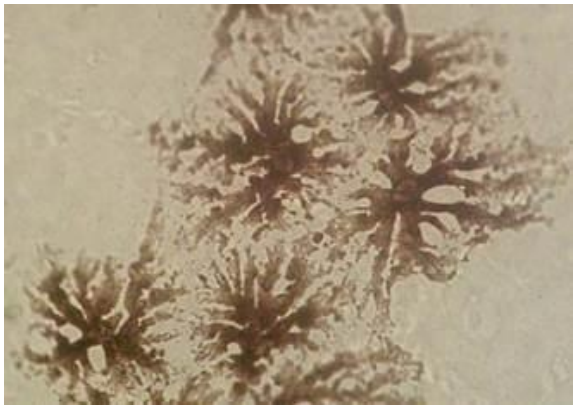


**Figure 1.16. Photomicrograph of the axolotl's skin cells**


**Figure 1.17. Diagram of melanin granules in the axolotl's skin cells** [18].

1. nucleus
2. melanin granules

## Question 8. General and special organelles: ribosomes; endoplasmic reticulum; Golgi complex; lysosomes; peroxisomes; mitochondria; centrosome; cytoskeleton (microtubules, microfilaments, intermediate filaments).

Organelles are the constant structures of cell cytoplasm.

Organelles are divided into 2 groups:

1. Special organelles, presenting in the some cells, to carry out their specialized function. They are myofibrils, neurofibrils, flagella, cilia, acrosome.

2. General organelles, presenting in all cells. Structurally they are divided into:

a) membranous organelles (mitochondria, endoplasmic reticulum, Golgi apparatus, endosomes, lysosomes and peroxisomes);

b) non - membranous organelles (centrioles, ribosomes, microtubules and filaments cytoskeleton of cell).

In cells, there are several functional apparatuses: cell synthetic apparatus**, c**ell digestive apparatus, energy apparatus and genetic apparatus.

Synthetic apparatus of cell includes ribosomes, endoplasmic reticulum, Golgi apparatus.

Digestive apparatus of cell includes endosomes, lysosomes and peroxisomes.

Energy apparatus of cell includes mitochondria.

Genetic apparatus of cell includes the nucleus.

## Ribosomes

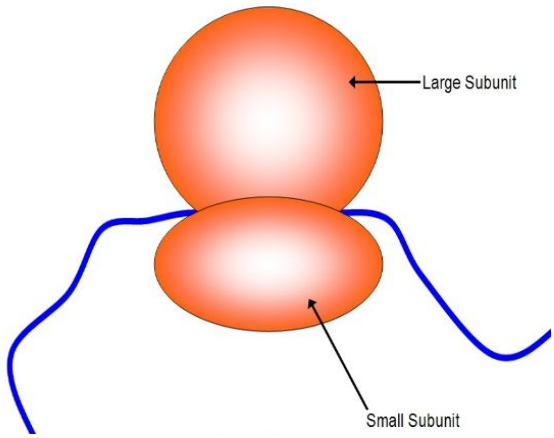



**Figure 1.18. Diagram of ribosome.**

Ribosomes are non - membranous organelles of protein biosynthesis. Ribosomes are small beadlike clusters. They are made up of small and large subunits. Each subunit consist of ribosomal RNA (r-RNA), as well as numerous different proteins.

Single ribosomes called monosomes are inactive for protein biosynthesis. Groups of ribosomes are active for protein biosynthesis.

In cell, the groups of ribosomes form short spiral arrays called polyribosomes or polysomes, in which many ribosomes are attached to a thread of messenger RNA (mRNA) [Ross].

Ribosomes may be free in the cytosol or bound to membranes of the rough endoplasmic reticulum or the cytoplasmic surface of the outer nuclear membrane [Leslie].

Proteins targeted to the nucleus, mitochondria, or peroxisomes are synthesized on free ribosomes, and then released into the cytosol. Thus "free" ribosomes synthesize proteins that will remain in the cell as cytoplasmic structural or functional elements (for cells own use).

In active protein secreting cells, the most of ribosomes are attached to membranes of the endoplasmic reticulum [13].

## Endoplasmic reticulum

Endoplasmic reticulum is a system of membranous connected canals, vacuoles and sacs, forming a network in the cell cytoplasm. There are two types of endoplasmic reticulum: granular (rough) (rER) and agranular (smooth) (sER).

## Rough endoplasmic reticulum (rER)

Rough endoplasmic reticulum is a membranous organelle usually in the form of cisternae. Membranes of rER are covered by ribosomes that attach to them by large subunits. The rER is continuous with the outer membrane of the nuclear envelope. The rER is most highly developed in active secretory cells.

**Ribosomes of the rER synthesize 3 categories of proteins:**

1) secretory (export) proteins which can be secreted from the cell;
2) proteins enzymes that become permanent components of the lysosomes;
3) cell membranes structural proteins [5].

