CHAPTER 2
THE CELL AND ITS FUNCTIONS

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PROTOPLASM CONSTITUENTS

Protoplasm is composed mainly of five basic substances:

1. Water
2. Electrolytes
3. Proteins
4. Lipids
5. Carbohydrates

Most cells, except for fat cells, are comprised mainly of water in a concentration of 70-85%

Important ions in the cell include potassium, magnesium, phosphate, sulfate, bicarbonate, and smaller quantities of sodium, chloride and calcium.

STRUCTURAL PROTEINS

- Present in form of long filaments
- Cellular filaments form microtubules
- Cytoskeleton
- Cilia, nerve axons, mitotic spindles
- Fibrillar proteins found outside the cells include collagen, elastin fibers of connective tissue, in blood vessel walls, tendons and ligaments.

LIPIDS

1. Phospholipids
2. Cholesterol
3. Triglycerides (neutral fats)

In fat cells (adipocytes), triglycerides often account for as much as 95% of cell mass.

LIPID BILAYER

Lipid bilayer is composed of three main types of lipids:

1. Phospholipids
2. Sphingolipids

3. Cholesterol

SPHINGOLIPIDS

- Derived from amino alcohol sphingosine
- Present in small amounts esp in nerve cells
- Provide protection from harmful environmental factors, signal transmission, and adhesion sites for extracellular proteins.

FUNCTIONS OF INTEGRAL PROTEINS IN CELL MEMBRANE

- Most of integral proteins are glycoproteins
- Integral proteins provide channels (or pores) for water-soluble substances
- Act as carrier proteins
- Some act as enzymes
- Serve as receptors for water-soluble chemicals

CARBOHYDRATES IN CELL MEMBRANE

- The glyco- portions of the molecules (glycoproteins and glycolipids) almost invariably protrude to the outside of cell, dangling outward from the cell surface.
- Proteoglycans which are mainly carbohydrates bound to small protein cores, are loosely attached to outer surface as well.
- Thus, the entire outside surface of the cell often has a loose carbohydrate coat called the glycocalyx.
- The carbohydrate moieties attached to the outer surface of the cell have several important functions:
    1. Many of them have a negative electrical charge, which gives most cells an overall negative surface charge that repels other negatively charged objects.
    2. The glycocalyx of some cells attaches to the glycocalyx of other cells, thus attaching cells to one another.
    3. Many of the carbohydrates act as receptors for binding hormones, such as insulin.
    4. Some carbohydrate moieties enter into immune reactions.

ENDOPLASMIC RETICULUM

- A network of tubular structures called cisternae and flat vesicular structures
- Helps in processing and transport
- Provides enzymes that control glycogen breakdown to be used for energy
- Ptovide detoxifying enzymes
- Endoplasmic matrix : space inside the tubules and vesicles

GOLGI APPARATUS

The golgi apparatus is usually composed of four or more stacked layers of thin, flat, enclosed vesicles lying near one side of the nucleus.

FUNCTIONS OF GOLGI APPARATUS

- Processing of substances formed in ER
- Can synthesize certain carbohydrates
- Formation of large polysaccharides bound with small amount of protein e.g hyaluronic acid and chondroitin sulfate.

FUNCTIONS OF HYALURONIC ACID AND CHONDROITIN SULFATE

1. They are the major components of proteoglycans secreted in mucus and other glandular secretions
2. They are the major components of the ground substance, or nonfibrous components of the extracellular matrix, which act as fillers between collagen fibers and cells.
3. They are principal components of the organic matrix in both cartilage and bone.
4. They are important in many cell activities, including migration and proliferation

LYSOSOMES

- Provide an intracellular digestive system
- Provide as many as 40 different hydrolase enzymes

FUNCTIONS OF LYSOSOMES

1. Regression of tissues to smaller size e.g
    a. Regression in uterus after pregnancy
    b. In muscles during long periods of inactivity
    c. In mammary glands at the end of lactation
2. Removal of damaged cells
3. Autolysis
4. Contain bactericidal agents that can kill phagocytized bacteria. They include:
    a. Lysozyme- dissolves bacterial cell wall
    b. Lysoferrin- binds with iron and other substances before they can promote bacterial growth
    c. Acid (pH=5) – activates hydrolases and inactivates bacterial metabolic systems

