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MZO-001: Molecular Cell Biology
Guess Paper-1

Q1. What are the different functions of plasma membrane?

Ans. Plasma membrane (also called the cell membrane or plasmalemma) is a thin, elastic, semifluid, living protective membrane which separates the internal contents (cytoplasm and cytoplasmic organelles) from external surroundings. The plasma membrane controls the passage of materials, such as organic molecules, ions and water between the cells and its surrounding. It also prevents the passage of some substances to cell exterior to maintain ionic concentration gradient between the cytoplasm and the surroundings.

The plasma membrane is made of proteins and lipids. Several models were proposed to explain the arrangement of proteins and lipids in the membrane; however, the fluid- mosaic model proposed by S.J. Singer and G. Nicholson (1972) is the most widely accepted model. According to the fluid-mosaic model:

a) Plasma membrane is composed primarily of a phospholipid bilayer along with several membrane bound proteins with a variety of functions.

b) Phospholipid molecule harbors a phosphate group on one end, called the head, and two fatty acid chains forming the lipid tails. Both the lipid layers are inter-linked by the non polar and hydrophobic inner ends of lipid molecules. This ensures that the non-polar tails remain protected from the aqueous environment.

c) The negatively charged phosphate group renders polarity and hydrophobicity to the head group. The hydrophilic ends contribute association of lipid molecules with the molecules of protein layers.

d) The protein molecules are arranged in two different ways in lipid bilayers:

(i) Peripheral proteins or extrinsic proteins – located on the outer and inner surfaces of the lipid bilayer.

(ii) Integral proteins or intrinsic proteins – penetrate the lipid bilayer partially or entirely.

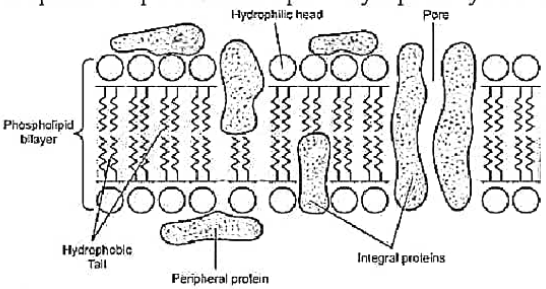

Fig.: Fluid-mosaic model of the plasma membrane.

Phospholipids are therefore amphipathic molecules. An amphipathic molecule harbors both a hydrophilic and a hydrophobic region. The cell membrane also possesses some other lipids (cholesterol) which contribute to the fluidity of the membrane.

Functions of Plasma Membrane

a) It protects intracellular organelles from the outside environment.

b) It has selective permeability as it selectively allows the flow of molecules. Molecules can be transported across the plasma membrane by any one of the following three methods:

(i) Diffusion – This process does not require energy. Molecules move from their regions of higher to lower concentration. Gases like carbon dioxide and oxygen pass through diffusion.

(ii) Osmosis – Osmosis is the diffusion of water through a semipermeable membrane. Osmosis occurs due to the imbalance of solutes between cell exterior and interior without expenditure of energy. Solutions can be of three types: isotonic, hypotonic and hypertonic.

Two solutions that have a similar solute (salt or sugar) and water concentration are said to be isotonic (equal tension). In isotonic solutions, cells maintain their normal shape and function.

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A solution that has a higher concentration of solutes or salts (less water concentration) than a cell is said to be hypertonic. A cell in a hypertonic solution shrinks because water molecules tend to diffuse into a hypertonic solution, resulting in the disruption of the plasma membrane.

In contrast, a solution that contains lesser salt (higher water concentration) in the medium than the cell is said to be hypotonic. Cells kept in a hypotonic solution take in excess water as water molecules enter inside the cells resulting in swelling and bursting of cells.

(iii) Active Transport – During active transport, energy or ATP is required for the movement of certain molecules across the membrane from the region of their lower concentration towards the region of their higher concentration with the help of protein carriers called transporters.

Apart from active transport and passive diffusion across the membrane, other mechanisms also allow certain substances in traversing the cell membrane:

(i) Endocytosis (taking the content in) – It is the process through which cells ingest extracellular substances. Endocytosis is of two types :

• Phagocytosis ("cell eating") is the endocytosis of large particles. Immune cells are engaged in the phagocytosis of invading pathogens. The membrane folds out around the particle, generating a cavity, thus engulfing the particle.