**Main functions of rER are:**

1) synthesis of proteins;
2) modification of proteins (mainly glycosylation, but also hydroxylation, sulphatation, phosphorilation and ets);

3) storage of proteins;
4) transport of proteins to the Golgi apparatus. Transportation of proteins takes place by the way of transport vesicles segregation from the rER to deliver proteins to the Golgi apparatus [13].

**Smooth endoplasmic reticulum (sER)**

Smooth endoplasmic reticulum is a membranous organell usually in the form of tubules. Membranes of sER are not associated with ribosomes. The lumen of sER is continuous with the rER.

**The main functions of sER are:**

1. Biosynthesis of lipids (especially phospholipids of cell membranes);
2. Peroxisomes formation;
3. Biosynthesis of steroid hormones (in cells of adrenal glands and gonads);
4. Detoxification of substances (drugs, hormones ets) (in liver hepatocytes);
5. Calcium ions storage (in muscle cells and muscle fibers) [5].

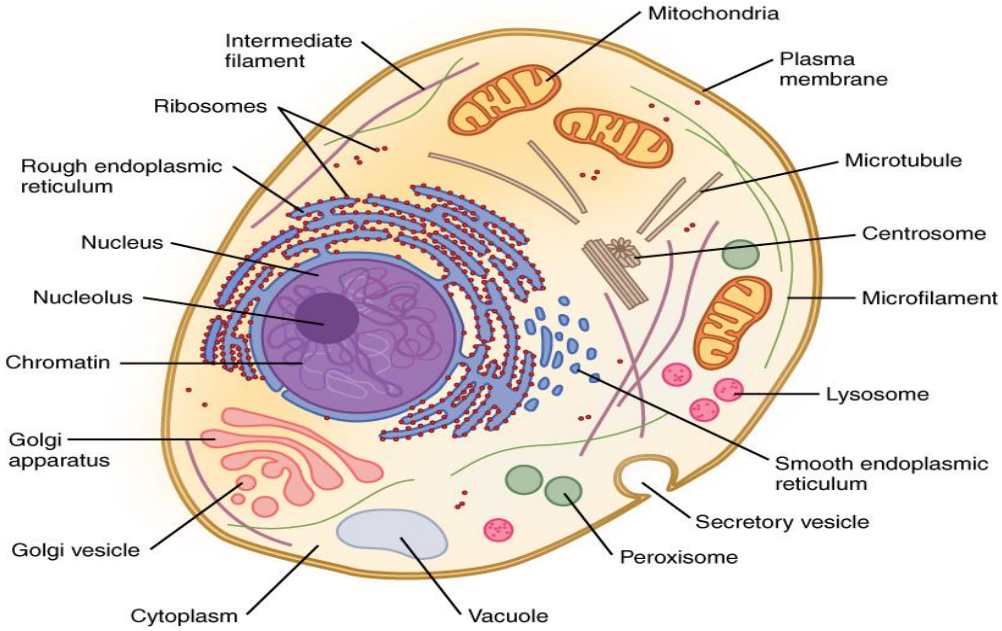



**Figure 1.19. Diagram of cell.**

**Golgi apparatus**

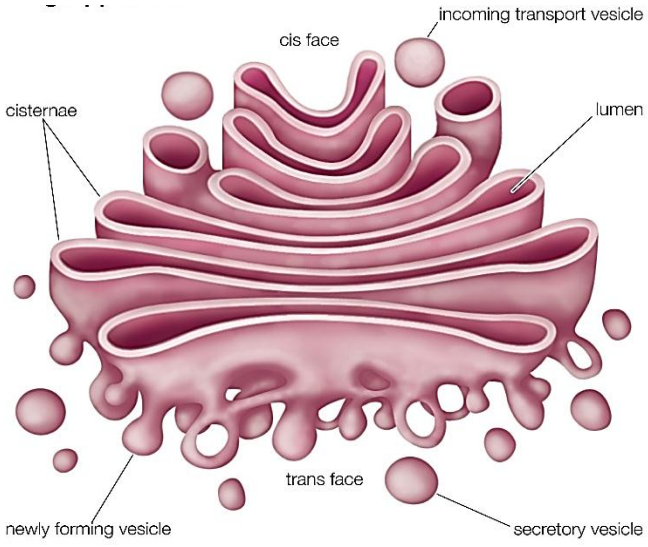



**Figure 1.20. Diagram of Golgi apparatus.**

Golgi apparatus is a membranous organelle of cell presenting by series of stacked, flattened, membrane-limited ampullar cisternae, which are continuous with vesicles and vacuoles.

The basic unit of the Golgi apparatus is the dictyosome. It consists of a stack of 3–8 slightly arcuate stacked membranes in close proximity to each other [8].

There is a number of Golgi apparatus stacks in active secretory cells.

In cells, the Golgi apparatus is polarized, because it has two faces - CIS and TRAN's. CIS face is proximal, immature, forming face of Golgi apparatus towards the rER. TRAN's face is distal, mature face of Golgi apparatus towards the cell surface [5].

