Lectures of Histology

(1st Stage)
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Anatomy and Histology Department

By

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Modifications (Specializations) of Plasma Membrane

Just as we need food to survive, so does every cell in our body, but while we have a mouth, the cells have not, and just as we do, the cell produces waste that must be eliminated. So how do nutrients get into cells, and how do waste materials get out? the key to this process is the cell membrane. Plasma membrane shows many modifications (specialized structures) in various tissues especially epithelial tissue compared to the other that show fewer modifications, to perform some additional functions.

Surface specializations or modifications

Each cell has **three surfaces**: an apical (free) surface, lateral surfaces, and a basal surface.

1. Apical surface modifications:

It is specialized to carry out functions including secretion, absorption, and movement of luminal contents. There are four types:

- **Cilia:** are membrane-extensions (hair-like motile processes, 7-10μm long) composed of microtubules. There is a ring of nine doublet microtubules, and a central pair of singlet microtubules, and at the base of cilium there is basal body, into which the microtubules are anchored. Dynein is a microtubule motor protein. When dynein molecules attach to their adjacent doublet microtubule, this makes cilium bend, via a sliding motion, when dynein releases, the cilium straightens up again. This cyclical action causes the cilia to beat in waves-like, e.g., cilia of trachea, cilia of oviducts. (Fig. 1a).

- **Flagella:** are also concerned with movement, its structure identical to cilium, much longer than cilium, its movement undulating (snake-like) (Fig. 1a). Sperm is the only flagellated human cell (tail of a sperm).

- **Stereocilia:** are not true cilia, like microvilli (increase surface area). They are much longer and less motile than microvilli and may show branched. Best seen on the lining of male reproductive system where they have an absorptive function, and in the internal ear (hair cells of Corti organ) where they have a sensory function (Fig. 1b).

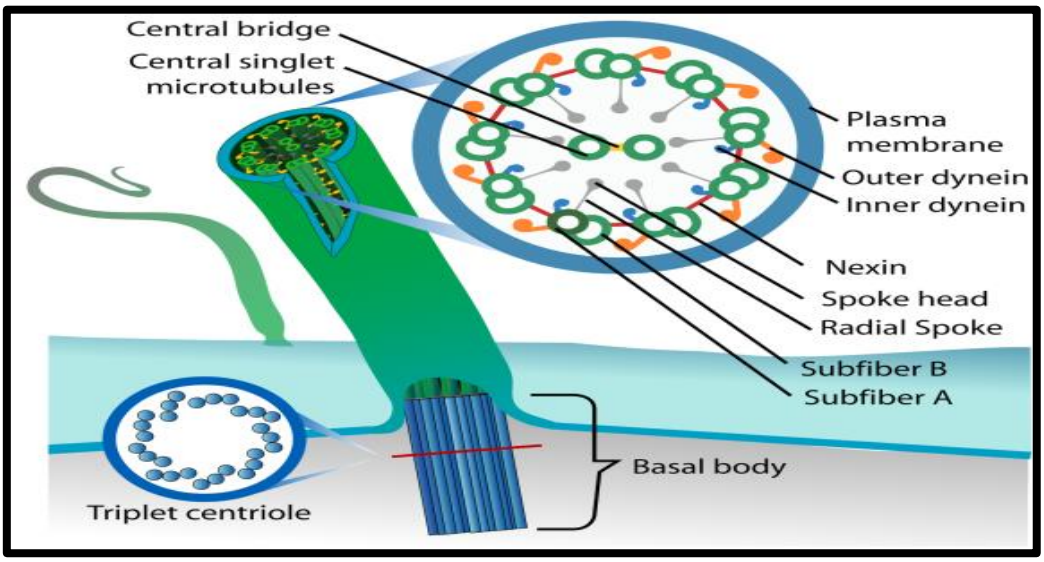


Fig. 1a: Cilia (Flagella).

