CELL BIOLOGY

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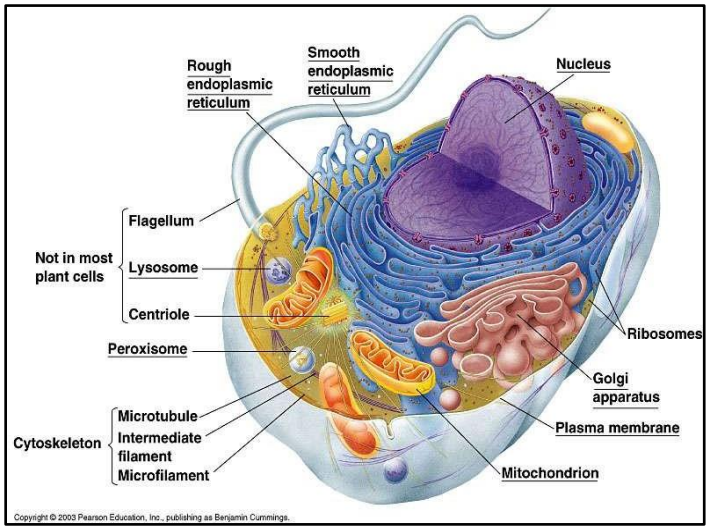
Lecture 6: Cytoskeleton of the Cell 8/11/2021

The cytoskeleton is a network of filaments and tubules that extends throughout a cell cytoplasm, It is found in all cells, eukaryotic cells, prokaryotic cells, and archaeans. In eukaryotic cells, these fibers consist of a complex mesh of protein filaments and motor proteins that aid in cell movement and stabilize the cell. The cytoskeleton supports the cell, gives it shape, organizes and tethers the organelles, and has roles in molecule transport, cell division and cell signaling.



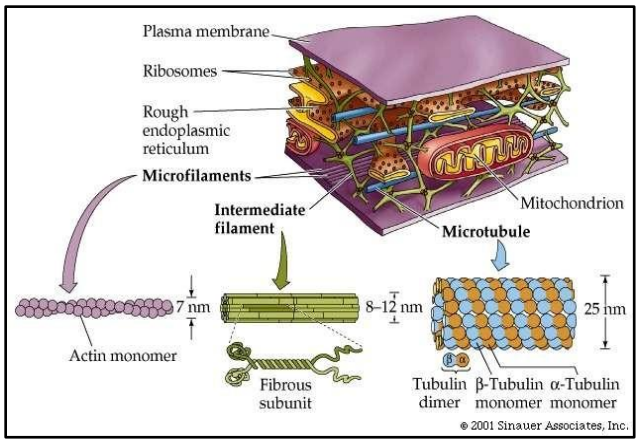
Cytoskeleton Function

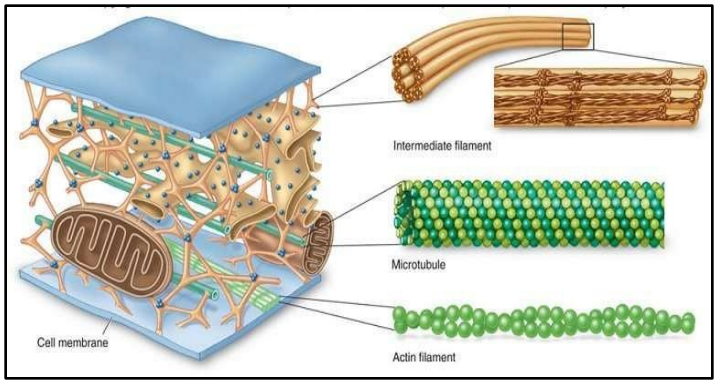
The cytoskeleton extends throughout the cell's cytoplasm and directs a number of important functions.

1- It helps the cell maintain its shape and gives support to the cell.
2- A variety of cellular organelles are held in place by the cytoskeleton.
3- It assists in the formation of vacuoles.
4- Types of intracellular movement supported by the cytoskeleton include transportation of vesicles into and out of a cell, chromosome manipulation during mitosis and meiosis, and organelle migration.
5- The cytoskeleton makes cell migration possible as cell motility is needed for tissue construction and repair, cytokinesis (the division of the cytoplasm) in the formation of daughter cells, and in immune cell responses to germs.
6- The cytoskeleton assists in the transportation of communication signals between cells.
7- It forms cellular appendage-like protrusions, such as cilia and flagella, in some cells.