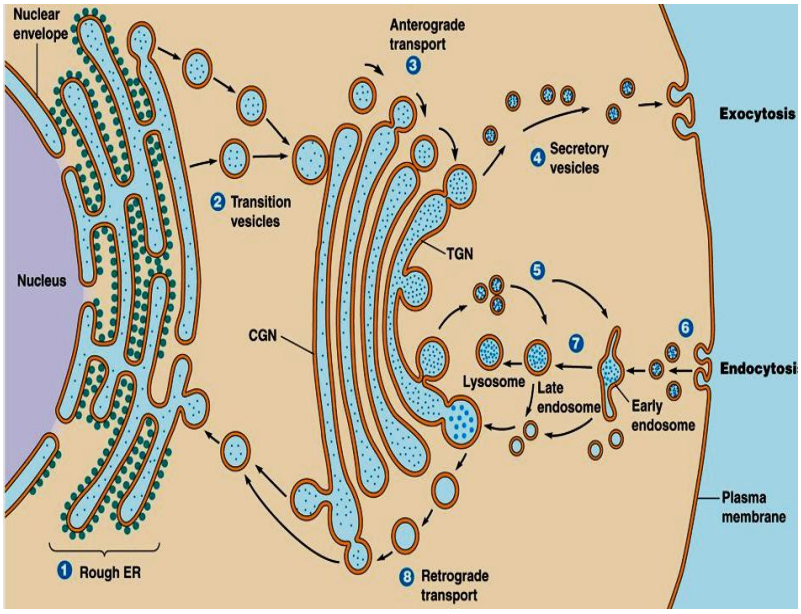



**Figure 1.21. Diagram of vesicular trafficking in the cell.**

CIS face of Golgi apparatus is the place accepting the transport vesicles from the endoplasmic reticulum. After the secretory products, transfer from one cisterna to next by way of peripheral vesicles, segregating from the cisternae dilated ends called ampullae. The vesicles bud from one cisterna and fuse with the adjacent cisternae. As proteins and lipids travel through the Golgi apparatus stacks, they undergo a series of posttranslational modifications such as glycosylation, phosphorylation and sulfatation.

The secretory vesicles and lysosomes are segregated from TRANS face of Golgi apparatus. Mature secretory vesicles eventually fuse with the plasma membrane to release the secretory products from the cell by exocytosis. This type of secretion is the characteristic of highly specialized secretory cells of exocrine glands [13].

**The main functions of Golgi apparatus are:**

1. Accumulation, sorting, packaging and transport of synthesized products;
2. Synthesis of polysaccharides;
3. Formation of glycoproteins and lipoproteins;
4. Formation of secretory inclusions and excretion them from the cell;
5. Formation of primary lysosomes;
6. Formation of cellular membranes;
7. Formation of sperms acrosomes.

## Endosomes

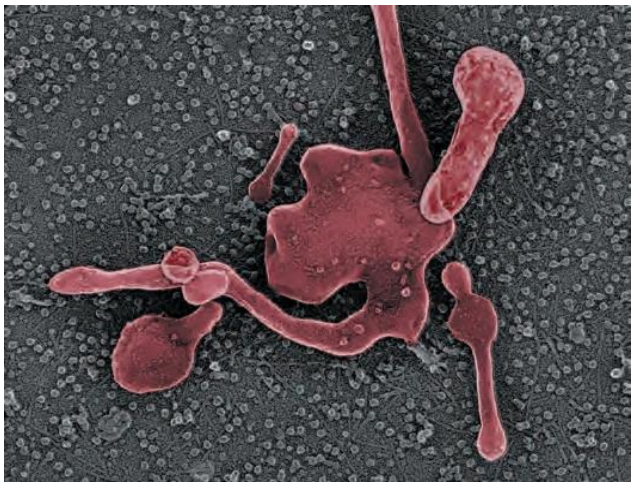
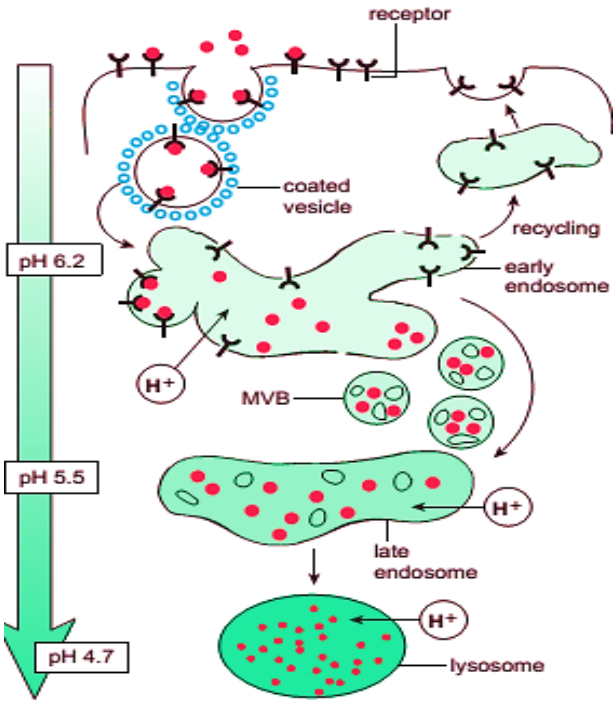


**Figure 1.22. Electron micrograph of an early endosome [13].**

Endosomes are membrane enclosed compartments derived from cell plasma membrane and associated with endocytotic pathways. In cells cytoplasm there are early and late endosomes.