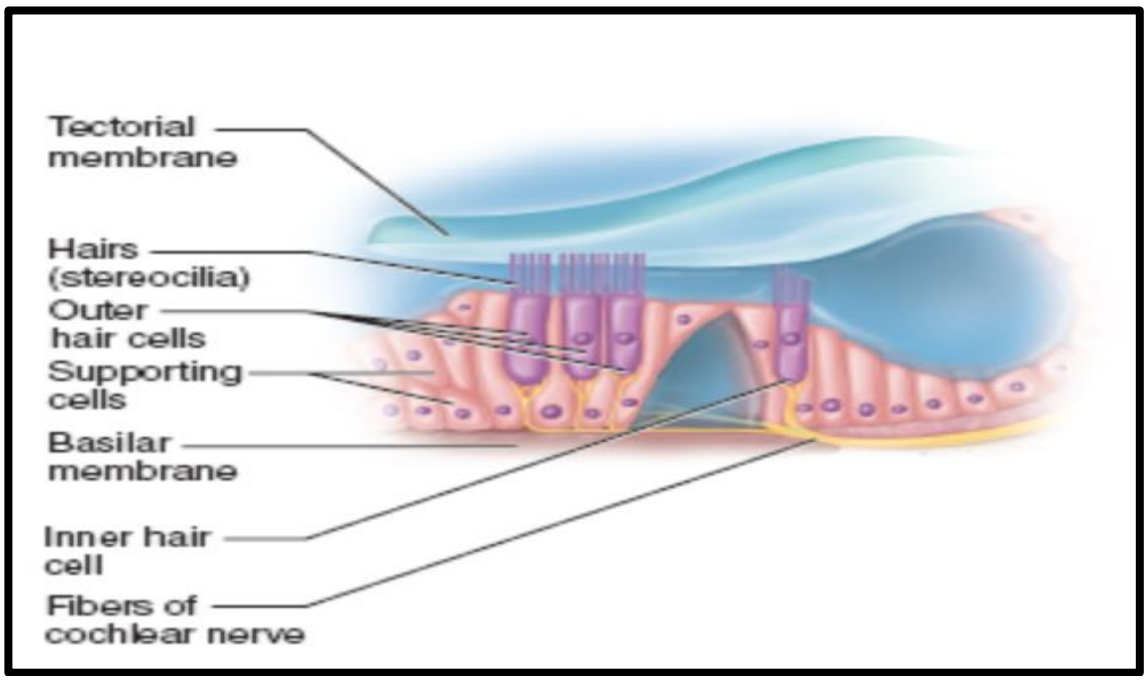


Fig. 1b: Stereocilia.

- **Microvilli:** are plasma membrane extensions (small-finger like projections, 1-2μm long), single cell contains more than 3000 microvilli. Their cores/center are composed of parallel actin microfilaments, these are anchored in a dense substance of filaments in the apical cytoplasm called the terminal web. By interacting with cytoplasmic myosin, the microfilaments can contract and shortening microvilli (microvilli greatly increase surface area about 15 to 40 times more), e.g., small intestine microvilli, proximal convoluted urinary tubules (Fig. 1c).