PEROXISOMES

- Formed by self-replication or by budding off from SER, rather than from Golgi apparatus
- Contain oxidases
- Several oxidases combine oxygen with hydrogen ions to form hydrogen peroxide (H_2O_2)
- H_2O_2 in association with catalase oxidize many substances that might be poisonous to cell.
- They catabolize long chain fatty acids

MITOCHONDRIA

- Outer and inner membranes
- Membrane infoldings called cristae
- Cristae has attached oxidative enzymes
- Cristae provides large surface area for chemical reactions
- Matrix contains enzymes
- Self-replicating due to presence of DNA
- In liver cells, the average mitochondria normally has a life span of only about 10 days before it is destroyed.

CELL CYTOSKELETON

1. ACTIN MICROFILAMENTS

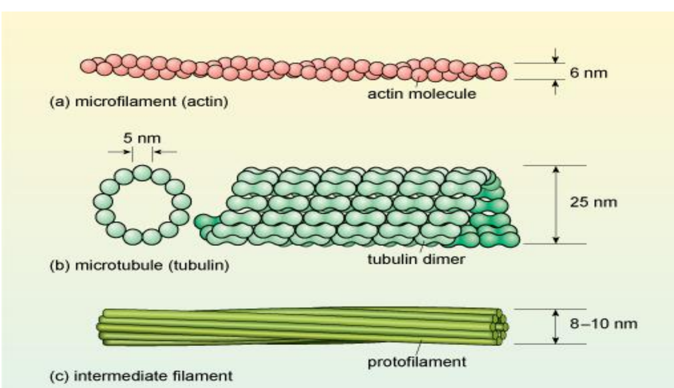
- Frequently occur in outer zone of cytoplasm (ectoplasm) to form an elastic support of cell membrane
- Found as actin and myosin filaments in muscles

2. INTERMEDIATE FILAMENTS

- Provide strength and support to microtubules
- Examples:
  - Desmin filaments in muscle cells
  - Neurofilaments in neurons
  - Keratins in epithelial cells

3. MICROTUBULES

- Stiff filaments composed of polymerized tubulin molecules
- Examples:
  - Tubular skeletal structure in center of cilium
  - Centrioles
  - Mitotic spindles



NUCLEUS

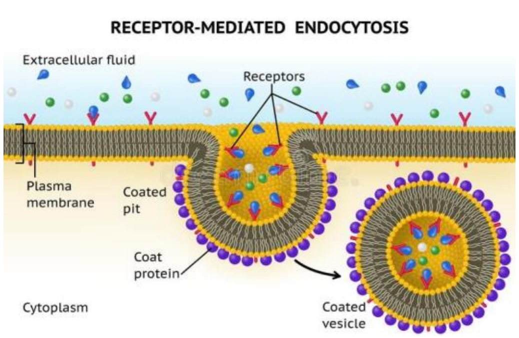
- The space between nuclear membranes is continuous with space inside endoplasmic reticulum
- Nucleolus is a non-membranous structure containing RNA and proteins

ENDOCYTOSIS

1. Receptor-mediated endocytosis
2. Phagocytosis
3. Pinocytosis

1. RECEPTOR-MEDIATED ENDOCYTOSIS

- Ligands bind to specialized protein receptors on surface of cell membrane forming ligand-receptor complex.
  Each receptor is associated with a protein, known as clathrin, on the membrane's cytoplasmic side. The regions of the plasma membrane in which these receptors and associated clathrin molecules are expressed are known as clathrin-coated pits.
- The clathrin-coated pit sinks into the cell, forming a vesicle that contains the ligand-receptor complexes.
- Once in the cytoplasm, the clathrin molecules coating the outer edge of the vesicle leave, and associate with new receptors on the plasma membrane.
- The uncoated vesicle fuses with an endosome, and the ligands and receptors separate, collecting at the opposite ends of the endosome.
- Sections of the endosome containing unbound receptors pinch off, forming transport vesicles that return the receptors to the plasma membrane.
- The remaining vesicles, which now contain free ligands, fuse with a lysosome containing digestive enzymes.
- The lysosome's enzymes breaks the ligand down into smaller molecules which are then released into the cytoplasm of the cell for use in a number of cell processes.