Early endosomes are tubulovesicular structures lying near the cell membrane and reserving incoming material by vesicles forming, as a result, of pinocytosis and receptor-mediated endocytosis. Early endosomes have a mildly acidic environment (pH 6.2 to 6.5) necessary to separate and to sort proteins internalized into the cell by endocytosis [13].




**.Figure 1.22. Diagram of endosomal compartments of the cell [13].**

After the endocytosed proteins are transported via multivesicular bodies (MVB) from early endosome to late endosomes lying near the Golgi apparatus and the nucleus. Late endosomes have more acidic environment (pH 5.5). It is accomplished by the active transport of protons into endosomal compartments.

Because late endosomes mature into lysosomes, they are also called prelysosomes [13].

## Lysosomes

Lysosomes are digestive organelles surrounding by a unique membrane. They contain more than 50 types of hydrolytic enzymes: proteases, nucleases, lipases, and phospholipases.

As late endosomes the lysosomes contain proton pumps that transport H ions into the lysosomal lumen, maintaining a low pH (4.7). The lysosomal membrane contains transport proteins to transport the final products of digestion (amino acids, sugars, nucleotides) to the cytoplasm, where they are used in the synthetic processes of the cell or are exocytosed.

**Principle stages of lysosomes formation are the following:**

1) Synthesis of lysosomal enzymes in rEPR;
2) Passing of lysosomal enzymes from the rER to the Golgi apparatus by transport vesicles;
3) Packaging of inactive lysosomal enzymes into membrane-limited vesicles called hydrolase vesicles or primary lysosomes and segregation of them from the Golgi apparatus.
4) Fusion of hydrolase vesicles with late endosome;
5) Maturation of late endosome into lysosome with active enzymes called endolysosomes or secondary lysosomes.

### Types of the lysosomes

1) Primary lysosomes (hydrolase vesicles). They are newly formed lysosomes with inactive enzymes.
2) Secondary lysosomes (endolysosomes). They are lysosomes with active enzymes producing as a result of fusion of primary lysosomes with late endosomes.
3) Tertiary lysosomes (phagolysosomes). They are formed by fusion of a phagosome (phagocytic vacuole) with a late endosome or a lysosome.

4) Autophagolysosomes. They are formed by fusion of an autophagosome (autophagic vacuole) with a late endosome or lysosome.
5) Residual bodies. They are lysosomes of any type that have expended their capacity to degrade material. They contain undegraded material (e.g., lipofuscin and hemosiderin) and eventually may be excreted from the cell.
6) Multivesicular bodies. They contain numerous small vesicles within them and are produced as a result of fusion of lysosomes with pinocytic vesicles [5,6.13].

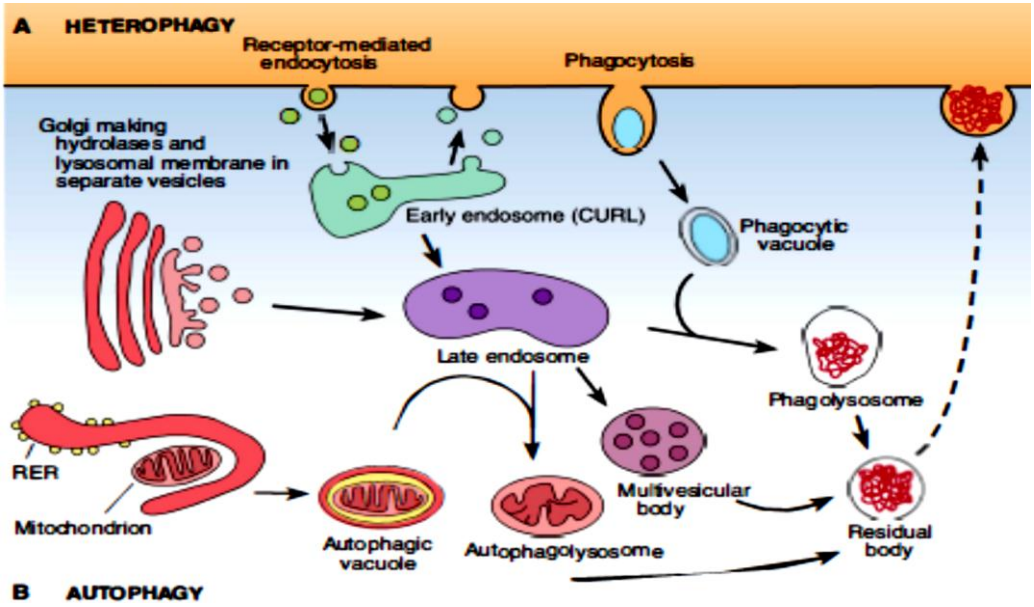



**Figure 1.23. Diagram of lysosomes formation** [5].

## Functions of lysosomes

In cells, the endolysosomes and phagolysosomes provide heterophagy or degradation of extracellular particles entering the cells by endocytosis.

