# Cytology Course (201h) for undergraduate students of (Zoology- Zoology Chemistry - Biochemistry - Chemistry)

**Preparation**

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**Academic year 2022 / 2023**

# رؤية الكلية

**التميز فى تعليم العلوم الأساسية والبحث العلمى للمساهمة في بناء اقتصاد الوطن**

# رسالة الكلية

**تقديم تعليم متميز فى مجالات العلوم الأساسية وإنتاج بحوث علمية تطبيقية تدعم اقتصاد الوطن من خلال إعداد خريجين متميزين طبقا للمعايير الأكاديمية القومية وتطوير مهارات وقدرات الموارد البشرية وتوفير خدمات مجتمعية وبيئية تلبى طموحات مجتمع جنوب الوادى وبناء الشراكات المجتمعية**

# رؤية القسم

**خريجون وباحثون متميزون علميا وبحثيا محليا ودوليا خدمة للمجتمع وتنمية للبيئة**

# رسالة القسم

**يسعى قسم علم الحيوان بكلية العلوم من خلال ما يقدمه من برامج تعليمية متطورة وبحث علمى تطبيقى وبنية أساسية مناسبة إلى خريجين متميزين محليا ودوليا فى مجالات العلوم البيولوجية ينتفع بهم المجتمع وسوق العمل**

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**Figures**

## الهدف من دراسة المقرر:

١- اعطاء الطالب معلومات وفيرة عن علم الخلية وكيفية دراسة الخلايا الحية؛ خواصها وبنيتها ومكوناتها، والعضيات الموجودة فيها وتفاعلاتها مع البيئة المحيطة ودورة حياتها وانقسامها ثم موتها.

٢- تعريف الطالب بالتركيب الكيميائي والجزيئى للخلية

٣- تعريف الطالب بأهم مكونات الخلايا المختلفة بشكل عام مع التركيز على معرفة عضيات الخلية الحيوانية ووظائفها المختلفة وعلاقتها ببعضها وتأثيرها على الكائن الحى.

# مقدمة

**بسم الله الرحمن الرحيم**

**الحمد لله والصلاة والسلام على رسول الله "صلى الله عليه وسلم" وعلى آله وصحبه ومن سار على هديه.....**

**قال سبحانه وتعالى:**

**" وفى الأرض آيات للموقنين، وفى أنفسكم آفلا تبصرون" صدق الله العظيم**

**يعتبر علم الخلية اللبنة الأولى والأساسية التي استندت عليها جميع فروع العلوم الحياتية. ويرجع الفضل فى ظهور هذا العلم إلى اختراع المجهر الضوئي (الميكروسكوب الضوئى) في عام ١٥٩١ حيث تمكن العلماء بواسطته عام ١٦٦٨ من رؤية وحدات دقيقة جدا لا ترى بالعين المجردة وقد أطلقوا عليها أسم الخلايا. واعتبرت الخلايا هي الوحدات الأساسية للمادة الحية. ويعتبر اكتشاف الخلية أمر بالغ الأهمية حيث ساهم كثيرا فى توضيح تفاصيل مثيرة عن الحياة لم تكن معروفة من قبل. أما معظم التفاصيل الدقيقة الخاصة بالخلايا تم التعرف عليها باستخدام المجهر الإلكتروني الذي يعمل على تكبير الأشياء عشرات الألوف من المرات.**

**يمكن تعريف علم الخلية ( Cytology)أو بيولوجيا الخلية ( Cell biology) هو أحد أفرع العلوم البيولوجية الذي يختص بدراسة تركيب الخلايا وكيميائيتها ووظائفها. أى أن هذا العلم يتناول بالتفصيل دراسة الخلايا ومحتوياتها وما يدور بداخلها من العمليات الحيوية المختلفة. فالخلية هي الوحدة التركيبية والوحدة الوظيفية فى الكائنات الحية.**

**عسى أن أستطيع تقديم معلومة وافية عن هذا العلم من خلال هذا الكتيب بطريقة ميسرة تساهم في فهم واستيعاب مفهوم الحياة وطبيعتها ويكون مناسبا للطلبة الجامعيين في أقسام علوم الحياة وغيرها. حيث ذود في سبيل هذا الهدف بالعديد من الرسوم التخطيطية. وأسأل الله سبحانه وتعالى أن يتقبل هذا العمل والجهد المتواضع ... وأسأله أن ينفع به طلبة العلم ويكون خالصا لوجهه الكريم... ويجعله لي ذخرا عند انقطاع عملي وانتهاء أجلى ويتجاوز به عن ذلتي ويمحو به خطيئتي ... إنه أهل التقوى وأهل المغفرة.**

# First chapter

# The cell and the cell membrane

# Cytology

The cell is actually too small to see with the unaided eye. It is visible here in such detail because it is being viewed with a very powerful microscope. Cells may be small in size, but they are extremely important for life. Like all other living things, you are made of cells. Cells are the basis of life, and without cells, life as we know it would not exist.

If you look at a living matter with a microscope — even a simple light microscope — you will see that it consists of cells. Cells are the basic units of the structure and function of living things. They are the smallest units that can carry out the processes of life. All organisms are made up of one or more cells, and all cells have many of the same structures and carry out the same basic life processes. Knowing the structure of cells and the processes they carry out is necessary to understanding life itself.

## Discovery of Cells

The first time the word cell was used to refer to these tiny units of life was in 1665 by a British scientist named Robert Hooke. Hooke was one of the earliest scientists to study living things under a microscope.

The microscopes of his day were not very strong, but Hooke was still able to make an important discovery. When he looked at a thin slice of cork under his microscope, he was surprised to see what looked like a honeycomb. Hooke made the drawing in the figure below to show what he saw. As you can see, the cork was made up of many tiny units, which Hooke called cells.

Soon after Robert Hooke discovered cells in cork, Anton van Leeuwenhoek in Holland made other important discoveries using a microscope. Leeuwenhoek made his own microscope lenses, and he was so good at it that his microscope was more powerful than other microscopes of his day. In fact, Leeuwenhoek's microscope was almost as strong as modern light microscopes. Using his microscope, Leeuwenhoek was the first person to observe human cells and bacteria.

## Cell Theory

By the early 1800s, scientists had observed the cells of many different organisms. These observations led two German scientists, named Theodor Schwann and Matthias Jakob Schleiden, to propose that cells are the basic building blocks of all living things. Around

1850, a German doctor named Rudolf Virchow was studying cells under a microscope when he happened to see them dividing and forming new cells. He realized that living cells produce new cells through division. Based on this realization, Virchow proposed that living cells arise only from other living cells.

The ideas of all three scientists — Schwann, Schleiden, and Virchow — led to cell theory, which is one of the fundamental theories unifying all of biology. Cell theory states that:

- All organisms are made of one or more cells.
- All the life functions of organisms occur within cells.
- All cells come from already existing cells.

Starting with Robert Hooke in the 1600s, the microscope opened up an amazing new world — the world of life at the level of the cell. As microscopes continued to improve, more discoveries were made about the cells of living things. However, by the late 1800s, light microscopes had reached their limit. Objects much smaller than cells, including the structures inside cells, were too small to be seen with even the strongest light microscope.

Then, in the 1950s, a new type of the microscope was invented. Called the electron microscope, it used a beam of electrons instead of light to observe

extremely small objects. With an electron microscope, scientists could finally see the tiny structures inside cells. In fact, they could even see individual molecules and atoms. The electron microscope had a huge impact on biology. It allowed scientists to study organisms at the level of their molecules and led to the emergence of the field of cell biology. With the electron microscope, many more cell discoveries were made.

## Structures Shared by All Cells

Although cells are diverse, all cells have certain parts in common. These parts include a plasma membrane, cytoplasm, ribosomes, and DNA.

- The plasma membrane (also called the cell membrane) is a thin coat of phospholipids that surrounds a cell. It forms the physical boundary between the cell and its environment, so you can think of it as the “skin” of the cell.
- Cytoplasm refers to all of the cellular material inside the plasma membrane. The Cytoplasm is made up of a watery substance called cytosol and contains other cell structures such as ribosomes.
- Ribosomes are structures in the cytoplasm where proteins are made.

- DNA is a nucleic acid found in cells. It contains the genetic instructions that cells need to make proteins. These parts are common to all cells, from organisms as different as bacteria and human beings.
https://humanbiology.pressbooks.tru.ca/chapter/4-2-discovery-of-cells-and-cell-

## Protoplasmic components

The protoplast of each cell contains the protoplasmic `and non-protoplasmic components. The protoplasmic or living components are—nucleus, mitochondria, plastids, endoplasmic reticulum, ribosomes, lysosomes, microtubules and Golgi bodies.

The chief non-protoplasmic or non-living components are—vacuoles, food products, secretory products and waste products.

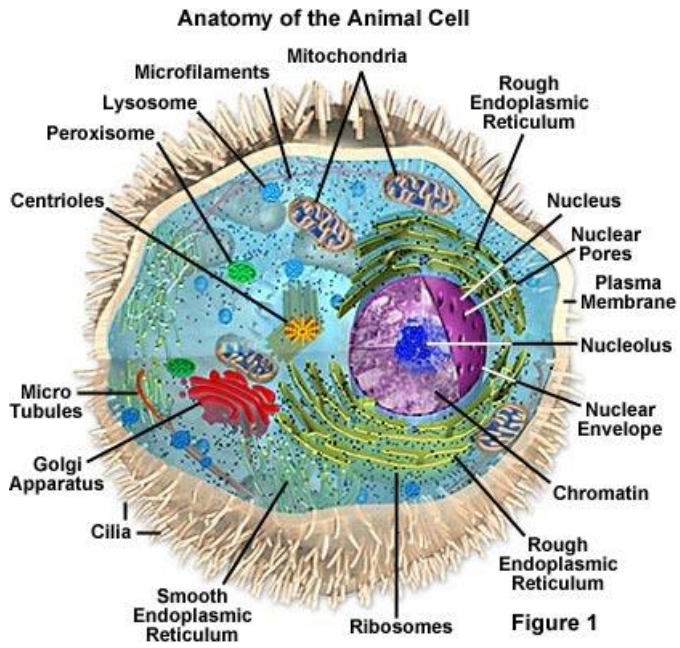
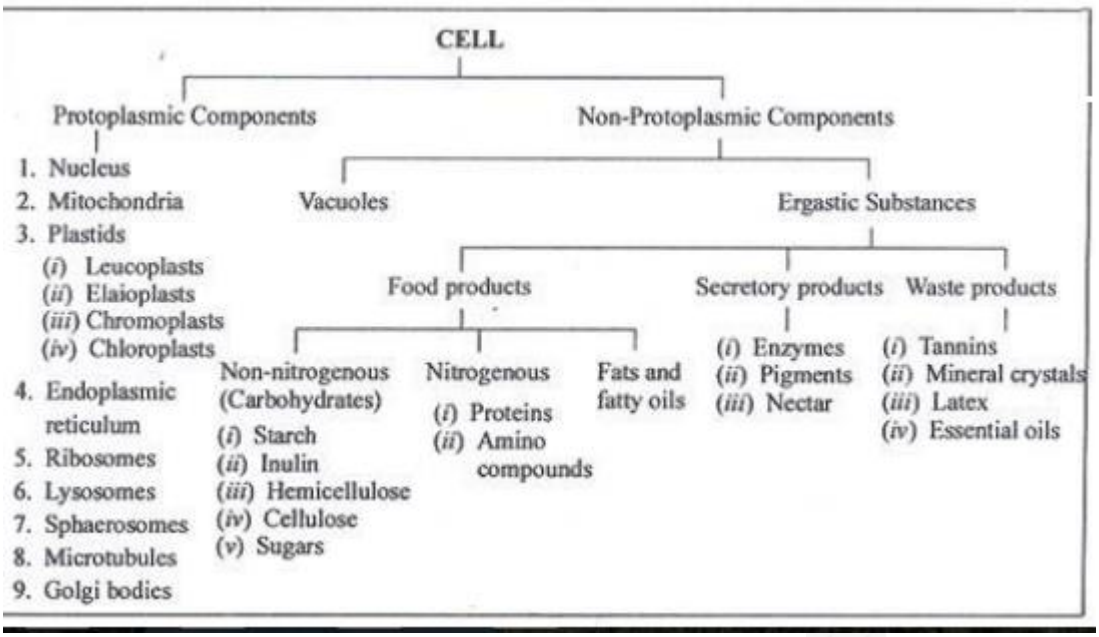



Fig (1): The animal cell




https://www.vedantu.com/biology/protoplasm

## Cytoplasm:

Kolliker (1862) gave the name ‘cytoplasm, to the substance found around the nucleus. According to Guilliermond

(1941) and Sharp (1934) the word cytoplasm has been used to designate all the matter in the cell exclusive of the nucleus. The cytoplasm and various protoplasmic bodies (e.g., nucleus, plastids, mitochondria, etc.,) have the same fundamental characteristics.

The cytoplasm is a transparent semi fluid substance denser than water with granules, vacuoles and vesicles of various sizes embedded in it. It is highly complex, both physically and chemically. Usually it consists of water which may be 85-90% in it. Many organic and inorganic substances also occur in the cytoplasm either in true solution or in colloidal state. Salts, carbohydrates and other water soluble substances are found in dissolved state.

Proteins and fats are also found in the form of very minute particles which are invisible in the microscopes of ordinary light. They are found in colloidal state.

It remains always in a dynamic state due to constant phase inversions. It is bounded by a monomolecular layer or a multimolecular layer on the outside called ectoplast (plasma membrane). Similar second layer on inside called tonoplast (vacuolar membrane).

The protoplasmic layers are semipermeable in nature which involve in differential absorption. In the cytoplasm, fatty substances such as lipids and certain proteins take part in the formation of ectoplast (plasma membrane). The tonoplast (vacuolar membrane) also develops from the same substance and possesses similar structure to that of plasma membrane.

The electron microscope reveals membranous differentiations in the interior of the cytoplasm notably, the endoplasmic reticulum and the dictyosomes. The cytoplasm also includes granules of various sizes. Granules of 0.25 to 1 micron in diameter, containing lipids and proteins.

These granules are highly mobile in living cells. At the submicroscopic level, a granule about 150 A in diameter, the ribosome a globular macromolecule of ribonucleoprotein that takes part in protein synthesis. Ribosomes occur free in the cytoplasm or they remain associated with the endoplasmic reticulum.

Some of the resolvable entities in the protoplast, such as the nucleus, plastids and mitochondria, are referred to as organelles, whereas the endoplasmic reticulum and the dictyosomes are called sometimes membrane systems and sometimes organelles.

https://en.wikipedia.org/wiki/Cytoplasm

## The plasma membrane:
## Ultra structure and functions

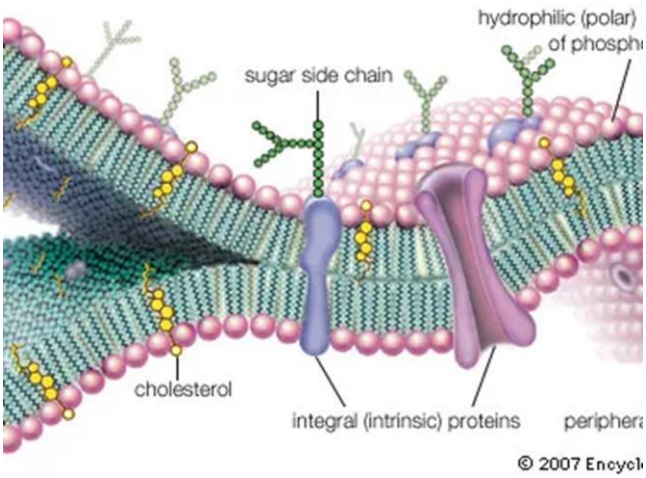



Fig (2) structure of plasma membrane

The plasma membrane consists of both lipids and proteins. The fundamental structure of the membrane is the phospholipid bilayer, which forms a stable

barrier between two aqueous compartments. Proteins embedded within the phospholipid bilayer carry out the specific functions of the plasma membrane, including selective transport of molecules and cell-cell recognition.

**The components of the plasma membrane**

| Component | Location |
|---|---|
| Phospholipids | Main fabric of the membrane |
| Cholesterol | Tucked between the hydrophobic tails of the membrane phospholipids |
| Integral proteins | Embedded in the phospholipid bilayer; may or may not extend through both layers |
| Peripheral proteins | On the inner or outer surface of the phospholipid bilayer, but not embedded in its hydrophobic core |
| Carbohydrates | Attached to proteins or lipids on the extracellular side of the membrane (forming glycoproteins and glycolipids) |

## 1- Lipids

The cell membrane consists of three classes of lipids: phospholipids, glycolipids, and sterols.

The amount of each depends upon the type of cell, but in the majority of cases phospholipids are the most abundant. The fatty chains in phospholipids and glycolipids usually contain an even number of carbon atoms, typically between 16 and 20. The 16- and 18-

carbon fatty acids are the most common. Fatty acids may be saturated or unsaturated.

## The Phospholipid Bilayer

The molecule of phospholipid consists of two parts:

1- The hydrophilic, or “water-loving,” portion of a phospholipid is its head, which contains a negatively charged phosphate group, which is a polar. The hydrophilic

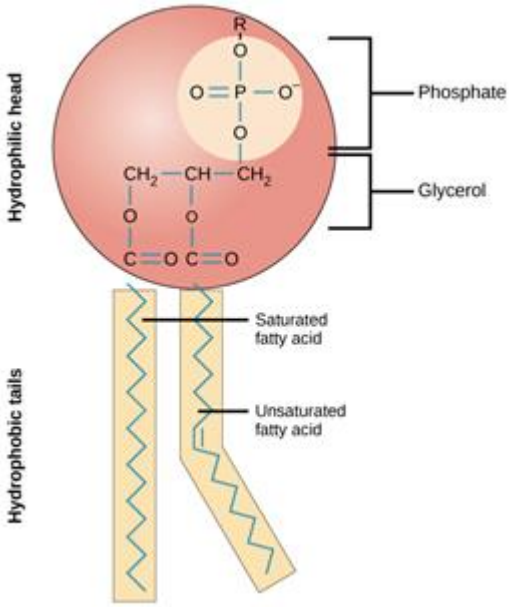



Fig. (3). Chemical structure of phospholipids molecule

hydrophilic heads of phospholipids in a membrane bilayer face outward, contacting the aqueous (watery)

fluid both inside and outside the cell. Since water is a polar molecule, it readily forms electrostatic (charge-based) interactions with the phospholipid.

