

CHAPTER 12

12.0 CYTOPLASMIC MICROTUBULES AND CYTOSKELETON

12.1 CYTOPLASMIC MICROTUBULE

Cytoplasmic microtubules are loosely organized.

Function.

- a. Involved in movement and interaction of subcellular components e.g chromosomes during cell division.
- b. Determine and maintain the cell shape.

Cytoplasmic microtubules and the cell surface.

Cell surface is taken to mean cytoplasmic membrane.
No the surface there is cytoplasmic membrane.

Functions of cytoplasmic microtubules

Involved in regulating and restraining the movement of the membrane proteins i.e. affect the selectivity of cytoplasmic membrane.

Cytoplasmic microtubules and cell shape

Function of microtubules is maintenance of shape of animal cell

NB: In plants cell microtubules play less significant role since cell wall serves this role.

12.2 THE CYTOSKELETON

This is a network of interconnected fibres and filaments found in cell sap, that together impart an architectural framework of the cell.

Basic functions of the cytoskeleton

Creates the skeleton (framework) of that supports and organizes the interior of the cell.

- a) This skeleton enables the cell to assume elaborate shape.
- b) Enables communication among intracellular organelles.

c) Enable movement of the cell as a whole as well as intracellular components e.g chromosome membrane and organelles.

Basic components of cytoskeleton

- a) Microtubules .
- b) Filaments.

12.2.1 Microtubules.

Is a long rod like structure that measures 25nm in diameter and several millimeters in length.

Function

- a) motion / movement of cilia, flagella, chromosome e.t.c
- b) modulation of plasma membrane topography.
- c) determination and maintenance of cell shapes.

These functions are achieved due to basic properties of the microtubules. These properties are :-

- a) It's rigid shape – enable anchoring , guiding , orienting and supporting other cellular constituents.
- b) Its ability to generate movement.

Composition of microtubule.

Contain a hollow 15nm in diameter.
The hollow is surrounded by a wall of longitudinal protofilaments.
The wall generally contains 13 protofilaments.



Protofilaments are made of proteins called tubulin dimmers.

Eukaryotic cilia and flagella

Cilia and flagella are large mobile organelles that project from the surface of Eukaryotic cells



Function .

- Cells that are firmly anchored employ ciliary motions to move fluids across their surface.
- Cells that are not firmly anchored e.g sperm cells or unicellular organisms employ ciliary or flagella movement to propel themselves through the liquid medium in which they are suspended.

Flagella.

Size – relatively large 15nm or more in length.

Present in small number per cell.

Beats in a regular planar wave that propels liquid parallel to the flagellar axis.

Cilia.

Shorter than flagella, 5 –10 nm average length.

More in number than flagella.

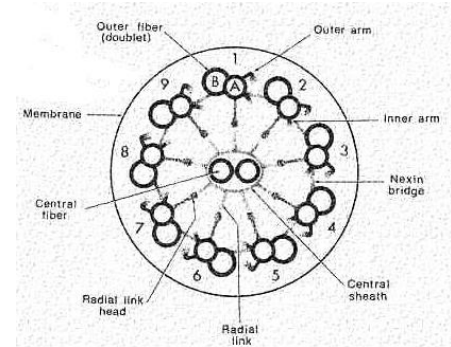
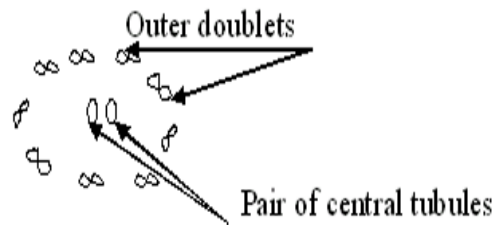
Beats in amore complex pattern leading to passage of fluid across the cells surface.

Architectural organization of cilia and flagella .

Cilia and flagella are made from microtubules called axoneme.

Axoneme is made of 9 +2 pattern i.e. 9 outer doublet tubules surrounded by a pair of central tubule.

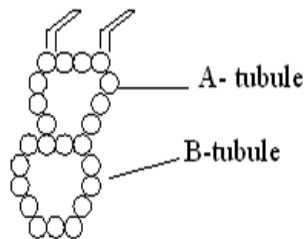
Axoneme definition - A bundle of microtubules and other proteins forming the core of each cilium or flagellum



Wall of **central microtubule** contain 13 protofilaments.