2. PINOCYTOSIS

- Droplets of extracellular fluid containing dissolved solutes collect in a pit at the surface of a cell

- Plasma membrane extends around these fluid droplets, forming a vesicle that is drawn into the cytoplasm of the cell.
- This fluid-filled vesicle then fuses with a lysosome
- The digestive enzymes break down the extracellular fluid, and the digested solutes are released into the cytoplasm.

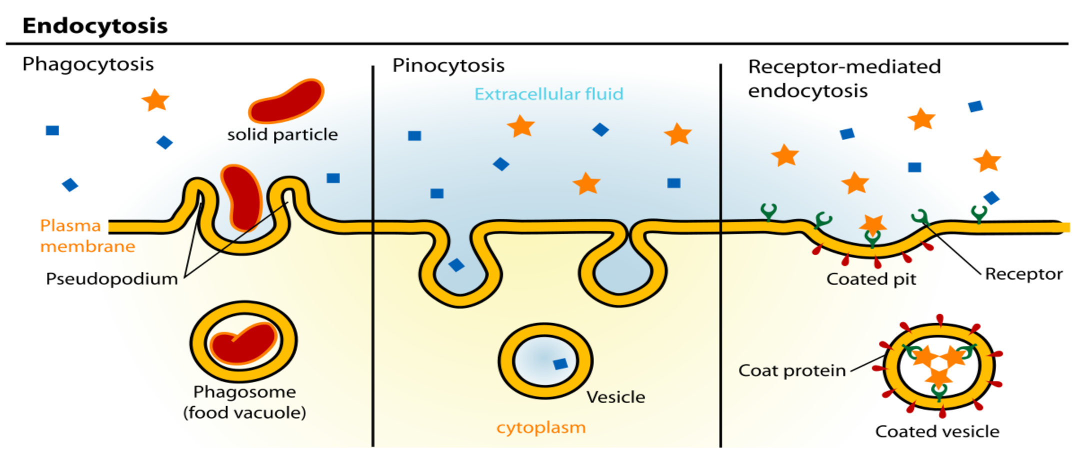
Unlike receptor-mediated endocytosis, pinocytosis is nonspecific in the substances that it transports. The cell takes in surrounding fluids, including all solutes present.

NECESSARY REQUIREMENTS FOR FORMATION OF PINOCYTIC VESICLES

1. ATP from within the cell
2. Presence of calcium ions in extracellular fluid which probably react with contractile protein filaments beneath the coated pits to provide the force for pinching the vesicles away from the cell membrane.

3. PHAGOCYTOSIS

- Occurs in specialized cells e.g macrophages and some WBCs
- Pinocytosis is for molecules while phagocytosis involve large particles
- **PROCESS**
  1. Receptors on a phagocyte's surface bind to large solid particles such as microbes, dead cells, and debris
  2. The binding action triggers the plasma membrane to extend finger-like projections, called pseudopods, around the bound particles forming a vesicle, known as phagosome
  3. This vesicle becomes detached from the plasma membrane with the help of actin and other contractile fibrils and enters the cytoplasm within the cell.
  4. The phagosome then fuses with a lysosome.
  5. The digestive enzymes breakdown the engulfed particles into smaller molecules, and the digested solutes enter the cytoplasm.
  6. Any remaining undigested material is contained in a vesicle, known as residual body, which remains in the phagocyte's cytoplasm.



EXOCYTOSIS

Exocytosis, in most cases, is stimulated by entry of calcium ions into the cell. calcium ions interact with the vesicular membrane, followed by opening of the membrane's outer surface and extrusion of its contents outside the cell.

ATP

ATP is composed of

1. Nitrogenous base adenine
2. Ribose sugar
3. Three phosphate radicals

The last two phosphate radicals are connected with the remainder of the molecule by high-energy bond.

USES OF ATP FOR CELLULAR FUNCTIONS

1. Transport of substances through multiple cell membranes
2. Synthesis of chemical compounds throughout the cell
3. Mechanical work

LOCOMOTION OF CELLS

1. AMOEBOID MOVEMENT

Amoeboid movement is movement of an entire cell in relation to its surroundings.

