Cytoskeleton

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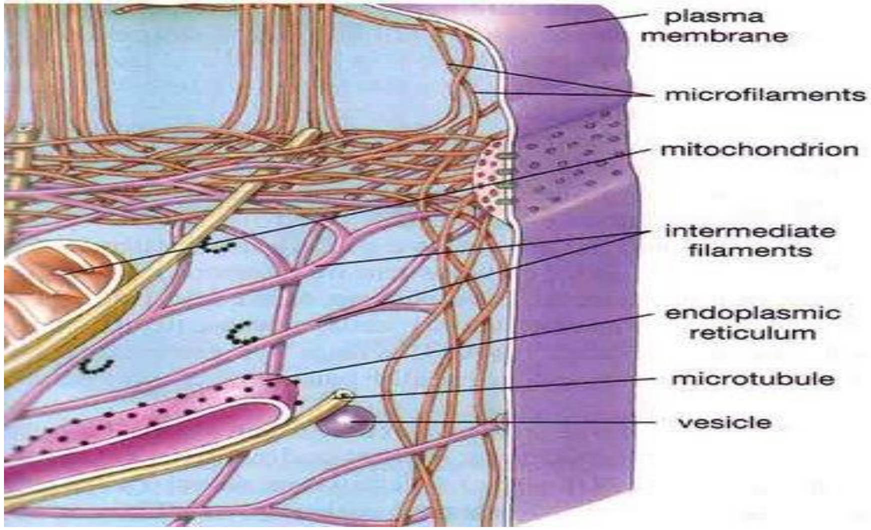
THE CYTOSKELETON

It has three components:

I- Microfilaments

II- Intermediate filaments

III- Microtubules



The functions of cytoskeleton:

- **Maintenance of the shape of the cells**
- **Supportive internal skeleton to the cell.**
- **It is important in cellular movements as:**

1-Movement of organelles and vesicles within the cytoplasm.

2-Movement of parts of the cell e.g. pseudopodia in macrophage.

3-Movement of the whole cell as in spermatozoa.

I- Microfilaments (Actin filaments)

size: They are thin filaments (6 nm in diameter) and consist of protein called actin.

Site: Their distribution depends on the location and type of the cell.

A.In non-muscle cells:

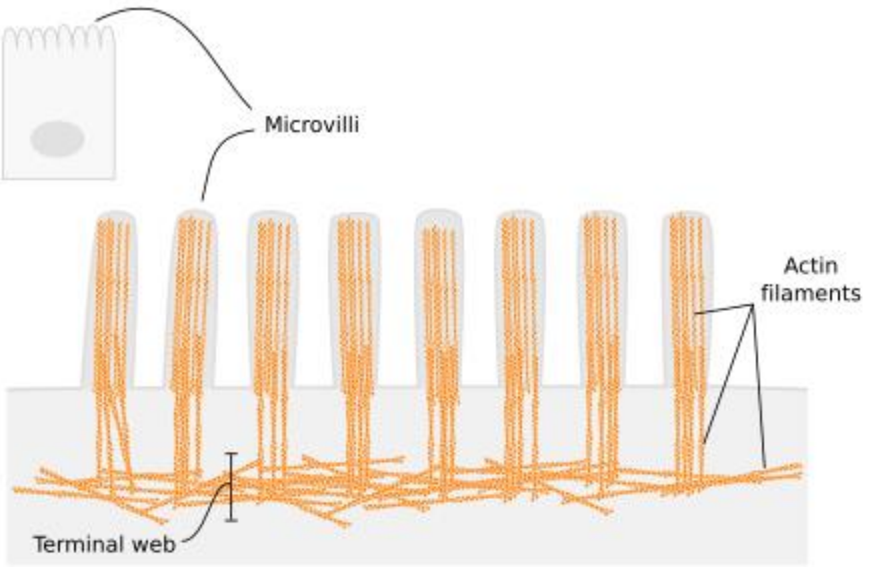
They form thin sheath under the cell membrane and present also in the cell extensions as pseudopodia and microvilli.

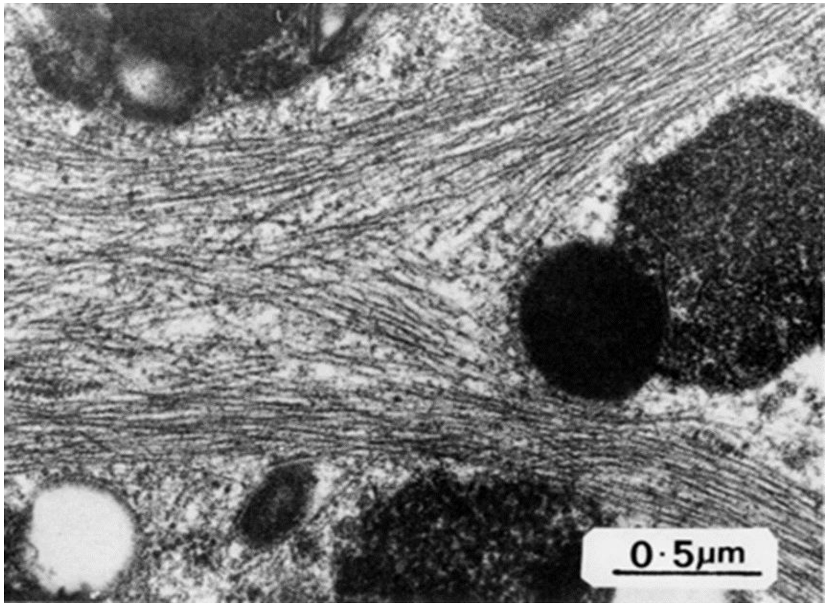
B. In muscle cells:

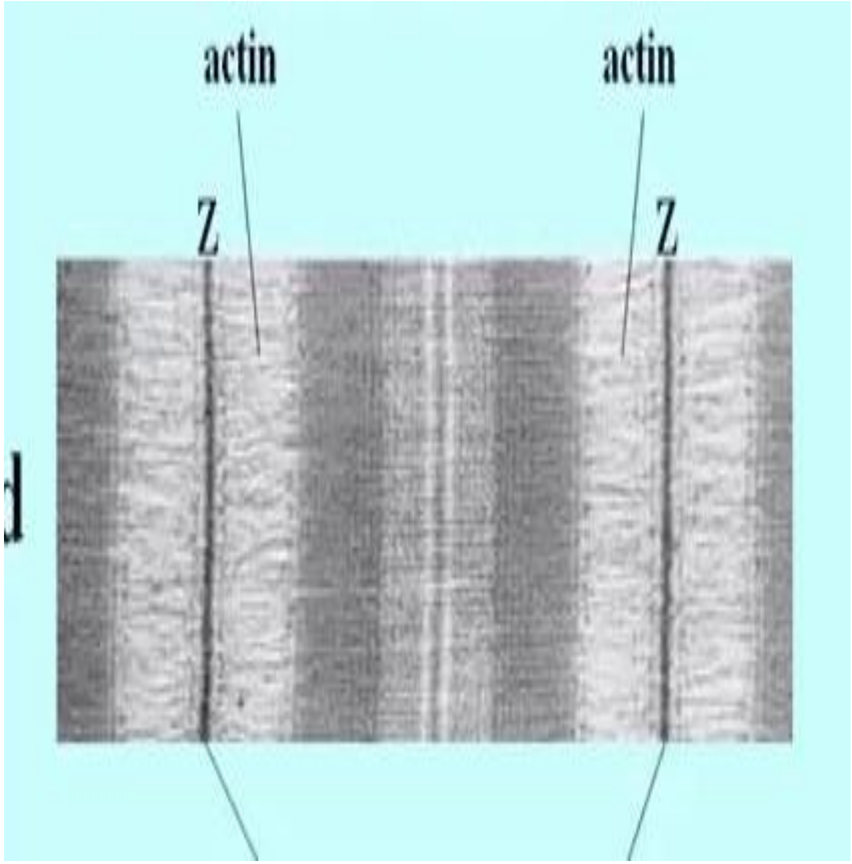
Actin filaments interdigitate with thick myosin filaments in parallel array (responsible for muscle contraction).