2- The hydrophobic, or “water-fearing,” part of a phospholipid consists of its long, nonpolar fatty acid tails.

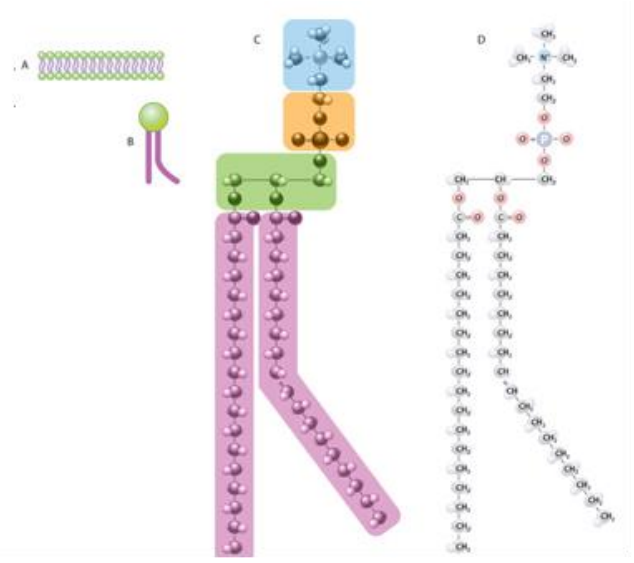


Fig (4) Altera structure of phospholipids molecule

The fatty acid tails can easily interact with other nonpolar molecules, but they interact poorly with water. The phospholipid bilayer formed by these interactions makes a good barrier between the interior and exterior of the cell, because water and other polar

or charged substances cannot easily cross the hydrophobic core of the membrane.

Phospholipids, arranged in a bilayer, make up the basic fabric of the plasma membrane. They are well-suited for this role because they are amphipathic, meaning that they have both hydrophilic and hydrophobic regions

A)- The plasma membrane of a cell is a bilayer of glycerophospholipid molecules.

B)- A single glycerophospholipid molecule is composed of two major regions: a hydrophilic head (green) and hydrophobic tails (purple).

C)- The hydrophilic head is composed of a choline structure (blue) and a phosphate (orange). This head is connected to a glycerol (green) with two hydrophobic tails (purple) called fattyacids.

D)- This view shows the specific atoms within the various subregions of the phosphatidylcholine molecule.

## 2- Proteins

Proteins are the second major component of plasma membranes. There are two main categories of membrane proteins: integral and peripheral.

In addition to lipids, membranes are loaded with proteins. In fact, proteins account for roughly half the mass of most cellular membranes. Many of these proteins are embedded into the membrane and stick out on both sides; these are called transmembrane proteins. The portions of these proteins that are

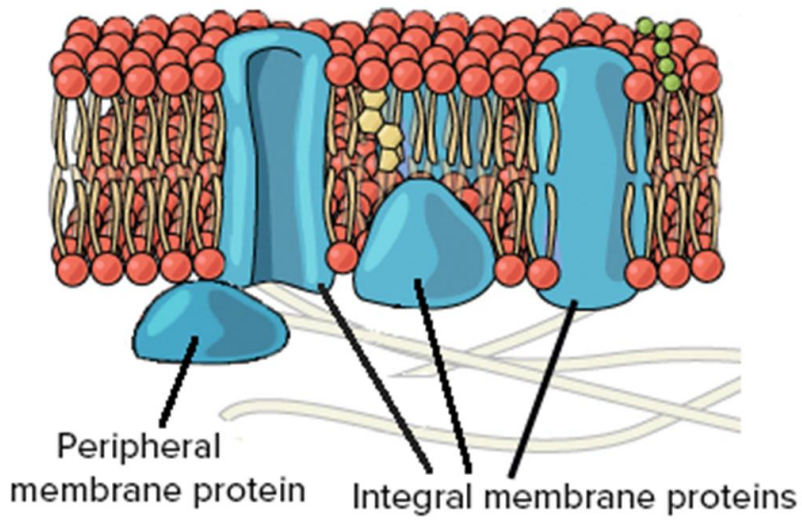



Fig. (5) Proteins in plasma membrane transmembrane proteins

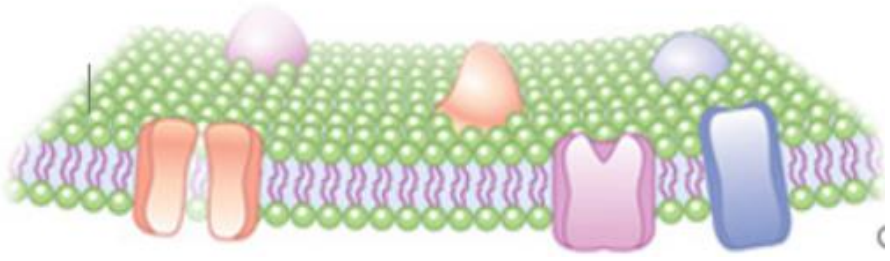


Fig. (6) The glycerophospholipid bilayer with embedded proteins

nested amid the hydrocarbon tails have hydrophobic surface characteristics, and the parts that stick out are hydrophilic.

At physiological temperatures, cell membranes are fluid; at cooler temperatures, they become gel-like. Scientists who model membrane structure and dynamics describe the membrane as a fluid mosaic in which transmembrane proteins can move laterally in the lipid bilayer. Therefore, the collection of lipids and proteins that make up a cellular membrane relies on natural biophysical properties to form and function.

## Types of protein in cell membrane:

### a- Integral membrane proteins.

Proteins that are found inside the membrane are hydrophobic, while those that are exposed to the cytoplasm or extracellular fluid tend to be hydrophilic. As their name suggests, integrated into the membrane: they have at least one hydrophobic region that anchors them to the hydrophobic core of the phospholipid bilayer. Some stick only partway into the membrane, while others stretch from one side of the membrane to the other and are exposed on either

side. Proteins that extend all the way across the membrane are called transmembrane proteins.

**b- Transmembrane proteins**.

Proteins may cross the membrane just once. A typical membrane-spanning segment consists of 20-25 hydrophobic amino acids arranged in an alpha helix, although not all transmembrane proteins fit this model. Some integral membrane proteins form a channel that allows ions or other small molecules to pass. it named Transmembrane proteins.

**c- Peripheral membrane proteins.**

Proteins are found on the outside and inside surfaces of membranes, attached either to integral proteins or to phospholipids. Unlike integral membrane proteins, peripheral membrane proteins do not stick into the hydrophobic core of the membrane, and they tend to be more loosely attached, fig (5). Peripheral membrane proteins are associated with the membrane but are not inserted into the bilayer. Rather, they are usually bound to other proteins in the membrane. Some peripheral proteins form a filamentous network just under the membrane that provides attachment sites for transmembrane

proteins. Other peripheral proteins are secreted by the cell and form an extracellular matrix that functions in cell recognition.

## Carbohydrates

Carbohydrates are the third major component of plasma membranes. In general, they are found on the outside surface of cells and are bound either to proteins (forming glycoproteins) or to lipids (forming glycolipids) (fig. 5) These carbohydrate chains may consist of 2-60 monosaccharide units and can be either straight or branched.

Along with membrane proteins, these carbohydrates form distinctive cellular markers, sort of like molecular ID badges, that allow cells to recognize each other. These markers are very important in the immune system, allowing immune cells to differentiate between body cells, which they shouldn’t attack, and foreign cells or tissues, which they should.

## Mobility of Membrane Proteins

The principal components of the plasma membrane are lipids (phospholipids and cholesterol), proteins, and carbohydrate groups that are attached to some of the lipids and proteins.

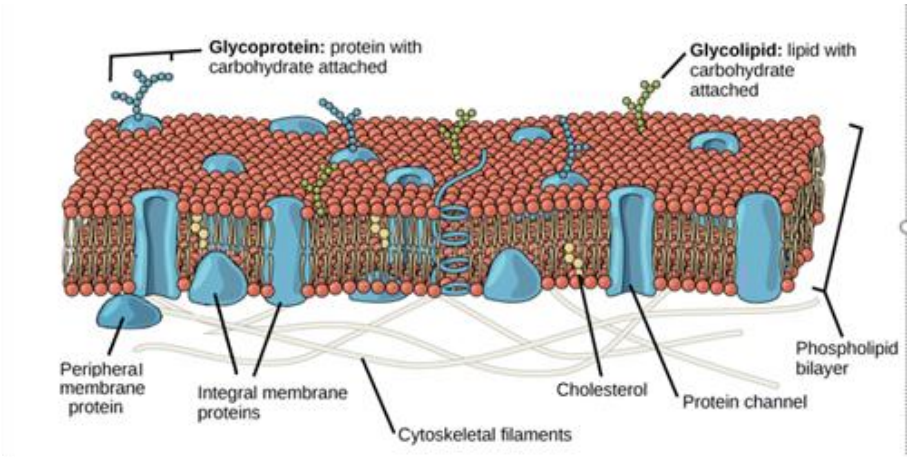



Fig (7) Membranes are made of lipids and proteins

- A phospholipid is a lipid made of glycerol, two fatty acid tails, and a phosphate-linked head group. Biological membranes usually involve two layers of phospholipids with their tails pointing inward, an arrangement called a phospholipid bilayer.
- Cholesterol, another lipid composed of four fused carbon rings, is found alongside phospholipids in the core of the membrane.
- Membrane proteins may extend partway into the plasma membrane, cross the membrane entirely, or be loosely attached to its inside or outside face.

- Carbohydrate groups are present only on the outer surface of the plasma membrane and are attached to proteins, forming glycoproteins, or lipids, forming glycolipids.

The proportions of proteins, lipids, and carbohydrates in the plasma membrane vary between different types of cells. For a typical human cell, however, proteins account for about 50 percent of the composition by mass, lipids (of all types) account for about 40 percent, and the remaining 10 percent comes from carbohydrates.

## Membrane fluidity

The structure of the fatty acid tails of the phospholipids is important in determining the properties of the membrane, and in particular, how fluid it is.

Saturated fatty acids have no double bonds (are saturated with hydrogens), so they are relatively straight. Unsaturated fatty acids, on the other hand, contain one or more double bonds, often resulting in a bend. The saturated and unsaturated fatty acid tails of phospholipids behave differently as temperature drops:

1- At cooler temperatures, the straight tails of saturated fatty acids can pack tightly together, making a dense and fairly rigid membrane.

2- Phospholipids with unsaturated fatty acid tails cannot pack together as tightly because of the bent structure of the tails. Because of this, a membrane containing unsaturated phospholipids will stay fluid at lower temperatures than a membrane made of saturated ones.

Most cell membranes contain a mixture of phospholipids, some with two saturated (straight) tails and others with one saturated and one unsaturated (bent) tail. Many organisms—fish are one example—can adjust physiologically to cold environments by changing the proportion of unsaturated fatty acids in their membranes.

In addition to phospholipids, animals have an additional membrane component that helps to maintain fluidity. Cholesterol, another type of lipid that is embedded among the phospholipids of the membrane, helps to minimize the effects of temperature on fluidity.

At low temperatures, cholesterol increases fluidity by keeping phospholipids from packing tightly together, while at high temperatures, it actually reduces fluidity.

In this way, cholesterol expands the range of temperatures at which a membrane maintains a functional, healthy fluidity.

## Function of cell membrane

### A Physical Barrier

- The plasma membrane surrounds all cells and physically separates the cytoplasm, which is the material that makes up the cell, from the extracellular fluid outside the cell. This protects all the components of the cell from the outside environment and allows separate activities to occur inside and outside the cell.
- The plasma membrane provides structural support to the cell. It tethers the cytoskeleton, which is a network of protein filaments inside the cell that hold all the parts of the cell in place. This gives the cell its shape
- Membranes are made of lipids and proteins, and they serve a variety of barrier functions for cells and intracellular organelles. Membranes keep the outside "out" and the inside "in," allowing only certain molecules to cross and relaying messages via a chain of molecular events cell membranes serve as barriers. They are semi-permeable, which means that some molecules can diffuse across the lipid bilayer but others cannot. Small hydrophobic molecules and

gases like oxygen and carbon dioxide cross membranes rapidly. Small polar molecules, such as water and ethanol, can also pass through membranes, but they do so more slowly. On the other hand, cell membranes restrict diffusion of highly charged molecules, such as ions, and large molecules, such as sugars and amino acids. The passage of these molecules relies on specific transport proteins embedded in the membrane.

- Membrane transport proteins are specific and selective for the molecules they move, and they often use energy to catalyze passage. Also, these proteins transport some nutrients against the concentration gradient, which requires additional energy. The ability to maintain concentration gradients and sometimes move materials against them is vital to cell health and maintenance. Thanks to membrane barriers and transport proteins, the cell can accumulate nutrients in higher concentrations than exist in the environment and, conversely, dispose of waste products.

Other transmembrane proteins have communication-related jobs. These proteins bind signals, such as hormones or immune mediators, to their extracellular portions. Binding causes a conformational change in the protein that transmits a signal to intracellular

messenger molecules. Like transport proteins, receptor proteins are specific and selective for the molecules they bind. Examples of the action of transmembrane proteins Transporters carry a molecule (such as glucose) from one side of the plasma membrane to the other. Receptors can bind an extracellular molecule (triangle), and this activates an intracellular process. Enzymes in the membrane can do the same thing they do in the cytoplasm of a cell: transform a molecule

into another form. Anchor proteins can physically link intracellular structures with extracellular structures.

1- The cell membrane surrounds the cytoplasm of living cells, physically separating the intracellular components from the extracellular environment.

2- The cell membrane also plays a role in anchoring the cytoskeleton to provide shape to the cell.

3- Attaching to the extracellular matrix and other cells to hold them together to form tissues.

4- The cell membrane is selectively permeable and able to regulate what enters and exits the cell, The cell membrane thus works as a selective filter that allows only certain things to come inside or go outside the cell.

## Ways of inter or out the cell:

- The important function of plasma membrane is to control what passes into or out of the cell. Cell membranes are selectively permeable, regulating which substances can pass through, as well as how much of each substance can enter or exit at a given time. Selective permeability is essential to

cells' ability to obtain nutrients, eliminate wastes, and the maintain a stable interior environment different than that of surroundings.

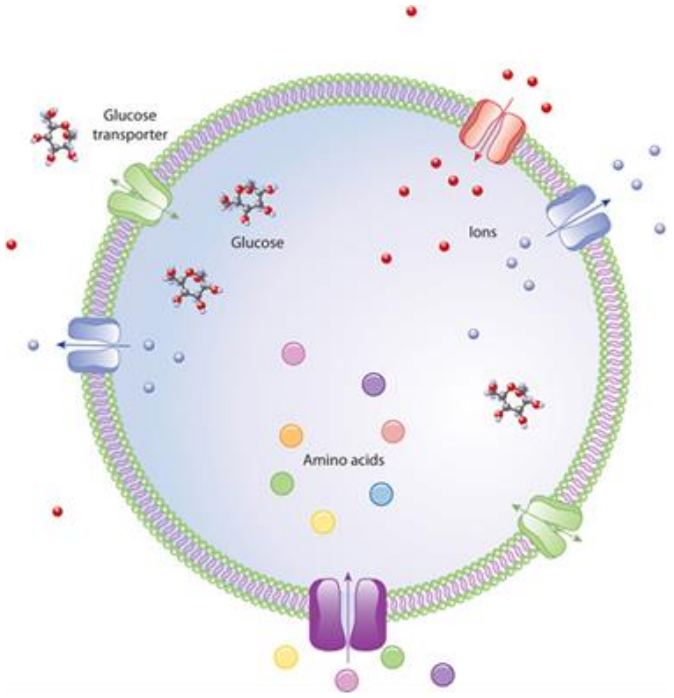



Fig. (8) Selective transport Specialized proteins in the cell membrane regulate the concentration of specific molecules inside the cell

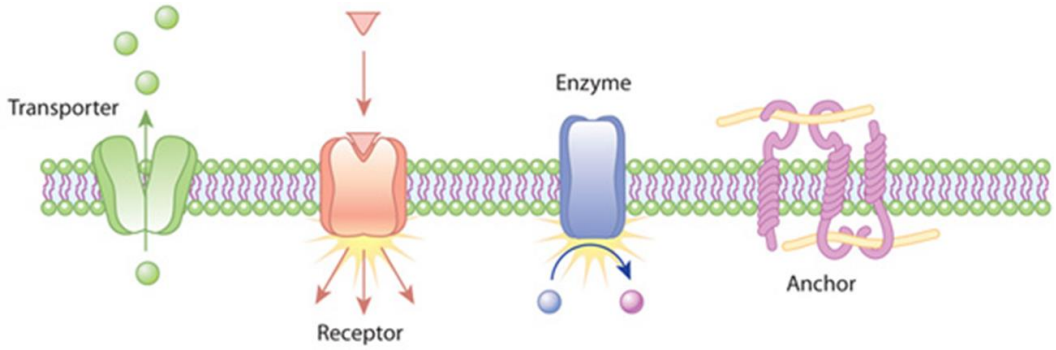



Fig. (9) Examples of the action of transmembrane proteins Transporters carry a molecule

## - Selective permeability:

The phospholipids of plasma membranes are amphipathic, they have both hydrophilic (water-loving) and hydrophobic (water-fearing) regions. The hydrophobic core of the plasma membrane helps some materials move through the membrane, while it blocks the movement of others. Polar and charged molecules have much more trouble crossing the membrane. Polar molecules can easily interact with the outer face of the membrane, where the negatively charged head groups are found, but they have difficulty passing through its hydrophobic core. Water molecules, for instance, cannot cross the membrane rapidly (although thanks to their small size and lack of a full charge, they can cross at a slow rate. Additionally, while small ions are the right size to slip

through the membrane, their charge prevents them from doing so. This means that ions like sodium, potassium, calcium, and chloride cannot cross membranes to any significant degree by simple diffusion, and must instead be transported by specialized proteins. Larger charged and polar molecules, like sugars and amino acids, also need help from proteins to efficiently cross the membrane. The movement of substances across the membrane can be either " passive " occurring without the input of cellular energy, or " active" requiring the cell to expend energy in transporting it. The forms of transport across a membrane are passive and active transport.

## 1- Passive transport

### a- Simple diffusion:

It does not require the cell to expend any energy and involves a substance diffusing down its concentration gradient across a membrane. A concentration gradient is a just a region of space over which the concentration of a substance changes, called facilitated diffusion. In the process of diffusion, a substance tends to move from an area of high concentration to an area of low concentration until its

concentration becomes equal throughout a space. This process does not require any energy input, in fact, a concentration gradient itself is a form of stored (potential) energy, and this energy is used up as the concentrations equalize.

