Cytoskeleton and Motor Proteins

The cytoskeleton acts to organize and maintain the cell's shape; anchors organelles in place; helps during endocytosis, the uptake of external materials by a cell, and cytokinesis, the separation of daughter cells after cell division; and moves parts of the cell in processes of growth and mobility.

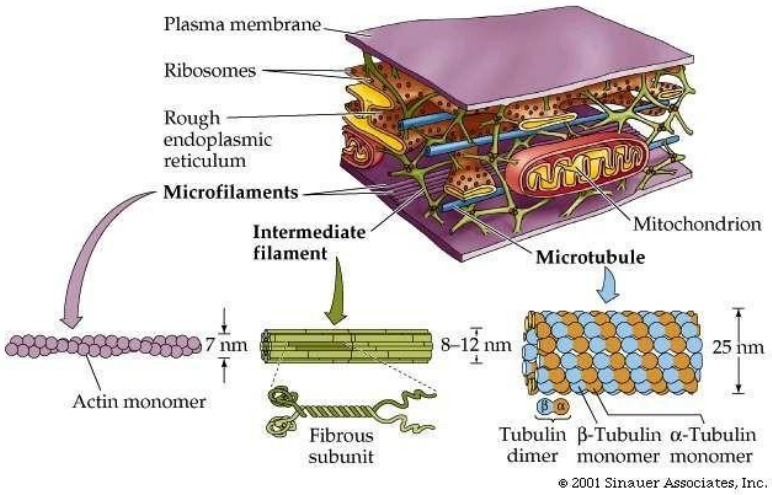
The basic shape of the cell is provided by its cytoskeleton formed primarily by three types of polymers – **actin filaments, microtubules and intermediate filaments**.

Actin filaments or microfilaments are 7 nm in width and are made of double stranded polymers of F-actin. These filaments are associated with a number of other proteins that help in filament assembly and are also involved in anchoring them close to the plasma membrane. This cytoplasmic location helps the microfilaments become involved in rapid responses to signal molecules from the extracellular environment and produce cellular responses through signal transduction or chemotaxis. In addition, myosin, an ATP-based motor protein transmits cargo and vesicles along the microfilament and is also involved in muscle contraction.

Microtubules are polymers of α and β tubulin, which form a hollow tube of 13 protofilaments. Each protofilament is a polymer of alternating α and β tubulin molecules. The inner diameter of a microtubule is 12 nm and its outer diameter is 24 nm. Microtubules radiate towards the periphery of the cell from microtubule organizing centers located close to the nucleus, and provide structure and shape to the cell.

The cytoplasm undergoes rapid reorganization during cell division with microtubules forming the spindle, which binds to chromosomes and form to two daughter cells. Microtubules are involved in cytoplasmic transport, chromosome segregation and in forming structures such as cilia and flagella for cellular movement.

Intermediate filaments are larger than microfilaments but smaller than microtubules and are formed by a group of proteins that share structural features. Though they are not involved in cell motility, they are important for cells to come together as tissues and to remain anchored to the extracellular matrix.



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.

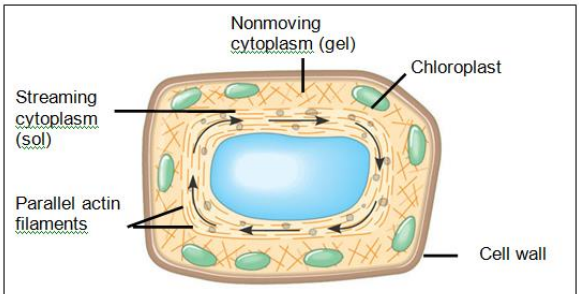


Fig.(1-16): Cytoplasmic streaming in plant cells

Cytoplasmic streaming is also important for positioning chloroplasts close to the plasma membrane to optimize photosynthesis and for distributing nutrients through the entire cell.

Nucleus

- The nucleus is a double membrane-bound structure responsible for controlling all cellular activities as well as a center for genetic materials, and it's transferring.
- It is one of the large cell organelles occupying 10% of total space in the cell.
- It is often termed the "brain of the cell" as it provides commands for the proper functioning of other cell organelles.
- A nucleus is clearly defined in the case of a eukaryotic cell; however, it is absent in prokaryotic organisms with the genetic material distributed in the cytoplasm.
- Structurally, the nucleus consists of a nuclear envelope, chromatin, and nucleolus.
- The nuclear envelope is similar to the cell membrane in structure and composition. It has pores that allow the movement of proteins and RNA in and outside the nucleus. It enables the interaction with other cell organelles while keeping nucleoplasm and chromatin within the envelope.
- The chromatin in the nucleus contains RNA or DNA along with nuclear proteins, as genetic material that is responsible for carrying the genetic information from one generation to another.
- The nucleolus is like a nucleus within the nucleus. It is a membrane-less organelle that is responsible for the synthesis of rRNA and assembly of ribosomes required for protein synthesis.

Nuclear envelope

* The nuclear envelope, otherwise known as nuclear membrane, consists of two cellular membranes, an inner and an outer membrane, arranged parallel to one another and separated by 10 to 50 nanometres (nm).

* The nuclear envelope completely encloses the nucleus and separates the cell's genetic material from the surrounding cytoplasm, serving as a barrier to prevent macromolecules from diffusing freely between the nucleoplasm and the cytoplasm.