non-muscle cells

muscle cells





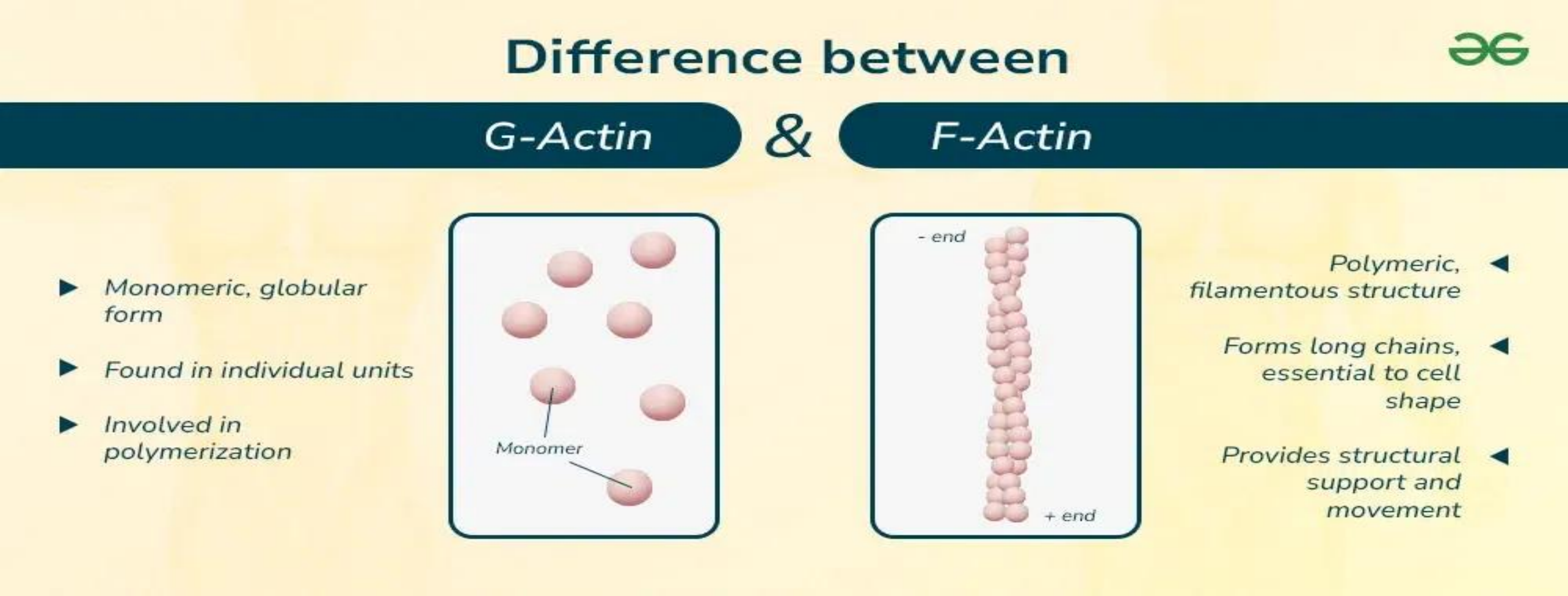


Forms:

- **The actin occurs in the cytoplasm in two forms:-**

➢ **G-actin(globular actin):globular molecules dispersed in the cytosol.**

➢ **F-actin(filamentous actin): polymer of G-actin consisting of two strands coiled around each other to form filaments in the presence of K+ and Mg2+**



- **Each actin filament has two ends:**

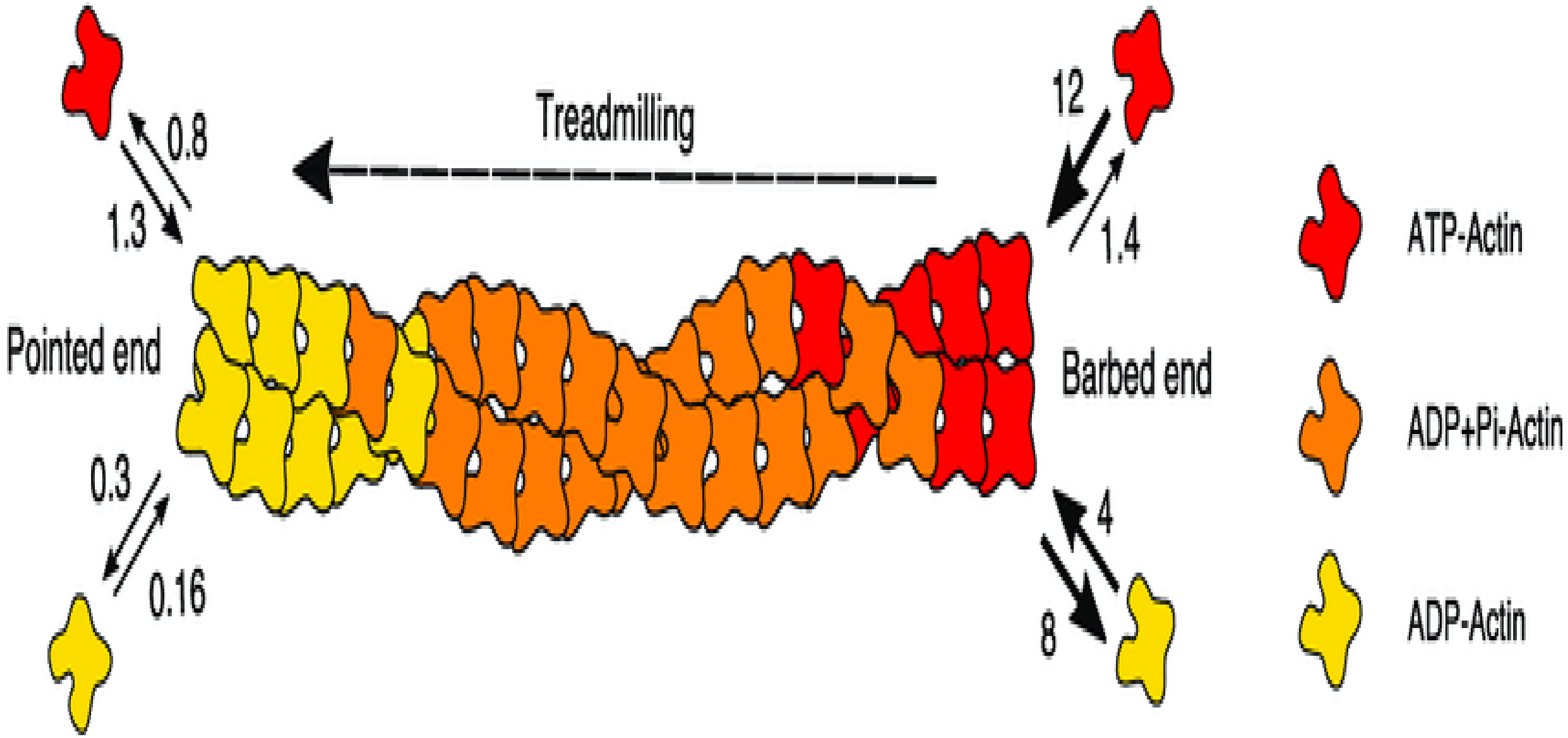
1- Plus end (barbed) (+) at which actin molecules are added leading to elongation of actin filament with hydrolysis of ATP at each addition.