GENERAL MOVEMENT

- Amoeboid locomotion begins with protrusion of a pseudopodium from one end of a cell.
- Partially secures itself in a new tissue area
- Then the remainder of the cell is pulled towards the psudopodium
- The membrane of this end of the cell is continually moving forward, and the membrane at the left-hand end of the cell is continually following as the cell moves
- Basically, it results from continual formation of new cell membrane at the leading edge of the pseudopodium and continual absorption of the membrane in mid and rear portions of the cell.

MECHANISM

Two effects are essential for forward movement of the cell:

1. The first effect is attachment of the pseudopodium to surrounding tissues so that it become fixed in its leading positions, while the remainder of the cell body is pulled forward towards the point of attachment.
2. The second essential effect for locomotion is to provide the energy required to pull the cell body in the direction of the pseudopodium.

FIRST EFFECT

- This attachment is affected by receptor proteins that line the insides of exocytotic vesicles. When the vesicles become part of the pseudopodial membrane, they open so that their insides overt to the outside, and the receptors now protrude to the outside and attach to ligands in the surrounding tissues.
- At the opposite end of the cell, the receptors pull away from their ligands and form new endocytotic vesicles. Then, inside the cell, these vesicles stream towards the pseudopodial end of the cell, where they are used to form still new membrane for the pseudopodium.

SECOND EFFECT

- In the cytoplasm of all cells is a moderate to large amount of the protein actin
- Much of the actin is the form of single molecules that donot provide any motive power; however, these polymerize to form a filamentous network, and the network contracts when it binds with an actin-binding protein such as myosin.
- The whole process is energized by ATP
- A network of actin filaments forms anew inside the enlarging pseudopodium
- Contraction also occurs in the ectoplasm of the cell body, where a pre-existing actin network is already present beneath the cell membrane.

TYPES OF CELLS EXHIBITING AMOEBOID MOVEMENT

1. WBCs
2. Fibroblasts
3. Embryonic cells
4. Movement of sarcoma cells (types of cancer cells) through metastasis

The most important initiator of amoeboid locomotion is the process called chemotaxis

2. CILIARY MOVEMENT

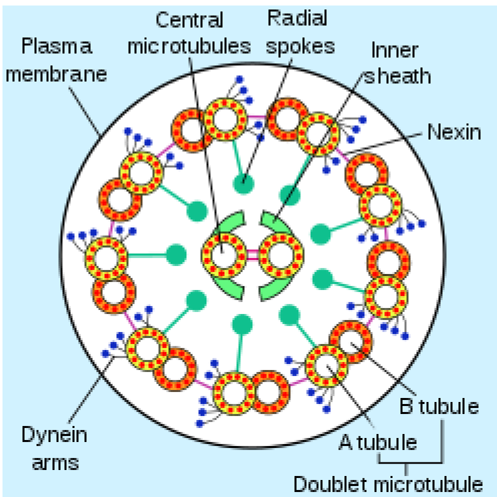
A second type of cellular motion, ciliary movement, is a whiplike movement of cilia on the surfaces of cells.

OCCURANCE

- On the surfaces of the respiratory airways in the nasal cavity and lower respiratory airways
- The whiplike motion of cilia causes a layer of mucus to move at a rate of about 1cm/min towards the pharynx, in this way continually clearing these passageways of mucus and particles that have become trapped in the mucus.
- On the inside surfaces of the uterine tubes (fallopian tubes) of the reproductive tract
- In the uterine tubes, the cilia causes slow movement of fluid from the ostium of the uterine tube towards the uterus cavity; this movement of fluid transports the ovum from the ovary to the uterus.

STRUCTURE

- Cilium has the appearance of a sharp-pointed straight or curved hair
- Projects 2 to 4 micrometers from the surface of the cell
- Many cilia often project from a single cell- for instance, as many as 200 cilia on the surface of each epithelial cell inside the respiratory passageways.
- Cilia are made of microtubules covered by an extension of the plasma membrane
- The set of microtubules inside cilia are called axoneme
  The axoneme consist of 9 pairs of microtubules arranged in a ring around a single central pair
- Axonemal dyneins from the inner and outer rows of arms associated with the doublet microtubules of motile cilia. These enzymes convert the chemical energy released from ATP hydrolysis into mechanical work by causing the doublets to slide with respect to eachother
- Each cilium is an outgrowth of a structure that lies immediately beneath the cell membrane, called the basal body of the cilium.