Endolysosomes provide the degradation of small extracellular particles entering the cells by both receptor-mediated endocytosis and pinocytosis.

Phagolysosomes provide the degradation of large extracellular particles such as bacteria and cellular debris entering the cells by phagocytosis.

Autophagolysosomes provide autophagy or degradation of own obsolete parts of cell such as nonfunctional organelles or unnecessary molecules. For autophagy, a portion of the cell cytoplasm or an obsolete organelle is surrounded by intracellular membrane of sER, to form a vacuole called an autophagosome. After the autophagosome fuses with lysosome and is subsequently degraded [13].

## Peroxisomes

Peroxisomes are membrane limited organells, containing about 50 oxidative enzymes. Oxidative enzymes are synthesized in cytosol by free ribosomes. They pass to the peroxisomes segregating from sER as polypeptide chains. Oxidative enzymes of peroxisomes provide the oxidation of fatty acids. It leads to production of toxic substance hydrogen peroxide ($H_2O_2$). For neutralization of hydrogen peroxide the peroxisomes produce enzyme catalase that break it down into water and oxygen [13].

**Main functions of peroxisomes:**

1. Breaking down of fatty acids and amino acids;
2. Degradation of hydrogen peroxide excess;
3. Detoxification of toxins (alcohol in liver cell);
4. Participation in metabolism of cholesterin and lipids.

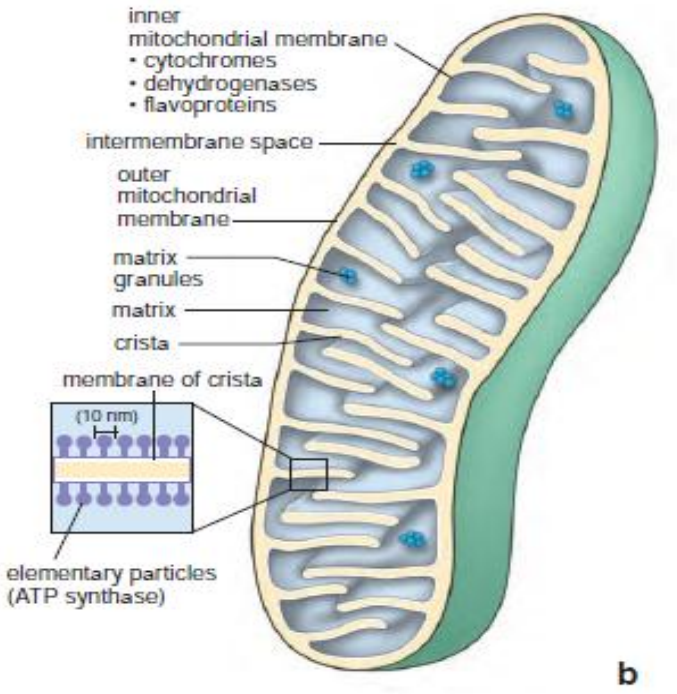



**Figure 1.24. Diagram of mitochondrion [13].**

Energy apparatus of the cell is represented by mitochondria. Mitochondria generate ATP to provide energy for various cellular functions. Mitochondria display a variety of shapes and sizes.

**Mitochondria**

All mitochondria, unlike other organelles of cells possess have two membranes – inner mitochondrial membrane and outer mitochondrial membrane. The space between them is called the intermembrane space. The outer mitochondrial membrane is closed and the inner mitochondrial membrane is arranged into numerous folds called cristae. Cristae project into the mitochondrial matrix that constitutes the inner compartment of the organelle.

Tennis racquet–shaped structures called elementary particles or ATP synthase particles are associated with membranes of cristae. They contain enzymes that carry out oxidative phosphorylation, which generates ATP.

The mitochondrial matrix contains the soluble enzymes of the citric acid cycle (Krebs cycle) and the enzymes involved in fatty-acid oxidation. The matrix also contains mitochondrial DNA, ribosomes, tRNAs and matrix granules. Matrix granules store Ca and other cations.

There are mitochondria with shelf like (flat) and tubular shape cristae. Mitochondria with tubular cristae participate in steroid hormone biosynthesis [13].

## Cytoskeleton of cell

Cytoskeleton of cell is represented by microtubules, microfilaments and intermediate filaments.