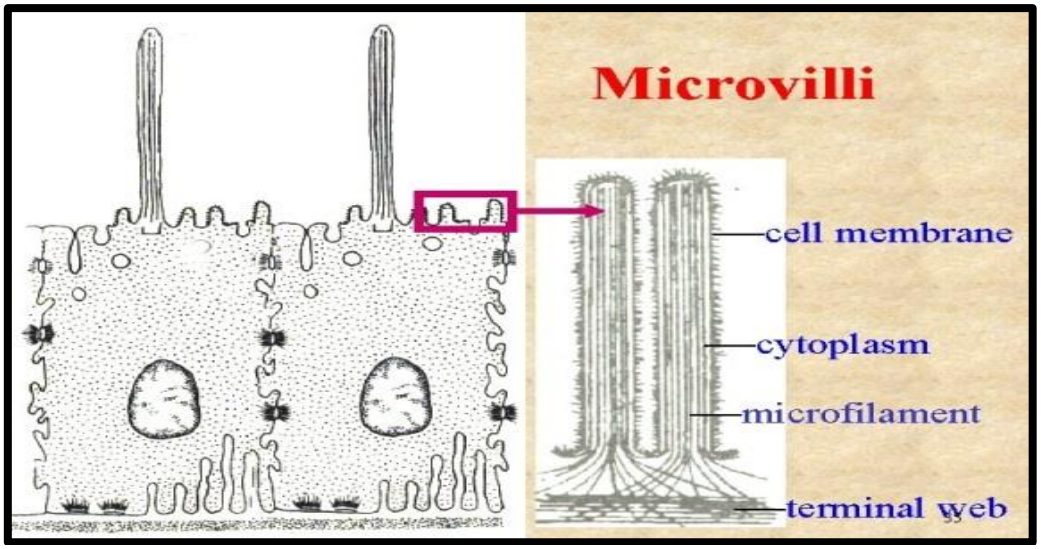


Fig. 1c: Microvilli.

2. Lateral surface modifications:

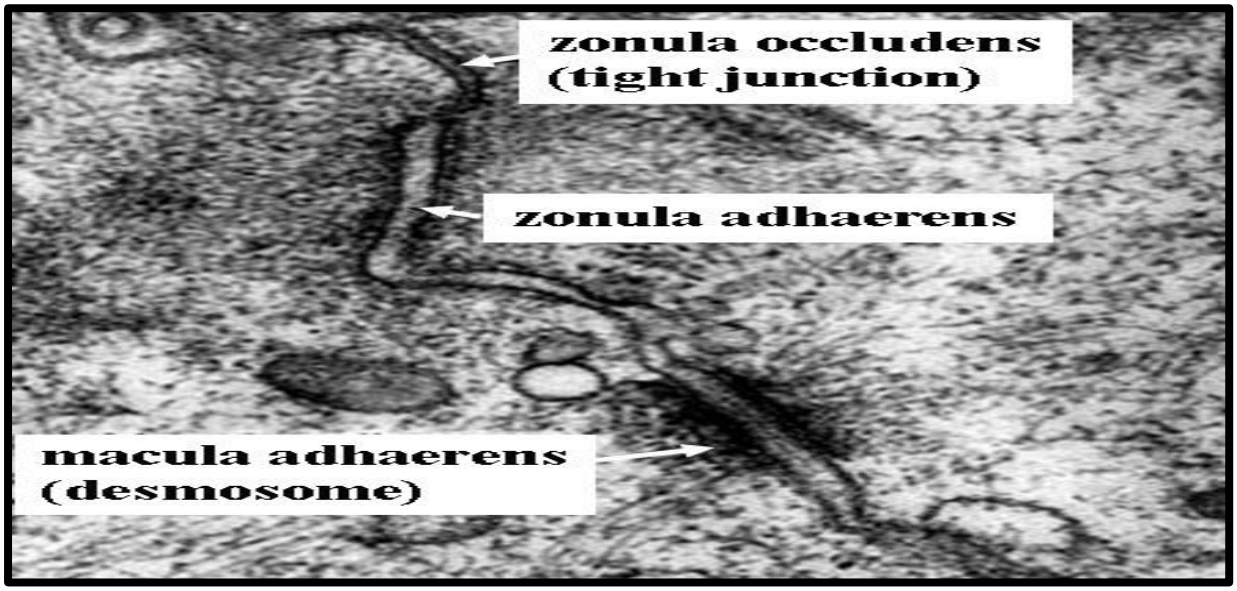
Cells attach to one another by specialized intercellular junctions which may be classified into three types (Fig.2):