• Pinocytosis ("cell drinking") brings fluid-containing solutes into the cell through membrane vesicles.

(ii) Exocytosis (passing the content out) – This process is the reverse of endocytosis and involves the fusion of the vacuoles, containing large quantities of materials, with the plasma membrane, as materials are discharged out of the cell.

The plasma membranes in some tissue cells are modified into fingerlike projections called microvilli (singular = microvillus). These projections greatly increase the surface area of the plasma membrane. Such cells are typically found in the lining of the small intestine, the organ that absorbs nutrients from digested food.

Intercellular junctions mediate cellular communications via direct contact. Plasmodesmata (singular = plasmodesma) are junctions between plant cells, whereas gap junctions are present in animal cells. Such junctions are important in maintaining the integrity of tissues and in controlling the passage of substances.

Q2. Elucidate the basic structure of nucleosome.

Ans. Chromatin fibers consist of a repeating pattern of bodies called nucleosomes. Nucleosomes are formed by the association of DNA and a specific nuclear protein called histone. Histones are present in vast quantities. The histone proteins form a core and a 2 nm thick molecule of DNA makes two turns around this core. The histone core is an octamer consisting of two of each of the four histones, viz., H2A, H2B, H3 and H4.The fifth histone (H1) appears to interact with the DNA at its entry and exit points in the nucleosome. The successive nucleosomes are connected by linker DNA (Fig. 1.6). The histone core along with the linker DNA and histone H1 constitute a unit called mononucleosomes or chromatosomes. The H1 histones are larger (220 amino acids) and have been less conserved during evolution than nucleosomal histones.

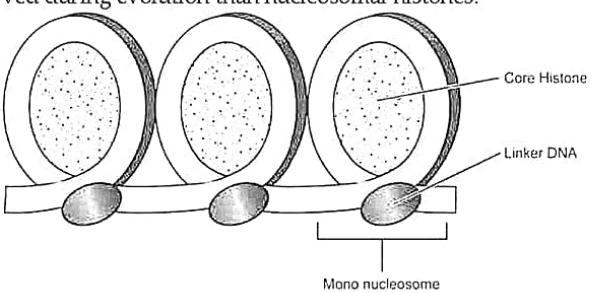

Fig.: Arrangement of successive nucleosomes connected by linker DNA.

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The nucleosome chain gives beads-on-string appearance under an electron microscope. The string includes DNA and each bead is a nucleosome core particle. The beaded string forms a cylindrical coil or solenoid having 6 nucleosomes per turn. As noted earlier, two classes of chromatin fibers exist having diameters of 10 and 30 nm. It appears that the 10 nm fiber is formed from a linear array of nucleosomes, while 30 nm fiber is formed by the helical coiling of 10 nm fibers. Each turn of the helix in a 30 nm fiber consists of about six nucleosomes and successive turns form a structure called a solenoid. This solenoid structure undergoes further coiling to produce a 30-80 nm chromatin fiber and a chromatid of 700 nm.

Q3. Discuss the different types of lysosomes.

Ans. Lysosomes are structurally heterogeneous group of organelles that are formed from the Golgi complex and are membrane-enclosed spherical vacuoles. The existence of lysosomes was discovered and named by Nobel Prize Laureate Christian de Duve and his co-workers. Lysosomes are bound by only a single membrane and lack internal structure, but they contain as many as 50 different kinds of powerful hydrolytic enzymes, capable of hydrolyzing proteins, polysaccharides, nucleic acids, lipids and other molecules. Further, these enzymes can also digest cell-invading bacteria. Human white blood cells, which ingest bacteria through phagocytosis, contain numerous lysosomes. Several different lysosomal forms have been identified within individual cells, including:

a) Primary lysosomes or Protolysosomes – They are newly synthesized organelles bounded by a single membrane and believed to be derived from the trans face of the Golgi complex.

b) Secondary lysosomes – These are of two kinds:

(i) Heterophagic vacuoles or Heterolysosomes or Phagolysosomes – They are formed by the fusion of primary lysosomes with cytoplasmic vacuoles (endosomes), enclosing extracellular materials taken up from the outside of the cell by the process of endocytosis. In phagocytosis, specialized cells called macrophages ingest large particles, including bacteria, cell debris and senescent cells that need to be removed. Such large particles are taken up in phagocytic vacuoles (phagosomes), which fuse with lysosomes. After fusion, enzymes of primary lysosomes are released into the vacuoles (phagosomes or endosomes), resulting in digestion of their contents.