2- Minus end (pointed) (-) at which actin molecules are removed leading to shortening of actin filament

- **Both the assembly and disassembly of subunits from F-actin are promoted by other proteins, such as profilin and cofilin respectively.**

- **Actin is very abundant in all cells, usually concentrated as networks of actin filaments and abundant free globular G-actin subunits concentrated near the cell membrane (a region sometimes called the cell cortex) and in cellular extensions.**

Actin filament treadmilling.



Functions of microfilaments:

1- In muscle cells :

Muscle contraction.

2- In non muscle cells:

- Movement of membrane proteins.
- Movement of the plasma membrane as endocytosis and exocytosis.
- Formation of structural core of microvillus and terminal web.
- Extension of cell processes.
- Locomotion of cells.
- Play a role in moving and shifting of cytoplasm components.
- Formation of contractile rings during cell division.

II- INTERMEDIATE FILAMENTS

- They are intermediate in size (about 10 nm in diameter) between thick filaments (myosin) and thin filaments (actin).

- They are stable structures.
- Function: They provide structural support for the cells

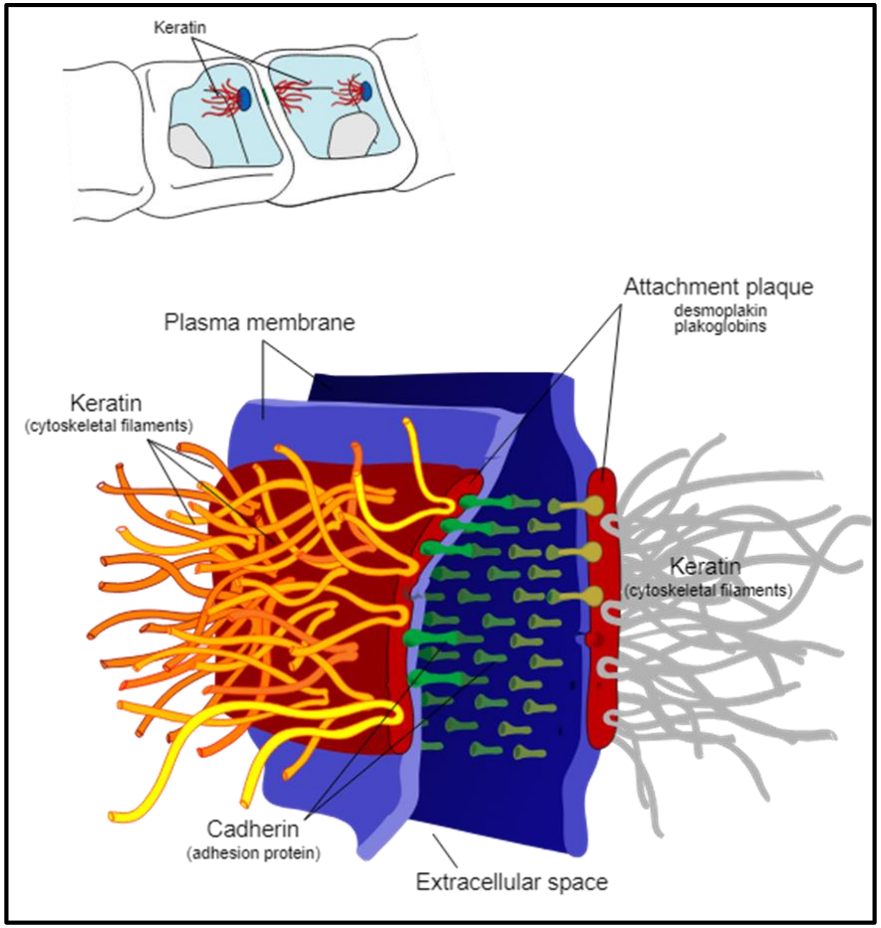
Types of intermediate filaments:

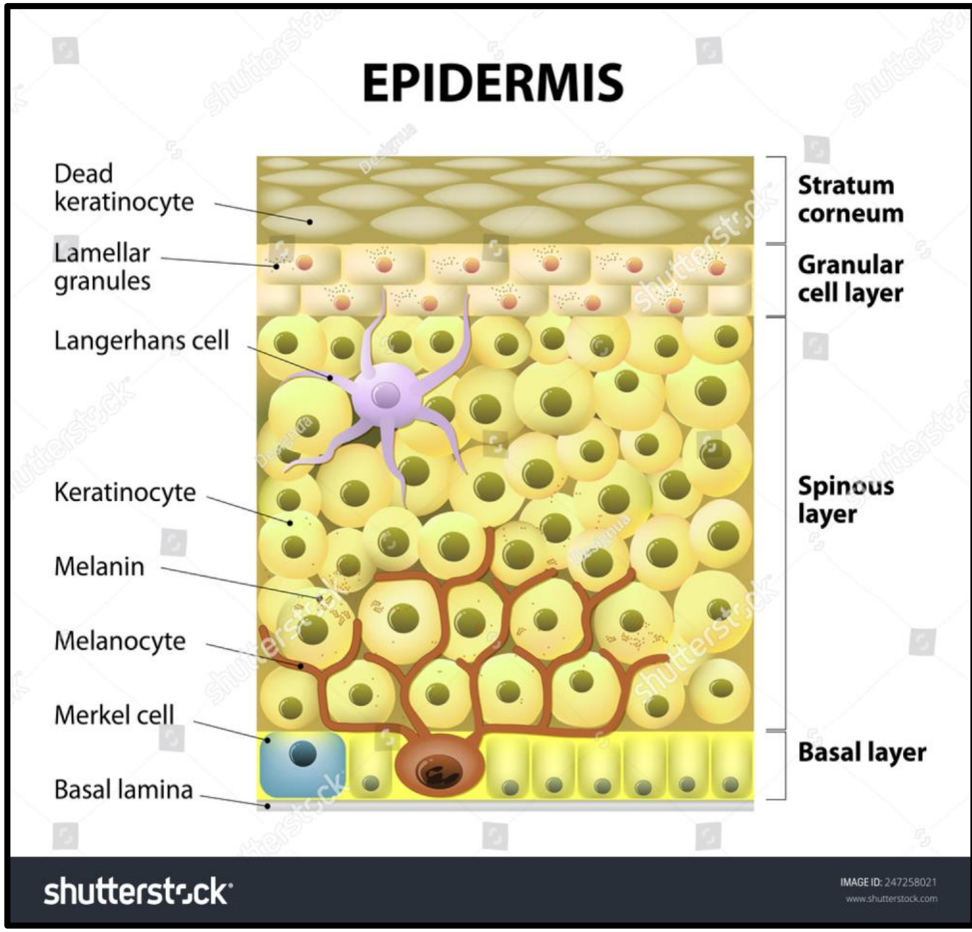
■ **keratins or cytokeratins:**

- They are a diverse family of acidic and basic isoforms that compose intermediate filaments in all epithelial cells.
- In epidermal cells, cytokeratins form outer layer of nonliving skin cells and produces hard protective structures such as nails.
- Intermediate filaments of keratins form large bundles (tonofibrils) that attach to certain junctions between epithelial cells.