## b- Osmosis:

Osmosis is the spontaneous net movement of solvent molecules through a semi-permeable membrane into a region of higher solute concentration to the lower concentration, in the direction that tends to equalize the solute concentrations on the two sides. Osmosis is a vital process in biological systems, as biological membranes are semipermeable. In these membranes are impermeable to large and polar molecules, such as ions, proteins, and polysaccharides, while being permeable to non-polar or hydrophobic molecules like lipids as well as to small molecules like oxygen, carbon dioxide, nitrogen, and nitric oxide. Permeability depends on solubility, charge, or chemistry, as well as solute size. Osmosis provides the primary means by which water is transported into and out of cells.

## c- Facilitated diffusion:

Facilitated transport proteins shield these molecules from the hydrophobic core of the membrane, providing a route by which they can cross. Two major classes of facilitated transport proteins are channels and carrier proteins:

**a- Channel proteins**

Channel proteins span the membrane and make hydrophilic tunnels across it, allowing their target molecules to pass through by diffusion. Channels are very selective and will accept only one type of molecule for transport. Passage through a channel protein allows polar and charged compounds to avoid the hydrophobic core of the plasma membrane, which would otherwise slow or block their entry into the cell. Some channel proteins are open all the time, but others are “gated,” meaning that the channel can open or close in response to a particular signal (like an electrical signal or the binding of a molecule). Cells

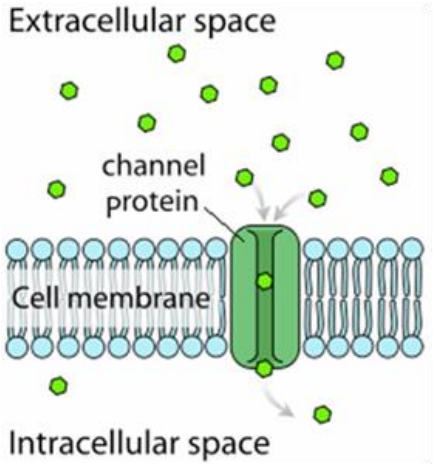



Fig. (10) Facillated diffusion by channel protein

involved in the transmission of electrical signals, such as nerve and muscle cells, have gated ion channels for sodium, potassium, and calcium ions in their membranes. The opening and closing of these channels, and the resulting shifts in ion levels inside the cell, play an important role in electrical transmission along membranes (in nerve cells) and in muscle contraction (in muscle cells).

**b- Carrier proteins**

Another class of trans membrane proteins involved in facilitated transport consists of the carrier proteins. Carrier proteins can change their shape to move a target molecule from one side of the membrane to the other. Like channel proteins, carrier proteins are typically selective for one or a few substances. Often,

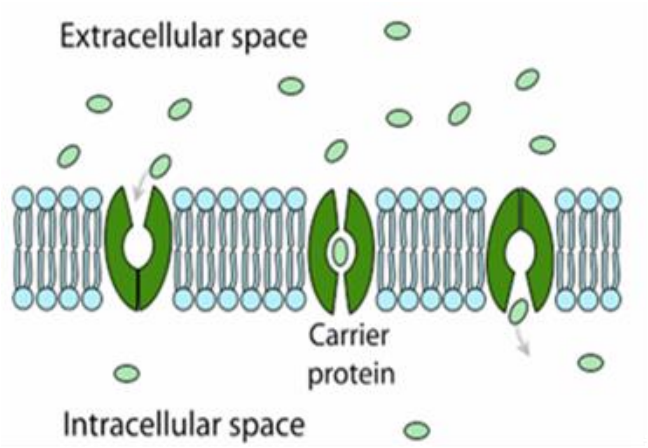



Fig. (11) Facillated diffusion by carrier protein

they will change shape in response
to binding of their target molecule, with the shape change moving the molecule to the opposite side of the membrane. The carrier proteins involved in facilitated diffusion simply
provide hydrophilic molecules with a way to move down an existing concentration gradient. Channel and carrier proteins transport material at different rates. In general, channel proteins transport molecules much more quickly than do carrier proteins. This is because channel proteins are simple tunnels, unlike carrier proteins, they don’t need to change shape and “reset” each time they move a molecule. A typical channel protein might facilitate diffusion at a rate of tens of millions of molecules per second, whereas a carrier

protein might work at a rate of a thousand or so molecules per second.

## Types of transport proteins:

Is a protein that serves the function of moving other materials within an organism. Transport proteins are vital to the growth and life of all living things. There are several different kinds of transport proteins. A transport protein are proteins involved in the movement of ions, small molecules, or macromolecules, such as another protein, across a biological membrane.

**1- Carrier proteins:**

Are integral membrane proteins, that is, they exist within and span the membrane across which they transport substances. The proteins may assist in the movement of substances by facilitated diffusion (i.e., passive transport or active transport).

**2- Receptor proteins:**

In biochemistry and pharmacology, a receptor is a protein molecule that receives chemical signals from outside a cell. When such chemical signals bind to a receptor, they cause some form of cellular/tissue response. e.g. The hormone insulin binds to a

receptor in liver cells, and therefore these cells store glucose.

**3- Enzymatic proteins:**

Enzymes are macromolecular biological catalysts. Enzymes accelerate chemical reactions. The molecules upon which enzymes may act are called substrates and the enzyme converts the substrates into different molecules known as products. Almost all metabolic processes in the cell need enzymes in order to occur at rates fast enough to sustain life. Enzymes are known to catalyze more than 5,000 biochemical reaction types. Most enzymes are proteins, although a few are catalytic RNA molecules. The latter are called ribozymes. Like all catalysts, enzymes increase the reaction rate by lowering its activation energy. Chemically, enzymes are like any catalyst and are not consumed in chemical reactions, nor do they alter the equilibrium of a reaction. Enzymes differ from most other catalysts by being much more specific. Enzyme activity can be affected by other molecules such as inhibitors are molecules that decrease enzyme activity, and activators are molecules that increase activity. Many therapeutic drugs and poisons are enzyme inhibitors. An enzyme's activity decreases

markedly outside its optimal temperature and pH. Some enzymes are used commercially, for example, in the synthesis of antibiotics. Some household products use enzymes to speed up chemical reactions such as enzymes in biological washing powders break down protein, starch or fat stains on clothes, and enzymes in meat tenderizer break down proteins into smaller molecules, making the meat easier to chew.

**4- Junction proteins:**

A cell junction or intercellular bridge is a type of structure that exists within the tissue of some multi cellular organisms, such as animals. Cell junctions consist of multi protein complexes that provide contact between neighboring cells or between a cell and the extra cellular matrix. Cell junctions are especially abundant in epithelial tissues. Cell junctions are especially important in enabling communication between neighboring cells via specialized proteins called communicating junctions. Cell junctions are also important in reducing stress placed upon cells.

## 5- Signaling at the Cell Membrane

The cell membrane also plays an important role in cell signaling and communication. The membrane contains several embedded proteins that can bind molecules found outside of the cell and pass on messages to the inside of the cell.

Importantly, these receptor proteins on the cell membrane can bind to substances produced by other areas of the body, such as hormones. When a molecule binds to its target receptor on the membrane, it initiates a signal transduction pathway inside the cell that transmits the signal to the appropriate molecules.

## 2- Active transport:

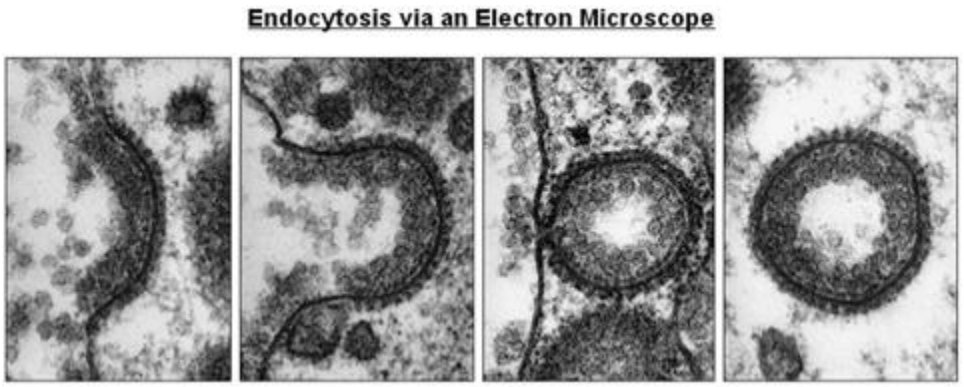
Active transport is the movement of molecules across a membrane from a region of their lower concentration to a region of their higher concentration in the direction against some. Active transport uses cellular energy to move them against a gradient, polar repulsion, or other resistance. Active transport is usually associated with accumulating high concentrations of molecules that the cell needs, such as ions, glucose and amino acids. If the process primary active transport uses chemical energy, such

as from adenosine triphosphate (ATP). Secondary active transport involves the use of an electrochemical gradient. Examples of active transport include the uptake of glucose in the intestines in humans. Active transport is specialized transmembrane proteins recognize the substance and allow it to move across the membrane when it otherwise would not, either because the phospholipid bilayer of the membrane is impermeable to the substance moved or because the substance is moved against the direction of its concentration gradient. There are two forms of active transport; primary active transport and secondary active transport. In primary active transport, the proteins involved are pumps that normally use the chemical energy in the form of adenosine triphosphate ATP. Secondary active transport, however, makes use of potential energy, which are usually derived through exploitation of an electrochemical gradient.

**a- Endocytosis:**

Endocytosis is a type of active transport that moves particles, such as large molecules, parts of cells, and even whole cells, into a cell. There are different variations of endocytosis, but all share a common characteristic: The plasma membrane of the cell

invaginates, forming a pocket around the target particle. The pocket pinches off, resulting in the particle being contained in a newly created intracellular vesicle formed from the plasma membrane. There are two main types of endocytosis: Pinocytosis, The process by which liquids dissolved substances are ingested (allows faster entry than via proteinn channels and Phagocytosis, The process by which solid substances are ingested (usually to be transported to the lysosome). Phagocytosis is a type of endosytosis (the condition of “cell eating”) is the process by which large particles, such as cells or relatively large particles, are taken in by a cell. For example, when microorganisms invade the human body, a type of white blood cell called a neutrophil will remove the invaders through this process, surrounding and engulfing the microorganism, which is then destroyed by the neutrophil.



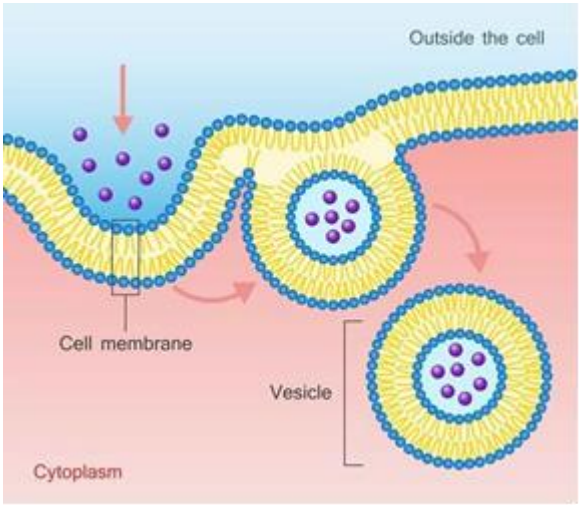




**Fig. (12) Large molecules can be taken into the cell through the process of endocytosis.**

## b- Exocytosis:

The process by which large substances (or bulk amounts of small substances) exit the cell without crossing the membrane Vesicles (typically derived from the Golgi) fuse with the plasma membrane,

endocytosis. expelling their contents into the extracellular environment. The process of exocytosis

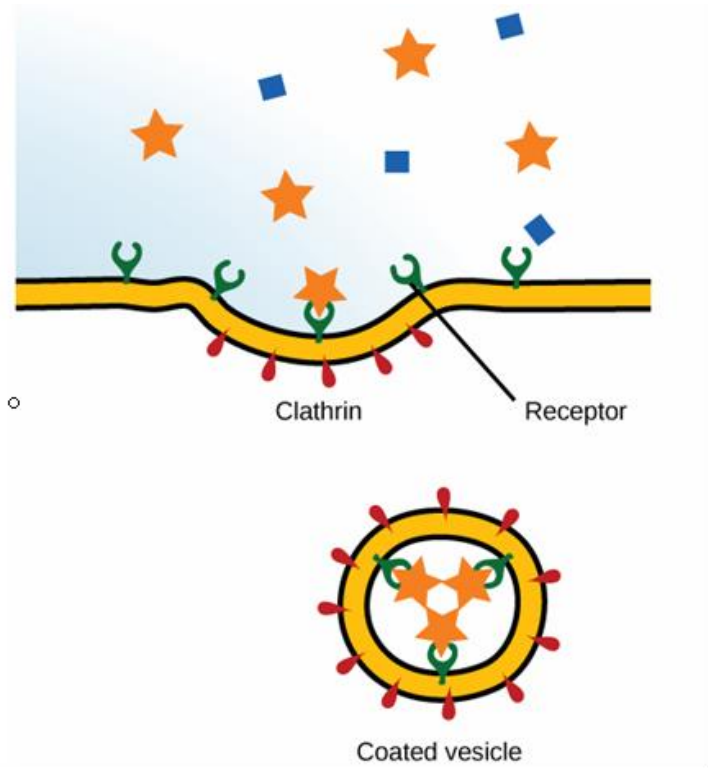



Fig. (13) Substance is bends to the receptor of the external surface of the cell membrane by endosytosis

adds vesicular phospholipids to the cell membrane, replacing those lost when vesicles are formed via Just as material can be brought into the cell by invagination and formation of a vesicle, the membrane of a vesicle can be fused with the plasma membrane, extruding its contents to the surrounding medium. This is the process of exocytosis. Exocytosis occurs in various

cells to remove undigested residues of substances brought in by endocytosis, to secrete substances such as hormones and enzymes, and to transport a substance completely across a cellular barrier. In the process of exocytosis, the undigested waste-containing food

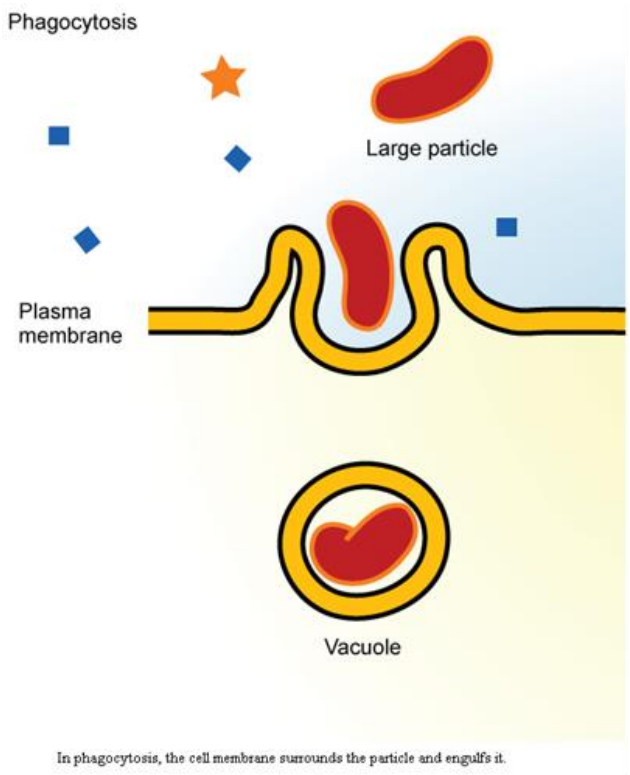



Fig. (14) Phagosytosis processes

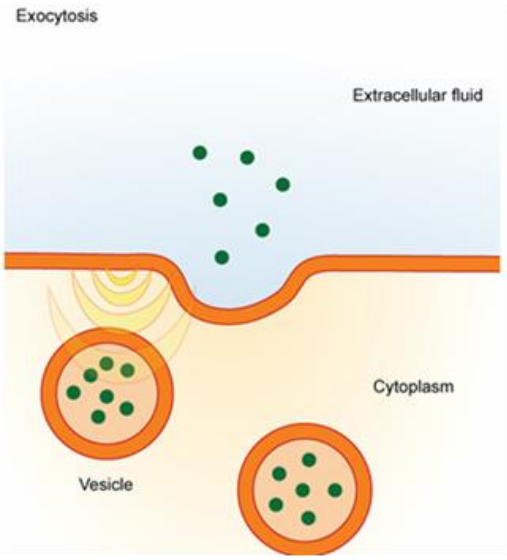


Fig. (15) Exocytosis process

vacuole or the secretory vesicle budded from Golgi apparatus, is first moved by cytoskeleton from the interior of the cell to the surface. The vesicle membrane comes in contact with the plasma membrane. The lipid molecules of the two bilayers rearrange themselves and the two membranes are, thus, fused. A passage is formed in the fused membrane and the vesicles discharges its contents outside the cell.

The difference between passive transport and active transport is active transport requires energy and moves substances against their respective concentration gradient, whereas passive transport

requires no energy and moves substances in the direction of their respective concentration gradient.

**Cell Signaling**

Another important function of the membrane is to facilitate communication and signaling between cells. It does so through the use of various proteins and carbohydrates in the membrane. Proteins on the cell "mark" that cell so that other cells can identify it. The membrane also has receptors that allow it to carry out certain tasks when molecules such as hormones bind to those receptors.

**Methods of Transport, Energy Requirements, and Types of Material Transported**

| Transport Method | Active/Passive | Material Transported |
|---|---|---|
| Diffusion | Passive | Small-molecular weight material |
| Osmosis | Passive | Water |
| Facilitated transport/diffusion | Passive | Sodium, potassium, calcium, glucose |
| Primary active transport | Active | Sodium, potassium, calcium |
| Secondary active transport | Active | Amino acids, lactose |
| Phagocytosis | Active | Large macromolecules, whole cells, or cellular structures |
| Pinocytosis and potocytosis | Active | Small molecules (liquids/water) |
| Receptor-mediated endocytosis | Active | Large quantities of macromolecules |

https://en.wikipedia.org/wiki/Cell_membrane

## Questions:

1- What is cholesterol's role in the membrane?

2- How is $h_2o$ moved across the membrane?