(ii) Autophagic vacuoles – These vacuoles contain materials derived from own cytoplasm of the cell including fragments of cellular organelles. These components are hydrolyzed by the lysosomal enzymes and the process is called autophagy. Auto digestion is a natural process during cell growth and repair.

c) Residual Bodies – Materials that are not digested within the secondary lysosomes or unabsorbed materials from the cytosol are all retained within the residual bodies. These bodies fuse with the plasma membrane during exocytosis.

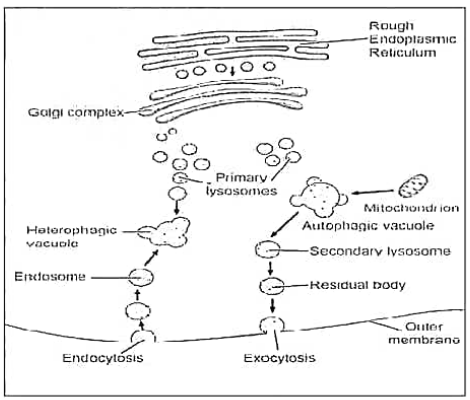

Fig.: Functioning of lysosomes.

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Endocytosis is the process which helps in the internalization of proteins and some other soluble macromolecules in the extracellular milieu across the lipid bilayer. Due to invagination of a portion of plasma membrane, a "coated pit" is formed, whose cytosolic face consists of specific proteins including clathrin. The pit pinches from the membrane into small membranous vesicle. The extracellular materials contained in the vesicle is targeted to some membranelimited tubules and vesicles called early endosomes, from where certain membrane proteins are targeted to a late endosome for protein sorting. The delivery of its membrane and internal contents by late endosome to lysosomes for degradation marks the end of endocytosis.

Aged or obsolete cellular components or organelle are degraded by lysosomes via a process called autophagy. A group of enzymes, housed within the lysosomes, degrade polymers into monomers, viz., nucleases degrade RNA and DNA into their mononucleotides, proteases degrade proteins and peptides; phosphatases remove phosphate groups from mononucleotides and phospholipids. Since such enzymes function at low pH, they are collectively termed acid hydrolases. Due to acidic pH, the proteins are denatured and are susceptible to attack by lysosomal hydrolases. Lysosomal enzymes do not function at the neutral pH of cells and in extracellular fluids. Nuclear and cytosolic proteins, instead of being degraded in lysosomes, are destroyed in large multiprotein complexes called proteasomes in the cytosol. Primary lysosomes are roughly spherical without particulate or membrane debris. Secondary lysosomes are larger and irregularly shaped, formed by the fusion of primary lysosomes with other membrane-bounded organelles and vesicles. Particles or membranes are digested within secondary lysosomes. One human genetic disease, characterized by a defect in a lysosomal enzyme, causing ganglioside degradation, is Tay-Sachs disease. Glycolipids accumulate in nerve cells which are enlarged with swollen lipid-filled lysosomes, leading to dementia and blindness by the age of 2 in new-born child and death by age of 3.

Q4. Discuss the role of the Actin in The Cortical Cytoskeleton.

Ans. The actin filament network and related actin-binding proteins are called the cell cortex. It is in charge of keeping the cell's structure intact. It also takes part in various processes on and inside the cell surface, including mobility, vesicular trafficking, and muscular movements. Due to the lack of microtubules and intermediate filaments in many mammalian RBCs, the cortical actin cytoskeleton is the primary determinant of their biconcave disc shape. The spectrin protein serves as the cytoskeleton in erythrocytes. Spectrin is a protein that binds to actin and is a member of the calponin family, including - actinin, filamin, and fimbrin. One actin-binding domain is located near the amino terminus of the -chain. Another protein, dystrophin, is a member of the calponin family, which is crucial because it is the product of a specific gene that causes Duchenne's and Becker's muscular dystrophy. The most severe of these "X-linked hereditary disorders", "Duchenne's muscular dystrophy", causes progressive skeletal muscle deterioration.

Q5. Discuss the biological significance of actin cytoskeleton.

Ans. • Filopodia or micro-spikes are formed with the help of the actin cytoskeleton. As sheet-like protuberances near the cell's surface, this actin meshwork appear part of the 'lamellipodia' structure.