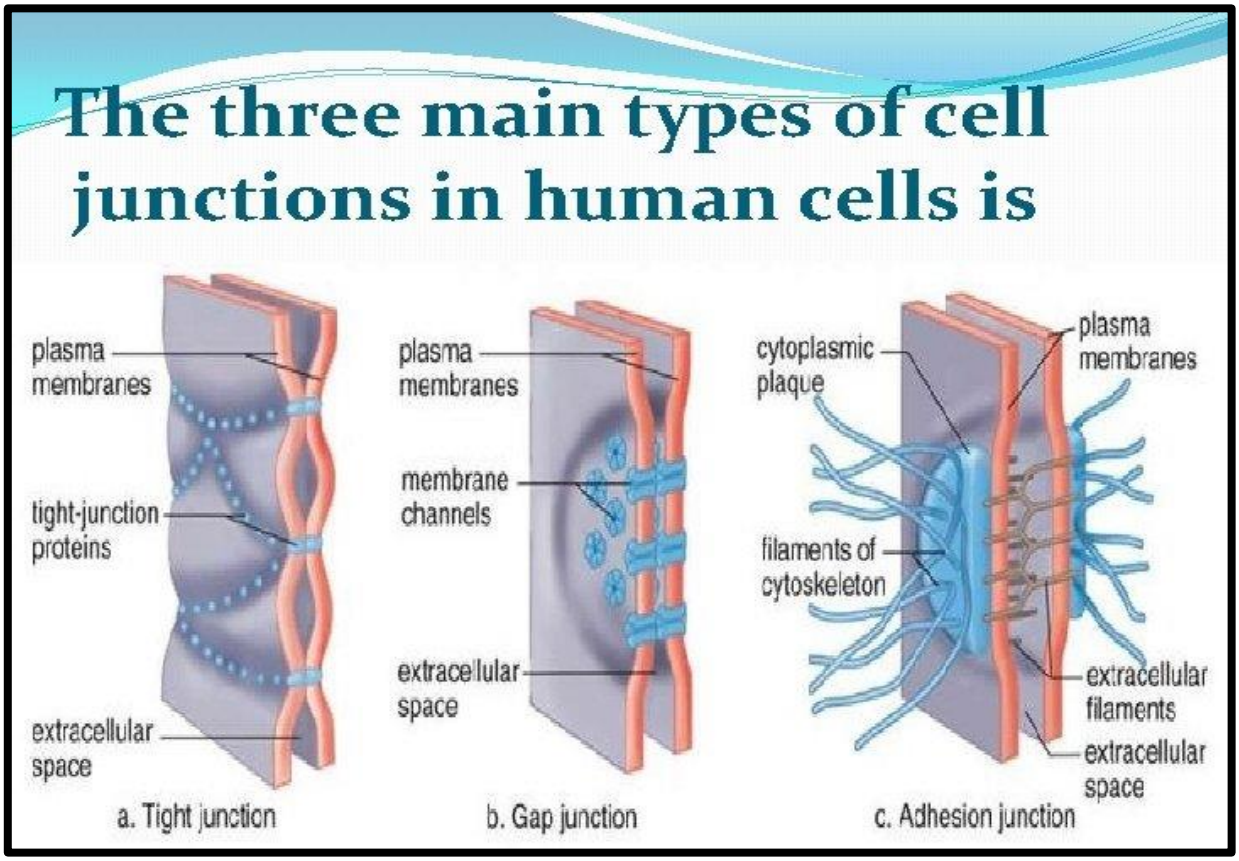
- **Zonula occludens (close connection):** at which the neighboring cells make contacts to each other. If the distance between membranes is less than (2nm), so the membranes fuse together (tight junction). Its length ranges between (2000-5000) Å, resulting in disappearance of the intercellular space.

- **Zonula adhaerens (gap junction):** it represents a continuity of the zonula occludens towards basal part of cells and its length ranges between (3000-5000) Å, so the two opposite membranes are separated from each other by an intercellular space of about (200) Å in width (i.e., they are not fully merged).

- **Macula adhaerens (desmosome):** strongest and most complex cell connections in shape of disk or an oval or circular space with a length of (2000-3000) Å which usually located/arises at (200) Å from the basal end of the cell. It develops by attachment of neighbor cell membranes which create cavities/space (~24nm) characterized of very dense and filled with electron dense grain mass (central lamella/attachment plaque), from it arises out adhesive tono-filaments contact cell membrane and heading to the cytoplasm of each neighboring cells.