## Multiple Choice Questions:

**1- A phospholipid has 2 parts. What are they called?**

a- Hydrophilic Head, Hydrophobic Tail

b- Hydrophobic Head, Hydrophilic Tail

**2- This forms a boundary between the inside of the cell and the outside of the cell.**

a- Cell Membrane

b- Lipid Cleric Layer

c- Membrane Gate

d- Protein Receptors

3- **A……. is composed of a phosphate and glycerol head and 2 fatty acid chain tails**

a- phospholipid

b- Carbohydrate

c- Cholesterol

d- Protein

**4- Water Loving**

a- Hydrophobic

b- Hydrophilic

c- Hydroelectric

d- Hydroloric

**5- "Water Fearing"**

a- Hydrophobic

b- Hydrophilic

c- Hydroelectric

d- Hydroloric

**6-……. allow cells to recognize each other.**

a- Carbohydrates

b- Proteins

c- Phospholipids

d- Cholesterol

**7- ……. helps keep the phospholipid tails from sticking together and makes it more fluid.**

a- Carbohydrates

b- Proteins

c- Phospholipids

d- Cholesterol

**8- The cell membrane is selectively permeable, which means.....**

a- All materials can enter and leave the cell

b- Certain things can enter while others cannot

c- The cell manually sorts through all materials

d- Only certain cells can interact with the cell.

**9- Which of the following macromolecules is NOT part of the cell membrane…….**

a- Lipids

b- Carbohydrates

c- Proteins

d- Nucleic Acids

**10- How many layers thick is the lipid bilayer…….**

a- 1

b- 2

c- 3

d- 4

**11- What structure acts like a doorway allowing larger and more polar molecules through the membrane……**

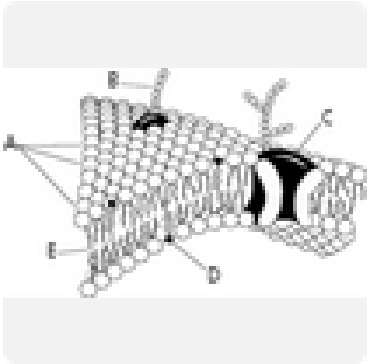
a- carbohydrates

b- proteins

c- hydrophilic heads

d- lipids

**12- Which part of the plasma membrane is responsible for cell to cell recognition…….**



a- C

b- E

c- B

d- D

**13- Hydrophobic region of the cell membrane…….**

a- E

b- B

c- C

d- A

**14- Hydrophilic portion of cell membrane…….**

a- A

b- C

c- D

d- E

## 15- Which is a integral protein…….

a- A

b- B

c- C

d- D

**16- Which component of the cell membrane functions actually creates the barrier between the inside and outside of the cell…….**

a- carbohydrates

b- cholesterol

c- phospholipids

d- proteins

17- **Which component of the cell membrane functions to help move larger materials across the membrane…….**

a- carbohydrates

b- cholesterol

c- phospholipids

d- proteins

**18- Which component of the cell membrane helps cells recognize each other…….**

a- carbohydrates

b- cholesterol

c- phospholipids

d- proteins

# Second chapter

# The cytoplasm and cell organelles

# The cytoplasm

In cell biology, the cytoplasm is all of the material within a eukaryotic cell, enclosed by the cell membrane, except for the cell nucleus. The material inside the nucleus and contained within the nuclear membrane is termed the nucleoplasm. The main components of the cytoplasm are cytosol (a gel-like substance), the organelles (the cell's internal sub-structures), and various cytoplasmic inclusions. The cytoplasm is about 80% water and is usually colorless.

The submicroscopic ground cell substance or cytoplasmic matrix which remains after exclusion of the cell organelles and particles is groundplasm. It is the hyaloplasm of light microscopy, a highly complex, polyphasic system in which all resolvable cytoplasmic elements are suspended, including the larger organelles such as the ribosomes, mitochondria, the plant plastids, lipid droplets, and vacuoles.

Most cellular activities take place within the cytoplasm, such as many metabolic pathways including glycolysis, and processes such as cell division. The concentrated inner area is called the

endoplasm and the outer layer is called the cell cortex or the ectoplasm.

Movement of calcium ions in and out of the cytoplasm is a signaling activity for metabolic processes.

## Constituents

The three major elements of the cytoplasm are the cytosol, organelles and inclusions.

**- Cytosol**

The cytosol is the portion of the cytoplasm not contained within membrane-bound organelles. Cytosol makes up about 70% of the cell volume and is a complex mixture of cytoskeleton filaments, dissolved molecules, and water. The cytosol's filaments include the protein filaments such as actin filaments and microtubules that make up the cytoskeleton, as well as soluble proteins and small structures such as ribosomes.

**- Organelles**

Organelles (literally "little organs") are usually membrane-bound structures inside the cell that have specific functions. Some major organelles that are suspended in the cytosol are the mitochondria, the endoplasmic reticulum, the Golgi apparatus, vacuoles, lysosomes, and in plant cells, chloroplasts

**-Cytoplasmic inclusions**

The inclusions are small particles of insoluble substances suspended in the cytosol. A huge range of inclusions exist in different cell types, and range from crystals of calcium oxalate or silicon dioxide in plants, to granules of energy-storage materials such as starch, glycogen. A particularly widespread example are lipid droplets, which are spherical droplets composed of lipids and proteins that are used in both prokaryotes and eukaryotes as a way of storing lipids such as fatty acids and sterols.

## - Ribosomes

Ribosomes, are macromolecular machines, found within all cells, that perform biological protein synthesis (mRNA translation). Ribosomes link amino acids together in the order specified by the codons of messenger RNA (mRNA) molecules to form polypeptide chains. Ribosomes consist of two major components: the small and large ribosomal subunits. Each subunit consists of one or more ribosomal RNA (rRNA) molecules and many ribosomal proteins (RPs or r-proteins). The ribosomes and associated molecules are also known as the translational apparatus.


Fig. (16) Structure of ribosome

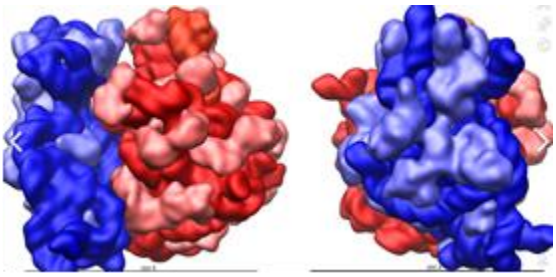


Fig. (17) Large (red) and small (blue) subunit fit together

A ribosome is made from complexes of RNAs and proteins and is therefore a ribonucleoprotein complex. Each ribosome is composed of small (30S) and large (50S) components, called subunits, which are bound to each other: (30S) has mainly a decoding function and is also bound to the mRNA (50S) has mainly a

catalytic function and is also bound to the aminoacylated tRNAs.

The synthesis of proteins from their building blocks takes place in four phases: initiation, elongation, termination, and recycling. The start codon in all mRNA molecules has the sequence AUG. The stop codon is one of UAA, UAG, or UGA; since there are no tRNA molecules that recognize these codons, the ribosome recognizes that translation is complete. When a ribosome finishes reading an mRNA molecule, the two subunits separate and are usually broken up but can be re-used. Ribosomes are ribozymes, because the catalytic peptidyl transferase activity that links amino acids together is performed by the ribosomal RNA.

Ribosomes are often associated with the intracellular membranes that make up the rough endoplasmic reticulum.

Ribosomes from bacteria, archaea and eukaryotes in the three-domain system resemble each other to a remarkable degree, evidence of a common origin. They differ in their size, sequence, structure, and the ratio of protein to RNA. The differences in structure allow some antibiotics to kill bacteria by inhibiting their ribosomes, while leaving human ribosomes

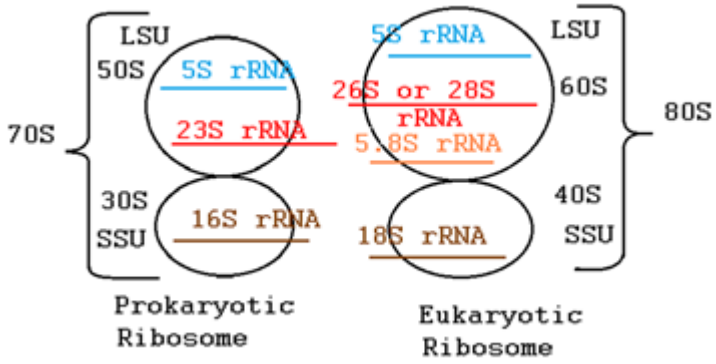



Fig (18) Ribosome rRNA composition for prokaryotic and eukaryotic rRNA

unaffected. In all species, more than one ribosome may move along a single mRNA chain at one time (as a polysome), each "reading" a specific sequence and producing a corresponding protein molecule.

protein synthesis (Figure 1). Because they are formed from two subunits of non-equal size, they are slightly longer in the axis than in diameter. The ribosome is a complex cellular machine. It is largely made up of specialized RNA known as ribosomal RNA (rRNA) as well as dozens of distinct proteins (the exact number varies slightly between species). The ribosomal proteins and rRNAs are arranged into two distinct

ribosomal pieces of different sizes, known generally as the large and small subunit of the ribosome. Ribosomes consist of two subunits that fit together (Figure 16) and work as one to translate the mRNA into a polypeptide chain during

## Function

Ribosomes are minute particles consisting of RNA and associated proteins that function to synthesize proteins. Proteins are needed for many cellular functions such as repairing damage or directing chemical processes. Ribosomes can be found floating within the cytoplasm or attached to the endoplasmic reticulum. Their main function is to convert genetic code into an amino acid sequence and to build protein polymers from amino acid monomers.

In summary, ribosomes have two main functions: Decoding the message, and the formation of peptide bonds. These two functions reside in the ribosomal subunits. Each subunit is made of one or more rRNAs and many r-proteins. The small subunit (30S in bacteria and archaea, (40S in eukaryotes) has the decoding function, whereas the large subunit. (50S in bacteria and archaea, 60S in eukaryotes) catalyzes

the formation of peptide bonds, referred to as the peptidyl-transferase activity. The bacterial (and

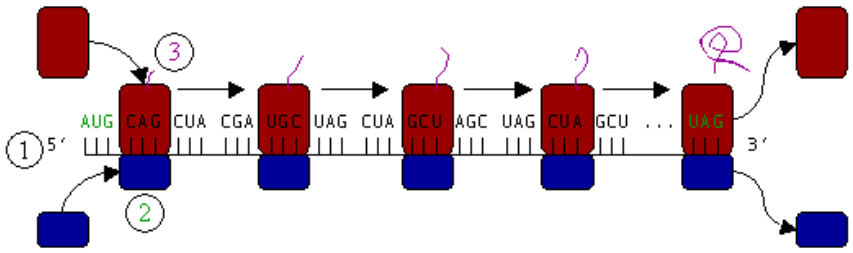



Fig (19) Translation of mRNA (1) by a ribosome (2)(shown as small and large subunits) into a polypeptide chain (3). The ribosome begins at the start codon of RNA (AUG) and ends at the stop codon (UAG).…

archaeal) small subunit contains the 16S rRNA and 21 r-proteins (Escherichia coli), whereas the eukaryotic small subunit contains the 18S rRNA and 32 r-proteins (Saccharomyces cerevisiae; although the numbers vary between species). The bacterial large subunit contains the 5S and 23S rRNAs and 34 r-proteins (E. coli), with the eukaryotic large subunit containing the 5S, 5.8S, and 25S / 28S rRNAs and 46 r-proteins (S. cerevisiae; again, the exact numbers vary between species.

**https://byjus.com/biology/ribosomes/**

## Cell organelles classification

Cytoplasm is the living fluid part between cell membrane and nucleus. It has special structures called Cell Organelles in it. Cytosol is the liquid part of cytoplasm formed of water having dissolved or suspended substances in it. Cell Organelles are organ like each performing specific functions but formed of molecules and membranes only: Single Membrane bound Organelles such as; Endoplasmic Reticulum, Golgi Apparatus, Lysosomes and Vacuoles. Double Membrane bound Organelles such as; Mitochondria, and Nucleus and Organelles lacking any membrane as; Ribosomes, Centrioles, Nucleolus.

## 1- Single membrane organelles:

### a- Endoplasmic Reticulum (ER)

ER is a type of organelle in eukaryotic cells that forms an interconnected network of flattened, membrane-enclosed sacs or tube-like structures known as cisternae. The
membranes of the ER are continuous with the outer nuclear membrane. The endoplasmic reticulum occurs in most types of eukaryotic cells, but is absent from

red blood cells and spermatozoa. There are two types of endoplasmic
reticulum; rough and smooth. The outer cytosolic face of the rough endoplasmic reticulum is studded with ribosomes
that are the sites of protein synthesis. The rough

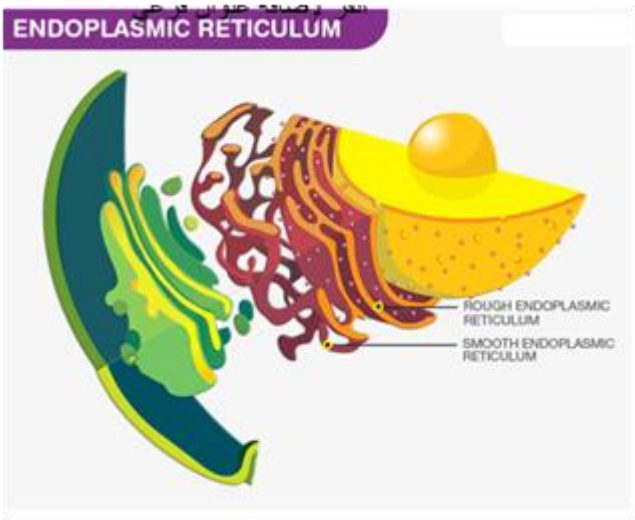



Fig (20) Endoplasmic Reticulum

endoplasmic reticulum is especially prominent in cells such as hepatocytes. The smooth endoplasmic reticulum lacks ribosomes and functions in lipid manufacture and metabolism, the production of steroid hormones, and detoxification. The mooth ER is especially abundant in mammalian liver and gonad

cells. The membranes of the endoplasmic reticulum were first seen in 1945 using electron microscopy.

## 1- Rough-surfaced endoplasmic reticulum (RER)

- The rough endoplasmic reticulum is named so because of its appearance.
- It is a series of connected flattened sacs having several ribosomes on its outer surface, hence the name.
- It synthesizes and secretes proteins in the liver, hormones and other substances in the glands.
- Rough ER is prominent in cells where protein synthesis happens (such as hepatocytes)

RER is very important in the synthesis and packaging of proteins. Ribosomes are attached to the membrane of the ER, making it “rough.” The RER is also attached to the nuclear envelope that surrounds the nucleus. The process of protein synthesis starts when mRNA moves from the nucleus to a ribosome on the surface of the RER. As the ribosome builds the amino acid chain, the chain is pushed into the cisternal space of the RER. When the proteins are complete, they collect and the RER pinches off a vesicle, that vesicle can move to the cell membrane or the Golgi

apparatus. Some of the proteins will be used in the cell and some will be sent out into intercellular space.

## 2- Smooth Endoplasmic Reticulum Structure

- The smooth endoplasmic reticulum, on the other hand, does not have ribosomes.
- The smooth endoplasmic reticulum has a tubular form.
- It participates in the production of phospholipids, the chief lipids in cell membranes and are essential in the process of metabolism.
- Smooth ER transports the products of the rough ER to other cellular organelles, especially the Golgi apparatus

## Functions of Endoplasmic Reticulum

- Endoplasmic reticulum function includes the Golgi apparatus, lysosomes, plasma membrane, etc.
- In addition, it is responsible for transport. Transport of carbohydrates and proteins to another organelle.
- They provide a wide area for cellular reactions.
- Furthermore, it helps in formation. Formation of the nuclear membrane at the time of cell division.

- In the skeletal framework formation, they play an important role.
- Most noteworthy, it plays an important role in the synthesis of lipids, glycogen, proteins. Also, other steroids like progesterone, testosterone, and cholesterols, etc.

The endoplasmic reticulum is categorised into two types, and both these types of ER perform specific functions:

## Smooth Endoplasmic Reticulum Function:

- Smooth ER is responsible for the synthesis of essential lipids such as phospholipids and cholesterol.
- Smooth ER is also responsible for the production and secretion of steroid hormones.
- It is also responsible for the metabolism of carbohydrates.
- The smooth ER store and releases calcium ions. These are quite important for the nervous system and muscular systems.

## - Lipid Synthesis

The smooth endoplasmic reticulum plays an important role in cholesterol and phospholipid biosynthesis. Therefore, this section of the ER is important not only

for the generation and maintenance of the plasma membrane but of the extensive endomembrane system of the ER itself.

The SER is enriched in enzymes involved in sterol and steroid biosynthetic pathways and is also necessary for the synthesis of steroid hormones. Therefore, the SER is extremely prominent in the cells of the adrenal gland that secrete five different groups of steroid hormones that influence the metabolism of the entire body. The synthesis of these hormones also involves enzymes within the mitochondria, further underscoring the relationship between these two organelles.

## - Calcium Store

The SER is an important site for the storage and release of calcium in the cell. A modified form of the SER called sarcoplasmic reticulum forms an extensive network in contractile cells such as muscle fibers. Calcium ions are also involved in the regulation of metabolism in the cell and can change cytoskeletal dynamics.

The extensive nature of the ER network allows it to interact with the plasma membrane and use Ca2+ for signal transduction and modulation of nuclear activity.

In association with mitochondria, the ER can also use its calcium stores to induce apoptosis in response to stress.

## Rough Endoplasmic Reticulum Function:

- The majority of the functions of rough ER is associated with protein synthesis.
- The rough endoplasmic reticulum also plays a vital role in protein folding.
- Also ensures quality control (regarding correct protein folding).
- The second most important function after protein synthesis and protein folding is protein sorting.

### - Protein Synthesis and Folding

Protein synthesis occurs in the rough endoplasmic reticulum. Although translation for all proteins begins in the cytoplasm, some are moved into the ER in order to be folded and sorted for different destinations. Proteins that are translocated into the ER during translation are often destined for secretion. Initially, these proteins are folded within the ER and then moved into the Golgi apparatus where they can be dispatched towards other organelles.

For instance, the hydrolytic enzymes in the lysosome are generated in this manner. Alternately, these

proteins could be secreted from the cell. This is the origin of the enzymes of the digestive tract. The third potential role for proteins translated in the ER is to remain within the endomembrane system itself. This is particularly true for chaperone proteins that assist in the folding of other proteins. The genes encoding these proteins are upregulated when the cell is under stress from unfolded proteins.

