PUC –I year Semester-2

Unit-I: Cell Bioloy

Module No 6. Cytoskeletal structures: cilia, flagella, centrioles (ultra structure and function)

In the cytosol there is a three-dimensional network of filamentous proteins called the cytoskeleton. It gives the scaffold structure for the positioning and movements of the organelles. The cytoskeleton extends throughout the cytoplasm and is a complex network of three types of protein filaments called microtubules, microfilaments and intermediate filaments of fixed diameter and variable lengths. These structures are found in all eukaryotic cells, but are absent in prokaryotes. Cytoskeleton determines both the shape of the cell and the changes in its form. The main proteins that are present in the cytoskeleton are tubulin (in the microtubules), actin, myosin and tropomyosin (in the microfilaments) and keratin, vimentin, desmin, lamin and others (in intermediate filaments)

Microfilaments: They are about 50 to 70A in diameter and are generally distributed in the cortical regions of the cell just beneath the plasma membrane. Microfilaments also extend into cell processes, especially where there is movement. Thus, they are found in the microvilli of the brush border of intestinal epithelium and in cell types where amoeboid movement and cytoplasmic streaming are prominent. Microfilaments are also involved in movement associated with furrow formation in cell division and cell migration during embryonic development. Actin is the main structural protein of microfilaments.

Microtubules: The cytoplasm of all eukaryotic cells contains hollow fibrillar structures called microtubules. They are not found in prokaryotes. They may occur either free in the cytoplasm or forming part of centrioles, cilia and flagella. They are also found in the basal bodies, nerve processes, the mitotic apparatus etc.

Microtubules are long, hollow, unbranched tubules with an outer diameter of 250A. The length of microtubules varies from a fraction of a micron to several microns. A transverse section of a cytoplasmic microtubule shows 13 sub units (proto filaments) which lie parallel to the long axis of the microtubule. Biochemically, a protofilament of microtubule is made of a protein called tubulin.

The shape of the cell and cell processes like axons, dendrites , microvilli etc have been correlated to the orientation and distribution of microtubules. During cell differentiation, the mechanical function of microtubules is used to determine the shape of the developing cells. Microtubules play a role in the contraction of the spindle and movement of chromosomes and centrioles as well as in ciliary and flagellar motion. Microtubules are involved in the transport of macromolecules, granules and vesicles within the cell.

Intermediate filaments:

Intermediate filaments are tough and durable protein fibres in the cytoplasm of most higher eukaryotic cells. Their diameter is about 8nm to 10nm which is intermediate between microfilaments and microtubules. In most animal cells they form a basket around the nucleus and extend out in gentle curving arrays to the cell periphery. Intermediate filaments are particularly prominent where cells are subjected to mechanical stress, such as epithelia. They are differently named in different tissues in epidermal cells they are called tonofilaments, in nerve cells they are referred to as neurofilaments and in neuroglial cells they are designated as glial filaments.

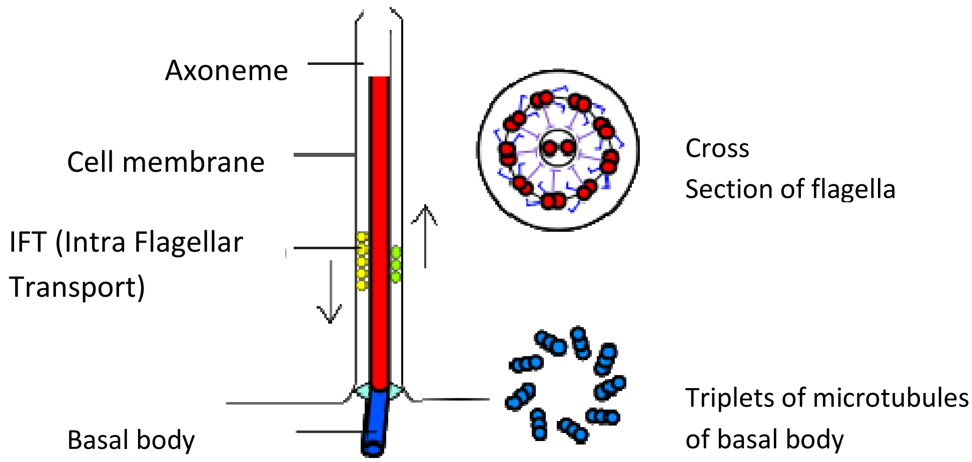
In cross section, intermediate filaments have a tubular appearance. Each tubule appears to be made up of 4 or 5 protofilaments arranged in parallel fashion and composed of polypeptides. The main function of most intermediate filaments is to provide mechanical support to the cell and its nucleus.