Those three modifications (Zonula occludens, Zonula adhaerens, Macula adhaerens/desmosome) in this sequence are called junctional complex (represent the modifications of lateral surfaces of cell), which are generally found near the apical ends of adjacent cells and extend to near the bases of cells, to make strong adhesion and increase surface area for exchange of substances between the cells.





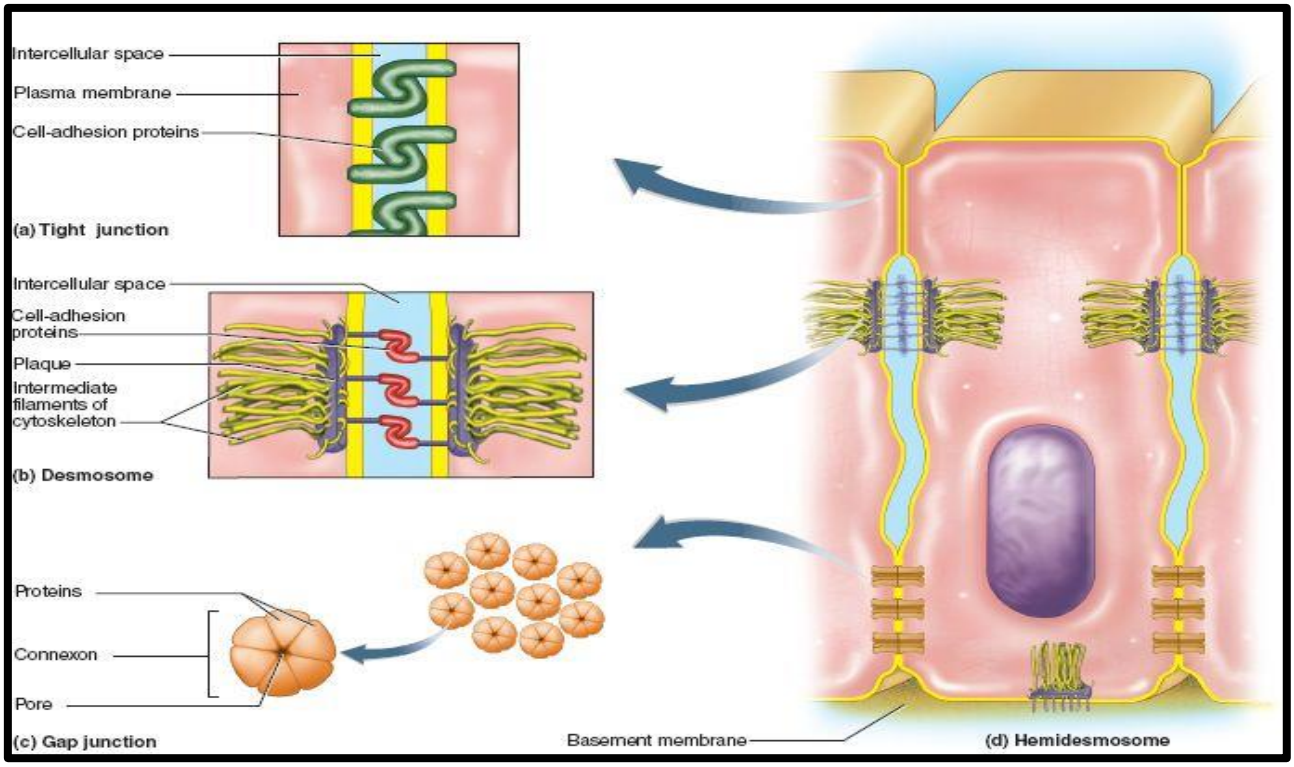


Fig. 2: Types of intercellular junctions.

3. Basal surface modification:

Basal surface of the cell contacts **basal lamina**, which is a sheet-like structure, usually composed of type IV collagen, proteoglycan, and laminin. Basal lamina composed of **electron-lucent** (termed lamina lucida or rara), and **electron-dense** (termed lamina dense) layers. Basal lamina produce by epithelial cells, it represents one of two component of basement membrane (the other one is reticular lamina, which composed of type III collagen, and produced by connective tissue).