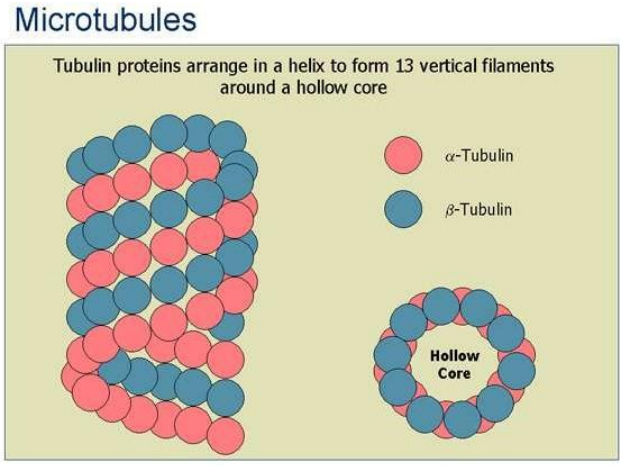
Cytoskeleton Structure

The cytoskeleton is composed of at least three different types of fibers: **microtubules**, **microfilaments,** and **intermediate** filaments. These fibers are distinguished by their size with microtubules being the thickest and microfilaments being the thinnest.



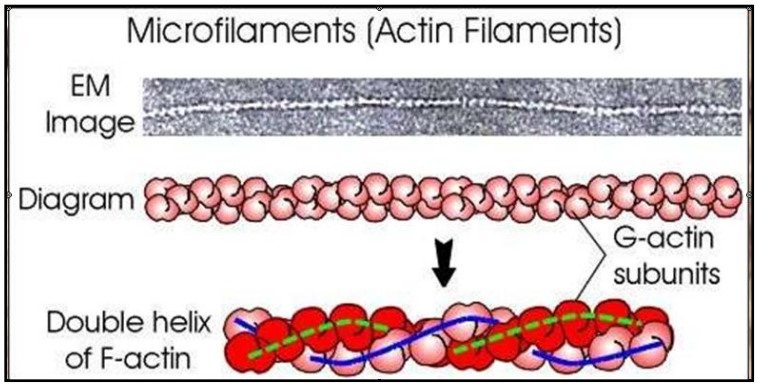


- **Microtubules** are the largest of the cytoskeleton's fibers at about 23 nm. They are hollow tubes made of alpha and beta tubulin.
- Microtubules form structures like flagella, which are "tails" that propel a cell forward.
- They are also found in structures like cilia, which are appendages that increase a cell's surface area and in some cases allow the cell to move.
- Most of the microtubules in an animal cell come from a cell organelle called the centrosome.
- Microtubules are important in forming the spindle apparatus (or mitotic spindle), which separates sister chromatids so that one copy can go to each daughter cell during cell division.
- They are also involved in transporting molecules within the cell and in the formation of the cell wall in plant cells.

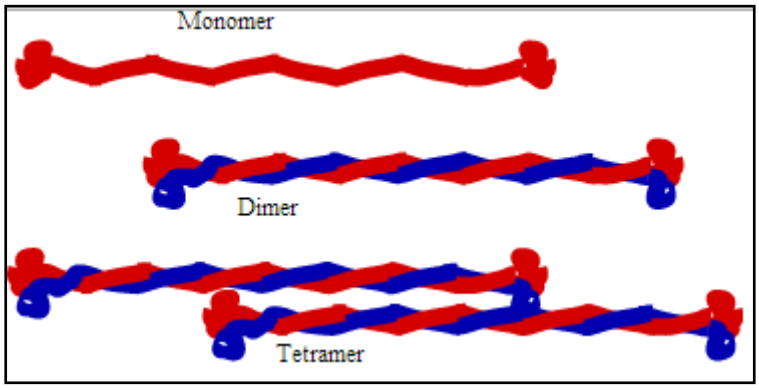


- **Microfilaments** or actin filaments because they are mostly composed of the protein actin; are thin, solid rods their structure is two strands of actin wound in a spiral. They are about 7 nanometers thick, making them the thinnest filaments in the cytoskeleton.

Microfilaments have many functions.
-They aid in cytokinesis, which is the division of a cytoplasm of a cell when it is dividing into two daughter cells.
-They aid in cell motility and allow single-celled organisms like amoebas to move.
- They are also involved in cytoplasmic streaming.
- Microfilaments are also part of muscle cells and allow these cells to contract, along with myosin. Actin and myosin are the two main components of muscle contractile elements.