• Representatives of a Rho, which is responsible for stress fiber formation, a Rho family component regulated by small guanosine triphosphatases (GTPases), including Rac and Cdc42 for lamellipodia and filopodia, respectively, mediate their functions via signaling pathways.

• The actin cytoskeleton connection is in charge of cell shape maintenance.

• The actin cytoskeleton plays various roles in cancer control, including immune cell activation, effector function, and cellular changes.

• The microfilament meshwork forms a translucent cortex barrier that protects the cell while creating the lamellipodium-like, advancing cell. These structures contain actin polymers, contributing 5-10% of cellular protein. The contractile mechanism required for cellular motility and internalization comprises actin and its associated proteins.

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• Chemotaxis signal activation causes a rapid increase in actin coupled to the cytoskeleton and a change in microfilament organization from a straight thread to a cross-hatched meshwork, most visible at the polarized cell's periphery.
• The actin cytoskeleton also performs osmosensing and osmosignaling along with the quantitative dynamics of actin polymerization in cell volume regulation.
• Exocytosis appears to be the intracellular trafficking stage in which a secretory vesicle binds to the cell membrane and releases its contents. Both actin and microtubules mediate this exocytosis process.

Q6. How do different drugs affect the actin filament?

Ans. Many drugs alter or disrupt the actin filament structure. Cytochalasin D, for example, is a mold-derived drug that inhibits the barbed terminus of actin's filament while allowing for depolymerization from pointed terminus. Other fungus-derived medicines, such as Phalloidin, are responsible for decreased actin filament turnover. Latrunculin is a nonlinear polypeptide derived from sponges that promotes actin cytoskeleton initiation and leads to actin polymerization, thereby stabilizing F-actin. Swinholide A is a naturally dimeric dilactone macrolide toxic drug that causes actin dissociation in cells.

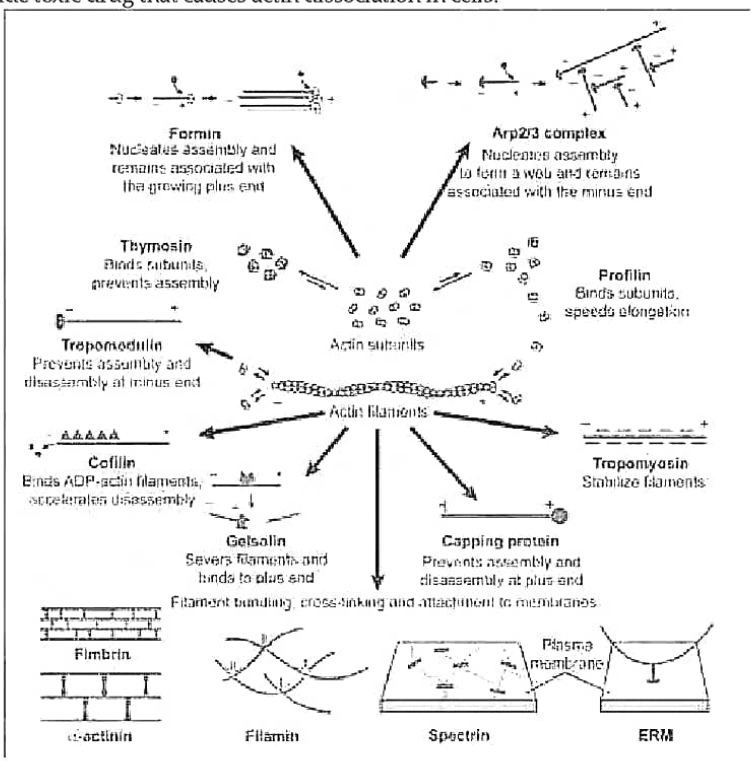

Fig: This diagram depicts several essential actin proteins that aid in the formation of the cytoskeleton. (Ref. Molecular Biology of the Cell, Sixth Edition, Chapter 16, Page 905, Authors: Bruce Alberts, Alexander Johnson, Julian Lewis, David Morgan, Martin Raff, Keith Roberts, and Peter Walter).

Q7. Describe the structure organisation of the microtubules.

Ans. Microtubules are composed of tubulin subunits. They form long, hollow tubes that radiate within cytoplasmic space. They are the largest, with diameters of 25nm compared to actin filaments and intermediate

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