## Endoplasmic Reticulum Location

The endoplasmic reticulum processes most of the instructions from the nucleus. As such, the endoplasmic reticulum surrounds the nucleus and radiates outward. In cells that secrete many products for the rest of the body, the endoplasmic reticulum can account for more than 50% of the cell.

In general, the nucleus expresses mRNA (messenger RNA), which tells the cell how to build proteins. The rough endoplasmic reticulum has many ribosomes, which are the primary location of protein production. This portion of the organelle creates proteins and begins to fold them into the proper formation. The smooth endoplasmic reticulum is the primary location for lipid synthesis. As such, it does not contain any ribosomes. Rather, it conducts a series of reactions

which create the phospholipid molecules necessary to create various membranes and organelles.

The rough version of the endoplasmic reticulum is often closer to the nucleus, whereas the smooth endoplasmic reticulum is further from the nucleus. However, both versions are connected to each other and the nucleus through a series of small tubules.

https://en.wikipedia.org/wiki/Endoplasmic_reticulum

## Relationships among E.R., plasma membrane and nuclear membrane

RER is very important in the synthesis and packaging of proteins. Ribosomes are attached to the membrane of the ER, making it “rough.” The RER is also attached to the nuclear envelope that surrounds the nucleus. The process of protein synthesis starts when mRNA moves from the nucleus to a ribosome on the surface of the RER. As the ribosome builds the amino acid chain, the chain is pushed into the cisternal space of the RER. When the proteins are complete, they collect and the RER pinches off a vesicle, that

vesicle can move to the cell membrane or the Golgi apparatus. Some of the proteins will be used in the cell and some will be sent out into intercellular space.

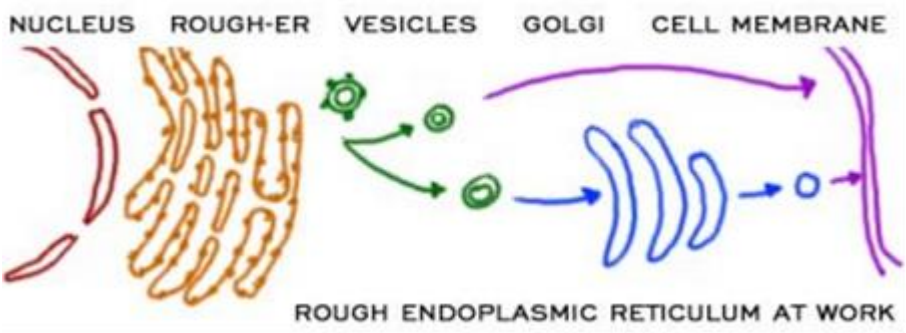



Fig (21) Rough endoplasmic reticulum at work

## 2- Golgi apparatus:

The Golgi apparatus, also known as the Golgi complex, Golgi body is an organelle found in most eukaryotic cells. It was identified in 1897 by the Italian scientist Camillo Golgi and named after him in 1898. The Golgi apparatus packages proteins into membrane-bound vesicles inside the cell before the vesicles are sent to their destination. It is of particular importance in processing proteins for

secretion, containing a set of glycosylation enzymes that attach various sugar monomers to proteins as the proteins move through the apparatus. In most

eukaryotes, the Golgi apparatus is made up of a series of compartments consisting of two main networks: the cis Golgi network (CGN) and the trans Golgi network (TGN). The CGN is a collection of fused, flattened membrane-enclosed disks known as ( cisternae) originating from vesicular clusters that bud off the endoplasmic reticulum. A mammalian cell typically contains 40 to 100 stacks. Between four and eight cisternae are usually present in a stack;

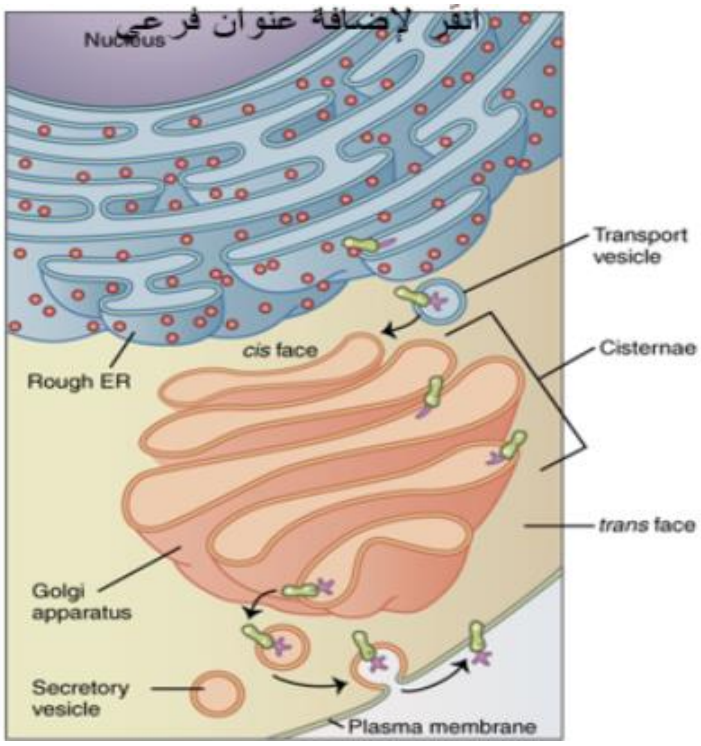



Fig (22) Relationships among E.R., plasma membrane and nuclear membrane

The Golgi apparatus tends to be larger and more numerous in cells that synthesize and secrete large amounts of substances. In all eukaryotes, each cisternal stack has a cis entry face and a trans exit face. These faces are characterized by unique morphology and biochemistry. Within individual stacks are assortments of enzymes responsible for selectively modifying protein cargo. These modifications influence the fate of the protein

The Golgi apparatus, also known as the Golgi complex, Golgi body, or simply the Golgi, is an organelle found in most eukaryotic cells. Part of the endomembrane system in the cytoplasm, it packages proteins into membrane-bound vesicles inside the cell before the vesicles are sent to their destination. It resides at the intersection of the secretory, lysosomal, and endocytic pathways. It is of particular importance in processing proteins for secretion, containing a set of glycosylation enzymes that attach various sugar monomers to proteins as the proteins move through the apparatus.

## Functions of Golgi Apparatus

Golgi Apparatus is responsible for some of the most important function inside our cell. Without the Golgi

Apparatus, the proteins that are formed in the cytoplasm will have no use.

- The proteins, after they are formed, undergoes into a series of modification which is done inside the Endoplasmic Reticulum first and then inside the Golgi Apparatus. This modification works as a tag on the proteins and tells them where to go in the cell. Just like an address on the package makes the package to get successfully delivered, similarly, the modification on the proteins helps them to get

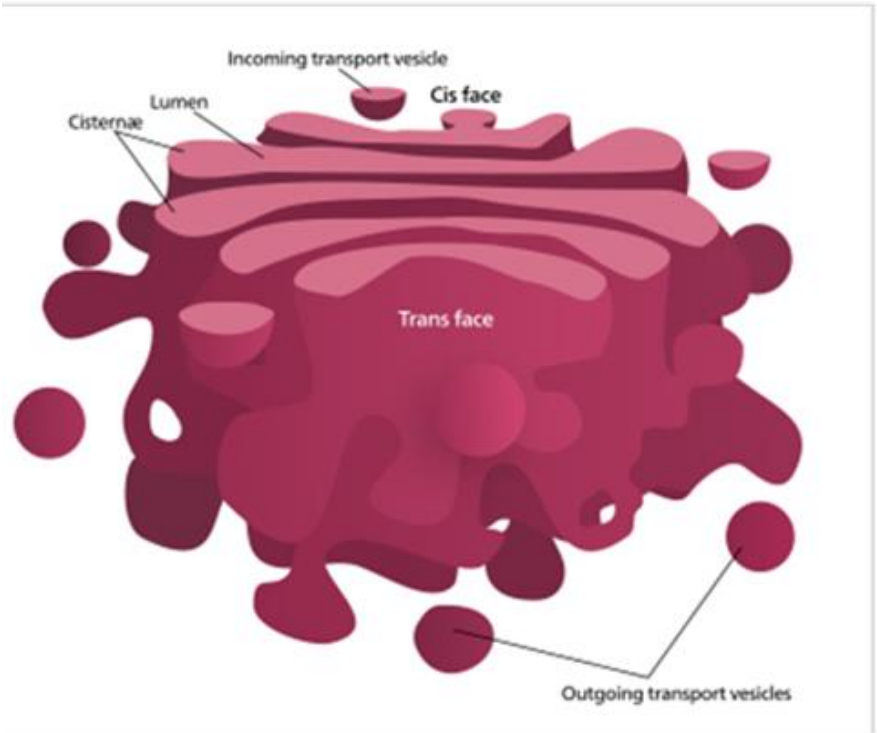



Fig. (23) Structure of Golgi apparatus

delivered to their address inside the cell or outside, depending upon the type.

- The Golgi apparatus also modifies the lipids which are to be inserted into the Plasma Membrane.
- The proteins coming from the Endoplasmic Reticulum is protected inside a vesicle, that vesicle is received by the cis face of the Golgi Apparatus which is near the Endoplasmic Reticulum.
- This vesicle gets fused with the membrane of the Golgi Apparatus and the protein is delivered inside the Golgi. This process of sending of vesicles packed with proteins from Endoplasmic Reticulum to Cis face of the Golgi Apparatus is called as the Anterograde movement. And opposite to this, when the vesicles move form cis face of the Golgi Apparatus to the Endoplasmic Reticulum, it is called a Retrograde movement.
- The proteins inside the matrix of the Golgi Apparatus which are embedded on the wall of the cisternae then modify the proteins and lipids by several steps.
- When the protein or lipid finally reach the Trans end of the Golgi Apparatus, it buds off along the membrane of the trans-Golgi face. The membrane protects the proteins and is called a vesicle.

- The modification on the proteins directs them to go to their particular location. For example, Mannose-6-phosphate is a modification done on their proteins which is destined to go to lysosomes. So any vesicle containing protein tagged with Mannose-6-phosphate inside them will automatically fuse with the membrane of the lysosomes.
- Similarly, the proteins or lipids of the plasma membrane with go and fuse with the plasma membrane and those tagged to go outside of the cell also called as secretory proteins like enzymes, hormones, etc, will be secreted out of the cell.
- Therefore the exocytosis process of the secretory proteins is regulated by the Golgi Apparatus.

## The mechanism of action of the Golgi apparatus can be summarized in points as follows

1. Golgi vesicles are often, referred to as the “traffic police” of the cell. They play a key role in sorting many of the cell’s proteins and membrane constituents, and in directing them to their proper destinations.
- To perform this function, the Golgi vesicles contain different sets of enzymes in different types of vesicles— cis, middle and trans cisternae—that react

with and modify secretory proteins passing through the Golgi lumen or membrane proteins and glycoproteins that are transiently in the Golgi membranes as they are en route to their final destinations.

The Golgi apparatus hence acts as the assembly factory of the cell where the raw materials are directed to the Golgi apparatus before being passed out from the cell.

2. In animals, the Golgi apparatus is involved in the packaging and exocytosis of the following materials; Zymogen of exocrine pancreatic cells;

Mucus (=a glycoprotein) secretion by goblet cells of the intestine ; Lactoprotein (casein) secretion by mammary gland cells (Merocrine secretion) ; Secretion of compounds (thyroglobulins) of thyroxine hormone by thyroid cells; Secretion of tropocollagen and collagen ; Formation of melanin granules and other pigments; and Formation of yolk and vitelline membrane of growing primary oocytes.

3. It is also involved in the formation of certain cellular organelles such as plasma membrane, lysosomes, acrosome of spermatozoa and cortical granules of a variety of oocytes.

4. They are also involved in the transport of lipid molecules around the cell.

5. The Golgi complex also plays an important role in the production of proteoglycans. The proteoglycans are molecules that are present in the extracellular matrix of the animal cells.

6. It is also a major site of synthesis of carbohydrates. These carbohydratres include the synthesis of glycosaminoglycans, Golgi attaches to these polysaccharides which then attaches to a protein produced in the endoplasmic reticulum to form proteoglycans.

7. The Golgi involves in the sulfation process of certain molecules.

8. The process of phosphorylation of molecules by the Golgi requires the import of ATP into the lumen of the Golgi.

9. In plants, Golgi apparatus is mainly involved in the secretion of materials of primary and secondary cell walls (e.g., formation and export of glycoproteins, lipids, pectins and monomers for hemicellulose, cellulose, lignin, etc.)

## Golgi Apparatus Location

The Golgi apparatus is situated in between the endoplasmic reticulum and the cell membrane. Most often, the Golgi appears to be an extension of the endoplasmic reticulum which is slightly smaller and smoother in appearance. However, the Golgi apparatus can be easily mistaken for smooth endoplasmic reticulum. Although they look similar, the Golgi is an independent organelle which has different functions. The Golgi apparatus modifies and sorts proteins for transport throughout the cell. The Golgi apparatus is often found in close proximity to the ER in cells. Protein cargo moves from the ER to the Golgi, is modified within the Golgi, and is then sent to various destinations in the cell, including the lysosomes and the cell surface. Three different types of vesicles:

| Types | Description | Example |
|---|---|---|
| **Exocytotic vesicles** ***(constitutive)*** | Vesicle contains proteins destined for extracellular release. After packaging, the vesicles bud off and immediately move towards the plasma membrane, where they fuse and release the contents into the extracellular space in a process known as *constitutive secretion*. | Antibody release by activated plasma B cells |
| **Secretory vesicles** ***(regulated)*** | Vesicles contain proteins destined for extracellular release. After packaging, the vesicles bud off and are stored in the cell until a signal is given for their release. When the appropriate signal is received they move toward the membrane and fuse to release their contents. This process is known as *regulated secretion*. | Neurotransmitter release from neurons |
| **Lysosomal vesicles** | Vesicles contain proteins and ribosomes destined for the lysosome, a degradative organelle containing many acid hydrolases, or to lysosome-like storage organelles. These proteins include both digestive enzymes and membrane proteins. The vesicle first fuses with the late endosome, and the contents are then transferred to the lysosome via unknown mechanisms. | Digestive proteases destined for the lysosome |

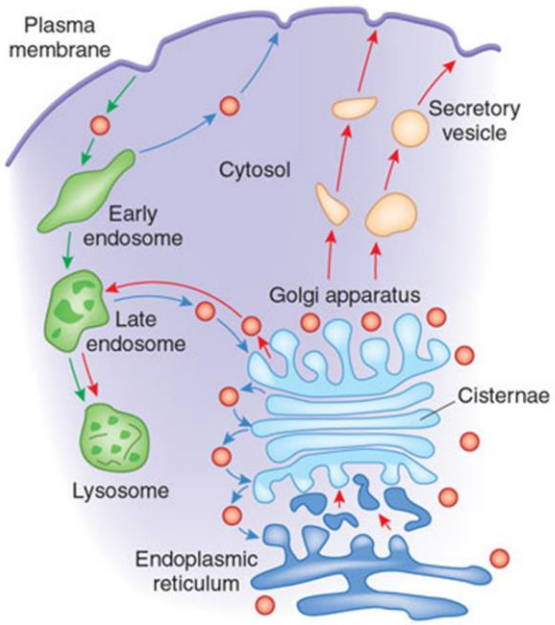



Fig (24) The Golgi apparatus at work

https://microbenotes.com/golgi-apparatus-structure-and-functions/

## 3- Lysosome (Function and structure)

### Lysosome Definition:

Lysosomes are specialized vesicles within cells that digest large molecules through the use of hydrolytic enzymes. Vesicles are small spheres of fluid surrounded by a lipid bilayer membrane, and they have roles in transporting molecules within the cell.

Lysosomes are only found in animal cells; a human cell contains around 300 of them. Not only do they digest large molecules, they are also responsible for breaking down and getting rid of waste products of the cell. Lysosomes contain over 60 different enzymes that allow them to carry out these processes.

**Functions of the Lysosome**

Lysosomes digest many complex molecules such as carbohydrates, lipids, proteins, and nucleic acids, which the cell then recycles for other uses. The pH of lysosomes is acidic (around pH 5) because their hydrolytic enzymes function best at this pH instead of at the neutral pH of the rest of the cell. Hydrolytic enzymes specifically break down large molecules through hydrolysis. During the process of hydrolysis, a molecule of water is added to a substance, causing it to cleave. Like the digestive system of the human body, which breaks down food using enzymes, the lysosome can be thought of as the “digestive system” of the cell because it breaks down molecules using enzymes.

The primary function of lysosomes in the cell is to break down materials. Lysosomes serve many purposes in the cell, such as:

- Breaking down larger polymers
- Digesting food
-Digesting extracellular material
-Aiding in the immune response
-Breaking down worn out cellular components
-Participating in apoptosis

Lysosomes break down larger polymers, such as lipids, carbohydrates, and proteins into their component parts. As a result, some protists use lysosomes to help digest food taken in from the environment.

In human cells, lysosomes are important for breaking down extracellular debris, including viruses and bacteria. Lysosomes are an important part of the immune response for phagocytic cells like macrophages. These cells hunt down and capture pathogens in endosomes within the cell. These endosomes fuse with lysosomes to allow for the destruction of the pathogen and isolation of antigens that can be used to activate other immune cells.

Lysosomes can also digest worn out intracellular components, such as entire organelles. During the process of programmed cell death, or apoptosis, lysosomes help to break down cell parts and destroy the cell itself.

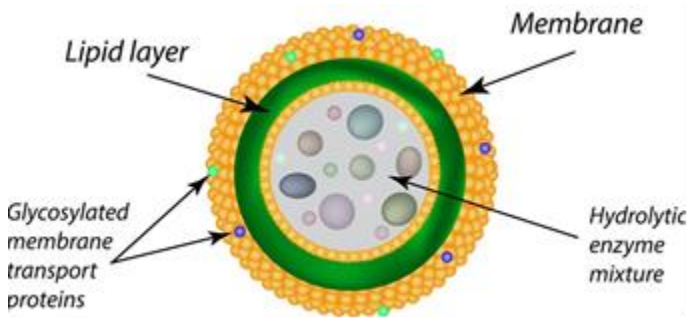



Fig (25) Diagram of Lysosomes

**Lysosomal Enzymes**

For degradation of extra and intracellular material, lysosomes filled with enzymes called hydrolases. It contains about 40 varieties of enzymes which are classified into the following main types, namely:

- Proteases, which digest proteins
- Lipases, which digests lipids
- Amylase, which digests carbohydrates
- Nucleases, which digest nucleic acids
- Phosphoric acid monoesters

Collectively the group of enzymes is called hydrolases which cause cleavage of substrates by the addition of water molecules. Most of the lysosomal enzymes function in the acidic medium.