* The outer nuclear membrane is continuous with the membrane of the rough endoplasmic reticulum(RER), the space between the membranes is called the perinuclear space and is continuous with the RER lumen

Nuclear pores

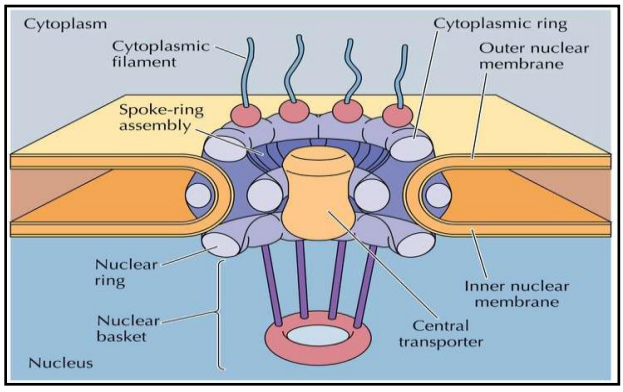
Nuclear pores, which provide aqueous channels through the envelope, are composed of multiple proteins, collectively referred to as nucleoporins.
This size selectively allows the passage of small water-soluble molecules while preventing larger molecules, such as nucleic acids and larger proteins, from inappropriately entering or exiting the nucleus. These large molecules must be actively transported into the nucleus instead.

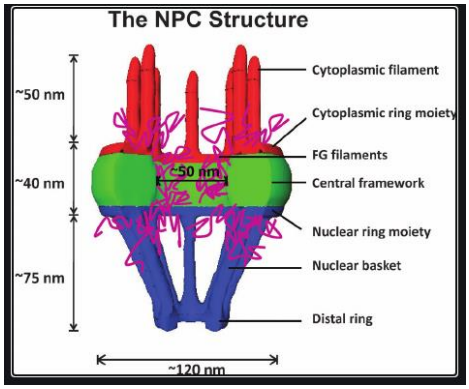
- The nucleus of a typical mammalian cell will have about 3000 to 4000 pores throughout its envelope.

- The pores are 100 nm in total diameter; however, the gap through which molecules freely diffuse is only about 9 nm wide, due to the presence of regulatory systems within the center of the pore.

The Nuclear Pore Complex (NPC)

- Each pore contains an **eight** fold-symmetric ring-shaped structure at a position where the inner and outer membranes fuse.
- Attached to the ring is a structure called the **nuclear basket** that extends into the nucleoplasm, and a series of filamentous extensions that reach into the cytoplasm. Both structures serve to mediate binding to nuclear transport proteins.
- Most proteins, ribosomal subunits, and some DNAs are transported through the pore complexes in a process mediated by a family of transport factors known as **karyopherins.** Those karyopherins that mediate movement into the nucleus are also called importins, whereas those that mediate movement out of the nucleus are called exportins.
- Proteins larger than ~50kDa are too large to passively diffuse from the cytoplasm to the nucleus and must be actively transported across the NPC. These proteins must contain a nuclear localization sequence/signal (NLS) in order to be recognized by the alpha subunit of importin. When the cargo protein binds to alpha importin, alpha importin binds to beta importin, and beta importin is recognized by the FG repeat domains on the cytoplasmic filaments of the NPC.





- Most karyopherins interact directly with their cargo, although some use adaptor proteins. Steroid hormones such as cortisol and aldosterone, as well as other small lipid-soluble molecules involved in intercellular signaling, can diffuse through the cell membrane and into the cytoplasm, where they bind nuclear receptor proteins that are trafficked into the nucleus.
- Large numbers of proteins synthesized in cytoplasm and transported into the nucleus, RNAs manufactured in nucleus transported to cytoplasm

Mitochondria

- Mitochondria are double membrane-bound cell organelles responsible for the supply and storage of energy for the cell.
- The oxidation of various substrates in the cell to release energy in the form of ATP (Adenosine Triphosphate) is the primary purpose of mitochondria.
- A mitochondrion contains two membranes with the outer layer being smooth while the inner layer is marked with folding and finger-like structures called cristae.
- The inner mitochondrial membrane contains various enzymes, coenzymes, and components of multiple cycles along with pores for the transport of substrates, ATP, and phosphate molecules.
- Within the membranes is a matrix that contains various enzymes of metabolic processes like Kreb's cycle.
- In addition to these enzymes, mitochondria are also home to single or double-stranded DNA called mtDNA that is capable of producing 10% of the proteins present in the mitochondria.
- Mitochondria also help in balancing the amount of Ca+ ions within the cell and assists the process of apoptosis.
- Mitochondria in the liver have the ability to detoxify ammonia.

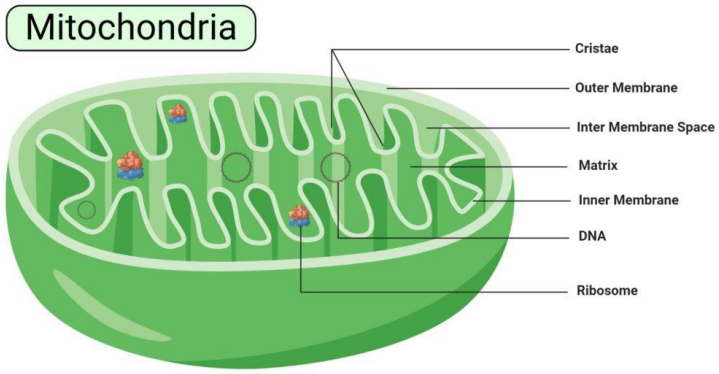


Figure: Mitochondria, Image Copyright © Sagar Aryal, www.microbenotes.com