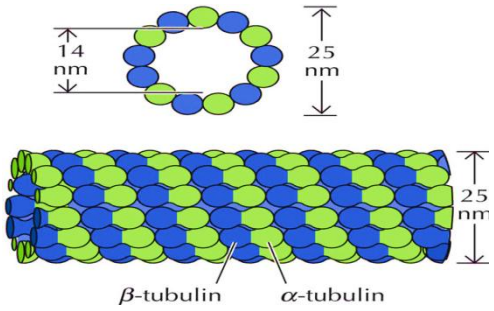



**Figure 1.25. Diagram of microtubule.**

**Microtubules**

Microtubules are hollow tubes whose measure 20 to 25 nm in diameter. The wall of the microtubule consists of 13 circularly arrayed tubulin molecules. The tubulin molecule is globular dimeric molecule including an α-tubulin and a β-tubulin having different molecular weight.

Microtubules are the most dynamic components of cytoskeleton because they can rapidly disassemble in one location and reassemble in opposite location. In general, microtubules grow from the microtubule-organizing center **(**MTOC) and extend toward the plasma membrane of cell.

In cells except cytoskeleton, the microtubules form the mitotic spindle for mitosis of cell and some organelles such as centrioles, cilia and flagella [13]. .

**Actin filaments**

Actin filaments are thinnest components of cells cytoskeleton whose measure 6 to 8 nm in diameter. They consist of contractile protein called an actin. The actin molecules assemble by

polymerization into a linear helical array to form actin filaments.

**Intermediate filaments**

They are most stable ropelike filaments of cells cytoskeleton, performing the supportive function in cell. Their diameter is 8 to 10 nm. In cells that belong to different tissues, the intermediate filaments consist of different types of stable proteins. Thus, in the cells of epithelial tissue the intermediate filaments consist of proteins called keratins (cytokeratins); in mesoderm-derived cells (e.g. fibroblasts) the intermediate filaments consist of protein called vimentin; in muscle cells they contain protein called desmin.

Considerable diversity and tissue specificity of intermediate filaments may be used as markers of cell origin for the diagnosis of tumor type.

**Functions of the cytoskeleton**

Cytoskeleton is involved in numerous essential cellular functions:

1. Maintenance of cell shape;
2. Cell migration;
3. Intracellular transport (e.g., movement of secretory vesicles and cells organells, movement of chromosomes during mitosis);
4. Integrity of cell-to-cell and cell-to-extracellular matrix junctions.

**Centrosome or microtubule-organizing center (MTOC)**

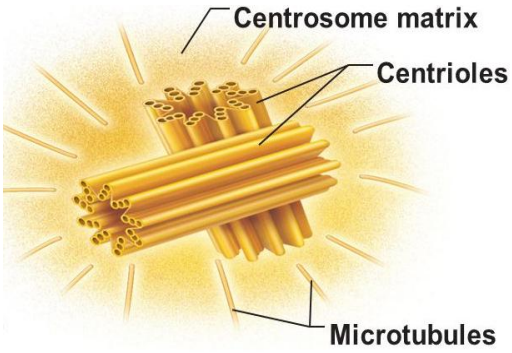



**Figure 1.26. Diagram of centrosome.**

Centrosome localizes near the nucleus of cell.

Centrosome consits of:

1) Pair of centrioles laying perpendicular to each other;
2) Pericentriolar (centrosome) matrix presenting by special proteins for microtubules growth.

The two centrioles of the pair differ from each other because one is older (mature centriole) and another is younger (immature centriole.

Each centriole is hollow cylinder whose wall is represented by nine microtubule triplets.

**Functions of centrosome are:**

1) Formation of microtubules during the interphase of the cell cycle;
2) Formation of mitotic spindle during cell mitosis [5].

## Question 9. Nucleus and its components.

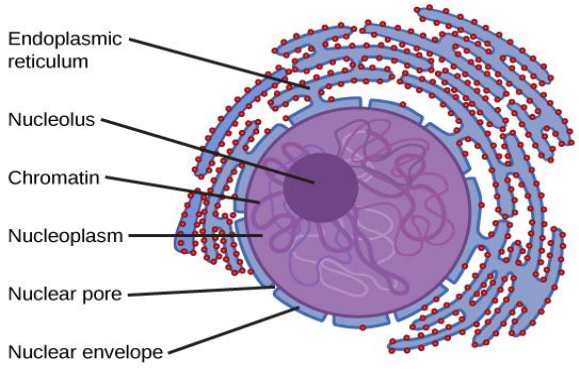



**Figure 1.27. Diagram of nucleus.**

Nucleus is the major cell component. It provides the storage, realization and transmitting of hereditary information.

Majority cells have one nucleus. Its shape and size depends on the cell type and functional state of a cell. Nucleus present in cell only during interphase.

Nucleus is composed of:

1) nuclear envelope;
2) nucleolus;
3) chromatin (chromosomes);
4) nucleoplasm.