CILIA MOVEMENT

- The cilium moves forward with a sudden, rapid, whiplike stroke 10 to 20 times per second, bending sharply where it projects from the surface of the cell. Then it moves backward slowly to its initial position
- The rapid forward-thrusting, whiplike movement pushes the fluid lying adjacent to the cell in the direction that the cilium moves; the slow, dragging movement in the backward direction has almost no effect on fluid movement. As a result, the fluid is continually propelled in the direction of the fast-forward stroke
- Because most ciliated cells have large numbers of cilia on their surfaces and because all the cilia are oriented in the same direction, this is an effective means for moving fluids from one part of the surface to another

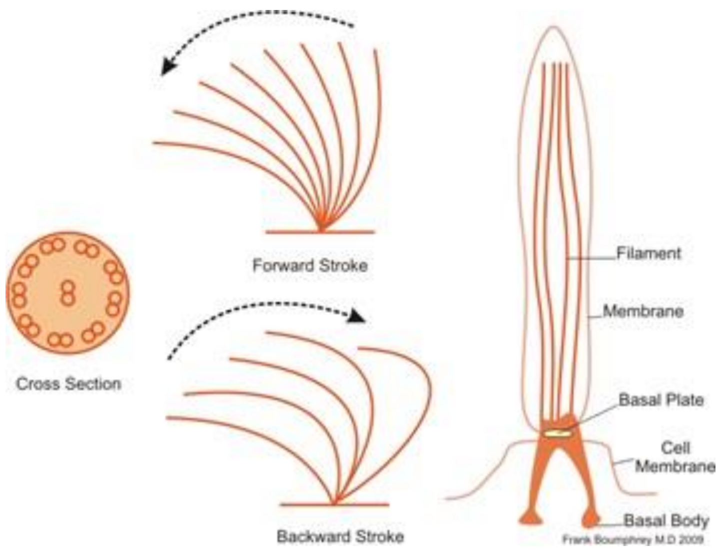
MECHANISM OF CILIARY MOVEMENT

Although not all aspects of ciliary movement are clear, we do know the following:

1. The nine double tubules and the two single tubules are all linked to one another by a complex of protein cross-linkages; this total complex of tubules and cross-linkages is called the axoneme.
2. Even after the removal of the membrane and destruction of other elements of the cilium besides the axoneme, the cilium can still beat under appropriate conditions
3. There are two necessary conditions for continued beating of axoneme after removal of the other structures of the cilium
    a) Availability of ATP
    b) Appropriate ionic conditions esp. Mg^{+2} and Ca^{+2} ions
4. During forward motion of the cilium, the double tubules on the front edge of the cilium slide outward towards the tip of the cilium, while those on the back edge remain in place
5. Multiple protein arms composed of the protein dynein, which has ATPase enzymatic activity, project from each double tubule towards an adjacent double tubule

ATPase DYNEIN

- The release of energy from ATP in contact with the ATPase dynein arms causes the heads of these arms to "crawl" rapidly along the surface of the adjacent double tubule
- If the front tubules crawl outward while the back tubules remain stationary, this will cause bending



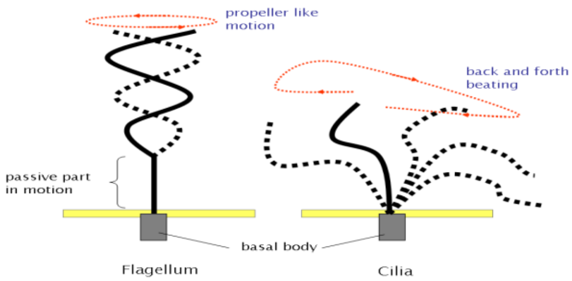
ABNORMALITIES

The way in which cilia contraction is controlled is not understood.

The cilia of some genetically abnormal cells donot have the two central single tubules, and these cilia fail to beat. Therefore, it is presumed that some signal, perhaps an electrochemical signal, is transmitted along these two central tubules to activate the dynein arms.

DIFFERENCE BETWEEN FLAGELLUM AND CILIUM

1. Flagellum is longer in size while cilium is shorter.
2. Flagellum show Quasi-sinosidal movement while cilium show whip like movement



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