DESMOSOMES

keratins or cytokeratins

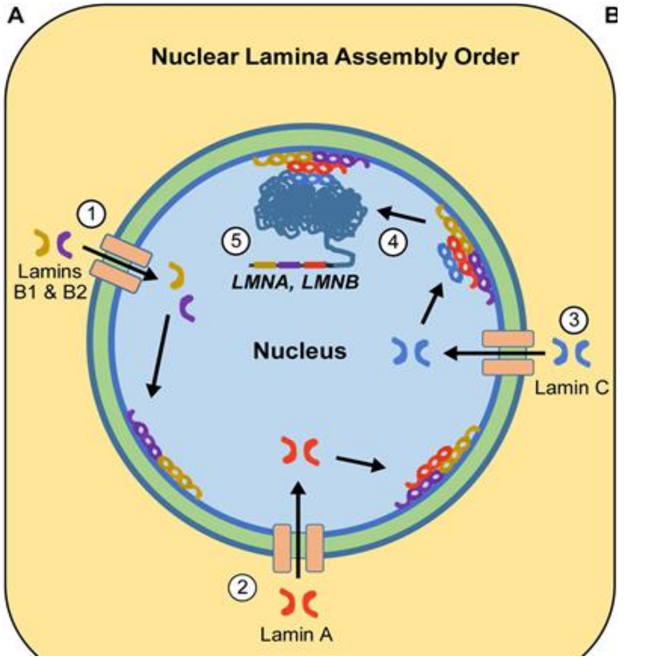




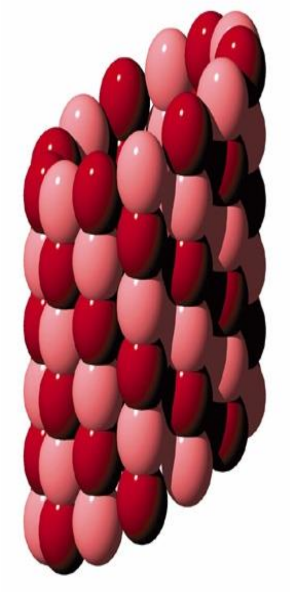
■ **Vimentin** is found in most cells derived from mesenchyme. Important vimentin-like proteins include **desmin** found in almost all muscle cells and **glial fibrillar acidic protein (GFAP)** found especially in astrocytes, supporting cells of central nervous system tissue.

■ **Neurofilament** the major intermediate filaments of neurons.

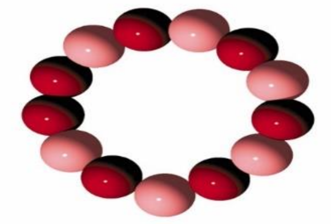
■ **Lamins** are present in the cell nucleus where they form a structural framework called the nuclear lamina just inside the nuclear envelope



III- MICROTUBULES



- They are non-membranous organelles.
- **L.M**: They are too small to be seen by light microscope.
- **E.M:** They are long, straight, rigid, hollow cylindrical structures 24nm in the outer diameter.
- In cross section they appear as fine circles consisting of dense wall and hollow core.



- They are formed of protein subunits called **tubulin**, There are two forms of tubulin subunits named **α and β** tubulin. When they unite together, they give tubulin dimers which are organized into spiral with total number of **13 subunits** in each **complete turn** of the spiral.

Microtubules have two ends:

a- **Plus (+) end**, at which tubulin subunits are added causing elongation of the microtubule.

b- **Minus (-) end** at which tubulin subunits are removed causing shortening of the microtubule.

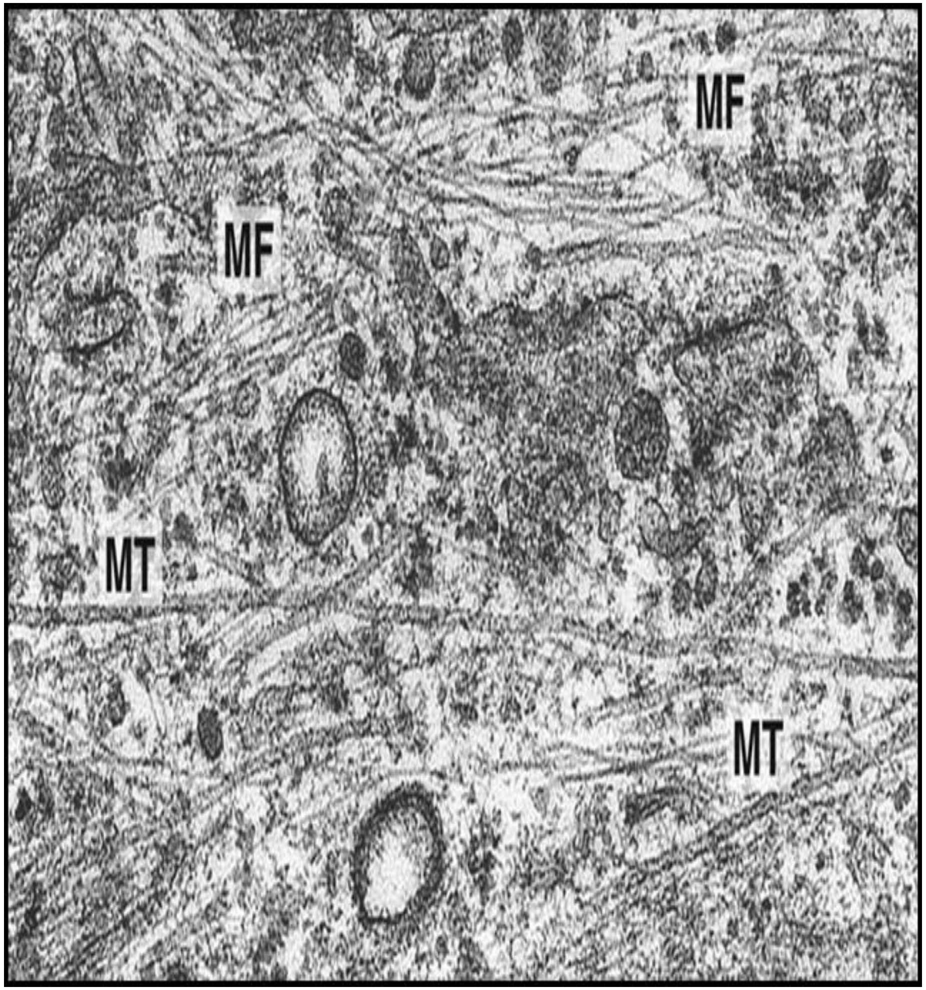
- They can rapidly change their length to meet the requirements of changing in cell shape.

- Microtubules are present in the cytoplasm in two forms:

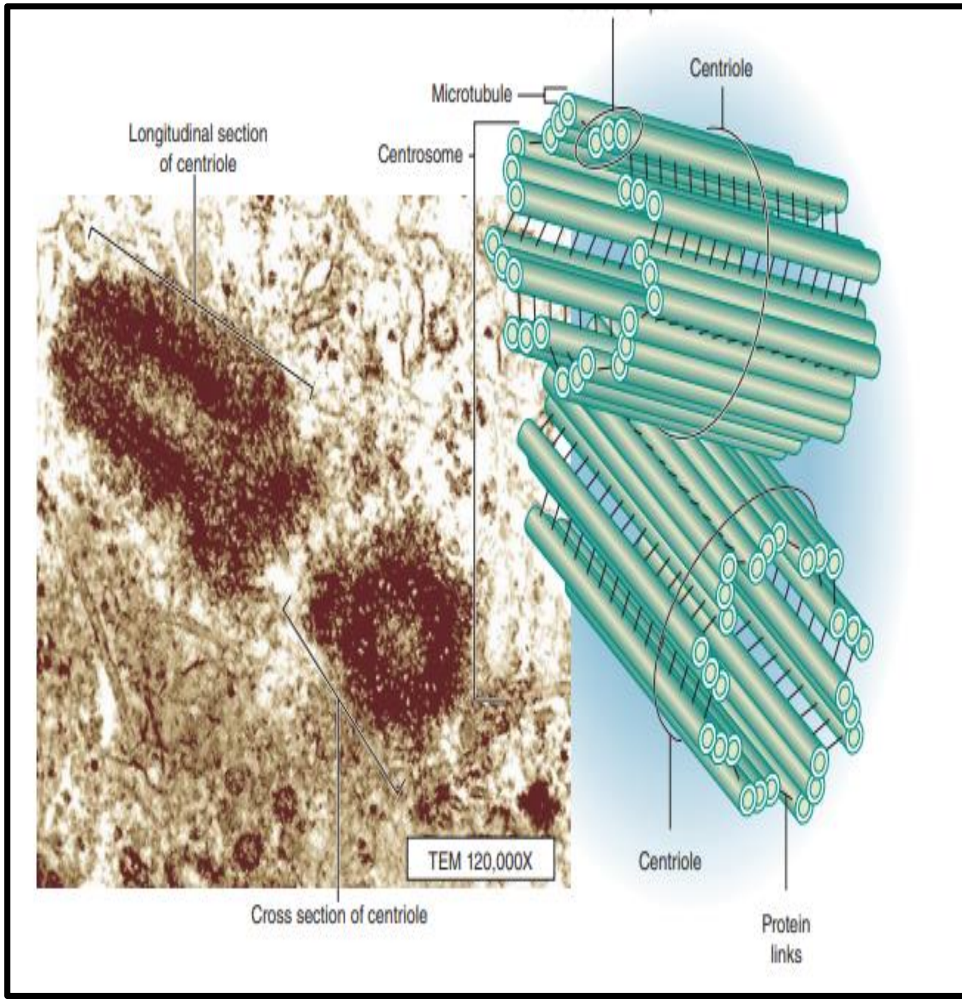
  A- Dispersed microtubules.

  B- Organized microtubules as in cilia and centriole.

EM Microtubules (MT) and Microfilaments (MF)



EM L.S &T.S Centriole



Microtubules organizing centers (MTOC)

- Definition: MTOC is a structure found in the eukaryotic cells from which the microtubules emerge.
- Function: They are responsible for polymerization of tubulin subunits to form microtubules.
- They include:

1- Basal bodies of the cilia.

2- Centrioles.

3- Centromeres of the chromosomes.

Microtubule-associated proteins (MAPs)

- **Definition:** They are special proteins that assist in the intracellular movement of organelles and vesicles along the microtubules (motor function) and also prevent depolymerization of the microtubules.
- **Types**: There are four main types:

1- **Kinesin** is a motor protein responsible for movement of vesicles and organelles along the microtubule towards its plus (+) end.

2- **Cytoplasm dynein** is a motor protein which moves vesicles and organelles along the microtubule towards its minus (-) end.

3- **Dynamin** is a protein which forms cross-bridges between the neighboring microtubules.

4- **Axonemal dynein** is a protein in the shaft of the cilia and responsible for ciliary movement

- **Functions of microtubules:**

1- They maintain the shape of the cell because of its rigidity.

2- The dispersed microtubules are responsible for the intracellular transport of organelles and vesicles.

3- Microtubules provide the basis for structure and function of:

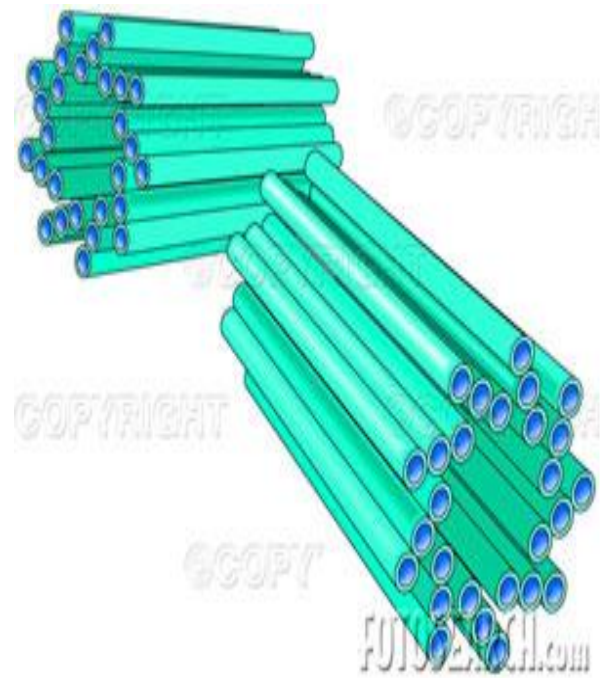
a- Centrioles.

b-Cilia & flagella.

c- Mitotic spindle (unstable structure formed during cell division).

CENTRIOLES

They are non membranous organelles. They are self-replicating organelles during cell division.



Functions:

1- They form the mitotic spindle during cell division.

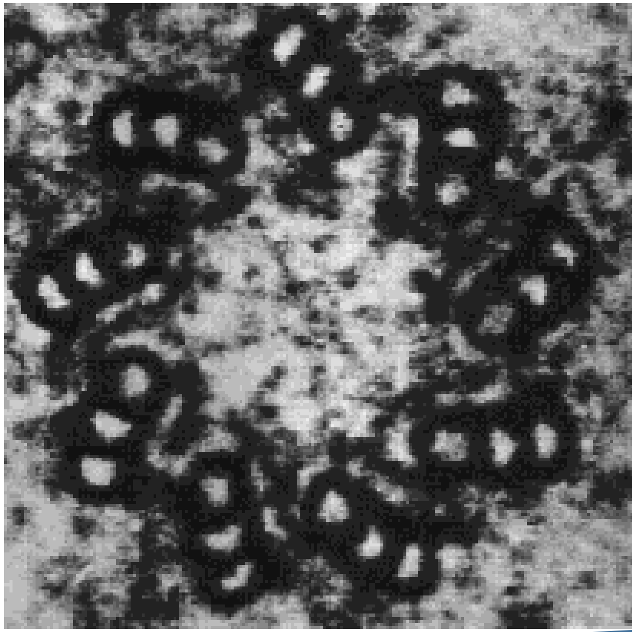
2- They form the basal bodies of the cilia and flagella.

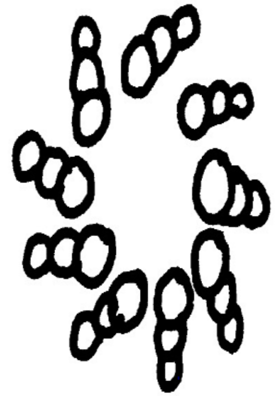
3- They form microtubules organizing centers (MTOC).