- Although it may seem dangerous for cells to contain enzymes that can digest most biological molecules, the contents of the cell are doubly protected from the digestive enzymes of the lysosome. First, the enzymes are enclosed in the lysosomal membrane and second, even if the enzymes were to leak out of the lysosome, they would not be active at the neutral pH of the cytosol.
- A group of genetic disorders caused by defective lysosomal enzymes, demonstrates the importance of lysosomes. Called lysosomal storage diseases, these disorders are characterized by the harmful accumulation of undigested substances.

## Types of Lysosomes

**Primary Lysosomes:** Small sac-like structures enclosing enzymes synthesized by the rough endoplasmic reticulum- Simply called as storage granules storing enzymes.

**Secondary Lysosomes**: Formed by the fusion of primary lysosome with phagosomes- Contain engulfed material plus enzymes- Materials are progressively digested.

## Other functions of Lysosomes

### 1- Lysosomes serve two major functions:

- Intracellular Digestion
- To digest food, the lysosome membrane fuses with the membrane of food vacuole and squirts the enzymes inside.
- The digested food then diffuses through the vacuole membrane and enters the cell to be used for energy and growth.

### 2- Autolytic Action

- Cell organelles that need to be get ridden are covered by vesicles or vacuoles by the process of autophagy to form autophagosome.
- The autophagosome is then destroyed by the action of lysosomal enzymes.

Processes in which lysosomes play crucial roles include:

### a- Heterophagy

The taking into the cell of exogenous material by phagocytosis or pinocytosis and the digestion of the ingested material after fusion of the newly formed vacuole with a lysosome.

**b. Autophagy**

A normal physiological process that deals with the destruction of cells in the body. It is essential for maintaining homeostasis, for normal functioning by protein degradation, turnover of destroyed cell organelles for new cell formation

**c. Extracellular Digestion**

Primary lysosomes secrete hydrolases outside by exocytosis resulting in degradation of extracellular materials. Eg. Saprophytic fungi

**d. Autolysis**

It refers to the killing of an entire set of cells by the breakdown of the lysosomal membrane. It occurs during amphibian and insect metamorphosis.

**e. Fertilization**

The acrosome of the sperm head is a giant lysosome that ruptures and releases enzymes on the surface of the egg. This provides the way for sperm entry into the egg by digesting the egg membrane.

f. As Janitors of the Cell

Lysosomes remove ‘junk’ that may accumulate in the cell helping to prevent diseases.

## Synthesis

The lysosome and the enzymes within it are synthesised separately. Lysosomal proteins are formed in the same way as any other protein. The first step is the initiatiation of mRNA strand production from relevant DNA segments. The mRNA strands proceed to the rough endoplasmic reticulum, where ribosomes construct the hydrolytic enzymes.

Importantly, these are tagged with mannose-6-phosphate within the Golgi apparatus to target them to the lysosome. As a result, vesicles containing these enzymes bud off from the Golgi apparatus. Two enzymes are responsible for the attachment of the mannose-6-phosphate tag: N-acetylglucosamine phosphotransferase and N-acetylglucosamine phosphoglycosidase.

This vesicle, now in the cytoplasm, then binds with a late endosome which is another acidic, membrane-bound organelle. The late endosome has proton pumps within its membrane that keep its internal environment acidic. The low pH causes dissociation of the protein from the mannose-6-phosphate receptor. This receptor can then be recycled back to the Golgi apparatus.

The phosphate group is also removed from the mannose-6-phosphate tag, to prevent the whole protein returning to the Golgi apparatus. The late endosome can eventually mature into a lysosome, after it has received the enzymes from the Golgi apparatus.

The hydrolytic enzymes contained within the lysosome allow foreign particles to be destroyed. Lysosomes play an important role in phagocytosis. When macrophages phagocytose foreign particles, they contain them within a phagosome. The phagosome will then bind with a lysosome to form a phagolysosome. These enzymes are critical in oxygen-independent killing mechanisms. Lysosomes also help to defend against pathogen entry via endocytosis by degrading pathogens before they reach the cytoplasm.

Lysosomes digest several different kinds of molecules. They can digest food molecules that enter the cell into smaller pieces if an endocytic vesicle (a vesicle that brings particles into the cell) fuses with them. They can also perform autophagy, which is the destruction of improperly functioning organelles. In addition, lysosomes have a role in phagocytosis, which is when a cell engulfs a molecule in order to

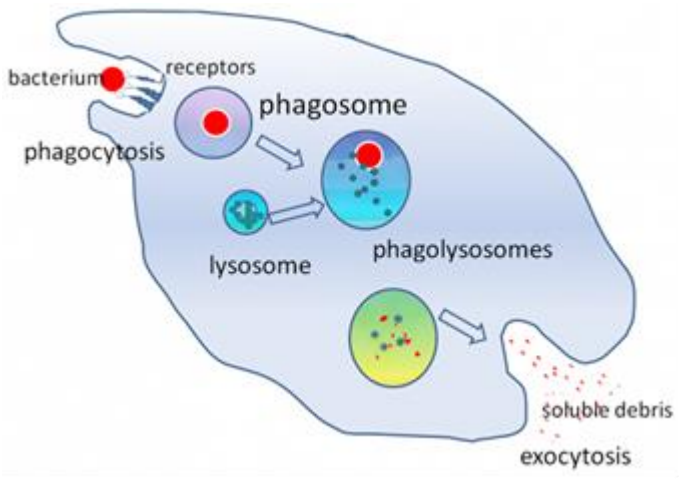



Fig (26) Lysosomes also help to defend against Pathogen

break it down; it is also known as “cell eating”. For example, the white blood cells called phagocytes ingest invading bacteria in order to break it down and destroy it, and the bacteria is enclosed by a vesicle that lysosomes fuse with. These lysosomes then break down the bacteria.

## Lysosome Structure

A lysosome is a membrane-bound organelle found in nearly all animal cells. They are spherical vesicles which contain hydrolytic enzymes that can break down many kinds of biomolecules. Simply a lysosome is a type of vesicle with specific

composition, of both its membrane proteins and proteins of its lumen. The lumen's pH (4.5–5.0 (is optimal for the enzymes involved in hydrolysis, analogous to the activity of the stomach. The size of lysosomes varies from 0.1 μm to 1.2 μm. The interior of the lysosomes is acidic compared to the slightly basic cytosol pH 7.2. The lysosomal membrane protects the cytosol, and therefore the rest of the cell, from the degradative enzymes within the lysosome. The cell is additionally protected from any lysosomal acid hydrolases that drain into the cytosol, as these enzymes are pH-sensitive and do not function well or at all in the alkaline environment of the cytosol. The lysosomes act by digesting unwanted materials in the cytoplasm, both from outside the cell and obsolete components inside the cell. Material from outside the cell is taken-up through endocytosis, while material from the inside of the cell is digested through autophagy. Their sizes can be very different; the biggest ones can be more than 10 times bigger than the smallest ones. They were discovered and named by Belgian biologist Christian de Duve, who eventually received the Nobel Prize in Physiology in 1974. Lysosomes are known to contain more than 60 different enzymes. Enzymes of the lysosomes are

synthesised in the rough endoplasmic reticulum. The enzymes are imported from the Golgi apparatus in small vesicles, which fuse with larger acidic vesicles. Synthesis of lysosomal enzymes is controlled by nuclear genes. Mutations in the genes for these enzymes are responsible for more than 30 different human genetic diseases, which are collectively known as lysosomal storage diseases. These genetic defects are related to several neurodegenerative disorders, cancer, cardiovascular diseases and ageing-related diseases.

https://en.wikipedia.org/wiki/Lysosome 

## A peroxisome:

Aperoxisome is a membrane-bound organelle, a type of microbody, found in the cytoplasm of virtually all eukaryotic cells. Peroxisomes are oxidative organelles. Frequently, molecular oxygen serves as a co-substrate, from which hydrogen peroxide (H2O2) is then formed. Peroxisomes owe their name to hydrogen peroxide generating and scavenging activities. They perform key roles in lipid metabolism

and the conversion of reactive oxygen species. Peroxisomes are involved in the catabolism of very long chain fatty acids, branched chain fatty acids, bile acid intermediates (in the liver), D-amino acids, and polyamines, the reduction of reactive oxygen species – specifically hydrogen peroxide– and the biosynthesis of plasmalogens, i.e., ether phospholipids critical for the normal function of mammalian brains and lungs. They also contain approximately 10% of the total activity of two enzymes (Glucose-6-phosphate dehydrogenase and 6-Phosphogluconate dehydrogenase) in the pentose phosphate pathway, which is important for energy metabolism. It is vigorously debated whether peroxisomes are involved in isoprenoid and cholesterol synthesis in animals.

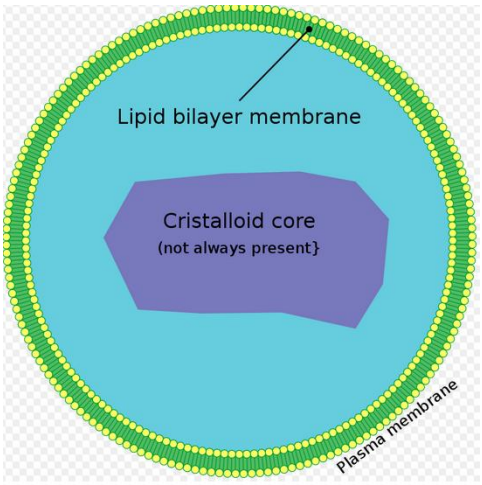



Fig (27) Basic structure of a peroxisome

## Structural Design

Peroxisomes are small (0.1–1 μm diameter) subcellular compartments (organelles) with a fine, granular matrix and surrounded by a single biomembrane which are located in the cytoplasm of a cell. Compartmentalization creates an optimized environment to promote various metabolic reactions within peroxisomes required to sustain cellular functions and viability of the organism.

The number, size and protein composition of peroxisomes are variable and depend on cell type and environmental conditions.

### Metabolic functions

A major function of the peroxisome is the breakdown of very long chain fatty acids through beta oxidation. In animal cells, the long fatty acids are converted to medium chain fatty acids, which are subsequently shuttled to mitochondria where they eventually are broken down to carbon dioxide and water. In yeast and plant cells, this process is carried out exclusively in peroxisomes.

The first reactions in the formation of plasmalogen in animal cells also occur in peroxisomes. Plasmalogen is the most abundant phospholipid in myelin. Deficiency of plasmalogens causes profound

abnormalities in the myelination of nerve cells, which is one reason why many peroxisomal disorders affect the nervous system. Peroxisomes also play a role in the production of bile acids important for the absorption of fats and fat-soluble vitamins, such as vitamins A and K. Skin disorders are features of genetic disorders affecting peroxisome function as a result. The specific metabolic pathways that occur exclusively in mammalian peroxisomes are:

- α-oxidation of phytanic acid
- β-oxidation of very-long-chain and polyunsaturated fatty acids
- biosynthesis of plasmalogens
- conjugation of cholic acid as part of bile acid synthesis

Peroxisomes contain oxidative enzymes, such as D-amino acid oxidase and uric acid oxidase. However the last enzyme is absent in humans, explaining the disease known as gout, caused by the accumulation of uric acid. Certain enzymes within the peroxisome, by using molecular oxygen, remove hydrogen atoms from specific organic substrates, in an oxidative reaction, producing hydrogen peroxide (H2O2, itself toxic).

Peroxisomes in mammals and humans also contribute to anti-viral defense. and the combat of pathogens.

Peroxisomes can be derived from the smooth endoplasmic reticulum under certain experimental conditions and replicate by membrane growth and division out of pre-existing organelles. Peroxisome matrix proteins are translated in the cytoplasm prior to import.

## Peroxisome interaction and communication

The diverse functions of peroxisomes require dynamic interactions and cooperation with many organelles involved in cellular lipid metabolism such as the endoplasmic reticulum (ER), mitochondria, lipid droplets, and lysosomes.

Peroxisomes interact with mitochondria in several metabolic pathways, including β-oxidation of fatty acids and the metabolism of reactive oxygen species. Both organelles are in close contact with the endoplasmic reticulum (ER) and share several proteins, including organelle fission factors. Peroxisomes also interact with the endoplasmic reticulum (ER) and cooperate in the synthesis of ether lipids (plasmalogens) which are important for nerve cells. https://en.wikipedia.org/wiki/Peroxisome

## Double membrane organelles:

## 1- Mitochondria:

## Structure

Mitochondria are often referred to as the powerhouses of the cell. They help turn the energy we take from food into energy that the cell can use.

Mitochondria are small, often between 0.75 and 3 micrometers and are not visible under the microscope unless they are stained.

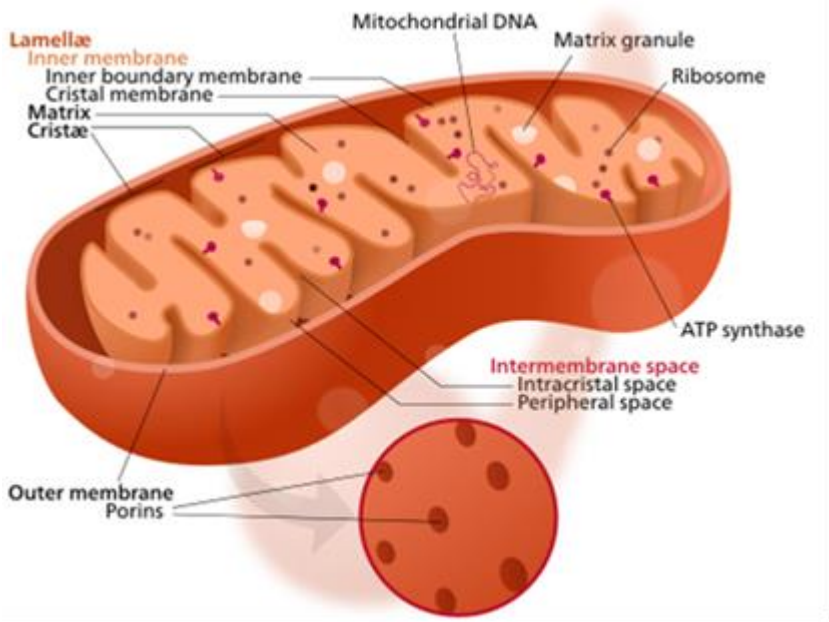



Fig. (28) Structure of mitochondria

**Mitochondrial DNA**

Although most of our DNA is kept in the nucleus of each cell, mitochondria have their own set of DNA. Interestingly, mitochondrial DNA (mtDNA) is more similar to bacterial DNA.

The mtDNA holds the instructions for a number of proteinsTrusted Source and other cellular support equipment across 37 genes.

The human genome stored in the nuclei of our cells contains around 3.3 billion base pairs, whereas mtDNA consists of less than 17,000 Trusted Source.

## Mitochondria function

The most prominent roles of mitochondria are to produce the energy currency of the cell, ATP, through respiration and to regulate cellular metabolism. The central set of reactions involved in ATP production are collectively known as the citric acid cycle, or the Krebs cycle, and oxidative phosphorylation. However, the mitochondrion has many other functions in addition to the production of ATP.

## - Producing energy

A dominant role for the mitochondria is the production of ATP, as reflected by the large number of proteins in

the inner membrane for this task. This is done by oxidizing the major products of glucose. This type of cellular respiration, known as aerobic respiration, is dependent on the presence of oxygen. When oxygen is limited, the glycolytic products will be metabolized by anaerobic fermentation, a process that is independent of the mitochondria. The production of ATP from glucose and oxygen has an approximately 13-times higher yield during aerobic respiration compared to fermentation. ATP crosses out through the inner membrane with the help of a specific protein, and across the outer membrane via pores.

ATP, a complex organic chemical found in all forms of life, is often referred to as the molecular unit of currency because it powers metabolic processes. Most ATP is produced in mitochondria through a series of reactions, known as the citric acid cycle or the Krebs cycle.

Energy production mostly takes place on the folds or cristae of the inner membrane.

Mitochondria convert chemical energy from the food we eat into an energy form that the cell can use. This process is called oxidative phosphorylation.

The Krebs cycle produces a chemical called NADH. NADH is used by enzymes embedded in the cristae to

produce ATP. In molecules of ATP, energy is stored in the form of chemical bonds. When these chemical bonds are broken, the energy can be used.

## - Cell death

- Cell death, also called apoptosis, is an essential part of life. As cells become old or broken, they are cleared away and destroyed. Mitochondria help decide which cells are destroyed.
- Mitochondria release cytochrome C, which activates caspase, one of the chief enzymes involved in destroying cells during apoptosis.
- Because certain diseases, such as cancer, involve a breakdown in normal apoptosis, mitochondria are thought to play a role in the disease.

## - Storing calcium

Calcium is vital for a number of cellular processes. For instance, releasing calcium back into a cell can initiate the release of a neurotransmitter from a nerve cell or hormones from endocrine cells. Calcium is also necessary for muscle function, fertilization, and blood clotting, among other things.
Because calcium is so critical, the cell regulates it

tightly. Mitochondria play a part in this by quickly absorbing calcium ions and holding them until they are needed.

Other roles for calcium in the cell include regulating cellular metabolism, steroid synthesis, and hormone signaling Trusted Source.

## - Heat production

When we are cold, we shiver to keep warm. But the body can also generate heat in other ways, one of which is by using a tissue called brown fat.

During a process called proton leak Trusted Source, mitochondria can generate heat. This is known as non-shivering thermogenesis. Brown fat is found at its highest levels in babies, when we are more susceptible to cold, and slowly levels reduce as we age.

## - Additional functions

Mitochondria play a central role in many other metabolic tasks, such as:

- Signaling through mitochondrial reactive oxygen species.
- Regulation of the membrane potential.
- Apoptosis-programmed cell death.