## Nuclear envelope

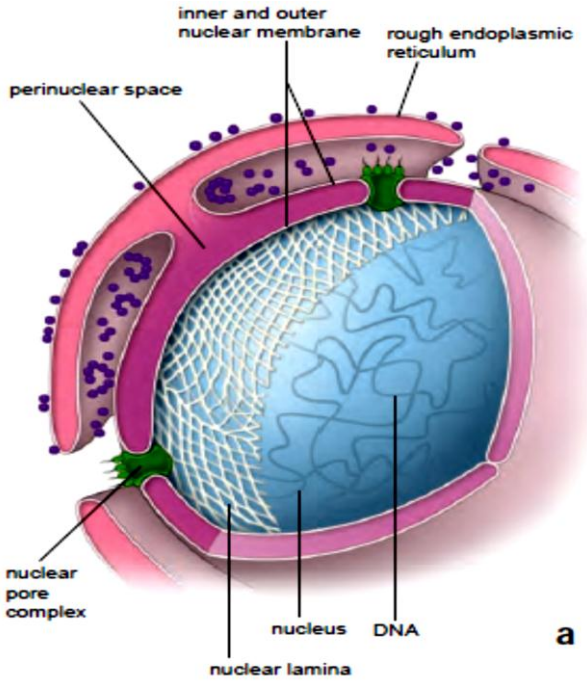



**Figure 1.27. Diagram of nuclear envelope [13].**

The nuclear envelope consists of two nuclear membranes – inner and outer. Outer nuclear membrane is continuous with rER. Inner nuclear membrane is smooth and closely connected with nuclear lamina presenting by a condensing of intermediate filaments. There is a perynuclear space (20-40 nm in width) between two membranes of nuclear envelope. At several points these membranes fuse, forming perforatings called nuclear pores [13].

## Nuclear pore

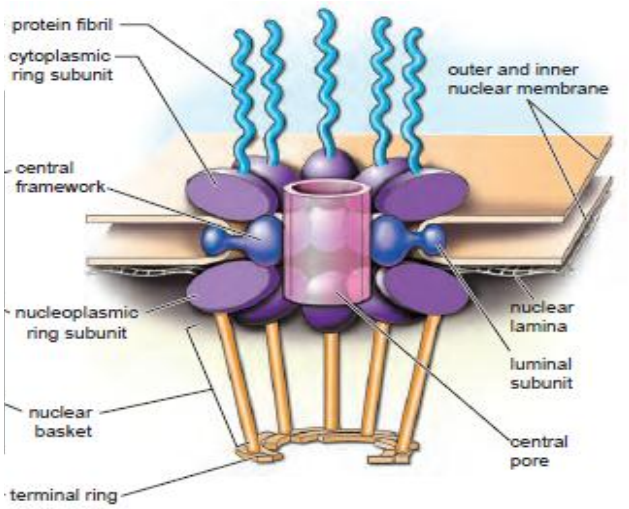



**Figure 1.28. Diagram of nuclear pore [13].**

Nuclear pore allow for selective bidirectional transport of molecules between nucleus and cytoplasm.

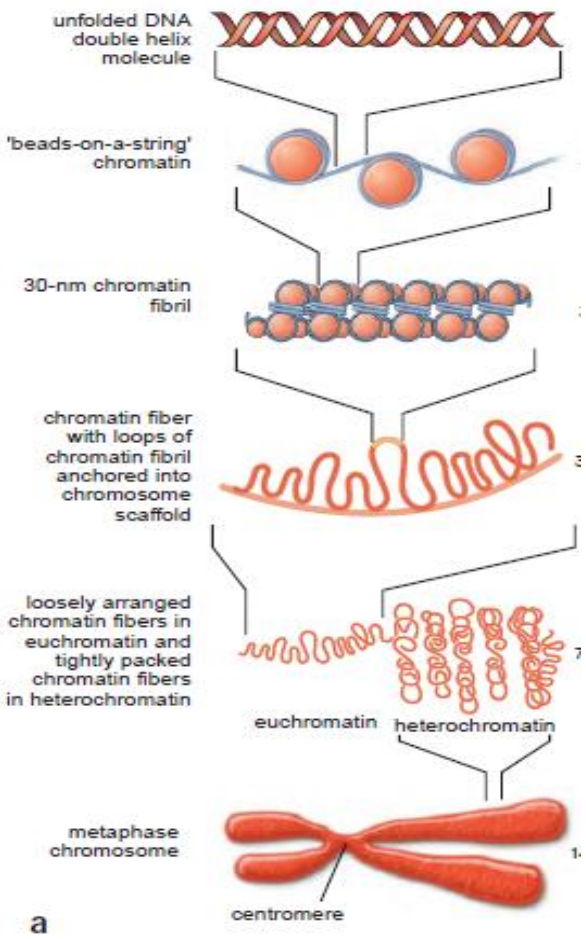
Each pore contains protein subunits in central framework at the periphery of the pore. This central framework is inserted between the cytoplasmic and the nucleoplasmic rings and encircles the central pore. Either ring consists of eight protein subunits. From the cytoplasmic ring, eight short protein fibrils protrude into the cytoplasm. The nucleoplasmic ring anchors a nuclear basket assembled from eight thin filaments [13].