- **Intermediate filaments** Intermediate filaments are about 8-12 nm wide; they are called intermediate because they are in-between the size of microfilaments and microtubules. Intermediate filaments are made of different proteins such as keratin (found in hair and nails, and also in animals with scales, horns, or hooves), vimentin, desmin, and lamin.
- All intermediate filaments are found in the cytoplasm except for lamins, which are found in the nucleus and help support the nuclear envelope that surrounds the nucleus. The intermediate filaments in the cytoplasm maintain the cell's shape, bear tension, and provide structural support to the cell. Intermediate filaments do not participate in ell motility. Composed of two anti parallel dimer

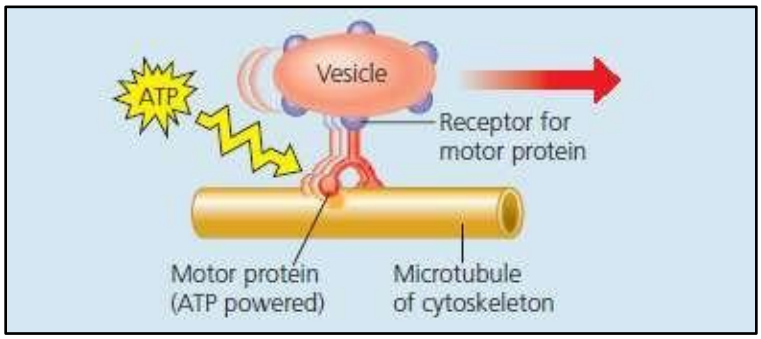


Motor Proteins

A number of motor proteins are found in the cytoskeleton. As their name suggests, these proteins actively move cytoskeleton fibers. As a result, molecules and organelles are transported around the cell. Motor proteins are powered by ATP, which is generated

through cellular respiration. There are three types of motor proteins involved in cell movement.

- **Kinesins** move along microtubules carrying cellular components along the way. They are typically used to pull organelles toward the cell membrane.
- **Dyneins** are similar to kinesins and are used to pull cellular components inward toward the nucleus. Dyneins also work to slide microtubules relative to one another as observed in the movement of cilia and flagella.
- **Myosins** interact with actin in order to perform muscle contractions. They are also involved in cytokinesis, endocytosis (endo-cyt-osis), and exocytosis (exo-cyt-osis).



Cytoplasmic Streaming

-The cytoskeleton helps to make cytoplasmic streaming possible. Also known as **cyclosis**, this process involves the movement of the cytoplasm to circulate nutrients, organelles, and other substances within a cell. Cyclosis also aids in endocytosis and exocytosis, or the transport of substance into and out of a cell.

-As cytoskeletal microfilaments contract, they help to direct the flow of cytoplasmic particles. When microfilaments attached to organelles contract, the organelles are pulled along and the cytoplasm flows in the same direction.

-Cytoplasmic streaming occurs in both prokaryotic and eukaryotic cells. In protists, like amoebae, this process produces extensions of the cytoplasm known as **pseudopodia**. These structures are used for capturing food and for locomotion.

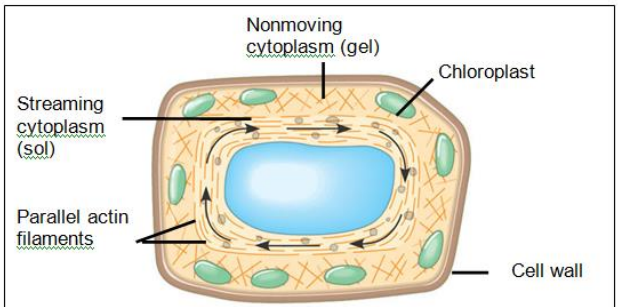


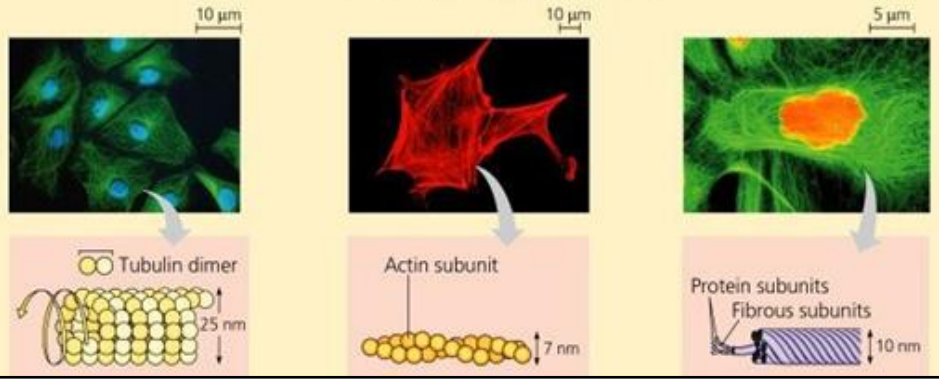
Fig.(1-16): Cytoplasmic streaming in plant cells

Cytoskeleton

- There are three main types of fibers in the cytoskeleton: **microtubules**, **microfilaments**, and **intermediate filaments**.