Cell membrane receptors

They are protein structures located in cell membrane, which are responsible for recognition and binding of signal molecules (e.g., hormones, neurotransmitters etc.) through which cell interacts with its surroundings.

Transport of substances through cell membrane

Transport of substances inside and outside of the cells occurs by two basic mechanisms, Passive and Active transport.

1. Passive transport: ensures transfer of substances in the direction of concentration gradient (difference between concentration inside and outside the cell) without consumption of energy (**Diffusion** and **Osmosis**). So only a few substances with low molecular weight (e.g., water, oxygen, carbon dioxide, urea, methanol, and ethanol) can be transported by this way.

- **Diffusion** is an unordered movement of molecules in solution. It results in the movement of dissolved substances from the higher concentration to places of lower concentration. This movement will stop as soon as the concentration of the substance on both sides membrane equalized.

- **Osmosis** is a process in which water passes through the cytoplasmic membrane from the side where it is more concentrated to the side where it is less concentrated. Water can diffuse through phospholipid bilayers, but osmosis is enhanced by aquaporin which is channel protein in membrane specialized for water passage.

If the solution in the extracellular environment is more concentrated than inside the cell, it is hypertonic solution, so the cells lose water and shrink. If the solution outside the cell is lower concentration than in the cell, it is hypotonic solution, so water penetrates the cell which increases in size and burst (Fig.3).

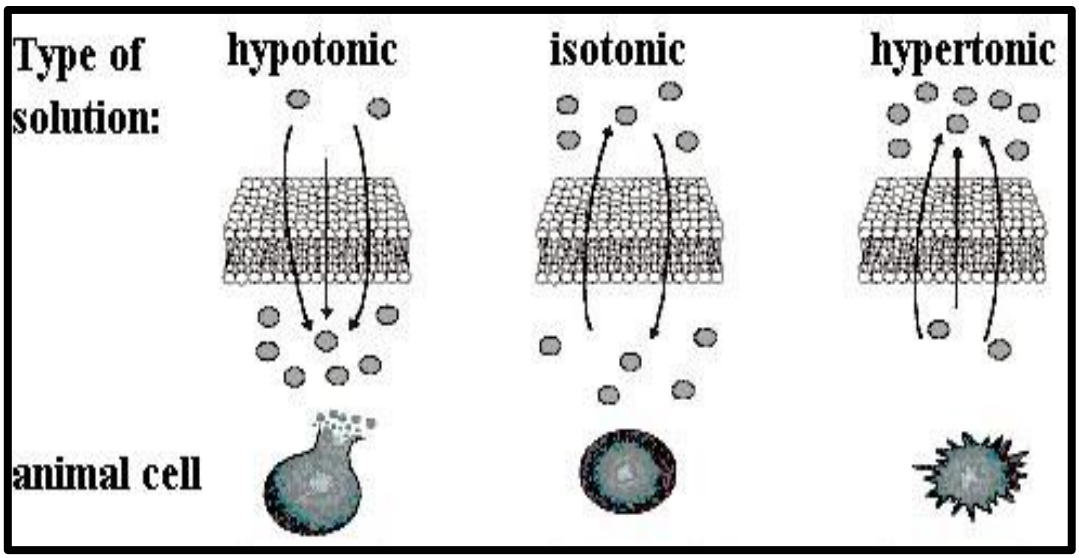


Fig. 3: Phenomena of Osmosis.

2. Active transport: transfer of substances against concentration. It's a selective process often controlled by receptors. Requires consumption energy obtained by dissociation of ATP, and it occurs by special transportation systems (channels and pumps), protein complexes, within the membrane.

The basic metabolites that do not dissolve in lipid (such as sugars and amino acids) enter the cell or its organelles through structures called carriers/transporters which are specialized proteins that are part of the structure of plasma membrane. It assumed that there is a special binding site in each carrier/transporter that is responsible for binding a specific type of molecules, after the molecule is transferred to the second side of cell membrane, transporter is released and may repeat the process again.

As for the principle of pumping action, the active pumping of one substance outside the cell provides the driving force for the active transfer of another substance into the cell, like pumped potassium ion inside the cell versus pumped sodium ion outside the cell.