The **outer microtubules** consist of **A – tubule** and **B-tubule**.

Walls of the A – tubule consists of 13 protofilaments while B- tubules has 10 protofilaments because it shares some with A – tubule.



Surrounding A-tubule are sets of arms.

Central microtubule **bridge** - they link the central microtubules together.

Central **sheath** -surround the central microtubules.

Radial spokes - connect the A – tubules to the central region.

A – tubule B- tubule are connected to each other by **interdoublet nexin** links.

Ciliary necklace – connect the doublet with the plasma membrane.

Central pair microtubules also connect with the plasma membrane at their end (where there is the central pair microtubule cap).

Basal bodies, central tubules and the biogenesis of cilia and flagella.

Basal body – is a cylindrical structure with a set of triplet tubules.

Functions of basal body

1. Anchor cilia and flagella to the cell.

Transitional fibres help anchor the basal body to the plasma membrane.

Rootlet fibres pass from basal body to the cell interior enhancing the anchoring.

2. Help in development of cilia and flagella.

Formation of cilia and flagella is triggered by centriole.

Centriole are small cylindrical organelles found adjacent to nucleus.

Centriole migrate to the cell surface and make contact with plasma membrane.

A – and B – tubules of centrioles then act as nucleation sites of microtubules assembly initiating polymerization of tubules that will make the 9 outer doublets of the ciliary axoneme.

NB – used centrioles are replenished by procentrioles (centriole precursor).

The mechanism of centriole and flagella motility

Ciliary and flagella movement involve bending of the axoneme at appropriate points along its length.

This movement (bending) is achieved through sliding of microtubules past one another during ciliary bending.

Sliding microtubule model.

Home work

1. What is cytoskeleton ?
2. Explain how microtubules are used to achieve movement of the cell.
3. Why are lysosomal enzymes do not digest the lysosome membrane?.

12.2.2 MICROFILAMENTS.

Found in eukaryotic cytoskeleton in addition to microtubule.

Size – **6nm** in diameter (smaller than microtubules).

Sometimes packed in parallel bundles called stress bundles.

Function

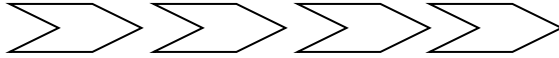
- 1) Cytoplasmic streaming
- 2) Amoebal locomotion.
- 3) Cell division.
- 4) Cell shape changer.
- 5) Involved in cell surface events such as endocytosis and secretion.

Microfilament are constructed from the **protein actin**.

Microfilament of non muscle cells comprise of β (**beta**) and γ actin.

Microfilaments of muscle cells comprise of α (**alpha**) actin

Actin filaments exhibit an intrinsic polarity e.g. heavy meromyosin (fragment of the muscle cell protein myosin) bind to the fibres to form an arrow-head pattern in which all the bound meromyosin molecules point the same direction.



Actin varietal structures.

- 1) Free monomers.
- 2) Individual organised filaments.
- 3) Regulatory cross-like filament bundles.
- 4) Less regulatory cross - linked filament bundles.

Over 60 actin building proteins are associated with varietal structures of actin.