- Calcium signaling (including calcium-evoked apoptosis).
- Regulation of cellular metabolism.
- Certain hemi synthesis reactions
- Steroid synthesis.
- Hormonal signaling Mitochondria are sensitive and responsive to hormones, in part by the action of mitochondrial estrogen receptors (mtERs). These receptors have been found in various tissues and cell types, including brain and heart .
- Immune signaling
- Neuronal mitochondria also contribute to cellular quality control by reporting neuronal status towards microglia through specialised somatic-junctions

## Organization and distribution

A single mitochondrion is often found in unicellular organisms, while human liver cells have about 1000–2000 mitochondria per cell, making up 1/5 of the cell volume.

Mitochondria in cells are always distributed along microtubules and the distribution of these organelles is also correlated with the endoplasmic reticulum.

## Genome:

Mitochondria contain their own genome. The human mitochondrial genome is a circular double-stranded DNA molecule of about 16 kilobases. It encodes 37 genes: 13 for subunits of respiratory complexes I, III, IV and V, 22 for mitochondrial tRNA (for the 20 standard amino acids, plus an extra gene for leucine and serine), and 2 for rRNA (12S and 16S rRNA. One mitochondrion can contain two to ten copies of its DNA. One of the two mitochondrial DNA (mtDNA) strands has a disproportionately higher ratio of the heavier nucleotides adenine and guanine, and this is termed the heavy strand (or H strand), whereas the other strand is termed the light strand (or L strand). The weight difference allows the two strands to be separated by centrifugation.

## DNA repair

Mitochondria can repair oxidative DNA damage by mechanisms analogous to those occurring in the cell nucleus. The proteins employed in mtDNA repair are encoded by nuclear genes, and are translocated to the mitochondria. The DNA repair pathways in mammalian mitochondria include base excision repair,

double-strand break repair, direct reversal and mismatch repair.

Of the several DNA repair process in mitochondria, the base excision repair pathway has been most comprehensively studied. Base excision repair is carried out by a sequence of enzyme-catalyzed steps that include recognition and excision of a damaged DNA base, removal of the resulting a basic site, end processing, gap filling and ligation. A common damage in mtDNA that is repaired by base excision repair is 8-oxoguanine produced by oxidation of guanine.

**https://en.wikipedia.org/wiki/Mitochondrion**

## 3- Non membranous organelles

## 1- Ribosomes

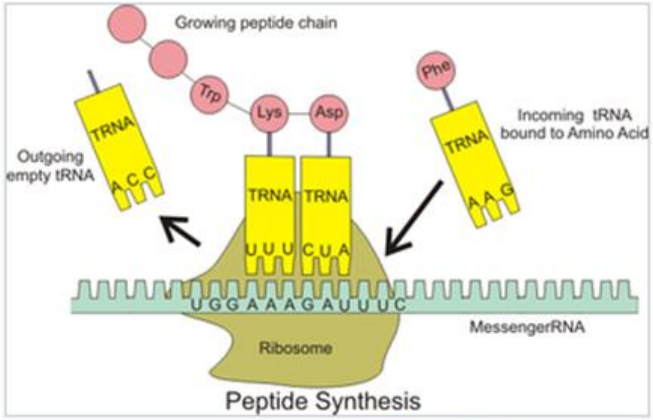



**Figure 1 :** Ribosomes assemble polymeric protein molecules whose sequence is controlled by the sequence of messenger RNA molecules. This is required by all living cells and associated viruses.

**Fig (29) Ribosomes in work**

## 2- Centriole

A centriole is a cylindrical cell structure, composed mainly of a protein called tubulin that is found in most eukaryotic cells. An associated pair of centrioles, surrounded by a shapeless mass of dense material, called the pericentriolar material, makes up a compound structure called a centrosome. Centrioles are present in the cells of most eukaryotes. Most

centrioles are made up of nine sets of microtubule triplets, arranged in a cylinder with a

9 + 0 pattern of microtubule triplets-that is, nine sets of triplets occur in a ring, and none are in the middle of the cylinder, deviations from this structure early embryos, with nine singlets. In animal cells two centrioles lie at right angles to one another in the middle of a centrosome. The main function of centrioles is to produce cilia during interphase and the spindle during cell division.

## Replication

In cells where centrioles are present as a pair, replication takes place during the whole of the cell cycle. In phase G1 the two centriole cylinders move very slightly apart from one another. During S phase new cylinders of microtubules form near, and at right angles to, the two ‘mother’ cylinders. The two pairs of centrioles keep very close to one another until the prophase stage of mitosis. At this point they separate with both pairs of centrioles moving over the outer surface of the nuclear envelope to opposite ends or ‘poles’ of the cell, to form the astral poles of the dividing cell.

The main function of centrioles is to produce cilia during interphase and the aster and the spindle during cell division.

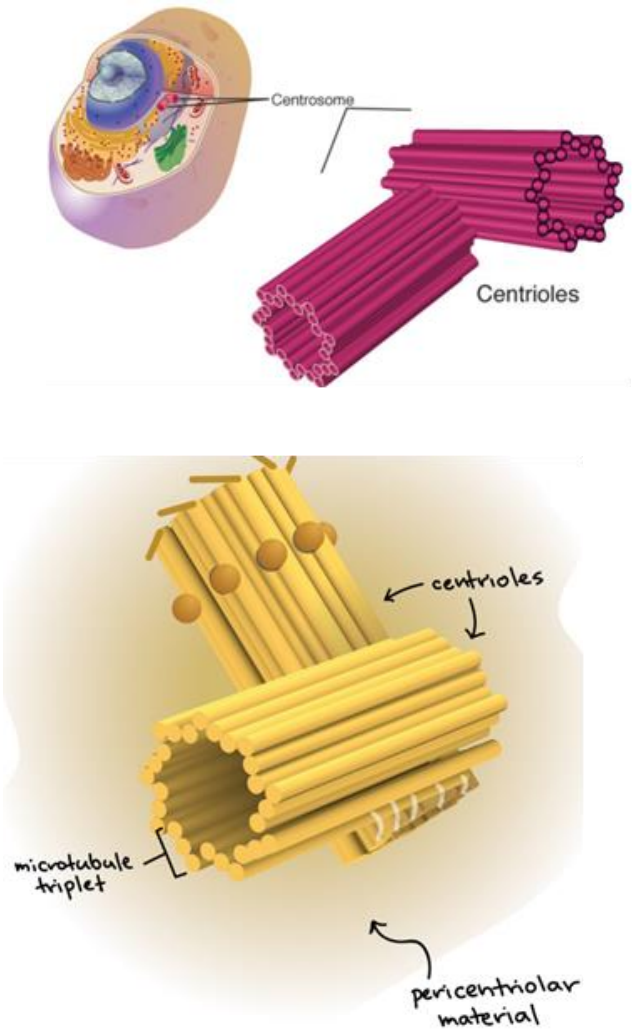



Fig.(30) Structure of centrioles

## Cellular organization

Centrioles are a very important part of centrosomes, which are involved in organizing microtubules in the cytoplasm. The position of the centriole determines the position of the
nucleus and plays a crucial role in the spatial arrangement of the cell.

### Fertility

Sperm centrioles are important for 2 functions: (1) to form the sperm flagellum and sperm movement and (2) for the development of the embryo after fertilization. The sperm supplies the centriole that creates the centrosome and microtubule system of the zygote.

### Animal development

Proper orientation of cilia via centriole positioning toward the posterior of embryonic node cells is critical for establishing left-right asymmetry, during mammalian development.

## Main Functions

During mitosis or cell division, the centrosome and centrioles replicate and migrate to opposite ends of the cell. Centrioles help to arrange the microtubules that move chromosomes during cell division to ensure each daughter cell receives the appropriate number of chromosomes.

Centrioles are also important for the formation of cell structures known as cilia and flagella. Cilia and flagella, found on the outside surface of cells, aid in cellular movement. A centriole combined with several additional protein structures is modified to become a basal body. Basal bodies are the anchoring sites for moving cilia and flagella.

### Important Role in Cell Division

Centrioles are located outside of, but near the cell nucleus. In cell division, there are several phases: in order of occurrence they are interphase, prophase, metaphase, anaphase, and telophase. Centrioles have a very important role to play in all phases of cell division. The end goal is in moving replicated chromosomes into a newly created cell.

**- Interphase and Replication,** In the first phase of mitosis, called interphase, centrioles replicate. which marks the start of mitosis and meiosis in the cell cycle.

- **Prophase and Asters and the Mitotic Spindle**, In prophase, each centrosome with centrioles migrates toward opposite ends of the cell. A single pair of centrioles is positioned at each cell pole. The mitotic spindle initially appears as structures called asters which surround each centriole pair. Microtubules form spindle fibers that extend from each centrosome, thereby separating centriole pairs and elongating the cell.

- **Metaphase and Positioning of Polar Fibers,** In metaphase, centrioles help to position polar fibers as they extend from the centrosome and position chromosomes along the metaphase plate.

**- Anaphase and the Sister Chromatids,** In anaphase, polar fibers connected to chromosomes shorten and separate the sister chromatids (replicated chromosomes). The separated chromosomes are pulled toward opposite ends of the cell by polar fibers extending from the centrosome.

**- Telophase and Two Genetically Identical Daughter Cells,** In telophase, the spindle fibers disperse as the chromosomes are cordoned off into

distinct new nuclei. After cytokinesis, which is the division of the cell's cytoplasm, two genetically identical daughter cells are produced each containing one centrosome with one centriole pair.

## 3- Cytoskeleton

A cytoskeleton is present in all cells of eukaryotes. It is a complex network of interlinking filaments and tubules that extend throughout the cytoplasm, from the nucleus to the plasma membrane. The cytoskeletal systems of different organisms are composed of similar proteins. In eukaryotes, the cytoskeletal matrix is a dynamic structure composed of three main proteins, which are capable of rapid growth. The structure, function and dynamic behavior of the cytoskeleton can be very different, depending on organism and cell type. Eukaryotic cells contain three main kinds of cytoskeletal filaments: Microfilaments, microtubules and intermediate filaments. Each cytoskeletal filament type is formed by polymerization of a distinct type of protein subunit and has its own characteristic shape and intracellular distribution.

**a- Microfilaments:**

Microfilaments are polymers of the protein actin and are 7 nm in diameter. Microfilaments are composed of linear polymers of G-actin proteins, actin filaments play structural roles in the cell. In most animal cells, a network of actin filaments is found in the region of cytoplasm at the very edge of the cell. This network is linked to the plasma membrane by special connector proteins, Its Functions include:

- Gives the cell shape and structure
- Muscle contraction
- Cell movement
- Intracellular transport/trafficking
- Maintenance of eukaryotic cell shape

**b- Microtubules:**

Microtubules are composed of tubulin and are 25 nm in diameter. Microtubules are hollow cylinders about 23 nm in diameter, are polymers of alpha and beta tubulin. They have a very dynamic behavior, They are commonly organized by the centrosome. In nine triplet sets (star-shaped), they form the centrioles "9+0", and in nine doublets oriented about two

additional microtubules (wheel-shaped), they form cilia and flagella. The latter formation is commonly referred to as a "9+2" arrangement, wherein each doublet is connected to another by the protein dynein. As both flagella and cilia are structural components of the cell, and are maintained by microtubules, they can be considered part of the cytoskeleton. Cilia are short and more numerous than flagella. Additionally, the microtubules control the movement of the cilia and flagella. In addition to providing structural support, microtubules play a variety of more specialized roles in a cell. For instance, they provide tracks for motor proteins called kinesins and dyneins, which transport vesicles around the interior of the cell. During cell division, microtubules assemble into a structure called the spindle, which pulls the chromosomes apart. Other functions are:

1- They are involved in maintaining the structure of the cell and together with microfilaments and intermediate filaments, they form the cytoskeleton.

2- Microtubules are also key components of three more specialized eukaryotic cell structures: flagella, cilia and centrosomes.

3- They provide platforms for intracellular transport and are involved in a variety of cellular processes,

including the movement of secretory vesicles, organelles and intracellular macromolecular.

4- They are also involved in chromosome separation mitosis and meiosis and are the major constituents of mitotic spindles.

**c- Intermediate filaments:**

Intermediate filaments are composed of various proteins, depending on the type of cell in which they are found, they are normally 8-12 nm in diameter. Intermediate filaments are a part of the cytoskeleton of many eukaryotic cells. These filaments are more stable than actin filaments, and heterogeneous constituents of the cytoskeleton. Like actin filaments, they function in the maintenance of cell-shape by bearing tension microtubules by contrast, resist compression but can also bear tension during mitosis and during the positioning of the centrosome. Intermediate filaments organize the internal tridimensional structure of the cell, anchoring organelles and serving as structural components of the nuclear lamina. They also participate in some cell-cell and cell-matrix junctions. They also provide protection for organs against metabolic, oxidative, and chemical stresses. Strengthening of epithelial cells

with these intermediate filaments may prevent onset of apoptosis, or cell death, by reducing the probability of stress. Intermediate filaments are most commonly known as the support system for the cell and nucleus.

## Functions of the cytoskeleton

There is a multitude of functions that the cytoskeleton can perform;

1- It gives the cell its shape and mechanical resistance to deformation, and through association with extracellular connective tissue and other cells it stabilizes entire tissues.

2- It is involved in many cell signaling pathways: in the uptake of extracellular material endocytosis.

3-Segregates chromosomes during cellular division

is involved in the division of a mother cell into two daughter cells.

4- Provides a scaffold to organize the contents of the cell in space and for intracellular transport. For example, the movement of vesicles and organelles within the cell.

5- It forms specialized structures, such as flagella and cilia.

6- A large-scale example of an action performed by the cytoskeleton is muscle contraction. In the muscle,

there are groups of highly specialized cells that work together to perform a function known as muscle contraction. A main component in the cytoskeleton that helps show the true function of this muscle contraction is known as a microfilament.

**How Do Cells Move?**

Cytoskeletal filaments provide the basis for cell movement. For instance, cilia and (eukaryotic) flagella move as a result of microtubules sliding along each other. In fact, cross sections of these tail-like cellular extensions show organized arrays of microtubules.

Other cell movements, such as the pinching off of the cell membrane in the final step of cell division (also known as cytokinesis) are produced by the contractile capacity of actin filament networks. Actin filaments are extremely dynamic and can rapidly form and disassemble. In fact, this dynamic action underlies the crawling behavior of cells such as amoebae. At the leading edge of a moving cell, actin filaments are rapidly polymerizing; at its rear edge, they are quickly depolymerizing . A large number of other proteins participate in actin assembly and disassembly as well.

https://www.nature.com/scitable/topicpage/microtubules-and-filaments-

## Cell junction:

Cell junctions (or intercellular bridges) are a class of cellular structures consisting of multiprotein complexes that provide contact or adhesion between neighboring cells or between a cell and the extracellular matrix in animals. They also maintain the paracellular barrier of epithelia and control paracellular transport. Cell junctions are especially abundant in epithelial tissues. Combined with cell adhesion molecules and extracellular matrix, cell junctions help hold animal cells together.

Cell junctions are also especially important in enabling communication between neighboring cells via specialized protein complexes called communicating (gap) junctions. Cell junctions are also important in reducing stress placed upon cells.

**In vertebrates, there are three major types of cell junction:**

- Adherens junctions, desmosomes and hemidesmosomes (anchoring junctions)
- Gap junctions (communicating junction)
- Tight junctions (occluding junctions)

## Anchoring junctions

Cells within tissues and organs must be anchored to one another and attached to components of the extracellular matrix. Cells have developed several types of junctional complexes to serve these functions, and in each case, anchoring proteins extend through the plasma membrane to link cytoskeletal proteins in one cell to cytoskeletal proteins in neighboring cells as well as to proteins in the extracellular matrix.

Three types of anchoring junctions are observed, and differ from one another in the cytoskeletal protein anchor as well as the transmembrane linker protein that extends through the membrane.

Anchoring-type junctions not only hold cells together but provide tissues with structural cohesion. These junctions are most abundant in tissues that are subject to constant mechanical stress such as skin and heart.