Endocytosis and Exocytosis

Transport of substances with high molecular weight is carried by Endocytosis and Exocytosis, both processes are associated with active participation of the cytoplasmic membrane (changes in its structure or its movement).

(Endocytosis) is the process by which substances are transported into cells, either by pinocytosis (transport of soluble substances, Fig. 4a) or phagocytosis (transport of solids, Fig. 4b), in addition to another special (less common) method called rhopheocytosis.

(Exocytosis) (Fig. 5), the substances are transported from inside to the outside of cell. Secreted material is in vesicles, which usually arise from endoplasmic reticulum and Golgi apparatus. Vesicle approaches plasma membrane and merging with it, then substances are released into the environment.

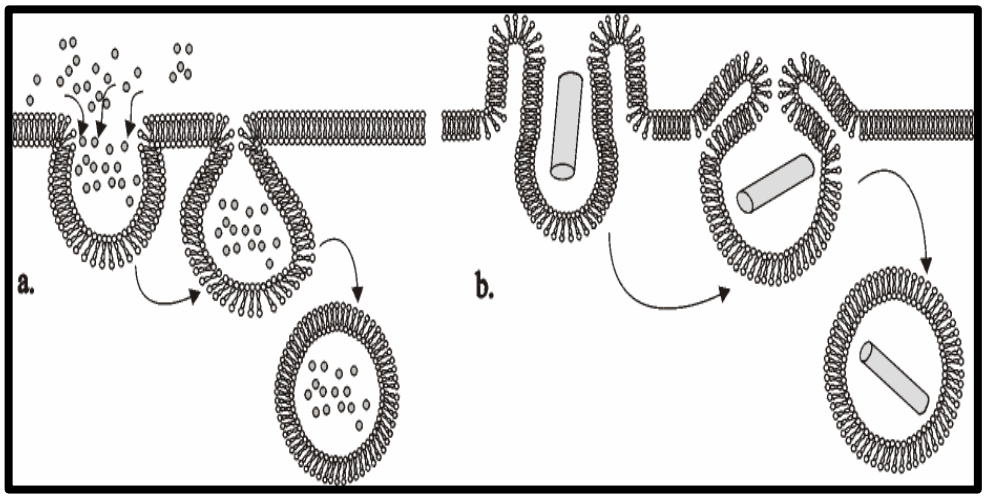


Fig. 4: a. Pinocytosis; b. Phagocytosis.

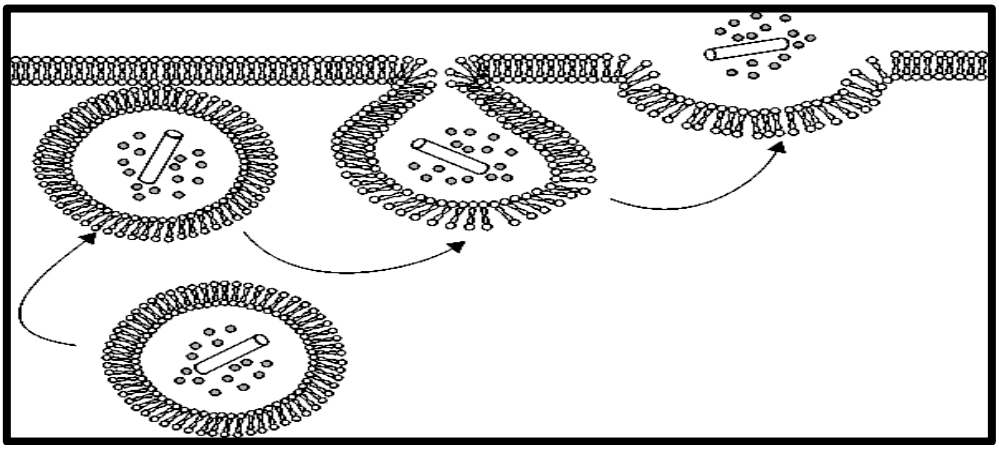


Fig. 5: Exocytosis.