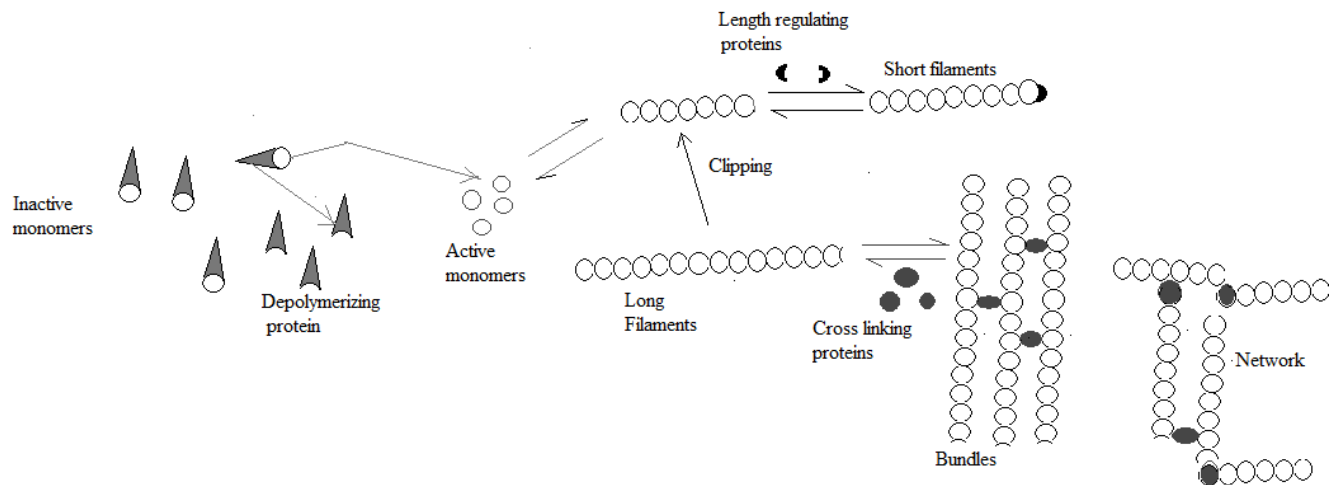
Basic classes of actin - building proteins.

Length regulating proteins – bind preferentially to one end so actin filament inhibiting the addition of monomers to the growing filament, therefore slowing the overall rate of polymerisation.

Depolymerising proteins – binds the monomeric actin shifting the equilibrium towards filament depolymerisation and therefore decreasing the overall number of filament that can be produced.

Cross linking. Proteins - promotes the formation of filament bundles and actin gel by cross linking individual actin filaments to one another.

NB - Ca^{2+} regulates actin behaviour by regulating interaction of these proteins.



Mechanism of microfilament movement .

Thin filaments of actin and thicker filaments of ATP – hydrolysing protein called **myosin** enable the microfilament movement.

The energy released during the hydrolysis of ATP allows myosin to bind actin and slide along its surface.

Troposin and tropomyosin proteins complex interfere with interaction between actin and myosin inhibiting muscle contraction.

Increase in Ca_2^+ permits actin-myosin to interact with each other thus ensuring muscle contraction.

Microfilament and cytoplasmic streaming.

Cytoplasmic streaming - this is a regular pattern of cytoplasmic flow.

Cyclosis (circling)

Is a cytoplasmic streaming in plant cells – so called because cytoplasmic streaming in plant cells follow a circular path around the central vacuole.

Ectoplasm (outer most region of the cytoplasm) is relatively non motile and gelatinous.

Endoplasm (inner region of cytoplasm is more fluid and more motile.

Microfilaments are implicated in these movements.

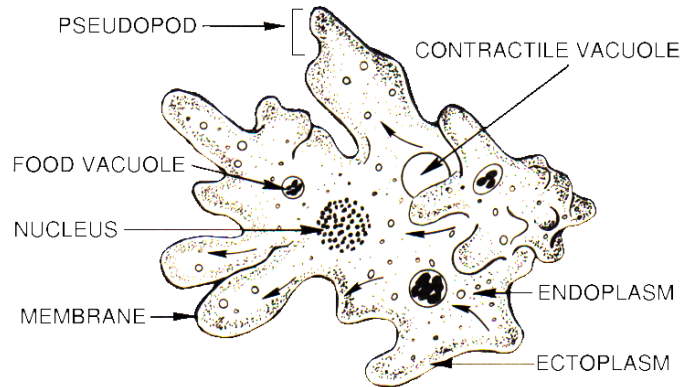
Shuttle streaming - found in animal cell.

So called because of its tendency to change direction.

Pressure produced by streaming can induce changes in cell shape that in turn lead to movement of cell as a whole.

Shuttle streaming lead to formation of cytoplasmic projections (pseudopodia) and amoeboid movements.

Many cells exhibit a more effective type of cytoplasmic movement in which cytoplasmic particles organelles suddenly move several micrometers in a particular staltatory (discontinuous) direction at a much greater velocity than they were previously moving (staltatory movements). This is addition to cytoplasmic streaming.