Table 7.2 The Structure and Function of the Cytoskeleton

Property	Microtubules	Microfilaments (Actin Filaments)	Intermediate Filaments
Structure	Hollow tubes; wall consists of 13 columns of tubulin molecules	Two intertwined strands of actin	Fibrous proteins supercoiled into thicker cables
Diameter	25 nm with 15-nm lumen	7 nm	8–12 nm
Protein subunits	Tubulin, consisting of α-tubulin and β-tubulin	Actin	One of several different proteins of the keratin family, depending on cell type
Main functions	Maintenance of cell shape (compression-resisting "girders") Cell motility (as in cilia or flagella) Chromosome movements in cell division Organelle movements	Maintenance of cell shape (tension-bearing elements) Changes in cell shape Muscle contraction Cytoplasmic streaming Cell motility (as in pseudopodia) Cell division (cleavage furrow formation)	Maintenance of cell shape (tension-bearing elements) Anchorage of nucleus and certain other organelles Formation of nuclear lamina



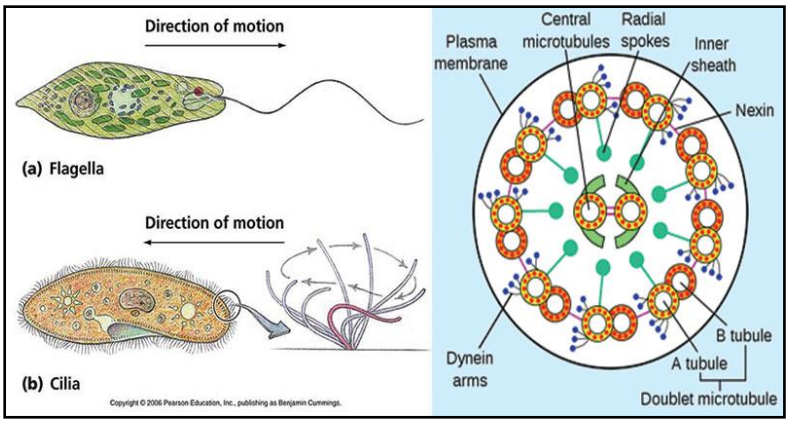
A **flagellum** (plural: **flagella**) is a long, whip-like structure that helps some single celled organisms move. It is composed of microtubules. They help propel cells and organisms in a whip-like motion. The **flagellum** of eukaryotes usually moves with an "S" motion, and is surrounded by cell membrane.

A **cilium** (plural *cilia*) is an organelle found in eukaryotic cells. Cilia are slender protuberances that project from the much larger cell body.[1]

There are two types of cilia:

1. *motile* cilia, which beat against fluid outside the cell.
2. *non-motile*, or *primary cilia*, which typically serve as sensory organelles.

Motile cilia are found on protist ciliates like *Paramecium*. They are how *Paramecium* moves around. They are also found on the epithelial cells of many internal organs of metazoans, such as the digestive system and the trachea of the lungs.



Characteristics	Cilia	Flagella
Definition	Cilia are short, hair like appendages extending from the surface of a living cell.	Flagella are long, threadlike appendages on the surface of a living cell.
Number	Numerous	Less in Number
Length	Short and hair like organelle (5-10µ)	Long wipe like organelle (150µ)
Occurrence	Occurs throughout the cell surface.	Presence at one end or two ends or all over the surface.
Cross section	Nexin arm present.	Nexin arm absent
Density	Many (hundreds) per cell	Few (less than 10) per cell
Beating	Cilia beat in a coordinated rhythm either simultaneously (synchronous) or one after the other (metachronic).	They beat independent of each other.
Motion	Rotational, like a motor, very fast moving	Wave-like, undulating, sinusoidal, slow movement compared to cilia
Found in	Eukaryotic cells	Eukaryotic and prokaryotic cells
Energy Production	Cilia use 'kinesin' which has an ATPase activity that produces energy to perform the movement.	Flagella are powered by the proton-motive force by the plasma membrane.
Functions	Helps in locomotion, feeding circulation, aeration, etc.	Help mainly in locomotion only.
Examples	Cilia present in *Paramecium*	Flagella present in *Salmonella*

Microvilli

The microvilli is a surface specialization that projects from cell membranes. It is covered by a plasma membrane and encloses cytoplasm and microfilaments. Typically microvilli are found in absorptive cells, whenever there is a need for an increase in surface area. The right figure shows a scanning electron micrograph of the luminal surface of the oviduct. It illustrates one difference between cilia and microvilli. The longer projections are cilia and the shorter projections are microvilli.

Cilia vs Microvilli

Difference between Cilia and Microvilli

Cilia and microvilli are special types of protuberances from the surface some eukaryotic cells with specific functions such as movement, sensory functions or facilitating absorption.

Cilia (singular – Cilium) are narrow and long hair like protuberances from the apical surface of some epithelial cells. Cilia are made up of microtubules with a length of 5 to 10 μm and 0.2 μm in diameter.

Microvilli (singular – Microvillus) are microscopic cellular membrane protrusions that increase the surface area for absorption. Numerous microvilli together act as a structure called 'Brush Borders'. The brush borders are abundantly present on the epithelial cells of the small intestine where they facilitate the absorption.