Structure:

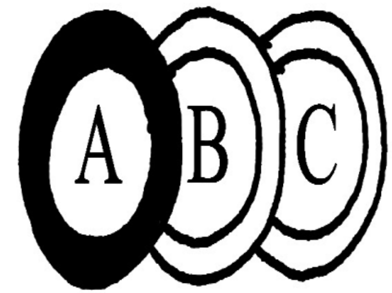
L/M: Centrioles are paired cylinders arranged perpendicular to each other, located near the nucleus and are called the **centrosome**

EM T.S Centriole

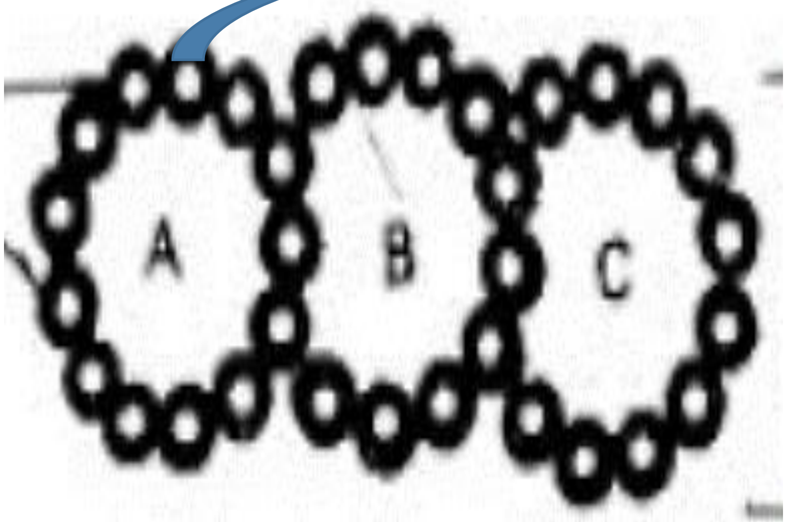


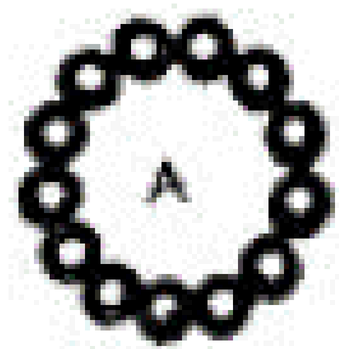


T.S of a centriole
showing 9 bundles of tripelts



One triplet showing
A,B,C microtubules





13 Tubulin
subunits

EM: Each centriole is a hollow cylinder with a dense wall around an electron-lucent central core.

- In cross section, it appears as a **pinwheel**.
- Its wall is made up of nine bundles of microtubules, each bundle consists of three microtubules (triplets) - Each triplet consists of A, B and C microtubules. **(9triplets)**
- In cross section, the innermost microtubule of each triplet (A microtubule) is a complete ring of 13 tubulin subunit, the middle and outer microtubules B & C are C shaped having 10 subunits as they share the wall with each other and with A microtubule.
- These bundles are embedded in fine fibrillar material.

CILIA

Definition: Tiny hair like processes on the free surface of certain cells.

Sites: 1- Some cells of the respiratory system.

2- Female genital tract (Fallopian tube and uterus).

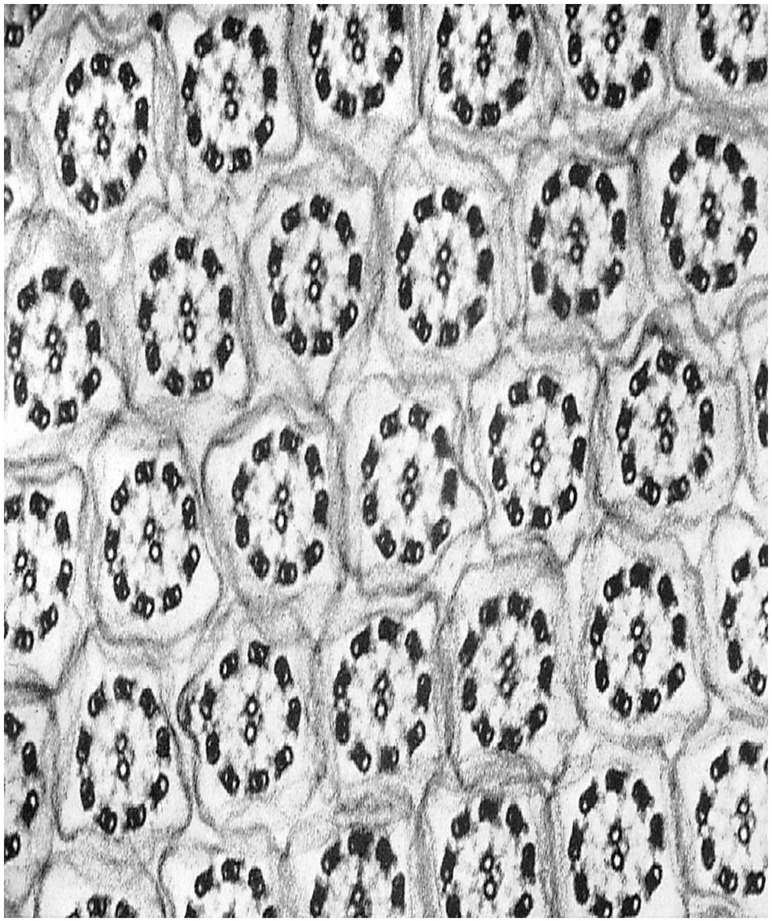
Size: Each cilium has a diameter of 0.2 μm and a length of 7-10 μm.

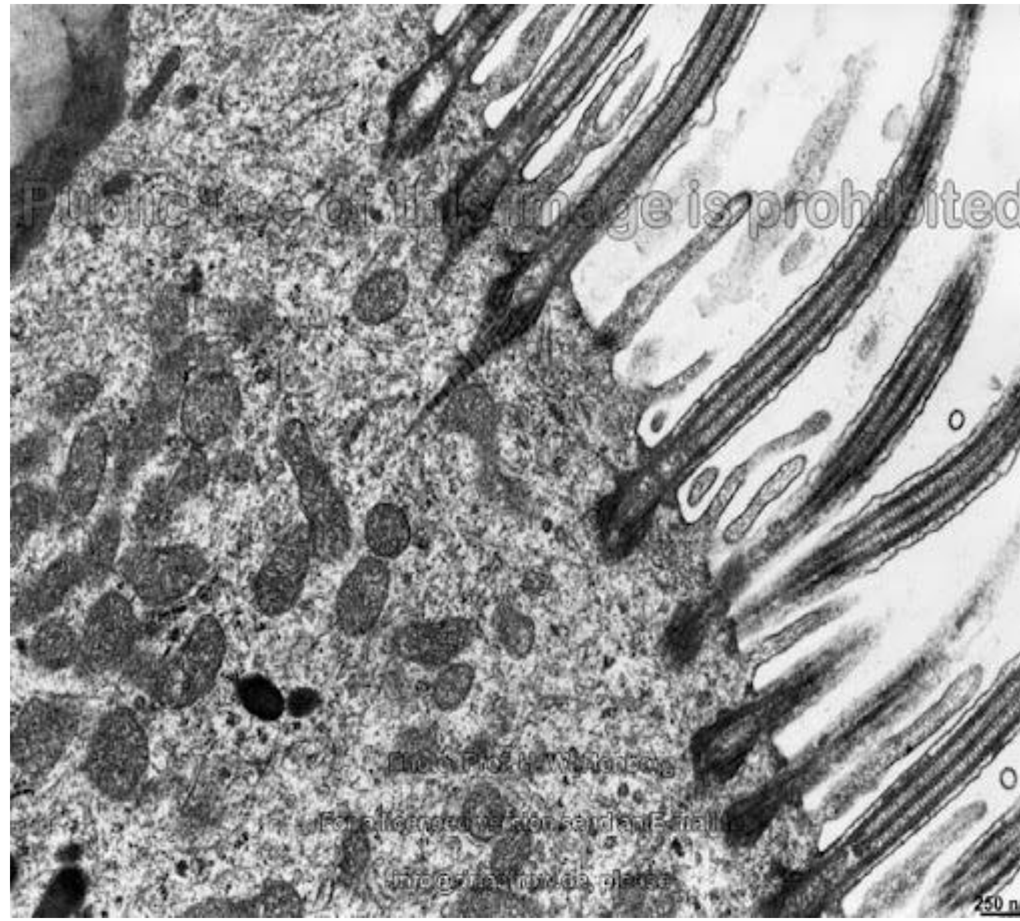
Structure:

LM: Cilia are motile hair-like projections arising from the free surface of certain epithelial cells.