Microfilament and amoeboid movement

This is bulk movement of the cell cytoplasm.

Called amoeboid movement because it was first studied in amoeba in the unicellular Eukaryotes. Other cells where amoeboid movement was found are :-

- i) Blood cells.
- ii) Embryonic cells.
- iii) Cancers cells grown in tissues culture e.t.c

Locomotion in amoebae.

Mechanism of movement.

Involves formation of cytoplasmic projections called pseudopodia.

Movement occurs in the direction of advancing pseudopodium ; with the rear proportion of the tail of the cell being pulled forward as the cell advances.

Endoplasm flows from the tail to the advancing pseudopodium.

As the stream of flowing cytoplasm reaches the pseudopodium, it (stream) is diverted towards the side of the cell.

Here it is converted to more rigid ectoplasm..

Meanwhile ectoplasmic wall is being broken down at the rear of the cell to provide new endoplasm for forward flow.

This process of converting cytoplasm from a rigid gelatinous consistently to a more fluid relaxed state is called **gel-sol transition**.

Formation of microfilament array at the rear end of the cell is believed to be triggering a sol – gel transition that pulls the endoplasm forward and converts it to a more rigid ectoplasm.

Locomotion in other cells

Chemotaxis - terms used to refer movements guided by chemical substances present in the environment.

Microfilament and cell division.

Charge of the cell in halt (cytokinesis) and migration of the two sets of chromosomes is mediated by microfilaments.

Microfilaments , cell shape and t he cell surface.

Microfilaments influence the development and maintainance of asymmetrical cell shape. Microfilament provide the structural core for cell surface, projections of microvilli, pseudopodium e.t.c.

Microfilament and endocytosis / exocytosis.

Microfilament influence both the endocytosis and exocytosis.

NB – endocytosis – uptake of particulate matter (phagocytosis) and the uptake of fluid in large vesicles(micropinocytosis).

Endocytosis —contraction of microfilament during endocytosis plays a role in invagination and pinching off of plasma membrane vesicles.

Exocytosis and cell secretion

Contraction of microfilaments also plays a role cell secretion.

Microfilament / microtubule interaction.

In cases where such interaction occur microtubules provide structural or architectural role while microfilaments provide the motile force.

Advantage .

Long rigid microtubules permit the forces generated by microfilaments to acquire direction and long range organisation that would be missing with microfilaments acting alone.

Example of interaction – embryonic nerve cells at the tome when they develop long cytoplasmic projections called axons.

Intermediate filaments

Their size is 10-15nm in diameter. Intermediate to microfilament (6nm) and microtubules (25nm) hence the name.

Protein composition of Intermediate microfilament differ from cell to cell e.g Epithelial cells- have keratin, neuronal cells have neurofilaments etc.

Functions of intermediate filaments – differ with protein constituents

Eg Keratin filaments

- i) Forms interconnected filament network that reinforces the mechanical strength of the epithelial cell layer.
- ii) Plays a role in tension-bearing e.g. Intermediate filaments in muscles cells are thought to maintain the proper alignment of centriole fibrils

Bacterial flagella.

Size 12 –20nm in diameter (smaller than that of Eukaryotic cells which is 500nm in diameter).

Parts of the flagella.

- Filament
- Hook
- Basal body.
- Rod
- Rings- 4 for gram negative and two for gram positive bacteria.

Chemical composition of flagella.

Flagella - is composed of flagellin (a protein monomer).

Mechanism of flagellum movement.

a) Rotation in a screw-like fashion possibly facilitated by the inner rings.

This movement is most likely induced by proton gradient (electrochemical gradient).

Movement can be clockwise - stumbling movement or counter clockwise direction – smooth line movement.

Chemotaxis – (movement guided by chemicals)

Chemical attracts – leads to counter clockwise rotation of flagellum hence straight line movement.

Chemical repellent lead to clockwise rotation movement of flagellum (stumbling movement).

Functions of the bacteria flagellum.

- Locomotion of the bacteria.

1. Explain the importance of cilia in the process of fertilization
2. Discuss the importance of cilia and flagellum in cell survival
3. Microtubules are needed for cell division. Explain.
4. Explain how depolymerizing proteins can be used to control cell growth.
5. Describe the structure of protofilaments