## Chromatin

Chromatin is a complex of DNA and structural proteins - histones and non-histones. Chromatin in the interphase less coiled form of chromosome. For mitosis further folding of chromatin producers chromosome. Each somatic cell of human organism contains diploid (46) chromosome number marking 2n.

There are two types of chromatin. Dispersed chromatin form is called euchromatin. Highly condensed chromatin form is called heterochromatin. The euchromatin predominates in metabolically active nuclei.

**Packaging of chromatin into the chromosomal structure**




The basic structural units of chromatin are molecular complexes of DNA and histones called nucleosomes.

Nucleosomes are the first level of chromatin folding and they are formed by the coiling of the DNA molecule around a protein core, including eight histone molecules (called an octamer). DNA molecule shortens because it forms two loops around the core octomer. In electron microscopy the nucleosomal structure of chromatin is visible as «beads on a string».

Second level of DNA folding is a chromatin fibril, in which nucleosomes form complexes. Six nucleosomes form one turn of the chromatin fibril.

Third level of DNA folding is a chromatin fiber which is the loops of chromatin fibril. Each loop corresponds to one or several genes.

Forth level of DNA folding is a chromatid in which loosely arranged chromatin fibers are tightly packed in heterochromatin.

Fifth level of DNA folding is a chromosome consisting of two chromatid [13].

.

**Figure 1.29. Diagram of packaging of chromatin into the chromosomal structure [13].**

**Nucleolus**

The nucleolus is the site of ribosomal RNA (rRNA) synthesis and initial site of ribosomal subunits production. The nucleolus varies in size but is particularly well developed in cells active in protein synthesis. Some cells contain more than one nucleolus. The nucleolus stains intensely with hematoxylin and basic dyes because contains high concentrations of acids (DNA, RNA).

The nucleolus has three morphologically distinct regions:

1) Fibrillar center presenting by DNA loops of chromosomes that contains rRNA genes, enzyme - RNA polymerase and transcription factors;

2) Fibrillar material (pars fibrosa) containing large amounts of rRNA;

3) Granular material (pars granulosa) represents by densely packed ribosomal subunits (preribosomes), as a result, of rRNA assembly using ribosomal proteins imported from the cytoplasm. After the ribosomal subunits are exported from the nucleus via nuclear pores for full assembly into mature ribosomes in the cell cytoplasm [13].

## Question 10. Cell cycle.

The cell cycle is the time from the mitotic division of cell to the next it's division or to the moment of cell's death. The cell cycle includes two principal phases: the I phase (interphase) and the M phase (mitosis).

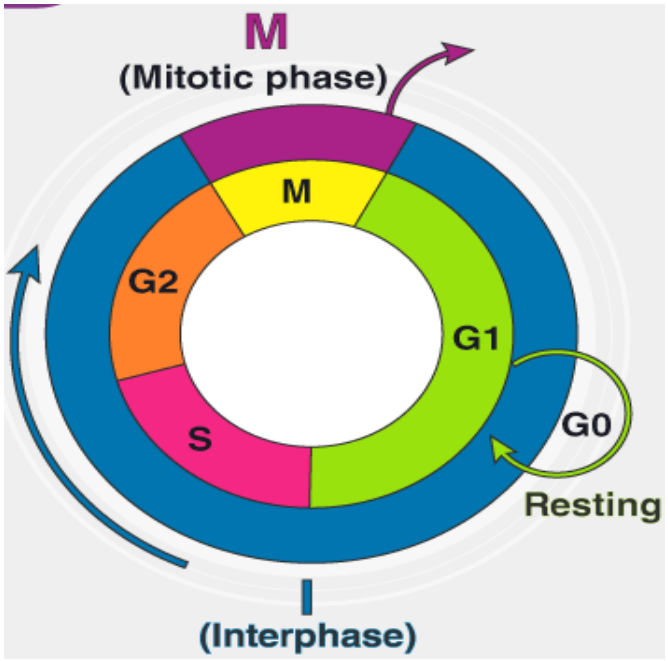



**Figure 1.30. Diagram of cell cycle.**

The interphase includes three following phases:

1) G1 (gap1) phase;
2) S (synthesis) phase;
3) G2 (gap 2) phase.

The G1 phase is usually the longest and it begins after M phase. During the G1 phase, the cell gathers nutrients and synthesizes RNA and proteins leading to the cellular growth. In G1 phase there is a checkpoint, when some cells leave the cycle by entering the Go phase. In Go phase the cells stop their division. The cell residing in Go may undergo terminal differentiation and produce a population of permanent nondividing cells (e.g., mature fat cell, cardiac muscle cells, neurons). However, there are cells that may reenter the cell cycle from Go phase after an appropriate stimulus (e.g., stem cells, hepatocytes).

The DNA and centrosome of cell is doubled during the S phase, and new chromatids are formed.

In the G2 phase, the cell prepares for new cell division [13].