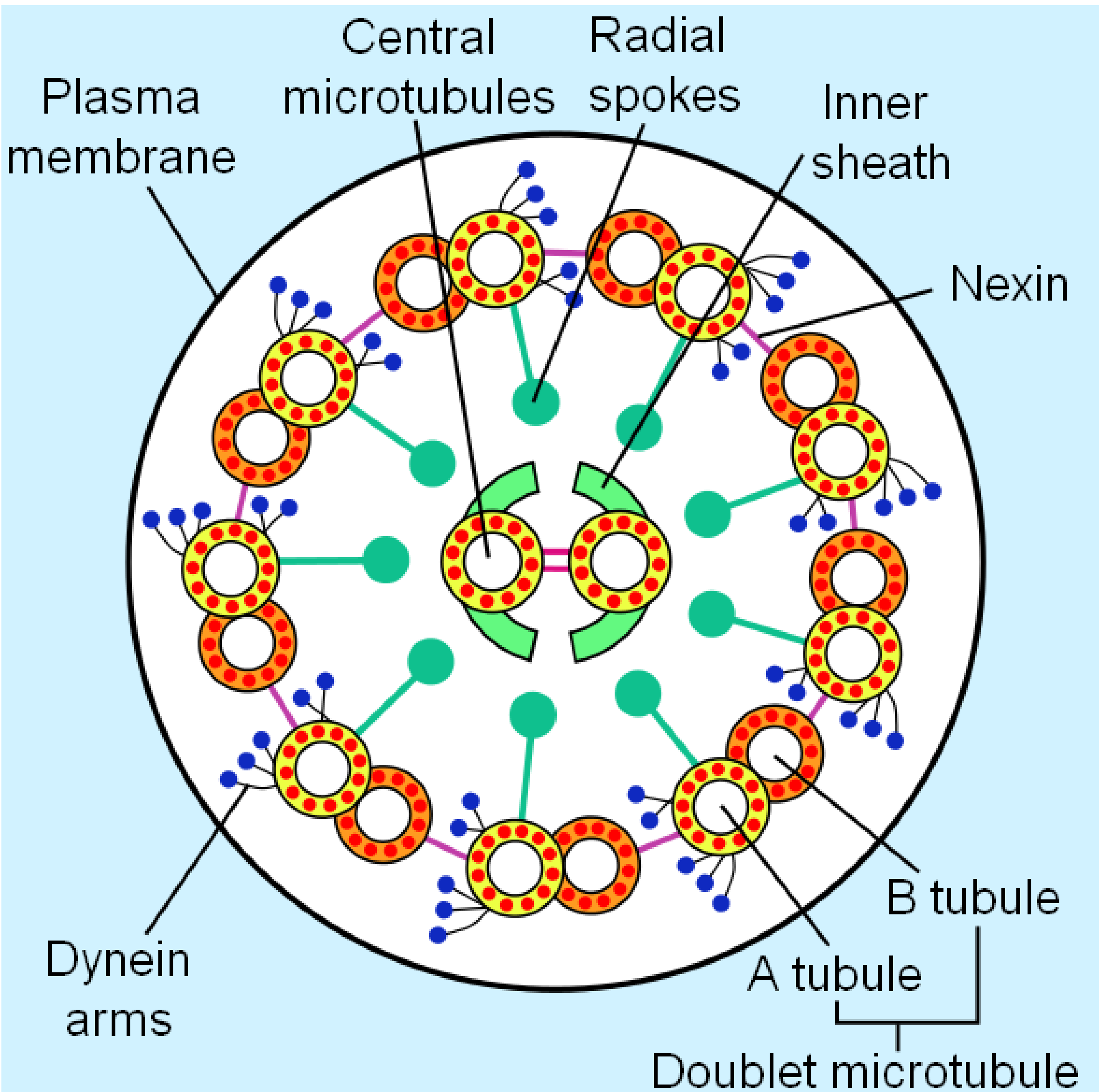
Ultra structure of the cilia and flagella