https://en.wikipedia.org/wiki/Cell_junction 

**Question on the second chapter:**

**Write on the following**

1- The function of the rough endoplasmic reticulum

2- A purpose of lysosomes

3- What mitochondria does

4- Which cell would have the largest number of mitochondria

5- A type of cell that would have large amounts of smooth endoplasmic reticulum

6- Define cytosol

7- Explain what the Golgi apparatus is essential for

8- Describe what peroxisomes contain

9- Identify which cells require a large amount of ATP

**Multiple Choice Questions:**

**1- The organelle functions in cellular respiration…….**

a- mitochondria

b- lysosome

c- Endoplasmic reticulum

d-Golgi apparatus

**2. The organelle functions to package and deliver proteins…….**

a- lysosome

b- Endoplasmic reticulum

c- Mitochondria

d- Golgi apparatus

**3- Cell organelles are located within the ……..of the cell.**

a- Nucleus

b- Cytoplasm

c- Cell membrane

d- Lysosomes

**4. The endoplasmic reticulum functions to…….**

a- Transport materials

b- Destroy old cell parts

c- Make ribosomes

d- Package proteins

**5. Genetic material is contained within the ….of the cell.**

a- Ribosomes

b- Cytoplasm

c- Nucleus

d- Nucleolus

**6. This organelle is responsible for destroying worn-out cell parts…….**

a- Lysosomes

b- Mitochondrion

c- Golgi apparatus

d- Ribosomes

**7. The ……. controls what enters and leaves the cell.**

a- Mitochondrion

b- Golgi apparatus

c- Nucleus

d- Cell membrane

8. The rough endoplasmic reticulum has …… located on it.

a- Lysosomes

b- Cytosol

c- Ribosomes

d- Proteins

**9. Located within the nucleus, it is responsible for producing ribosomes…….**

a- Centrosome

b- Nucleolus

c- Lysosome

d- Endoplasmic reticulum

# Third chapter

# Cell nucleus

# Cell nucleus

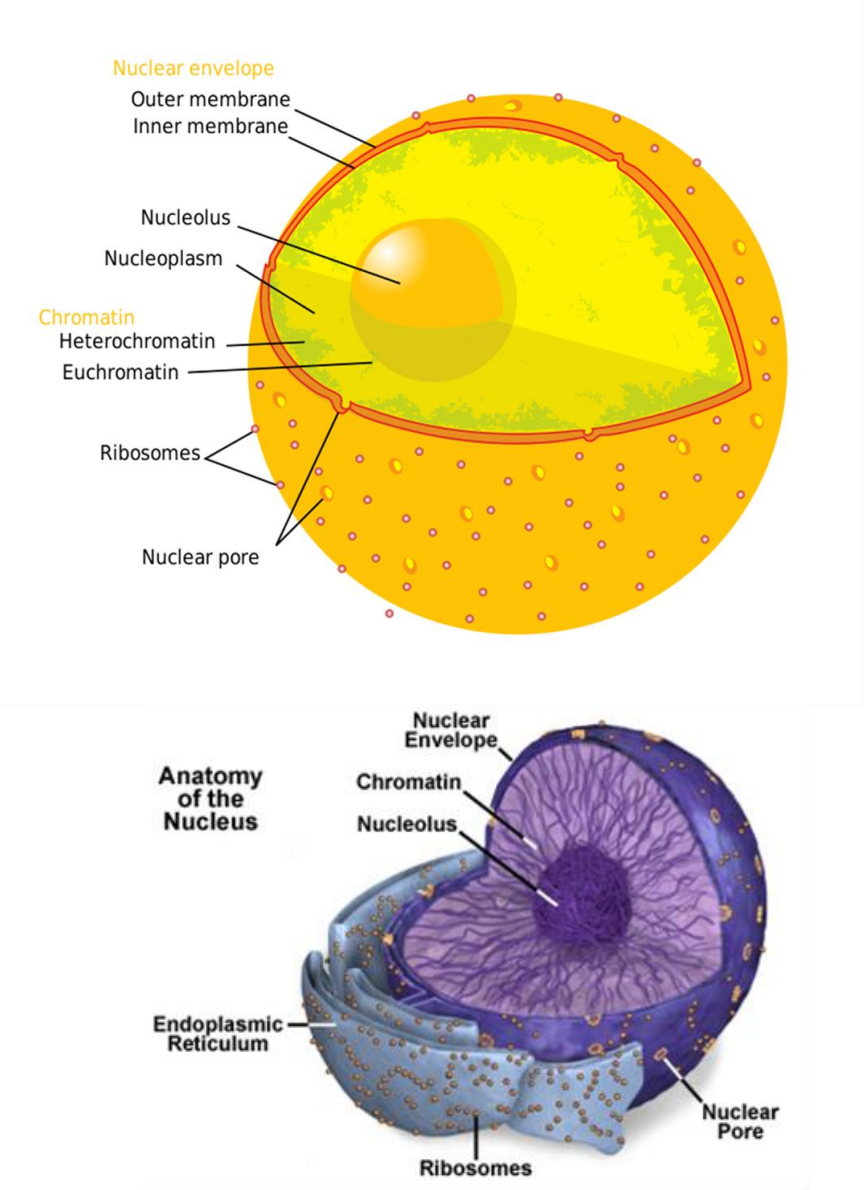



Fig. (31) Structure of the nucleus

The nucleus is the largest cellular organelle in animal cells. In mammalian cells, the average diameter of the nucleus is approximately 6 micrometres6) µm), which occupies about 10% of the total cell volume . The liquid within it is called nucleoplasm, and is similar in composition to the cytosol found outside the nucleus. It appears as a dense, roughly spherical or irregular organelle. The composition by dry weight of the nucleus is approximately: DNA 9%, RNA 1%, Histone Protein 11%, Residual Protein 14%, and Acidic Proteins 65%. It structure from:

1- Nuclear envelope and pores

2- Chromosomes

3- Nucleolus

**1- Nuclear envelope and pores:**

The nuclear envelope is a double-layered membrane that encloses the contents of the nucleus during most of the cell's lifecycle. The nuclear envelope consists of two cellular membranes, an inner and an outer membrane, arranged parallel to one another and separated by 10 to 50 nanometres. The nuclear envelope completely encloses the nucleus and separates the cell's genetic material from the

surrounding cytoplasm, serving as a barrier to prevent macromolecules from diffusing freely between the nucleoplasm and the cytoplasm. The outer nuclear membrane is continuous with the membrane of the rough endoplasmic reticulum RER, and is similarly studded with ribosomes. The space between the membranes is called the perinuclear space and is continuous with the RER lumen. Nuclear pores, which provide aqueous channels through the envelope, are composed of multiple proteins. The pores are 100 nm in total diameter, however, the gap through which molecules freely diffuse is only about 9 nm wide, due to the presence of regulatory systems within the center of the pore. This size selectively allows the passage of small water-soluble molecules while preventing larger molecules, such as nucleic acids and larger proteins, from in appropriately entering or exiting the nucleus.

**2- Chromosomes:**

The cell nucleus contains the majority of the cell's genetic material in the form of multiple linear DNA molecules organized into structures called chromosomes. During most of the cell cycle these are organized in a DNA-protein complex known as

chromatin, and during cell division the chromatin can be seen to form the well-defined chromosomes familiar from a karyotype. Packed inside the nucleus of every human cell is nearly 6 feet of DNA, which is divided into 46 individual chromosomes, and each about 1.5 inches long.

**3- The nucleolus:**

The nucleolus is a densely stained structure found in the nucleus. It is not surrounded by a membrane. These regions are called nucleolar organizer regions (NOR). The main roles of the nucleolus are to synthesize rRNA and assemble ribosomes.

## Function:

The nucleus is a highly specialized organelle that serves as the information processing and administrative center of the cell. This organelle has two major functions: it stores the cell's hereditary material, or DNA, and it coordinates the cell's activities, which include growth, protein synthesis, and reproduction (cell division):

**a- protein synthesis**:

1- When the cell needs to make a protein, mRNA is created in the nucleus. The mRNA is then sent out of

the nucleus to the ribosomes. When it is time to make the protein, the two subunits come together and combine with the mRNA. The subunits lock onto the mRNA and start the protein synthesis. The process of making proteins is quite simple. First, you need an amino acid.

2- Another nucleic acid that lives in the cell is transfer RNA. tRNA is bonded to the amino acids floating around the cell. With the mRNA offering instructions, the ribosome connects to a tRNA and pulls off one amino acid. The tRNA is then released back into the cell and attaches to another amino acid. The ribosome builds a long amino acid (polypeptide) chain that will eventually be part of a larger protein.

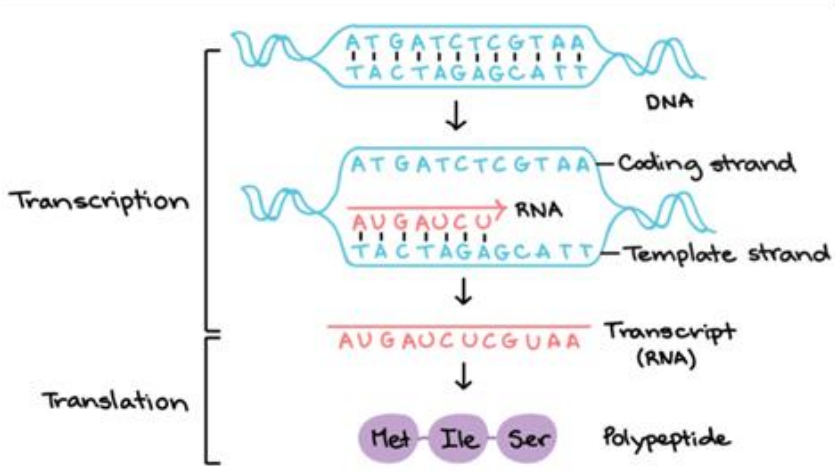



Fig. (32) steps of protein synthesis

https://en.wikipedia.org/wiki/Cell_nucleus

## c-cell division:

The cell cycle is an ordered series of events involving cell growth and cell division that produces two new daughter cells. Cells on the path to cell division proceed through a series of precisely timed and carefully regulated stages of growth, DNA replication, and division that produces two identical cells. The cell cycle has two major phases; interphase and the mitotic phase. During interphase, the cell grows and DNA is replicated. During the mitotic phase, the replicated DNA and cytoplasmic contents are separated, and the cell divides.

**1- Interphase:**

During interphase, the cell undergoes normal growth processes while also preparing for cell division. In order for a cell to move from interphase into the mitotic phase, many internal and external conditions must be met. The three stages of interphase are called G1, S, and G.2.

**a- G1 Phase (First Gap):**

During the G1 phase, the cell is accumulating the building blocks of chromosomal DNA and the associated proteins as well as accumulating sufficient energy reserves to complete the task of replicating each chromosome in the nucleus

**b-S Phase (Synthesis of DNA):**

Throughout interphase, nuclear DNA remains in a semi-condensed chromatin. In the S phase, DNA replication can proceed through the mechanisms that result in the formation of identical pairs of DNA molecules—sister chromatids—that are firmly attached to the centromeric region. The centrosome is duplicated during the S phase. The two centrosomes will give rise to the mitotic spindle, the apparatus that the movement of chromosomes during mitosis. At the center of each animal cell,

**c-G2 Phase (Second Gap):**

In the G2 phase, the cell replenishes its energy stores and synthesizes proteins necessary for chromosome. Some cell organelles are duplicated, and the cytoskeleton is dismantled to provide resources for the mitotic phase. There may be additional cell growth during G2. The final preparations for the mitotic phase must be completed before the cell is able to enter the first stage of mitosis.

**2- The Mitotic Phase:**

The mitotic phase is a multistep process during which the duplicated chromosomes are aligned, separated,

and move into two new, identical daughter cells. The first portion of the mitotic phase is called karyokinesis, or nuclear division. The second portion of the mitotic phase, called cytokinesis, is the physical separation of the cytoplasmic components into the two daughter cells. Mitosis is divided into a series of phases:

a- Prophase

b- Metaphase

c- Anaphase

d- Telophase

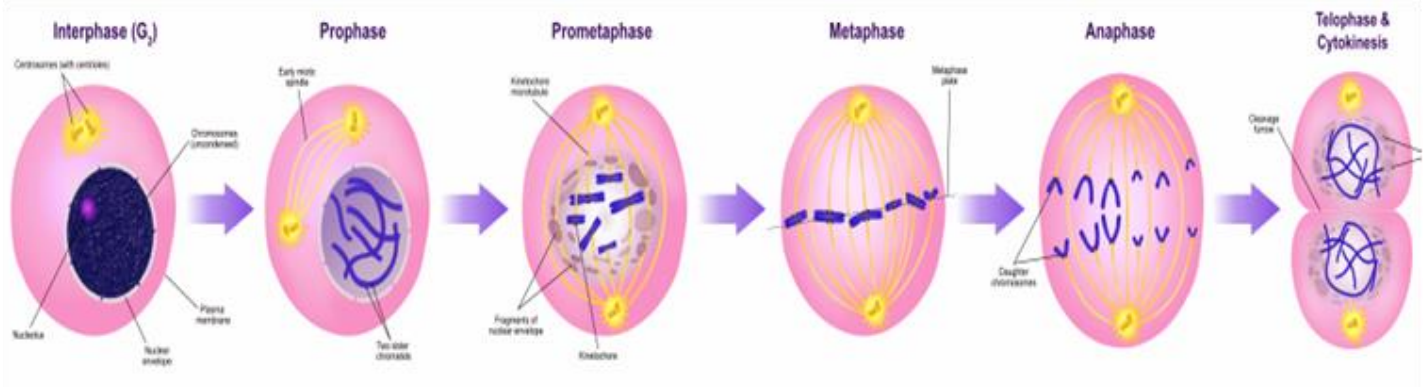
## a- Prophase:

The nuclear envelope starts to dissociate into small vesicles, and the membranous organelles (such as the Golgi apparatus, and endoplasmic reticulum), fragment and disperse toward the periphery of the cell. The nucleolus disappears. The centrosomes begin to move to opposite poles of the cell. Microtubules that will form the mitotic spindle extend between the centrosomes, pushing them farther apart as the microtubule fibers lengthen. The sister chromatids of the chromosomes begin to coil and become visible under a light microscope

**Karyokinesis:**

**b- Prometaphase:**

Many processes that were begun in prophase continue to advance. The remnants of the nuclear envelope fragment. The mitotic spindle continues to develop as more microtubules assemble and stretch across the length of the former nuclear area. Chromosomes become more condensed and discrete. Each sister chromatid develops a protein structure called a kinetochore in the centromeric region. The proteins of the kinetochore attract and bind mitotic spindle microtubules. As the spindle microtubules extend from the centrosomes, some of these microtubules come into contact with and firmly bind to the kinetochores. Once a mitotic fiber attaches to a chromosome, the chromosome will be oriented until the kinetochores of sister chromatids face the opposite poles. Eventually, all the sister chromatids will be attached via their kinetochores to microtubules from opposing poles. During metaphase, all the chromosomes are aligned in a plane called the metaphase plate, or the equatorial plane, midway between the two poles of the cell. The sister chromatids are still tightly attached to each other by cohesin proteins.




This diagram shows the five phases of mitosis and cytokinesis. During prophase, the chromosomes condense and become visible, spindle fibers emerge from the centrosomes, the nuclear envelope breaks down, and the nucleolus disappears. During prometaphase, the chromosomes continue to condense and kinetochores appear at the centromeres. Mitotic spindle microtubules attach to the kinetochores, and centrosomes move toward opposite poles. During metaphase, the mitotic spindle is fully developed, and centrosomes are at opposite poles of the cell. Chromosomes line up at the metaphase plate and each sister chromatid is attached to a spindle fiber originating from the opposite pole. During anaphase, the cohesin proteins that were binding the sister chromatids together break down. The sister chromatids, which are now called chromosomes, move toward opposite poles of the cell. During telophase, chromosomes arrive at the opposite poles and begin to decondense. The nuclear envelope reforms. During cytokinesis in animals, a cleavage furrow separates the two daughter cells.

Fig. (33) Phases of cell division

**c- Anaphase:**

The cohesin proteins degrade, and the sister chromatids separate at the centromere. Each chromatid, now called a chromosome, is pulled rapidly toward the centrosome to which its microtubule is attached. The cell becomes visibly elongated (oval shaped).

**d- Telophase**:

The chromosomes reach the opposite poles and begin to decondense relaxing into a chromatin configuration. The mitotic spindles are depolymerized into tubulin monomers that will be used to assemble cytoskeletal components for each daughter cell. Nuclear envelopes form around the chromosomes, and nucleosomes appear within the nuclear area.

## Cytokinesis:

Cytokinesis, is the second main stage of the mitotic phase during which cell division is completed via the physical separation of the cytoplasmic components into two daughter cells. Division is not complete until the cell components have been apportioned and completely separated into the two daughter cells.

## Nucleolus:

The nucleolus is the largest structure in the nucleus of eukaryotic cells. It is best known as the site of ribosome biogenesis, which is the synthesis of ribosomes. The nucleolus also participates in the formation of signal recognition particles and plays a role in the cell's response to stress. Nucleoli are made of proteins, DNA and RNA, and form around specific chromosomal regions called nucleolar organizing regions.

## Structure:

Three major components of the nucleolus are recognized: the fibrillar center (FC), the dense fibrillar component (DFC), and the granular component (GC). Transcription of the rDNA occurs in the FC. The DFC contains the protein fibrillarin, which is important in rRNA processing. The GC contains the protein nucleophosmin, which is also involved in ribosome biogenesis.

The nucleolus ultrastructure can be seen through an electron microscope, while the organization and dynamics can be studied through fluorescent protein tagging and fluorescent recovery after photobleaching (FRAP).

## Cell cycle:

The cell cycle, or cell-division cycle, is the series of events that take place in a cell that cause it to divide into two daughter cells. These events include the duplication of its DNA (DNA replication) and some of its organelles, and subsequently the partitioning of its cytoplasm and other components into two daughter cells in a process called cell division.

In cells with nuclei (eukaryotes, i.e., animal, plant, fungal, and protist cells), the cell cycle is divided into two main stages: interphase and the mitotic (M) phase (including mitosis and cytokinesis). During interphase, the cell grows, accumulating nutrients needed for mitosis, and replicates its DNA and some of its organelles. During the mitotic phase, the replicated chromosomes, organelles, and cytoplasm separate into two new daughter cells.

In cells without nuclei (prokaryotes, i.e., bacteria and archaea), the cell cycle is divided into the B, C, and D periods. The B period extends from the end of cell division to the beginning of DNA replication. DNA replication occurs during the C period. The D period refers to the stage between the end of DNA replication and the splitting of the bacterial cell into two daughter cells.

The cell-division cycle is a vital process by which a single-celled fertilized egg develops into a mature organism, as well as the process by which hair, skin, blood cells, and some internal organs are regenerated and healed (with possible exception of nerves; see nerve damage). After cell division, each of the daughter cells begin the interphase of a new cell cycle. Although the various stages of interphase are not usually morphologically distinguishable, each phase of the cell cycle has a distinct set of specialized biochemical processes that prepare the cell for initiation of the cell division.

The eukaryotic cell cycle consists of four distinct phases: G1 phase, S phase (synthesis), G2 phase (collectively known as interphase) and M phase (mitosis and cytokinesis). M phase is itself composed of two tightly coupled processes: mitosis, in which the cell's nucleus divides, and cytokinesis, in which the cell's cytoplasm divides forming two daughter cells. Activation of each phase is dependent on the proper progression and completion of the previous one. Cells that have temporarily or reversibly stopped dividing are said to have entered a state of quiescence called G0 phase.

| State | Phase | Abbreviation | Description |
|---|---|---|---|
| Resting | Gap 0 | $G_0$ | A phase where the cell has left the cycle and has stopped dividing. |
| Interphase | Gap 1 | $G_1$ | Cell growth. The *$G_1$ checkpoint* ensures that everything is ready for DNA synthesis. |
| | Synthesis | S | DNA replication. |
| | Gap 2 | $G_2$ | Growth and preparation for mitosis. The *$G_2$ checkpoint* ensures that everything is ready to enter the M (mitosis) phase and divide. |
| Cell division | Mitosis | M | Cell division occurs. The *Metaphase Checkpoint* ensures that the cell is ready to complete cell division. |

https://le.ac.uk/vgec/topics/cell-cycle/the-cell-cycle-higher-education

Questions:

1- Give an example of the non-nucleate cell.

2- What is Nucleus?

3- Describe the structure and function of the nucleus?

4- Which organism would have the two nuclei?

5-Function of nuclear pores?

6- What is the importance of the nuclear export signal?

**4- Multiple Choice Questions:**

**1- Nucleoporins are …….**

**a**) Nuclear pores

b) Ribosomes on nuclear membranes

c) rRNAs in the nucleolus

d) None of the mentioned

**2- The transport factors that help in the transport of molecules through the nuclear pores are known as……..**

a) Nucleopherins

b) Nucleoporins

c) Karyopherins

d) Karyoporins

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