T.S shaft of CILIA

L.S CILIA





EM: They are developed from the centriole. Each cilium is composed of:

1- Basal body: It is present in the cytoplasm under the free surface and is identical to the centriole in structure.

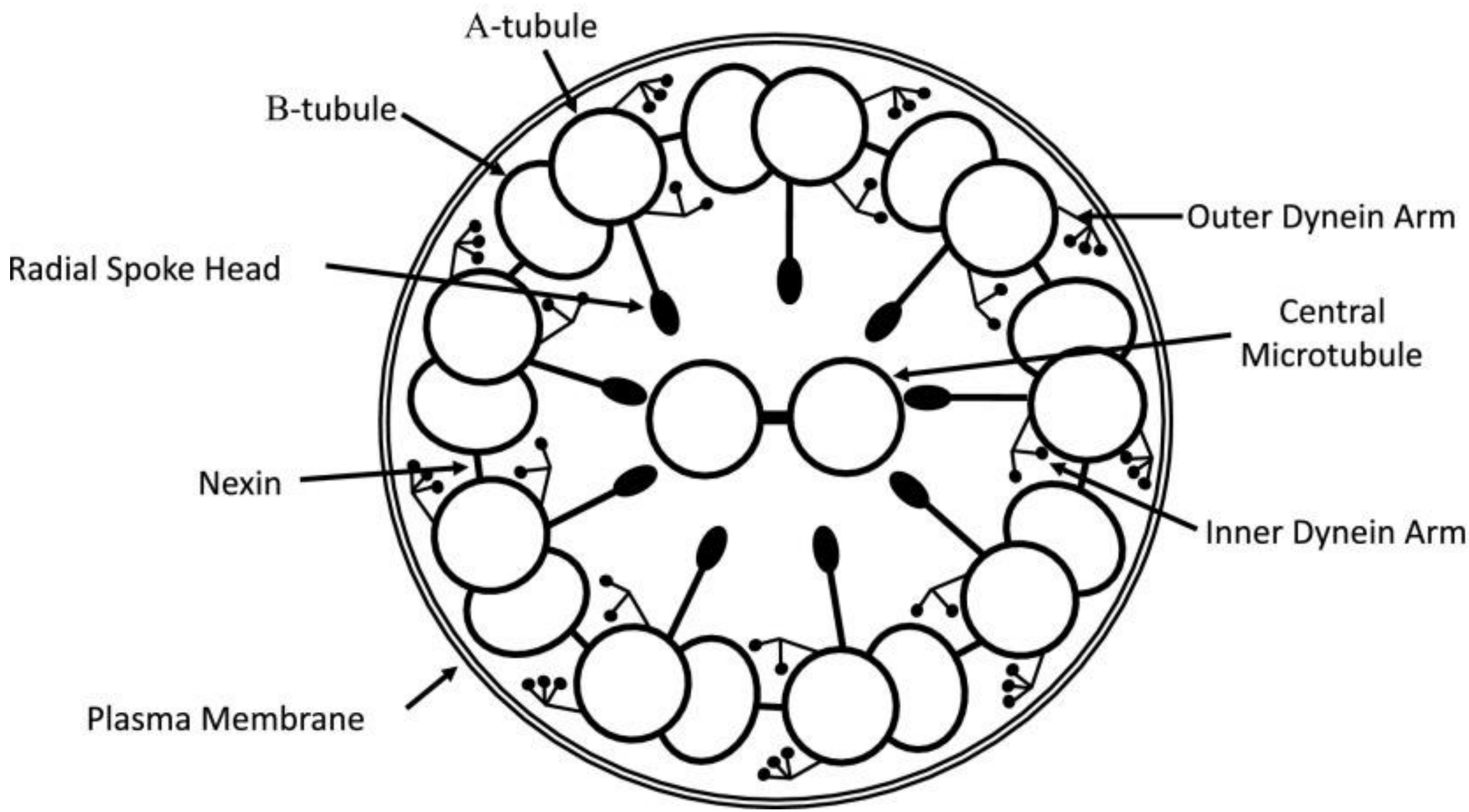
2- The axoneme (shaft): is formed of:

a- **Two central singlets** of microtubules surrounded by a central sheath.

b- **Outer nine doublets** of microtubules surrounding the central two singlets microtubules. Each doublet is formed of A&B microtubules.

c- **Two Dynein arms** which have ATPase activity radiating from the A microtubule of one doublet to the B microtubule of the adjacent doublet.

T.S shaft of CILIA



D- **Elastic protein** complexes which are:

i- **Radial spokes** projecting from the A microtubule of the doublet toward the central sheath.

ii- **Nexin** which links the adjacent doublets, extending from the A microtubule of one doublet to the B microtubule of the adjacent doublet.

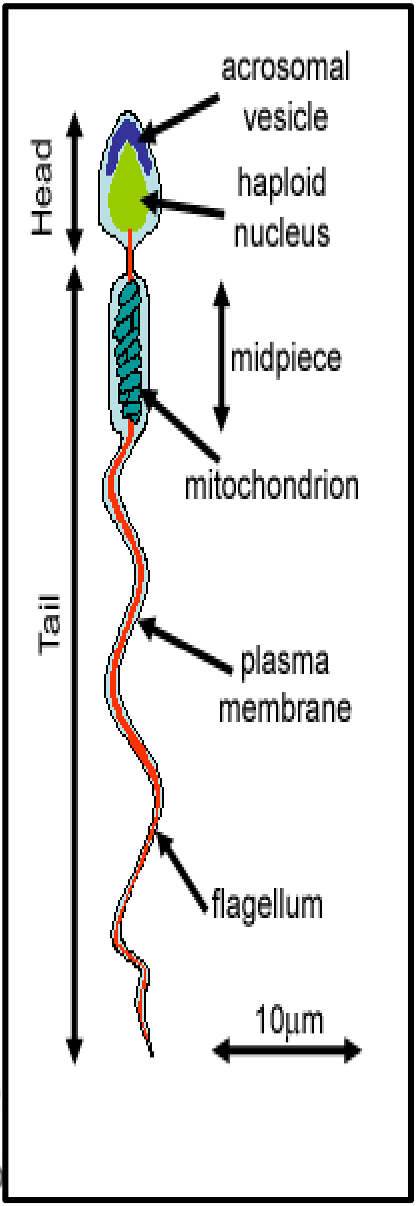
Function of cilia:

1- In trachea: They move to keep the airways clear of mucus and dirt.

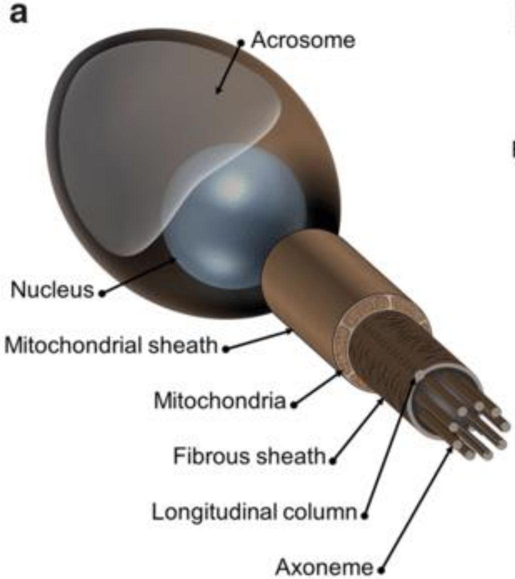
2- In Fallopian tube: cilia help to move the ovum towards the uterus for possible pregnancy.