The cilia and flagella are microscopic, contractile and filamentous processes of the cytoplasm which create food currents act as sensory organs and perform many mechanical functions of the cell. Morphologically and physiologically, the cilia and flagella are identical structures. The only difference is that the flagella are longer.

Cilia and flagella are made up of microtubules, which are composed of linear polymers of globular proteins called tubulin. A typical flagellum or cilia consists of central axial filament called axoneme, enclosed by an outer cytoplosmic sheath. The axoneme consists of two central longitudinal unpaired fibers that are surrounded by an outer ring of nine double fibers and covered by the cellular membrane. (2+9 arrangement of fibers). At the base of eukaryotic flagellum is a basal body, “blepheroplast” or kinetosome, which is the microtubule organizing centre for flagellar microtubules. This characteristic 9+2 arrangment of microtubules is seen when the axoneme is viewed in cross section with the electon microscope. As shown in figure each doublet microtubule consists of A and B tubules or sub fibers. The A tubule is a complete microtubule with 13 protofilaments, while the B tubule contains 10 protofilaments.

Each of the outer 9 doublet microtubules extends a pair of dynein arms (an inner and an outer arm) to the adjacent microtubule, these dynein arms are responsible for flagellar beating, as the force produced by the arms causes the microtubule doublets to slide against each other and the flagellum as a whole to bend. These dynein arms produce force through ATP hydrolysis. The flagellar axoneme also contains radials spokes, polypeptide complexes extending from each of the outer 9 microtubule doublets towards the central pair, with the ‘head’ of the spoke facing inwards. The radial spoke is thought to be involved in the regulation of flagellar motion, although its exact function and method of action are net yet understood.


Axoneme
Cell membrane
IFT (Intra Flagellar
Transport)
Basal body
Cross
Section of flagella
Triplets of microtubules
of basal body


Central
microtubules
Radial
spokes
Plasma
membrane
Inner
sheath
Nexin
B tubule
A tubule
Doublet microtubule
Dynein
arms

Functions of cilia and flagella

Cilia and flagella are involved in locomotion,feeding, cleansing, respiration, circulation and passage of materials.

1. The ciliary or flagellar movement provides the locomotion to the cell or organism.
2. Cilia creates food currents in lower aquatic animals. Ciliary currents bring in fine particle of food which are then trapped by the animal.
3. In many seanemones and corals, cilia on the tentacles and the oral region sweep unrequired particles away from the mouth and thus have a cleansing effect.
4. Water currents created by cilia facilitate respiration.
5. In starfishes, the coelomic fluid is circulated by ciliary action.
6. The cilia lining the lumen of nephridia, kidney tubules and genital duct help in the passage of materials through these structures.

Centrioles

Cytoplasm of some eukaryotic cells contains two cylindrical, rod shaped, microtubular structures, called centrioles, near the nucleus. Centrioles lack limiting membrane and form a spindle of microtubules, the mitotic apparatus during mitosis or meiosis and some times get arranged just beneath the plasma membrane to form and bear flagella or cilia in flagellated or ciliated cells. When a centriole bears a flagellum or cilium it is called basal body. They are absent in prokaryotes, red algae, yeast, cone bearing and flowering plants and some non flagellated or non ciliated protozons. Centrioles are cylindrical structures which are 0.15-0.25 µm in diameter and usually 0.3-0.7µm in length.