Flagella

- The flagellum has the same structure as cilium but is much longer. The only example in human is the tail of spermatozoon. Flagellated cells have only one long flagellum.



a



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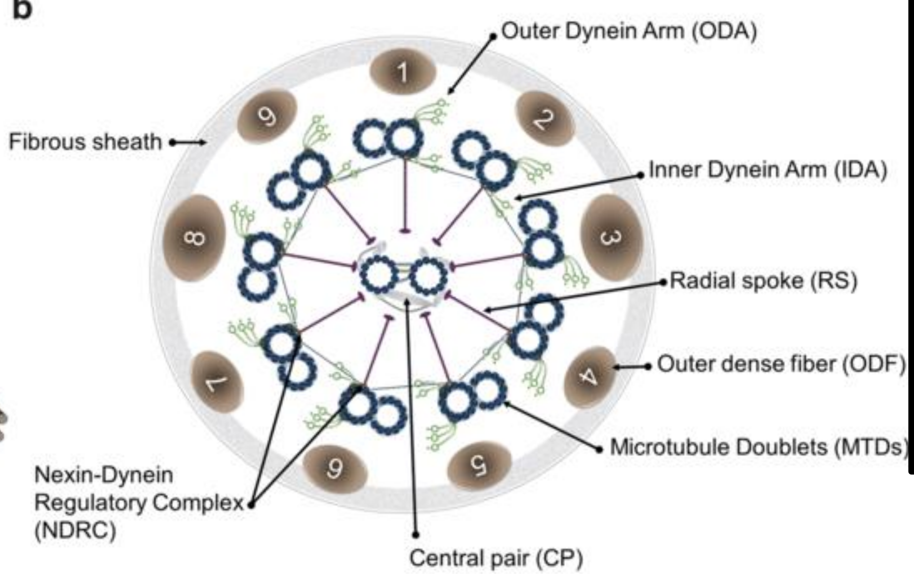


Cell Inclusions

- Inclusions are non-living components of the cell. They include:

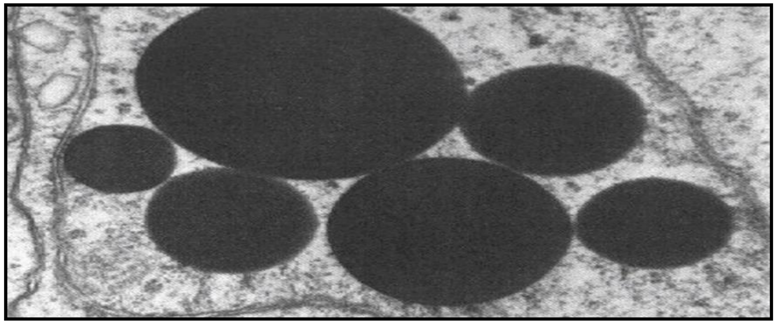
1. Stored foods:

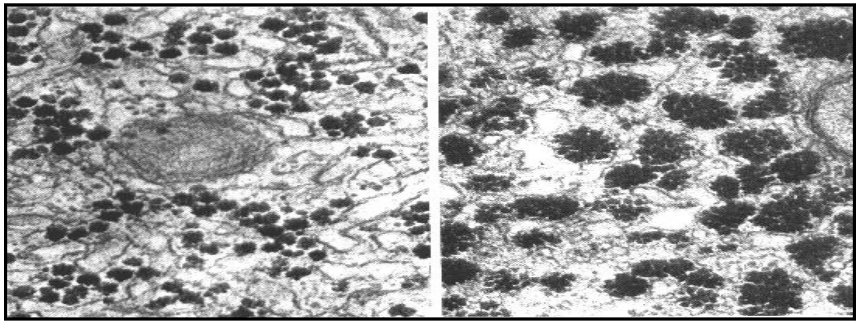
a. Lipids: stored mainly in fat cells.

- **EM:** Fat droplets appear round and black without limiting membrane.

b. Carbohydrates (Glycogen): stored in the form of glycogen in liver cells and muscle fibers.

- **EM:** Glycogen is seen as electron dense particles with no membrane boundary.



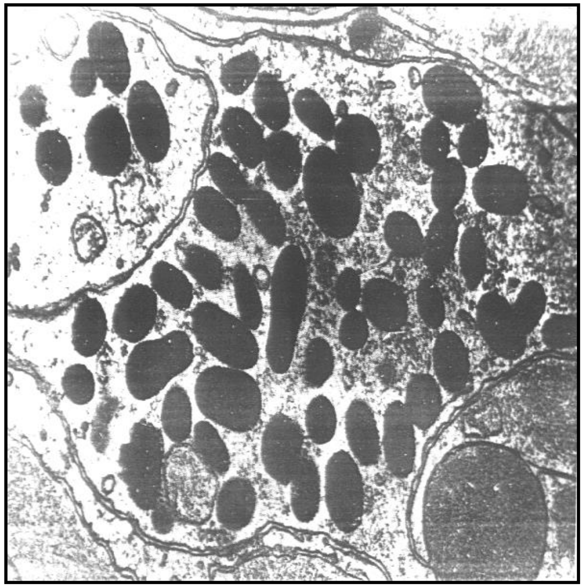


2- Pigments:

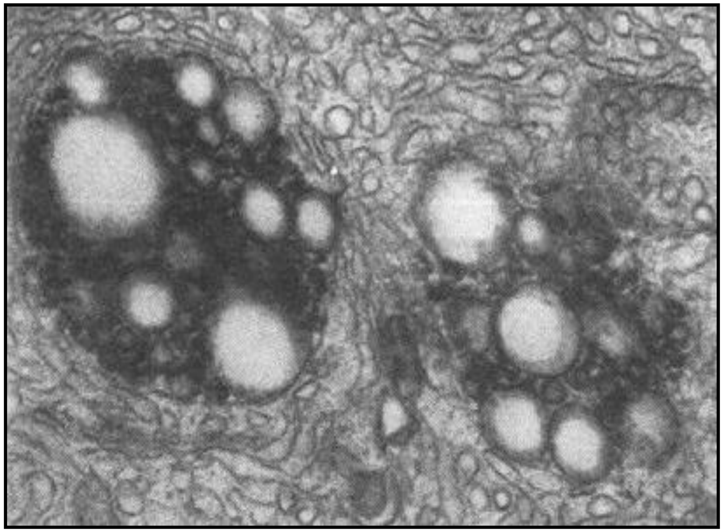
•Pigments are materials with **natural colors** and **need no stain** to be seen. They are classified into two types:

- **Exogenous pigments:** they are formed outside the body, they include:
  - Carotenes [yellowish or red pigment] present in some vegetables as carrots.
  - Minerals e.g. lead (blue) & silver (gray).
  - Carbon particles, they are black pigments which may be inhaled and phagocytosed by phagocytic cells in the lung.
  - Tattooing, a process by which pigments are introduced by needles into deeper layers of the skin.

▪ **Endogenous pigments:** they are formed inside the body. They include:



- **Hemoglobin,** present in RBCs and is the cause of their red color.
- **Melanin**, dark brown or black pigment that cause the black color of the skin, hair, eye
- **Lipofuscin pigment:** They are yellowish-brown granules



found in liver, heart and nerve cells. It is produced from accumulation of residual bodies [secondary lysosomes].