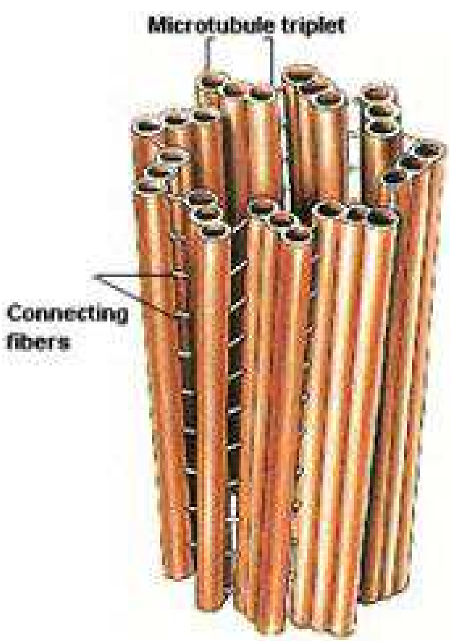
Chemical composition : Microtubules of centriole contain the structural protein, tubulin and lipid molecules. The centriole contain a high concentration of ATPase enzyme. Presence of nucleic acid in centriole is doubtful.

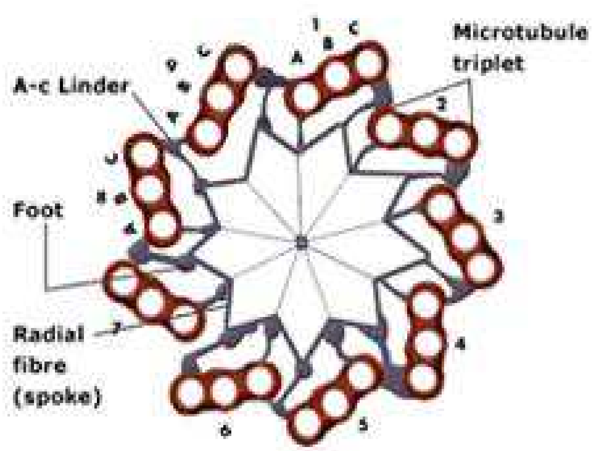
Ultra structure:

The wall of the centriole has nine groups of microtubules arranged in a circle. Each group is a triplet formed of three tubules (in cilia only two) that are skewed toward the center. Each unit formed by the triplet has also been called a blade. Within each blade the tubules twist from one end to the other or describe a helical course. As shown in figure, the tubules are designated, A,B and C from the center toward the periphery. Both A and B cross the ciliary plate and are continuous with the corresponding tubules in the axoneme.

In the formation of the axoneme of a cilium or flagellum, the centriole serves a template function and the polymerization of tubulin occurs at the distal end of tubules A and B, while the termination of tubule C occurs near the basal plate. In this way the centriolar triplet is converted into the ciliary doublet.

There are no central microtubules in the centrioles and no special arms, however, they are linked by connectives. The proximal portion of the centriole has a cart wheel appearance, which provides the centriole with a structural and functional polarity.





Functions

1. Formation of basal bodies and ultimately the cilia is the specialized function of the centrioles in the cell.
2. In spermatozoon one centriole give rise to the tail fibre or flagellum
3. Centrioles and basal bodies are also found to be involved in ciliary and flagellar beat
4. Recently, it has been suggested that centrioles could serve as devices for locating the directions of signal sources.
5. Centrioles form the mitotic poles in higher animals
6. Centrioles and basal bodies are involved in the organization of cytoplasmic microtubules, and the reception of optical, acoustic and olfactory signals.

Question

1. Describe the ultra structure and functions of cilia and flagella
2. Describe the structure and functions of centrioles.
3. Describe the cytoskeletal structures present in a cell?